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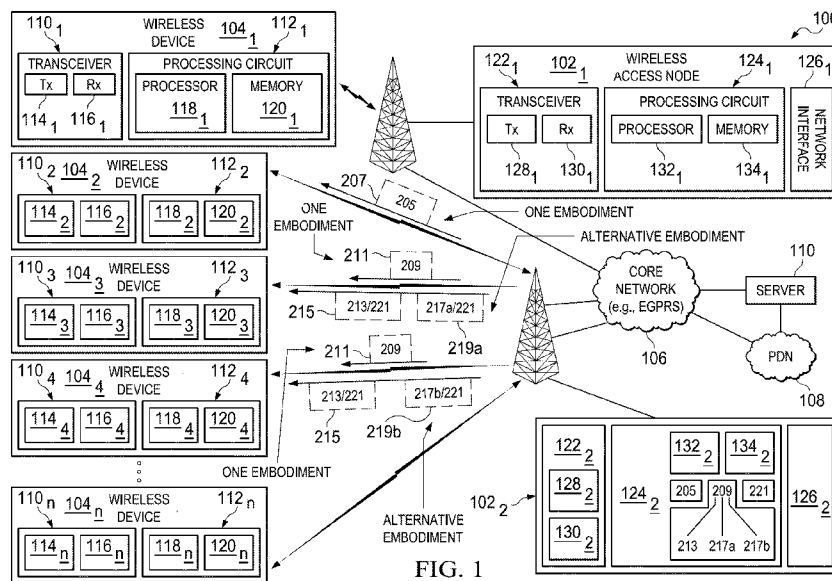


FIG. 1

(57) Abstract: A wireless access node and method are described herein for improving a bandwidth utilization efficiency of a common downlink (DL) channel when transmitting device-related information included in one or more messages to a wireless device or a group of wireless devices, wherein the one or more messages have one or more transport block formats that meet a coverage class need of the wireless device or the group of wireless devices. In addition, a wireless device and method are described herein for improving a bandwidth utilization efficiency of the common DL channel by receiving one or more messages including device-related information on the common DL channel from the wireless access node, wherein the one or more messages have one or more transport block formats that meet a coverage class need of the wireless device.

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MAXIMIZING CHANNEL CAPACITY FOR COMMON DOWNLINK CHANNELS

CLAIM OF PRIORITY

5 This application claims the benefit of priority to Indian Application No. 2161/DEL/2014, filed on July 31, 2014, and to U.S. Provisional Application Serial No. 62/050,517, filed on September 15, 2014, the entire contents of each of which are hereby incorporated by reference for all purposes.

10 **TECHNICAL FIELD**

 The present disclosure relates generally to common downlink channels in wireless communication networks and, more particularly, to techniques for increasing or maximizing channel capacity of a common downlink channel by utilizing different transport block formats in the common downlink channel to meet the coverage class
15 needs of a specific wireless device or a group of wireless devices.

BACKGROUND

 The following abbreviations and terms are herewith defined, at least some of which are referred to within the following description of the present disclosure.

20

- 3GPP 3rd-Generation Partnership Project
- AGCH Access Grant Channel
- ASIC Application Specific Integrated Circuit
- BCCH Broadcast Control Channel
- 25 BLER Block Error Rate
- BS Base Station
- CC Coverage Class
- CCCH Common Control Channel
- CN Core Network
- 30 CRC Cyclic Redundancy Check
- CS Coding Scheme
- DL Downlink

	DRX	Discontinuous Reception
	DSP	Digital Signal Processor
	EDGE	Enhanced Data rates for GSM Evolution
	EGPRS	Enhanced General Packet Radio Service
5	eNB	evolved Node B
	ETWS	Earthquake and Tsunami Warning System
	E-UTRA	Evolved Universal Terrestrial Radio Access
	GSM	Global System for Mobile Communications
	GERAN	GSM/EDGE Radio Access Network
10	GMSK	Gaussian Minimum Shift Keying
	GPRS	General Packet Radio Service
	HARQ	Hybrid Automatic Repeat Request
	LTE	Long-Term Evolution
	MTC	Machine Type Communications
15	MS	Mobile Station
	PCH	Paging Channel
	PDN	Packet Data Network
	PG	Paging Group
	P-TMSI	Packet Temporary Mobile Station Identity
20	PTCCH/D	Packet Timing Control Channel/Downlink
	RAN	Radio Access Node
	RACH	Random Access Channel
	RLC	Radio Link Control
	TA	Timing Advance
25	TDMA	Time Division Multiple Access
	TMSI	Temporary Mobile Station Identity
	UE	User Equipment
	UL	Uplink
	UMTS	Universal Mobile Telecommunications System
30	WCDMA	Wideband Code Division Multiple Access
	WiMAX	Worldwide Interoperability for Microwave Access

In existing wireless communication networks, the communication between wireless devices and wireless access nodes in the network are typically handled by the use of different logical channels. Each logical channel has its own purpose(s) and is typically mapped onto a physical channel following a certain frame structure in time and frequency.

One type of logical channel on the downlink (DL) is one that is monitored by a multiplicity of wireless devices, and is also used for addressing a multiplicity (i.e., not necessarily all wireless devices monitoring the channel, but at least a subset) of wireless devices with a message sent by the wireless access node using a single radio block transmitted on the channel. This type of logical channel is referred to herein as a “common DL channel” and could include, for example, in Global System for Mobile (GSM), the Common Control Channel (CCCH).

In the existing wireless communication networks, the wireless access node typically uses the same transport block format (e.g., channel coding rate and error detection capability) for transmitting a message on a common DL channel irrespective of the type of wireless device or channel conditions applicable to any given wireless device. In particular, the wireless access node uses the same transport block format for each of the radio blocks used to send a message on the common DL channel, where the transport block format has a generic format that can be received by all of the wireless devices that are addressed by the message.

For example, one possible system implementation of the transport block format would be to have the wireless access node choose a channel coding rate that is sufficiently robust to ensure that all of the addressed wireless devices can correctly receive the corresponding transmitted radio block (message) with a certain minimum level of probability (i.e., regardless of the radio channel conditions experienced by any of the addressed wireless devices). In particular, to realize a sufficiently high probability of radio block (message) reception by all of the addressed wireless devices, the wireless access node may use a robust transmit block coding rate in combination with repeated transmissions of that transport radio block (message).

However, the wireless access node's configuration of the transport block format according to a worst case scenario regarding the channel conditions (for example) would typically result in a waste of radio resources. This waste of radio resources could, for example, occur when the wireless access node makes repeated
5 transmissions (i.e., multiple repetitions) of a message on a common DL channel according to the number of repetitions that is needed by the wireless device with the worst radio channel conditions that is addressed by the message while many or all of the other wireless devices addressed by the same message may, for example, only need a single transmission. This waste of radio resources and other shortcomings are
10 addressed in the present disclosure.

SUMMARY

A wireless access node, a wireless device, and various methods for addressing at least the aforementioned shortcoming and other shortcomings are described in the
15 independent claims. Advantageous embodiments of the wireless access node, the wireless device, and the various methods are further described in the dependent claims.

In one aspect, the present disclosure provides a wireless access node configured to improve a bandwidth utilization efficiency on a common downlink (DL) channel when transmitting device-related information to a wireless device or a group of wireless
20 devices. The wireless access node comprises a processor and a memory that stores processor-executable instructions, wherein the processor interfaces with the memory to execute the processor-executable instructions, whereby the wireless access node is operable to perform a determine operation. In the determine operation, the wireless access node determines one or more transport block formats to be utilized for
25 transmitting the device-related information on the common DL channel to the wireless device or the group of wireless devices, wherein the one or more transport block formats meet a coverage class need of the wireless device or the group of wireless devices. The wireless access node, by determining one or more transport block formats to be utilized in this manner, has an advantage in that it helps to maximize the use of
30 radio resources when transmitting device-related information on the common downlink DL channel to the wireless device or the group of wireless devices.

In another aspect, the present disclosure provides a method in a wireless access node for improving a bandwidth utilization efficiency on a common downlink (DL) channel when transmitting device-related information to a wireless device or a group of wireless devices. The method comprises a determining step. In the determining step, 5 the wireless access node determines one or more transport block formats to be utilized for transmitting the device-related information on the common DL channel to the wireless device or the group of wireless devices, wherein the one or more transport block formats meet a coverage class need of the wireless device or the group of wireless devices. The method has an advantage in that it helps to maximize the use of 10 radio resources when transmitting device-related information on the common downlink DL channel to the wireless device or the group of wireless devices.

In yet another aspect, the present disclosure provides a wireless device configured to improve a bandwidth utilization efficiency on a common downlink (DL) channel when receiving device-related information from a wireless access node. The 15 wireless device comprises a processor and a memory that stores processor-executable instructions, wherein the processor interfaces with the memory to execute the processor-executable instructions, whereby the wireless device is operable to perform a receiving operation. In the receiving operation, the wireless device receives one or more messages including the device-related information on the common DL channel 20 from the wireless access node, wherein the one or more messages have one or more transport block formats that meet a coverage class need of the wireless device. The wireless device, by adopting one or more transport block formats in this manner, has an advantage in that it helps to maximize the use of radio resources when receiving device-related information on the common downlink DL channel from the wireless 25 access node.

In still yet another aspect, the present disclosure provides a method in a wireless device for improving a bandwidth utilization efficiency on a common downlink (DL) channel when receiving device-related information from a wireless access node. The method comprises a receiving step. In the receiving step, the wireless device receives 30 one or more messages including the device-related information on the common DL channel from the wireless access node, wherein the one or more messages have one or more transport block formats that meet a coverage class need of the wireless device.

The method has an advantage in that it helps to maximize the use of radio resources when receiving device-related information on the common downlink DL channel from the wireless access node.

5 Additional aspects of the invention will be set forth, in part, in the detailed description, figures and any claims which follow, and in part will be derived from the detailed description, or can be learned by practice of the invention. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention as disclosed.

10

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present invention may be obtained by reference to the following detailed description when taken in conjunction with the accompanying drawings:

15

FIGURE 1 is a diagram of an exemplary wireless communication network in accordance with an embodiment of the present disclosure;

FIGURE 2 is a flowchart of a method implemented in a wireless access node to improve a bandwidth utilization efficiency on a common DL channel when transmitting device-related information to a wireless device or a group of wireless devices in accordance with an embodiment of the present disclosure;

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FIGURE 3 is a block diagram illustrating structures of an exemplary wireless access node configured in accordance with an embodiment of the present disclosure;

FIGURE 4 is a flowchart of a method implemented in a wireless device to improve a bandwidth utilization efficiency on a common DL channel when receiving device-related information from a wireless access node in accordance with an embodiment of the present disclosure;

25

FIGURE 5 is a block diagram illustrating structures of an exemplary wireless device configured in accordance with an embodiment of the present disclosure; and,

FIGURE 6 is a graph illustrating the simulation results of a performance of a four burst radio block carrying 184 information bits compared to a one burst radio block carrying different amounts of information bits.

