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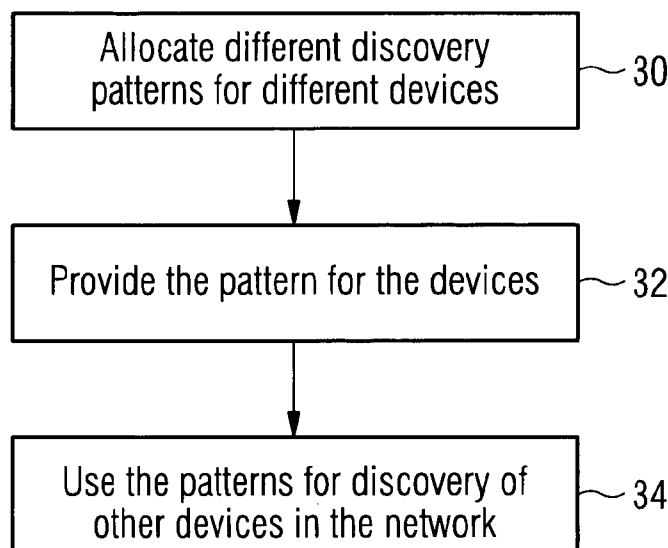
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(54) Title: CODEWORD BASED DISCOVERY SCHEDULING IN A DEVICE TO DEVICE COMMUNICATION SYSTEM

FIG 4



(57) Abstract: A method comprising: obtaining signal pattern information at a node, the signal carrying a discovery message for device to device communication, said information being a code-word of a code block with specific properties indicating when the half duplex node is allowed to transmit discovery message and when it shall listen to discovery messages of other nodes; and using said information for configuring said node for reception of at least two copies of a signal from a further node.

CODEWORD BASED DISCOVERY SCHEDULING IN A DEVICE TO DEVICE COMMUNICATION SYSTEM

Background

5 This disclosure relates to device discovery in a communication system.

A communication system can be seen as a facility that enables communications between two or more nodes or devices such as fixed or mobile communication devices, access points (AP) such as base stations, relays, servers and so on. A communication system and compatible
10 communicating entities typically operate in accordance with a given standard or specification which sets out what the various entities associated with the system are permitted to do and how that should be achieved. For example, the standards, specifications and related protocols can define the manner how various devices shall communicate with each other, how various aspects of the communications shall be implemented and how the devices shall be
15 configured.

Signals can be carried on wired or wireless carriers. Examples of wireless communication systems include architectures that are standardized by the 3rd Generation Partnership Project (3GPP). A recent development in this field is often referred to as the long-term evolution
20 (LTE) of the Universal Mobile Telecommunications System (UMTS) radio-access technology. Further developments of the communication systems are expected.

A communication device can be provided with an appropriate signal receiving and transmitting arrangement for enabling communications with other devices. Typically a
25 communication device is used for enabling receiving and transmission of communications such as speech and data. A user can access wirelessly a communication system by means of an appropriate wireless communication device or terminal, often referred to as user equipment (UE). Other types of wireless communication devices are also known, for example various access points, relays, and so on that are capable of communicating wirelessly with
30 other devices.

New services and communication architectures are emerging. For example, proximity-based applications and services have been proposed. The introduction of a proximity services (ProSe) capability in systems such as LTE can be used to enable use of the proximity-based

applications. Another example of users of proximity services are various public safety organisations.

One aspect of proximity services is the need for devices capable of device-to-device communications (D2D) to be able to discover each other i.e. to be made aware of each other's existence so that they can communicate with each other. This should preferably be provided in a power-efficient manner. The issue of discovery relates not only to D2D communications, but a more generic scenario, in addition to traditional access point to a user equipment (AP2UE) links both direct D2D and access point to access point (AP2AP) links as well. An example of a possible topology for such a system is shown in Figure 1. In ProSe, D2D and AP2AP services a device and /or node may communicate directly with another device and/or node respectively of similar hierarchy. For example a user device may transmit directly to another user device without having to traverse a base station, or node (such as a (e)NodeB).

The following types of D2D discovery are defined in 3GPP specification TR 36.843:

Type 1: a discovery procedure where resources for discovery signal transmission are allocated on a non UE specific basis. It should be appreciated that all the resources may be for all UEs or group of UEs.

Type 2: a