30

DETAILED DESCRIPTION

To describe the technical features of the present disclosure, a discussion is provided first to describe an exemplary wireless communication network which includes multiple wireless access nodes and multiple wireless devices, each of which are configured in accordance with the present disclosure (illustrated in FIGURE 1). Then, a discussion is provided to explain in more detail how the wireless access node and the wireless device each implement the technical features of the present disclosure (illustrated in FIGURES 2-5). Finally, a discussion is provided to explain the technical features of the present disclosure when applied to a GSM wireless communication network (illustrated in FIGURE 6).

Exemplary Wireless Communication Network 100

Referring to FIGURE 1, there is illustrated an exemplary wireless communication network 100 in accordance with the present disclosure. The wireless communication network 100 includes multiple wireless access nodes 102₁ and 102₂ (only two shown), multiple wireless devices 104₁, 104₂, 104₃, 104₄...104_n, and a core network 106 (e.g., EGPRS core network 106). The wireless communication network 100 includes many other well-known components, but for clarity, only the components needed to describe the technical features of the present disclosure are described herein. Further, the wireless communication network 100 is described herein as being an GSM/EGPRS wireless communication network 100 which is also known as an EDGE wireless communication network 100. However, those skilled in the art will readily appreciate that the techniques of the present disclosure, which are applied to the GSM/EGPRS wireless communication network 100, are generally applicable to other types of wireless communication systems, including, for example, WCDMA, LTE, and WiMAX systems.

The wireless communication network 100 includes the wireless access nodes 102₁ and 102₂ (only two shown) which provide network access to the wireless devices 104₁, 104₂, 104₃, 104₄...104_n. In this example, the wireless access node 102₁ is providing network access to wireless device 104₁ while the wireless access node 102₂ is providing network access to wireless devices 104₂, 104₃, 104₄...104_n. The wireless

access nodes 102₁ and 102₂ are connected to the core network 106 (e.g., EGPRS core network 106). The core network 106 is connected to an external packet data network (PDN) 108, such as the Internet, and a server 110 (only one shown). The wireless devices 104₁, 104₂, 104₃, 104₄...104_n may communicate with one or more servers 110
5 (only one shown) connected to the core network 106 or the PDN 108.

The wireless devices 104₁, 104₂, 104₃, 104₄...104_n may refer generally to an end terminal (user) that attaches to the wireless communication network 100, and may refer to either a MTC device or a non-MTC device. Further, the term “wireless device” is generally intended to be synonymous with the term “User Equipment,” or
10 UE, as that term is used by the 3rd-Generation Partnership Project (3GPP), and includes standalone wireless devices, such as terminals, cell phones, smart phones, tablets, and wireless-equipped personal digital assistants, as well as wireless cards or modules that are designed for attachment to or insertion into another electronic device, such as a personal computer, electrical meter, etc.

15 Likewise, the wireless access nodes 102₁ and 102₂ may refer in general to a base station or central node in the wireless communication network 100, and may refer to wireless access nodes 102₁ and 102₂ that are controlled by a physically distinct radio network controller as well as to more autonomous access points, such as the so-called evolved Node Bs (eNBs or eNodeBs) in Long-Term Evolution (LTE)
20 networks. Accordingly, the term “wireless access node” may also refer to Radio Network Controllers (RNCs) and Node Bs (NBs) in 3G, or Base Station Controllers (BSCs) or Base Transceiver Stations (BTSs) in 2G.

Each wireless device 104₁, 104₂, 104₃, 104₄...104_n may include a transceiver circuit 110₁, 110₂, 110₃, 110₄...110_n for communicating with the wireless access nodes
25 102₁ and 102₂, and a processing circuit 112₁, 112₂, 112₃, 112₄...112_n for processing signals transmitted from and received by the transceiver circuit 110₁, 110₂, 110₃, 110₄...110_n and for controlling the operation of the corresponding wireless device 104₁, 104₂, 104₃, 104₄...104_n. The transceiver circuit 110₁, 110₂, 110₃, 110₄...110_n may include a transmitter 114₁, 114₂, 114₃, 114₄...114_n and a receiver 116₁, 116₂,
30 116₃, 116₄...116_n, which may operate according to any standard, e.g., the GSM/EDGE standard. The processing circuit 112₁, 112₂, 112₃, 112₄...112_n may include a processor 118₁, 118₂, 118₃, 118₄...118_n and a memory 120₁, 120₂, 120₃,

120₄...120_n for storing program code for controlling the operation of the corresponding wireless device 104₁, 104₂, 104₃, 104₄...104_n. The program code may include code for performing the procedures (e.g., identifying a transport block format of multiple transport block formats included in a common downlink channel; 5 determining values for properties of a transport block format; receiving information common to multiple wireless devices; receiving device-specific information; and identifying, from a transport block format, information allowing unique identification of common information corresponding to device-specific information) as described hereinafter.

10 Each wireless access node 102₁ and 102₂ may include a transceiver circuit 122₁ and 122₂ for communicating with wireless devices 104₁, 104₂, 104₃, 104₄...104_n, a processing circuit 124₁ and 124₂ for processing signals transmitted from and received by the transceiver circuit 122₁ and 122₂ and for controlling the operation of the corresponding wireless access node 102₁ and 102₂, and a network interface 126₁ 15 and 126₂ for communicating with the core network 106 (e.g., via core network nodes such as Serving GPRS Support Nodes (SGSNs) in GPRS or Mobility Management Entity (MMEs) in LTE). The transceiver circuit 122₁ and 122₂ may include a transmitter 128₁ and 128₂ and a receiver 130₁ and 130₂, which may operate according to any standard, e.g., the GSM/EDGE standard. The processing circuit 124₁ and 124₂ 20 may include a processor 132₁ and 132₂ and a memory 134₁ and 134₂ for storing program code for controlling the operation of the corresponding wireless access node 102₁ and 102₂. The program code may include code for performing the procedures (e.g., determining coverage class for one or more wireless devices; determining respective values for properties of different transport block formats; determining 25 different transport block formats for including in a common downlink channel; formatting a common downlink channel to include different transport block formats; identifying/extracting/sending information common to multiple wireless devices; identifying/extracting/sending wireless device-specific information; adding to or formatting transport block formats to include information that allows each of multiple 30 wireless devices to uniquely identify which common information corresponds to its device-specific information; and determining a number of repetitions for transmitting

information to a particular wireless device or group of wireless devices) as described hereinafter.

Technical Features of Present Disclosure

5 In the present disclosure, a scenario of interest is where N wireless devices 104₂, 104₃, 104₄ (for example) are performing procedures during which they are attempting to read information (e.g., messages) on the DL of a common DL channel within the same time interval. It is proposed herein for the wireless access node 102₂ (for example) to determine and utilize/adopt different transport block formats in a
10 common DL control channel to meet the coverage class need of each specific user (e.g., wireless device 104₂) or a group of users (e.g., wireless devices 104₃ and 104₄ with the same coverage class) attempting to read messages on the common DL control channel utilizing the determined different transport block formats, thereby improving bandwidth utilization efficiency on the common DL control channel when
15 compared to the case where the wireless access node simply assumes the wireless devices are in the worst coverage class when utilizing/adopting transport block formats.

 The term “transport block format” used herein refers to the way in which device-related information (e.g., messages) in the common DL channel is transmitted
20 including, but not limited to:

- the number of payload bits (i.e., message information bits) per transport block;
- transport block modulation type;
- transport block coding rate, which affects the number of payload bits per
25 transport block;
- time duration of the transport block (i.e., time interval spanned by the transmitted block); and

- if repetitions are used to achieve a lower transport block coding rate (i.e., allowing more payload bits per transport block), the number of transport block repetitions of a pre-defined format.

5 The term “coverage class” as used herein can be defined as follows: The coverage class of any given wireless device is essentially a measure of its current radio environment such that a wireless device in the worst coverage class supported by the network will need to make use of the most robust transport block format to help ensure that the wireless device remains operational. Conversely, wireless devices in the best
10 coverage class will remain operational when the least robust transport block format is used. Additional transport block formats can be used for wireless devices that experience radio conditions worse than those of wireless devices in the best coverage class. At any point in time a wireless device belongs to a specific coverage class which determines the total number of blind transmissions to be used when receiving radio
15 blocks. A coverage class applicable at any point in time can differ between different logical channels. Upon initiating a system access, a wireless access node determines the coverage class applicable to the RACH/AGCH based on estimating the number of blind repetitions of a radio block needed by the wireless device’s receiver to experience a BLER (block error rate) of approximately 10%. The wireless access node determines
20 the coverage class to be used by a wireless device on its assigned packet channel resources based on estimating the number of blind repetitions of a radio block needed to satisfy a target BLER and considering the number of HARQ retransmissions (of a radio block) that will, on average, result from using that target BLER.

25 Furthermore, in accordance with an alternative technical feature of the present disclosure, if a message normally sent on the common DL channel includes information common to a multiplicity of the wireless devices 104₃ and 104₄ (for example) monitoring that channel and addressed by that same message, it is proposed that the following alternative approach can be used by the wireless access node 102₂
30 (for example) for delivering the message content to the group of wireless devices 104₃ and 104₄ (for example):

- 5 • extract the common information 213 that is applicable to the group of wireless devices 104₃ and 104₄ (for example) from the device-related information 209 and transmit the common information 213 included in a message 215 using a transport block format that all of the addressed wireless devices 104₃ and 104₄ (for example) can decode;
- 10 • extract the device-specific information 217a and 217b from the device-related information 209 and transmit the device-specific information 217a and 217b included in messages 219a and 219b respectively using a transport block format applicable to that respective wireless device 104₃ or 104₄ (for example) alone; and
- 15 • include information 221 in each transport block (message 219a and 219b) including the device-specific information 217a and 217b and in the transport block(s) (message(s) 215) including the common information 213 that allows each wireless device 104₃ and 104₄ (for example) to uniquely identify the transport block(s) (message(s) 215) including the common information 213 that corresponds to the transport block (message 219a and 219b) including its device-specific information.

20 Using this alternative technical feature of sending information to N wireless devices 104₃ and 104₄ (for example) on a common DL channel allows for the use of fewer radio resources when compared to what would be required without such a separation of device-related information.

25 The following are some advantages associated with using the first technical feature (one embodiment) and the alternative technical feature (alternative embodiment) of the present disclosure:

- Efficient usage of common DL channel in the wireless communication network 100.

- Increased number of wireless devices addressable by the same common DL channel per unit of time.
- Ensuring a Block Error Rate (BLER) performance similar to that of a legacy coding scheme CS-1 coded radio block for information received using the new transport block formats.
- Improved wireless device power saving when receiving information addressed to the wireless device on the common DL channel.

The technical features of the present disclosure help to exploit these advantages in various ways, as described in the following examples:

- 10 (a) Optimum resource utilization: as each instance of information transmission consumes some available radio resources (e.g., time slot and frequency), transmitting the needed information using more radio resources than necessary is a waste of these scarce radio resources. As such, transmitting the needed information using device-appropriate transport blocks (messages) per the present disclosure is a preferred way of information transmission. This can be realized, for example, by introducing transport blocks (messages) that have a reduced number of information (i.e., payload) bits per burst compared to legacy operation, wherein for legacy operation the number of information bits per burst is determined based on the assumption that multiple instances of these bursts will be repeated and potentially include information addressing multiple devices. If transport blocks (messages) are instead realized using a single burst (which may be sufficient for cases where a small volume of payload information needs to be sent to a given wireless device) with the intent of the information carried therein only addressing a single wireless device, then better common DL control channel resource usage and capacity improvement becomes possible. This will be especially true for systems where transport block (message) repetitions will range from a single repetition for wireless devices in the best coverage class to X repetitions (e.g., 16) for wireless devices in the worst coverage class.

(b) Wireless device power saving: the disclosed techniques provide a clear advantage of wireless device power saving. For receiving a transport block in GSM, which is referred to as a radio block and transmitted over four bursts (spread over four Time Division Multiple Access (TDMA) frames, each consisting of eight timeslots), a wireless device will typically consume: $V_{cc} * I_{avg} * T = (3.3 \text{ V}) * (50,000 \text{ } \mu\text{A}) * (4 * 577 \text{ } \mu\text{s}) + (3.3 \text{ V}) * (1000 \text{ } \mu\text{A}) * (28 * 577 \text{ } \mu\text{s}) = 434.13 \text{ } \mu\text{J}$. Whereas, for receiving a transport block that is transmitted over a single burst, a wireless device will typically consume: $V_{cc} * I_{avg} * T = (3.3 \text{ V}) * (50,000 \text{ } \mu\text{A}) * (1 * 577 \text{ } \mu\text{s}) = 95.2 \text{ } \mu\text{J}$. Thus, the power saving ratio per transport block will be approximately 4:1.

The term “radio block” is used herein and can be defined as follows: a message is sent using one or more radio blocks where each radio block may be transmitted using multiple repetitions at the physical layer (e.g., a legacy RLC data block is a radio block sent using four bursts). One or more radio blocks are used to send a message where each radio block in the set makes use of the same transport block format (e.g. same modulation scheme, same channel coding scheme, and the same number of repetitions per radio block). The radio resources are shared but are typically used to send a message to one wireless device at a time by including unique information in each radio block header to indicate the intended wireless device. However, the concept of group messaging also exists where information in each radio block header indicates the group of wireless devices for which the message is intended. The case where several messages (each message sent using a set of one or more radio blocks) are addressed to different wireless devices using the group messaging concept is possible but is not very typical, i.e., the more typical concept involves sending a single message to a single wireless device or to a group of wireless devices using a corresponding set of radio blocks.

Referring to FIGURE 2, there is a flowchart of a method 200 implemented in a wireless access node 102₂ (for example) for improving a bandwidth utilization efficiency on a common DL channel when transmitting device-related information to a wireless device 104₂ (for example) or a group of wireless devices 104₃ and 104₄ (for example) in accordance with an embodiment of the present disclosure. At step 202, the

wireless access node 102₂ determines one or more transport block formats to be utilized for transmitting the device-related information on the common DL channel to the wireless device 104₂ or the group of wireless devices 104₃ and 104₄, wherein the one or more transport block formats meet a coverage class need of the wireless device 104₂ or the group of wireless devices 104₃ and 104₄ (e.g., the wireless devices 104₃ and 104₄ have the same coverage class).

In one embodiment, the wireless access node 102₂ has device-related information 205 for the wireless device 104₂. In this case, the wireless access node 102₂ at step 204 transmits a message 207 including the device-related information 205 to the wireless device 104₂ utilizing one of the one or more transport block formats specifically determined based at least in part on the coverage class need of the wireless device 104₂ (illustrated in FIGURE 1). As an example, if the wireless device 104₂ has a coverage class of "1" then the wireless access node 102₂ would determine a transport block format to be utilized specifically for the wireless device 104₂ that has a specific number of payload bits, modulation type, coding rate, time duration etc... and no repetitions based at least in part on the coverage class "1" (e.g., the coverage class "1" corresponds to an initial transmission and no repetitions). The wireless access node 102₂ then transmits the message 207 including the device-related information 205 to the wireless device 104₂ utilizing the determined transport block format (illustrated in FIGURE 1).

In the same embodiment, the wireless access node 102₂ has device-related information 209 for the group of wireless devices 104₃ and 104₄. In this case, the wireless access node 102₂ at step 204 transmits a message 211 including the device-related information 209 to the group of wireless devices 104₃ and 104₄ utilizing one of the one or more transport block formats specifically determined based at least in part on the coverage class need of the group of wireless devices 104₃ and 104₄ (illustrated in FIGURE 1). As an example, if the group of wireless devices 104₃ and 104₄ have a coverage class of "2" then the wireless access node 102₂ would determine a transport block format to be utilized specifically for the the group of wireless devices 104₃ and 104₄ that has a specific number of payload bits, modulation type, coding rate, time duration etc... and one repetition based at least in part on the coverage class "2" (e.g., the coverage class "2" corresponds to an initial transmission and one repetition). The

wireless access node 102₂ then transmits the message 211 including the device-related information 209 to the group of wireless devices 104₃ and 104₄ utilizing the determined transport block format (illustrated in FIGURE 1).

In an alternative embodiment, the wireless access node 102₂ has device-related
5 information 209 for the group of wireless devices 104₃ and 104₄, and the wireless
access node 102₂ instead of performing step 204 could perform steps 206, 208, 210,
212 and 214. More specifically, in this alternative embodiment, the wireless access
node 102₂ at step 202 determines a plurality of transport block formats to be utilized
10 for transmitting the device-related information 209 on the common DL channel to the
group of wireless devices 104₃ and 104₄. The wireless access node 102₂ at step 206
would identify common information 213 included in the device-related information
209 applicable to the group of wireless devices 104₃ and 104₄, and transmit at step 208
a message 215 including the common information 213 to the group of wireless devices
15 104₃ and 104₄ utilizing one of the plurality of transport block formats that is decodable
by the group of wireless devices 104₃ and 104₄ (illustrated in FIGURE 1). Further, the
wireless access node 102₂ would identify at step 210 device-specific information 217a
and 217b included in the device-related information 209 applicable to each individual
wireless device 104₃ and 104₄ in the group of wireless devices 104₃ and 104₄, and
20 transmit at step 212 individual messages 219a and 219b including the device-specific
information 217a and 217b to the respective individual wireless devices 104₃ and 104₄
utilizing more than one of the plurality of transport block formats that are applicable to
the respective individual wireless devices 104₃ and 104₄ (illustrated in FIGURE 1). It
is to be noted that the transport block format utilized to transmit the message 215
25 including the common information 213 to the group of wireless devices 104₃ and 104₄
can be the same as or different from at least one of the transport block formats utilized
to transmit the individual messages 219a and 219b including the device-specific
information 217a and 217b to the respective individual wireless devices 104₃ and 104₄.
If desired, the wireless access node 102₂ at step 214 can add information 221 in the
30 message 215 including the common information 213 and in each of the individual
messages 219a and 219b including the device-specific information 217a and 217b
that enables each of the individual wireless devices 104₃ and 104₄ to uniquely identify
the message 215 including the common information 213 that corresponds to its

respective individual message 219a and 219b including the device-specific information 217a and 217b.

As an example, if the wireless devices 104₃ and 104₄ each have a coverage class of “2” then the wireless access node 102₂ would determine a transport block format to be utilized specifically for the wireless devices 104₃ and 104₄ that has a specific number of payload bits for the common information 213, modulation type, coding rate, time duration etc... and one repetition based at least in part on the coverage class “2” (e.g., the coverage class “2” corresponds to an initial transmission and one repetition). In addition, the wireless access node 102₂ would determine a transport block format to be utilized specifically for the wireless device 104₃ that has a specific number of payload bits for the device-specific information 217a, modulation type, coding rate, time duration etc... and one repetition based at least in part on the coverage class “2”. Plus, the wireless access node 102₂ would determine a transport block format to be utilized specifically for the wireless device 104₄ that has a specific number of payload bits for the device-specific information 217b, modulation type, coding rate, time duration etc... and one repetition based at least in part on the coverage class “2”. The wireless access node 102₂ then transmits the message 215 including the common information 213 (possibly including the added information 221) to the wireless devices 104₃ and 104₄ utilizing the specially determined transport block format (illustrated in FIGURE 1). Plus, the wireless access node 102₂ would transmit the message 219a including the device-specific information 217a (possibly including the added information 221) to the wireless device 104₃ utilizing the specially determined transport block format (illustrated in FIGURE 1). It is to be noted that the transport block formats used to transmit the messages 215 and 219a can be the same or different. Finally, the wireless access node 102₂ would transmit the message 219b including the device-specific information 217b (possibly including the added information 221) to the wireless device 104₄ utilizing the specially determined transport block format (illustrated in FIGURE 1). It is to be noted that the transport block formats used to transmit the messages 215 and 219b can be the same or different.

Referring to FIGURE 3, there is a block diagram illustrating structures of an exemplary wireless access node 102₂ (for example) for improving a bandwidth utilization efficiency on a common DL channel when transmitting device-related information to a wireless device 104₂ (for example) or a group of wireless devices 104₃ and 104₄ (for example) in accordance with an embodiment of the present disclosure. The wireless access node 102₂ may comprise a determine module 302, a first transmit module 304, a first identify module 306, a second transmit module 308, a second identify module 310, a third transmit module 312, and an add module 314. The determine module 302 is configured to determine one or more transport block formats to be utilized for transmitting the device-related information on the common DL channel to the wireless device 104₂ or the group of wireless devices 104₃ and 104₄, wherein the one or more transport block formats meet a coverage class need of the wireless device 104₂ or the group of wireless devices 104₃ and 104₄. In one embodiment, if the wireless access node 102₂ has device-related information 205 for the wireless device 104₂, then the first transmit module 304 is configured to transmit a message 207 including the device-related information 205 to the wireless device 104₂ utilizing one of the one or more transport block formats specifically determined based at least in part on the coverage class need of the wireless device 104₂ (illustrated in FIGURE 1). In the same embodiment, if the wireless access node 102₂ has device-related information 209 for the group of wireless devices 104₃ and 104₄ (e.g., having the same coverage class), then the first transmit module 304 is configured to transmit a message 211 including the device-related information 209 to the group of wireless devices 104₃ and 104₄ utilizing one of the one or more transport block formats specifically determined based at least in part on the coverage class need of the group of wireless devices 104₃ and 104₄ (illustrated in FIGURE 1).

The determine module 302 may determine a plurality of transport block formats to be utilized for transmitting the device-related information 209 on the common DL channel to the group of wireless devices 104₃ and 104₄. In an alternative embodiment, if the wireless access node 102₂ has device-related information 209 for the group of wireless devices 104₃ and 104₄, then the first identify module 306 is configured to identify common information 213 included in the device-related information 209 for the group of wireless devices 104₃ and 104₄, and the second

transmit module 308 is configured to transmit a message 215 including the common information 213 to the group of wireless devices 104₃ and 104₄ utilizing one of the plurality of transport block formats that is decodable by the group of wireless devices 104₃ and 104₄ (illustrated in FIGURE 1). Further, the second identify module 310 is configured to identify device-specific information 217a and 217b included in the device-related information 209 applicable to each individual wireless device 104₃ and 104₄ in the group of wireless devices 104₃ and 104₄, and the third transmit module 312 is configured to transmit individual messages 219a and 219b including the device-specific information 217a and 217b to the respective individual wireless devices 104₃ and 104₄ utilizing more than one of the plurality of transport block formats that are applicable to the respective individual wireless devices 104₃ and 104₄ (illustrated in FIGURE 1). It is to be noted that the transport block format utilized to transmit the message 215 including the common information 213 to the group of wireless devices 104₃ and 104₄ can be the same as or different from the transport block formats utilized to transmit the individual messages 219a and 219b including the device-specific information 217a and 217b to the respective individual wireless devices 104₃ and 104₄. The add module 314 is configured to add information 221 in the message 215 including the common information 213 and in each of the individual messages 219a and 219b including the device-specific information 217a and 217b that enables each of the individual wireless devices 104₃ and 104₄ to uniquely identify the message 215 including the common information 213 that corresponds to its respective individual message 219a and 219b including the device-specific information 217a and 217b.

As those skilled in the art will appreciate, the above-described modules 302, 304, 306, 308, 310, 312, and 314 of the wireless access node 102₂ may be implemented separately as suitable dedicated circuits. Further, the modules 302, 304, 306, 308, 310, 312, and 314 can also be implemented using any number of dedicated circuits through functional combination or separation. In some embodiments, the modules 302, 304, 306, 308, 310, 312, and 314 may be even combined in a single application specific integrated circuit (ASIC). As an alternative software-based implementation, the wireless access node 102₂ may comprise a memory 134₂, a processor 132₂ (including but not limited to a microprocessor, a microcontroller or a Digital Signal Processor

(DSP), etc.) and a transmitter 128₂. The memory 134₂ stores machine-readable program code executable by the processor 132₂ that cause the wireless access node 102₂ to perform the steps of the above-described method 200. It is to be noted that the wireless access nodes 102₁ and 102₂ and other wireless access nodes can be configured to
5 implement the above-described method 200.

Referring to FIGURE 4, there is a flowchart of a method 400 implemented in a wireless device 104₂, 104₃ or 104₄ (for example) for improving a bandwidth utilization efficiency on a common DL channel when receiving device-related information from a
10 wireless access node 102₂ (for example) in accordance with an embodiment of the present disclosure. At step 402, the wireless device 104₂, 104₃ or 104₄ receives one or more messages 207, 211, 215, 219a and 219b including the device-related information on the common DL channel from the wireless access node 102₂, wherein the one or more messages 207, 211, 215, 219a and 219b have one or more transport block formats
15 that meet a coverage class need of the wireless device 104₂, 104₃ or 104₄. In one embodiment, the wireless device 104₂ receives at step 402a the device-related information 205 included in message 207 having one transport block format based at least in part on the coverage class of the wireless device 104₂. In the same embodiment, the wireless device 104₃ receives at step 402a the device-related
20 information 209 included in message 211 having one transport block format based at least in part on the coverage class of the wireless device 104₃.

At step 402, the wireless device 104₂, 104₃ or 104₄ may receive a plurality of messages including the device-related information, wherein the plurality of messages has a plurality of transport block formats. In an alternative embodiment, the wireless
25 device 104₃ receives at step 402b the common information 213 included in message 215 having one of the plurality of transport block formats based at least in part on the coverage class of the wireless device 104₃. In addition, the wireless device 104₃ receives at step 402c the device-specific information 217a included in message 219a having one of the plurality of transport block formats based at least in part on the
30 coverage class of the wireless device 104₃. It is to be noted that the transport block formats used for messages 215 and 219a can be the same or different. Plus, the wireless device 104₃ at step 402d identifies information 221 in the message 215

including the common information 213 and the message 219a including the device-specific information 217a that enables the wireless device 104₃ to uniquely identify the message 215 including the common information 213 that corresponds to the message 219a including the device-specific information 217a. In one embodiment, 5 the wireless devices 104₄ receives at step 402a the device-related information 209 included in message 211 having one transport block format based at least in part on the coverage class of the wireless device 104₄. In an alternative embodiment, the wireless device 104₄ receives at step 402b the common information 213 included in message 215 having one of the plurality of transport block formats based at least in part on the 10 coverage class of the wireless device 104₄. In addition, the wireless device 104₄ receives at step 402c the device-specific information 217b included in message 219b having one of the plurality of transport block formats based at least in part on the coverage class of the wireless device 104₄. It is to be noted that the transport block formats used for messages 215 and 219b can be the same or different. Plus, the 15 wireless device 104₄ at step 402d identifies information 221 in the message 215 including the common information 213 and the message 219b including the device-specific information 217b that enables the wireless device 104₄ to uniquely identify the message 215 including the common information 213 that corresponds to the message 219b including the device-specific information 217b.

20 Referring to FIGURE 5, there is a block diagram illustrating structures of an exemplary wireless device 104₂, 104₃ or 104₄ (for example) for improving a bandwidth utilization efficiency on a common DL channel when receiving device-related information from the wireless access node 102₂ (for example) in accordance with an embodiment of the present disclosure. The wireless device 104₂, 104₃ or 104₄ (for 25 example) may comprise a receive module 502, a first receive module 502a, a second receive module 502b, a third receive module 502c, and an identify module 502d. The receive module 502 is configured to receive one or more messages 207, 211, 215, 219a and 219b including the device-related information on the common DL channel from the wireless access node 102₂, wherein the one or more messages 207, 211, 215, 219a and 30 219b have one or more transport block formats that meet a coverage class need of the wireless device 104₂, 104₃ or 104₄. In one embodiment, the wireless device 104₂ comprises the first receive module 502a that is configured to receive the device-related

information 205 included in message 207 having one transport block format based at least in part on the coverage class of the wireless device 104₂. In one embodiment, the wireless device 104₃ comprises the first receive module 502a that is configured to receive the device-related information 209 included in message 211 having one
5 transport block format based at least in part on the coverage class of the wireless device 104₃.

The receive module 502 may receive a plurality of messages including the device-related information, wherein the plurality of messages has a plurality of transport block formats. In an alternative embodiment, the wireless device 104₃
10 comprises the second receive module 502b that is configured to receive the common information 213 included in message 215 having one of the plurality of transport block formats based at least in part on the coverage class of the wireless device 104₃. In addition, the wireless device 104₃ comprises the third receive module 502c that is configured to receive the device-specific information 217a included in message 219a
15 having one of the plurality of transport block formats based at least in part on the coverage class of the wireless device 104₃. It is to be noted that the transport block formats used for messages 215 and 219a can be the same or different. Plus, the wireless device 104₃ comprises the identify module 502d that is configured to identify information 221 in the message 215 including the common information 213 and the
20 message 219a including the device-specific information 217a that enables the wireless device 104₃ to uniquely identify the message 215 including the common information 213 that corresponds to the message 219a including the device-specific information 217a.

In one embodiment, the wireless device 104₄ comprises the first receive module
25 502a that is configured to receive the device-related information 209 included in message 211 having one transport block format based at least in part on the coverage class of the wireless device 104₃. In an alternative embodiment, the wireless device 104₄ comprises the second receive module 502b that is configured to receive the common information 213 included in message 215 having one of the plurality of
30 transport block formats based at least in part on the coverage class of the wireless device 104₄. In addition, the wireless device 104₄ comprises the third receive module 502c that is configured to receive the device-specific information 217b included in

message 219b having one of the plurality of transport block formats based at least in part on the coverage class of the wireless device 104₄. It is to be noted that the transport block formats used for messages 215 and 219b can be the same or different. Plus, the wireless device 104₄ comprises the identify module 502d that is configured to
5 identify information 221 in the message 215 including the common information 213 and the message 219b including the device-specific information 217b that enables the wireless device 104₄ to uniquely identify the message 215 including the common information 213 that corresponds to the message 219b including the device-specific information 217b.

10 As those skilled in the art will appreciate, the above-described modules 502, 502a, 502b, 502c and 502d of the wireless device 104₂, 104₃ or 104₄ (for example) may be implemented separately as suitable dedicated circuits. Further, the modules 502, 502a, 502b, 502c and 502d can also be implemented using any number of dedicated circuits through functional combination or separation. In some embodiments,
15 the modules 502, 502a, 502b, 502c and 502d may be even combined in a single application specific integrated circuit (ASIC). As an alternative software-based implementation, the wireless device 104₂, 104₃ or 104₄ (for example) may comprise a memory 120₂, 120₃ and 120₄, a processor 118₂, 118₃ and 118₄ (including but not limited to a microprocessor, a microcontroller or a Digital Signal Processor (DSP),
20 etc.) and receiver 116₂, 116₃ and 116₄. The memory 120₂, 120₃ and 120₄ stores machine-readable program code executable by the processor 118₂, 118₃ and 118₄ that cause the wireless device 104₂, 104₃ or 104₄ (for example) to perform the steps of the above-described method 400. It is to be noted that the wireless devices 104₁, 104₂, 104₃, 104₄...104_n and other wireless devices can be configured to implement the
25 above-described method 400.

Application to GSM wireless communication network

1. Paging Channel (PCH)

30 In one embodiment, the above techniques are applied to the GSM wireless communication network and the PCH channel, part of the CCCH in the DL. The current PCH can at most carry paging-related information to four wireless devices

addressed within a PCH message. The default transport block format used by GSM today for sending PCH messages is known as a radio block, containing 23 octets of payload space (mapped into 456 bits after cyclic redundancy check (CRC) addition and encoding). A radio block consists of four normal bursts, each occupying one timeslot in the TDMA frame structure in GSM. Furthermore, the transport block format consists of using Gaussian Minimum Shift Keying (GMSK) modulation and a code rate provided by coding scheme CS-1 to convey the information to the wireless devices.

In the following discussion, it is assumed that the changes to the legacy transport block format needed for the new transport block format proposed pursuant to the present disclosure involves:

1. Reduced time duration from a four burst radio block to as little as a single burst radio block.
2. Reduced payload information per transport block. Different mechanisms may be used to reduce the size of PCH messages. For example, the 'type of identity' in a paging message may be fixed to a Packet Temporary Mobile Station Identity (P-TMSI). As Temporary Mobile Station Identity (TMSI) is 32 bits only, only 32 bits will be needed in the Mobile Identity information element field (e.g., 'MS identity' in paging message) to address the MS using P-TMSI. Thus, using P-TMSI will help to reduce the total number of information bits that need to be carried within the transport block.
3. Allowing for a variable number of transport block repetitions to reflect the radio channel conditions specific to each of the N wireless devices to be paged. It is to be noted that it is possible to adapt the number of transport block repetitions dynamically, for example, according to device-specific radio channel quality (e.g., detected or based on ongoing device-specific feedback received) or according to a fixed coverage class associated with a given wireless device.

2. PCH Example

The following properties of the transport block format are assumed to be the same for this example as for the current (i.e., legacy) PCH:

1. Modulation used (i.e., GMSK)
- 5 2. Code rate used (i.e., around 1/2). It is assumed that a one burst radio block and a four burst radio block of roughly the same code rate provide roughly the same performance. This is supported by the simulation results illustrated in the graph shown in FIGURE 6 where the performance of a four burst radio block carrying 184 information bits is compared to a one burst radio block carrying different amounts of information bits. The results were simulated over a slowly moving, non-hopping channel with a Doppler spread of around
10 1 Hz.

Further, it is assumed that the four users (wireless devices) multiplexed in the current PCH block need 1, 4, 8, and 2 repetitions, respectively, for user 1, 2, 3, and 4.

- 15 Hence, the current PCH consisting of 4 bursts per radio block transmitted needs to be transmitted 8 times to ensure the decoding (i.e., reception performance) of user 3 (i.e., the user with the worst radio channel conditions, in this example), and hence, in total $8*4 = 32$ normal bursts need to be transmitted. If instead, the modulation and code rate above are followed, but within the context of the new
20 device-specific transport block format techniques described in the present disclosure, then the same information could be carried with $1+4+8+2=15$ bursts. Hence, a bandwidth reduction of 53% is achieved.

- More detailed simulations have also been performed where the probability of a wireless device needing extended coverage (i.e., more than a single repetition) is
25 assumed to be 20%, and within that 20%, the number of repetitions needed for different levels of extended coverage is:

- 10%: 2 transmissions

- 5%: 4 transmissions
- 3%: 8 transmissions
- 2%: 16 transmissions

In the case of using the disclosed techniques proposed in the present disclosure, the average resource utilization is: $(0.8 * 1 \text{ burst}) + [(0.1 * 2 \text{ bursts}) + (0.05 * 4 \text{ bursts}) + (0.03 * 8 \text{ bursts}) + (0.02 * 16 \text{ bursts})] = 1.76$ bursts. However, if assuming multiplexing of four users (wireless devices) in the same paging block as per current operation (i.e., the Broadcast Control Channel (BCCH) makes no attempt to address wireless devices of the same or similar coverage class within the same paging block), then the corresponding resource utilization, when using the current 4 burst PCH block, is 3.7 bursts. Even though users (wireless devices) needing 16 repetitions are rare in the system, these users will, when paired with three other users in the same block, most probably be paired with users needing only a single repetition. For those users needing only a single repetition, the number of repetitions used is a vast waste of radio resources. In this example, the bandwidth saving with the new transport block formats of the present disclosure is around 53%.

The use of the new transport block formats pursuant to the present disclosure will effectively generate a quadrupling of the number of paging groups associated with any given coverage class for any given Discontinuous Reception (DRX) cycle, since repetitions will be performed on the burst level instead of at the radio block level. For example, a wireless device needing eight repetitions and using a DRX cycle of approximately one minute will result in the following:

- DRX cycle = 256 51-multiframes \sim 60 sec (208 DRX cycles within the overall frame number (FN) space).
- PCH blocks (4 bursts each) per DRX cycle = $PB_DRX_CYCLE = 256 * 8 = 2048$.
- Paging groups per DRX cycle = $PG_DRX_CYCLE = (PB_DRX_CYCLE * 4) / 8 = 1024$.

- No inherent difficulty is seen to arise from a paging group perspective when using the new burst based transport block format described herein.

3. Managing Common Information on the PCH

PCH messages currently contain information common to all wireless devices including the set of N wireless devices to be paged within that PCH message (e.g., implicit reject information and Earthquake and Tsunami Warning System (ETWS) information) as well as device-specific information (e.g., MS identification such as P-TMSI). If the common information is not sent separately from the device-specific information, then together their payload space could be large enough to need a reduced channel coding rate for the transport blocks used to send them, and thereby result in a reduced BLER performance for these transport blocks, as illustrated in FIGURE 6. As such, from a transport block BLER perspective, it may be beneficial if the common information is sent using transport blocks separate from transport blocks used to send the N instances of device-specific information as described in the present disclosure. This can be realized, for example, using one or more of the technical features of the present disclosure as follows:

- Identify the common information applicable to a set of N wireless devices that need to be paged and send the common information using a transport block format that all N devices can decode;
- Send each of the N instances of device-specific information using an applicable transport block format. The device-specific information could also include, for example, a flag indicating whether or not the wireless device needs to still acquire common information, since the common information could be semi-static and therefore may not have changed since the last time the common information was read by the wireless device; and
- Include information in each of the transport block formats used to send the device-specific information and in the transport block format used to send the common information that enables each of the N wireless devices to uniquely

identify which common information corresponds to its device-specific information.

Using the previous example where four users (wireless devices) are to be
5 paged and respectively need 1, 4, 8, and 2 repetitions, there will be 15 transport
blocks including device-specific information and 8 transport blocks including the
common information, where all 23 transport blocks (bursts) maintain payload space
specific transport block BLER performance, as illustrated in FIGURE 6. This is still a
large improvement (i.e., 28% fewer bursts needed) compared to the 32 bursts that
10 would need to be transmitted using the legacy transport block format, wherein each
PCH block consists of 4 bursts and is repeated 8 times.

3.1 Management of PCH Resources

In today's GSM wireless communication network, the base station (BS)
needs to send valid layer 3 messages continuously on all paging sub-channels on the
15 CCCH. However, when wireless devices of different coverage classes monitor the
same physical resource for layer 3 messages, it might turn out that wireless device B
of a device class experiencing better coverage than the corresponding class for
wireless device A (i.e., implying, for example, that less repetitions are needed to
reach the wireless device B) is sent a layer 3 message using one or more radio blocks
20 that include radio block(s) of wireless device A's paging group. Although these
paging messages will not include a layer 3 message addressing wireless device A, it is
of interest for wireless device A to decode the radio block sent from the BS to get a
confirmation that wireless device A is still connected to a suitable cell and that
wireless device A is still monitoring a correct CCCH. However, wireless device A
25 will not be able to correctly decode the radio block unless the radio block is
transmitted using a sufficiently high number of repetitions.

3.2 Overload Control Management Using PCH Resources

In addition, wireless devices may still need to be subject to an overload
control mechanism, e.g., the legacy Implicit Reject feature, in which the wireless
30 devices first need to read a PCH/Access Grant Channel (AGCH) message (sent to any

wireless device) to obtain access permission related information prior to attempting a system access.

When sending information on a CCCH, the network takes into account wireless devices associated with the highest coverage class (e.g., needing 16 repetitions) since these wireless devices may be monitoring the channel. This can be realized by ensuring a certain minimum periodicity with which this information (e.g., overload control, valid Layer 3 header) is sent using the transport formats needed by these wireless devices. For example, the network can periodically send Implicit Reject information as common information using a transport block format appropriate for 16 repetitions regardless of whether or not the network needs to send information to any specific high coverage class wireless device at that point in time.

4. Access Grant Channel (AGCH)

Support for new transport block formats used for sending messages on the AGCH per the present disclosure can be realized in the same manner as described above for PCH messages, since the same payload volume dependent BLER performance applies as illustrated in FIGURE 6. One difference may be that the volume of common information associated with an AGCH message sent using legacy procedures can be expected to be significantly larger than for a PCH message. As such, for the AGCH case, there may be an even greater incentive for sending common information (i.e., information applicable to a set of N wireless devices looking for an AGCH message) using a transport block format that all N wireless devices can decode per the present disclosure.

5. Packet Timing Control Channel/Downlink (PTCCH/D)

In one embodiment, the above techniques of the present disclosure can be applied to the PTCCH/D channel, which is used to support the Continuous Timing Advance (TA) procedure in GSM for all wireless devices (MSs) in packet transfer mode, as described in 3GPP TS 45.010 V11.0.0, entitled "Technical Specification Group GSM/EDGE Radio Access Network; Radio subsystem synchronization (Release 11)." The contents of this document are hereby incorporated by reference.

The PTCCH/D can at most carry eight bits of TA related information to 16 wireless devices (users) addressed by the same radio block. The default transport

block format used by GSM today is to transmit the PTCCH/D over a radio block consisting of four normal bursts, each occupying one timeslot distributed evenly over two 52-multi-frames. The transport block format consists of using GMSK modulation and a code rate provided by coding scheme CS-1 to convey the information to the wireless device's receiver.

However, per the present disclosure, the transmit time duration of the PTCCH/D is reduced from a four burst radio block to a single burst radio block. In the single burst format, at least four wireless devices (users) using eight bits of TA information can be addressed. Over four bursts, the numbers of addressed wireless devices (users) are at least 16, as today.

In another embodiment of the present disclosure, up to six users using eight bits of TA information can be supported per burst, with the same code rate as today (i.e., as defined by coding scheme CS-1). The simulation results illustrated in FIGURE 6 for the PCH are applicable also to the PTCCH/D.

In another embodiment of the present disclosure, where less than eight bits of TA information are transmitted per wireless device (user), the code rate can be made more robust than coding scheme CS-1 to improve link level performance, and/or to lower the number of repetitions needed in an extended coverage scenario. Alternatively, the number of wireless devices (users) supported by a single burst can be extended beyond six.

In yet another embodiment of the present disclosure, the number of repetitions for the single burst format used in an extended coverage scenario is adapted, e.g., according to the need of the wireless devices (users) addressed in the single burst format. Groupings of wireless devices (users) with similar or the same coverage class needs will minimize the total number of burst transmissions in the Continuous TA procedure.

In contrast to the PTCCH/D block multiplexing scheme used today, where each wireless device assigned the same physical channel (i.e., where the PTCCH/D is mapped) monitors each PTCCH/D block on that channel, the PTCCH/D channel when mixing wireless devices (users) of different coverage classes will have to be assigned such that wireless devices know or can determine which radio resources are applicable and with which periodicity the radio resources should be read.

An alternative approach to realizing PTCCH/D for extended coverage in accordance with the present disclosure is to provide an update interval of the TA information, for example, according to the worst coverage class wireless devices. In one example, the worst coverage class needs 16 repetitions. In this case, each PTCCH block (addressing all wireless devices as per current operation) may only change TA information every 16th PTCCH/D block interval.

Summary

A scenario addressed by the present disclosure is where N wireless devices are performing procedures during which the N wireless devices are attempting to read information (e.g., messages) on the DL of a common channel within the same time interval and the network introduces new transport block formats in the DL of a common channel to send the N wireless devices information (e.g., messages) in a way that satisfies the specific coverage class needs of these N wireless devices and that will result in the ability to realize a significantly improved utilization of the bandwidth available on the common DL channel when compared to the case where the wireless devices are simply assumed to be in the worst coverage class. In addition, another scenario discussed herein considers the case where information that is common to all N wireless devices is identified and sent using transport blocks that are separate from transport blocks used to send device-specific information, thereby allowing the use of fewer radio resources when compared to what would be required without such separation of information. Finally, an improved power saving for wireless devices reading the common channel can be realized since the use of these new transport formats results in fewer bursts being read and processed, especially for the wireless devices in the best coverage class (e.g., coverage class 1 wherein only a single initial transmission/reception is needed).

Those skilled in the art will appreciate that the use of the term “exemplary” is used herein to mean “illustrative,” or “serving as an example,” and is not intended to imply that a particular embodiment is preferred over another or that a particular feature is essential. Likewise, the terms “first” and “second,” and similar terms, are used simply to distinguish one particular instance of an item or feature from another, and do not indicate a particular order or arrangement, unless the context clearly

indicates otherwise. Further, the term “step,” as used herein, is meant to be synonymous with “operation” or “action.” Any description herein of a sequence of steps does not imply that these operations must be carried out in a particular order, or even that these operations are carried out in any order at all, unless the context or the
5 details of the described operation clearly indicates otherwise.

Of course, the present disclosure may be carried out in other specific ways than those herein set forth without departing from the scope and essential characteristics of the invention. One or more of the specific processes discussed above may be carried out in a cellular phone or other communications transceiver
10 comprising one or more appropriately configured processing circuits, which may in some embodiments be embodied in one or more application-specific integrated circuits (ASICs). In some embodiments, these processing circuits may comprise one or more microprocessors, microcontrollers, and/or digital signal processors programmed with appropriate software and/or firmware to carry out one or more of
15 the operations described above, or variants thereof. In some embodiments, these processing circuits may comprise customized hardware to carry out one or more of the functions described above. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

Although multiple embodiments of the present disclosure have been illustrated
20 in the accompanying Drawings and described in the foregoing Detailed Description, it should be understood that the invention is not limited to the disclosed embodiments, but instead is also capable of numerous rearrangements, modifications and substitutions without departing from the present disclosure that as has been set forth and defined within the following claims.

25

CLAIMS:

1. A wireless access node (102₁, 102₂) configured to improve a bandwidth utilization efficiency on a common downlink (DL) channel when transmitting device-related information (205, 209) to a wireless device (104₂) or a group of wireless devices (104₃, 104₄), the wireless access node comprising:
5 a processor (132₁, 132₂); and,
a memory (134₁, 134₂) that stores processor-executable instructions, wherein the processor interfaces with the memory to execute the processor-executable
10 instructions, whereby the wireless access node is operable to determine (202) one or more transport block formats to be utilized for transmitting the device-related information on the common DL channel to the wireless device or the group of wireless devices, wherein the one or more transport block formats meet a coverage class need of the wireless device or the group of wireless devices.
15
2. The wireless access node of claim 1, wherein the wireless access node is further operable to:
transmit (204) a message (207, 211) including the device-related information
to the wireless device or the group of wireless devices utilizing one of the one or more
20 transport block formats.
3. The wireless access node of claim 1, wherein a plurality of transport block formats is determined to be utilized for transmitting the device-related information on the common DL channel to the group of wireless devices, and wherein
25 the wireless access node is further operable to:
identify (206) common information (213) included in the device-related information applicable to the group of wireless devices, and transmit (208) a message (215) including the common information to the group of wireless devices utilizing one of the plurality of transport block formats that is decodable by the group of wireless
30 devices; and,
identify (210) device-specific information (217a, 217b) included in the device-related information applicable to each individual wireless device in the group of

wireless devices, and transmit (212) individual messages (219a, 219b) including the device-specific information to the respective individual wireless devices utilizing more than one of the plurality of transport block formats that are applicable to the respective individual wireless devices.

5

4. The wireless access node of claim 3, wherein the one of the plurality of transport block formats utilized to transmit the message including the common information to the group of wireless devices is the same as at least one of the more than one of the plurality of transport block formats utilized to transmit the individual
10 messages including the device-specific information to the respective individual wireless devices.

5. The wireless access node of claim 3, wherein the wireless access node, before transmitting the message including the common information and before
15 transmitting the individual messages including the device-specific information, is further operable to:

add (214) information (221) in the message including the common information and in each of the individual messages including the device-specific information, wherein the added information enables each of the individual wireless
20 devices to uniquely identify the message including the common information that corresponds to its respective individual message including the device-specific information.

6. A method (200) in a wireless access node (102₁, 102₂) for improving a
25 bandwidth utilization efficiency on a common downlink (DL) channel when transmitting device-related information (205, 209) to a wireless device (104₂) or a group of wireless devices (104₃, 104₄), the method comprising:

determining (202) one or more transport block formats to be utilized for transmitting the device-related information on the common DL channel to the wireless
30 device or the group of wireless devices, wherein the one or more transport block formats meet a coverage class need of the wireless device or the group of wireless devices.

7. The method of claim 6, further comprising:

transmitting (204) a message (207, 211) including the device-related information to the wireless device or the group of wireless devices utilizing one of the one or more transport block formats.

8. The method of claim 6, wherein a plurality of transport block formats is determined to be utilized for transmitting the device-related information on the common DL channel to the group of wireless devices, and the method further comprises:

identifying (206) common information (213) included in the device-related information applicable to the group of wireless devices, and transmitting (208) a message (215) including the common information to the group of wireless devices utilizing one of the plurality of transport block formats that is decodable by the group of wireless devices; and,

identifying (210) device-specific information (217a, 217b) included in the device-related information applicable to each individual wireless device in the group of wireless devices, and transmitting (212) individual messages (219a, 219b) including the device-specific information to the respective individual wireless devices utilizing more than one of the plurality of transport block formats that are applicable to the respective individual wireless devices.

9. The method of claim 8, wherein the one of the plurality of transport block formats utilized to transmit the message including the common information to the group of wireless devices is the same as at least one of the more than one of the plurality of transport block formats utilized to transmit the individual messages including the device-specific information to the respective individual wireless devices.

10. The method of claim 8, wherein before transmitting the message including the common information and the individual messages including the device-specific information, the method further comprises:

adding (214) information (221) in the message including the common information and in each of the individual messages including the device-specific information, wherein the added information enables each of the individual wireless devices to uniquely identify the message including the common information that
5 corresponds to its respective individual including containing the device-specific information.

11. A wireless device (104₁, 104₂, 104₃, 104₄...104_n) configured to improve a bandwidth utilization efficiency on a common downlink (DL) channel when
10 receiving device-related information (205, 209) from a wireless access node (102₁, 102₂), the wireless device comprising:

a processor (118₁, 118₂, 118₃, 118₄...118_n); and,

a memory (120₁, 120₂, 120₃, 120₄...120_n) that stores processor-executable instructions, wherein the processor interfaces with the memory to execute the
15 processor-executable instructions, whereby the wireless device is operable to receive (402) one or more messages (207, 211, 215, 219a, 219b) including the device-related information on the common DL channel from the wireless access node, wherein the one or more messages have one or more transport block formats that meet a coverage class need of the wireless device.

20

12. The wireless device of claim 11, wherein the wireless device is further operable to:

receive (402a) the device-related information (205, 209) included in one
(207, 211) of the one or more messages having one of the one or more transport block
25 formats.

13. The wireless device of claim 11, wherein a plurality of messages including the device-related information is received, wherein the plurality of messages has a plurality of transport block formats, wherein the device-related information (209)
30 includes (1) common information (213) applicable to the wireless device and one or more other wireless devices, and (2) device-specific information (217a, 217b)

applicable to the wireless device, and wherein the wireless device is further operable to:

receive (402b) the common information included in one (215) of the plurality of messages having one of the plurality of transport block formats; and

5 receive (402c) the device-specific information included in another one (219a, 219b) of the plurality of messages having one of the plurality of transport block formats.

14. The wireless device of claim 13, wherein the one of the plurality of
10 transport block formats utilized to transmit the one of the plurality of messages including the common information is the same as the one of the plurality of transport block formats utilized to transmit the one of the plurality of messages including the device-specific information.

15 15. The wireless device of claim 13, wherein the wireless device is further operable to:

identify (402d) information (221) in the one of the plurality of messages including the common information and the one of the plurality of messages including the device-specific information, where the identified information uniquely identifies
20 the one of the plurality of messages including the common information that corresponds to the one of the plurality of messages including the device-specific information.

16. A method (400) in a wireless device (104₁, 104₂, 104₃, 104₄...104_n) for
25 improving a bandwidth utilization efficiency on a common downlink (DL) channel when receiving device-related information (205, 209) from a wireless access node (102₁, 102₂), the method comprising:

receiving (402) one or more messages (207, 211, 215, 219a, 219b) including the device-related information on the common DL channel from the wireless access
30 node, wherein the one or more messages have one or more transport block formats that meet a coverage class need of the wireless device.

17. The method of claim 16, further comprising:

receiving (402a) the device-related information (205, 209) included in one (207, 211) of the one or more messages having one of the one or more transport block formats.

5

18. The method of claim 16, wherein a plurality of messages including the device-related information is received, wherein the plurality of messages has a plurality of transport block formats, wherein the device-related information (209) includes (1) common information (213) applicable to the wireless device and one or more other
10 wireless devices, and (2) device-specific information (217a, 217b) applicable to the wireless device, and the method further comprises:

receiving (402b) the common information included in one (215) of the plurality of messages having one of the plurality of transport block formats; and

receiving (402c) the device-specific information included in another one (219a,
15 219b) of the plurality of messages having one of the plurality of transport block formats.

19. The method of claim 18, wherein the one of the plurality of transport block formats utilized to transmit the one of the plurality of messages including the
20 common information is the same as the one of the plurality of transport block formats utilized to transmit the one of the plurality of messages including the device-specific information.

20. The method of claim 16, further comprising:

25 identifying (402d) information (221) in the one of the plurality of messages including the common information and the one of the plurality of messages including the device-specific information, where the identified information uniquely identifies the one of the plurality of messages including the common information that corresponds to the one of the plurality of messages including the device-specific
30 information.

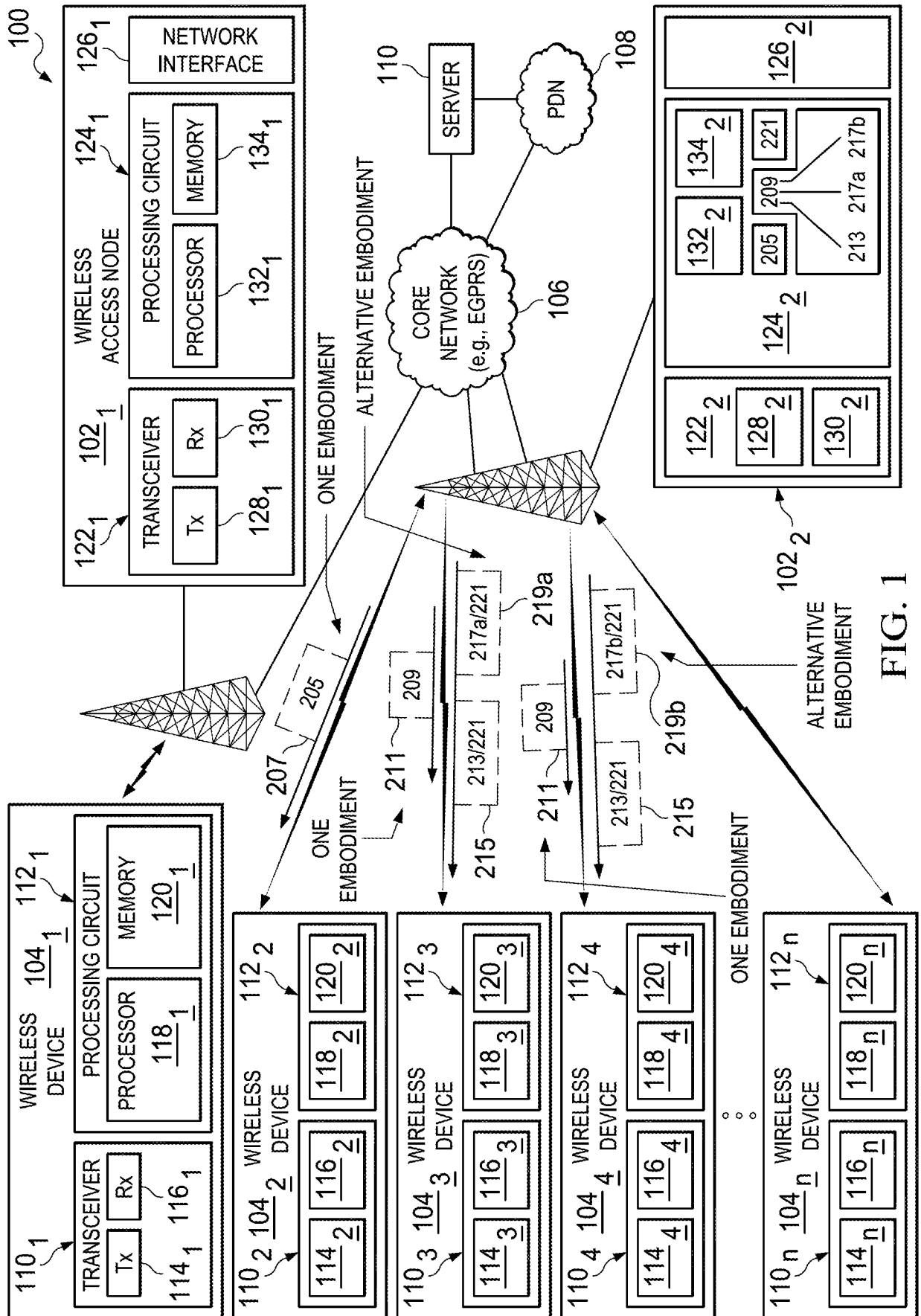


FIG. 1

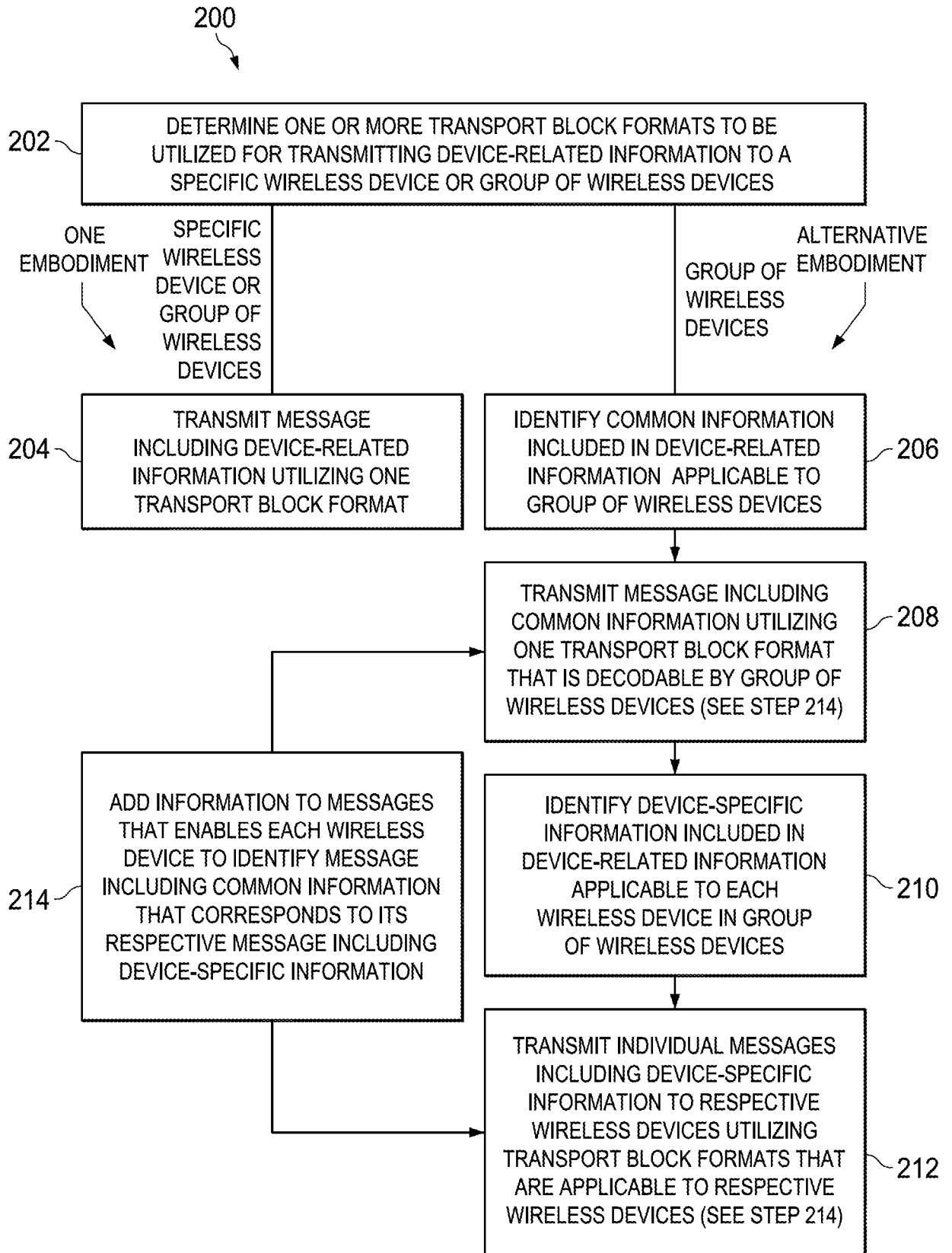


FIG. 2

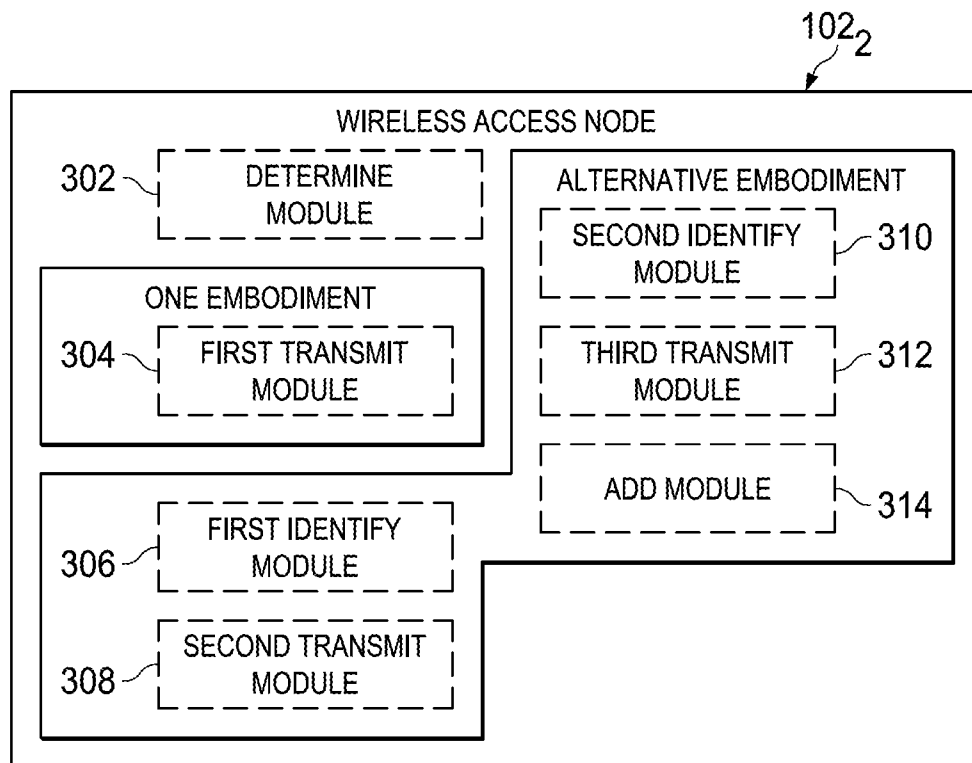


FIG. 3

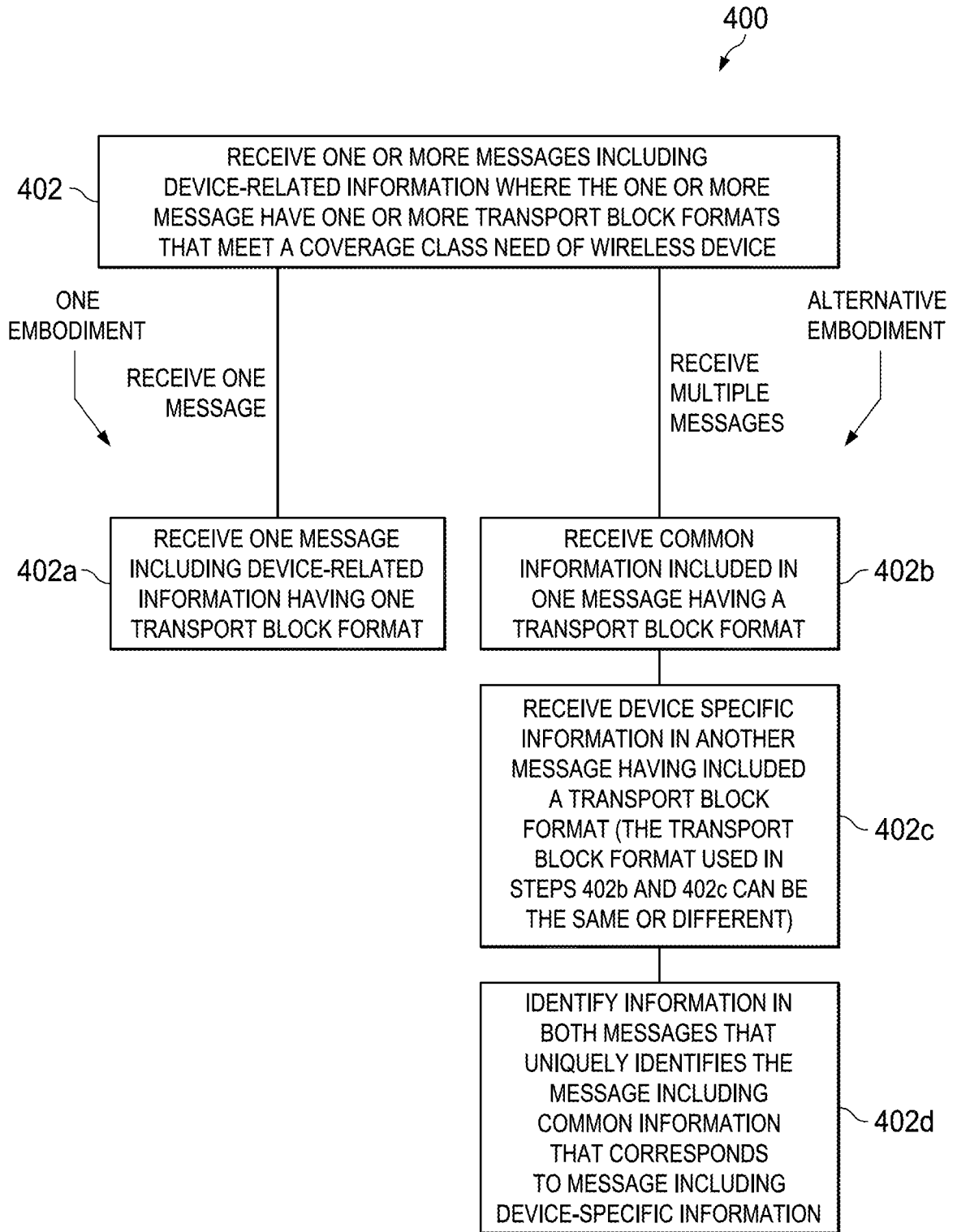


FIG. 4

FIG. 5

104₂, 104₃, 104₄

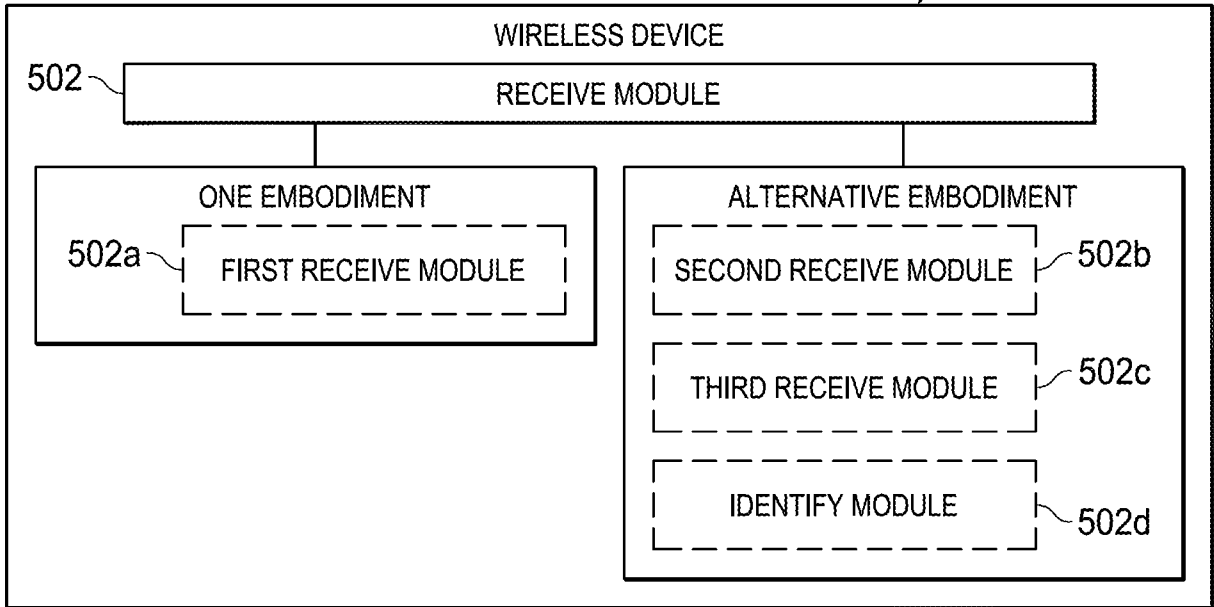
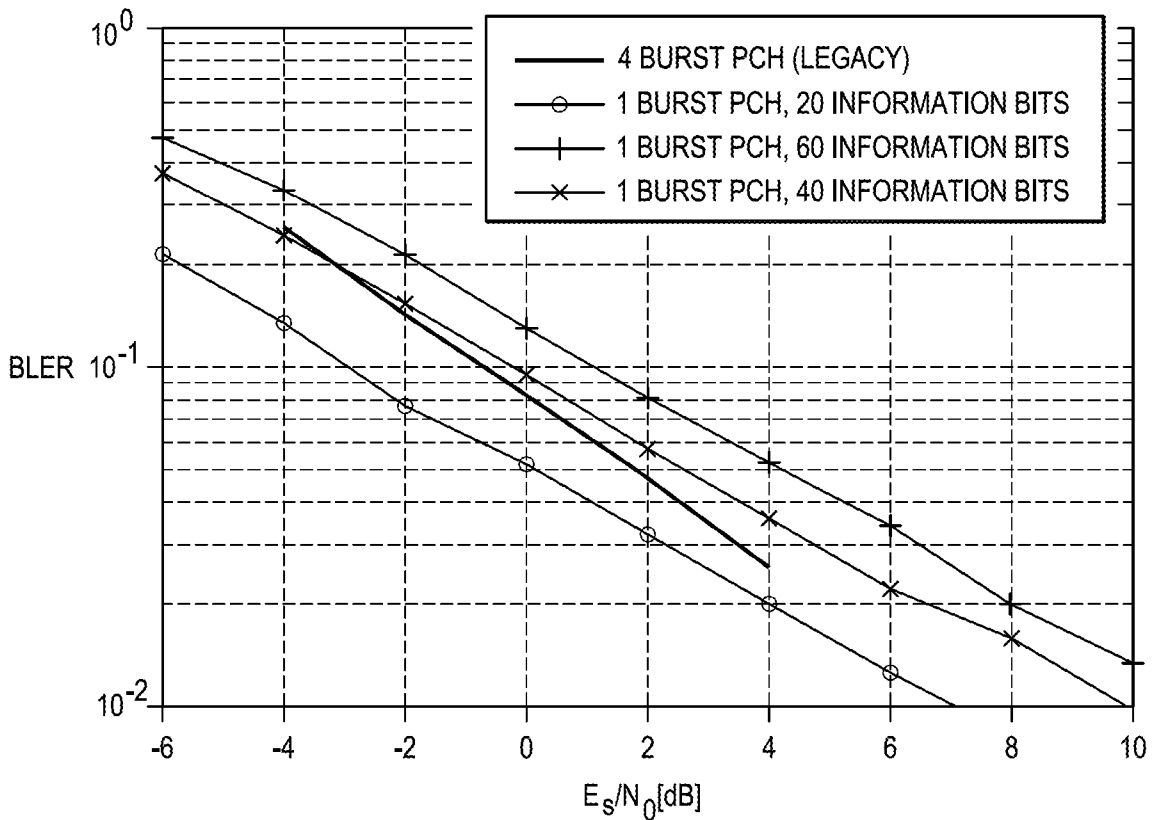


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2015/055697

A. CLASSIFICATION OF SUBJECT MATTER
 INV. H04L1/00
 ADD. H04W68/00

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)
 H04W H04L

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 practicable, search terms used)
 EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 855 424 A1 (MATSUSHITA ELECTRIC IND CO LTD [JP]) 14 November 2007 (2007-11-14) paragraph [0010] - paragraph [0012] paragraph [0013] - paragraph [0016] paragraph [0019] - paragraph [0025] paragraph [0072] - paragraph [0074] paragraph [0079] - paragraph [0083] paragraph [0107] - paragraph [0109] paragraph [0111] - paragraph [0116] paragraph [0127] - paragraph [0129] paragraph [0143] - paragraph [0145] ----- -/--	1-20

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 December 2015	10/12/2015

Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Puiulet, Alexandru
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INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2015/055697

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>NOKIA ET AL: "D2D Communication without network coverage", 3GPP DRAFT; R1-133495, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE</p> <p>, vol. RAN WG1, no. Barcelona, Spain; 20130819 - 20130823 10 August 2013 (2013-08-10), XP050716602, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_74/Docs/ [retrieved on 2013-08-10] section "3 D2D communication without network coverage" "Table 1. Correspondence between cellular and D2D channels" "Figure 2. Basic D2D communication without NW coverage", including the associated description; section "5 Groupcast communication" "Figure 3. Groupcast communication according to alternative 2", including the associated description.</p> <p style="text-align: center;">-----</p>	1-20
X	<p>NSN ET AL: "Necessity on category 0 indication to network before UE capability delivery", 3GPP DRAFT; R2-142474 (LOW COST CAPABILITY INDICATION), 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE</p> <p>, vol. RAN WG2, no. Seoul, Korea; 20140519 - 20140523 9 May 2014 (2014-05-09), XP050818520, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_86/Docs/ [retrieved on 2014-05-09] section "2 Discussion" section "Observation 1" section "Observation 2" section "Observation 5" section "Observation 6"</p> <p style="text-align: center;">-----</p>	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2015/055697

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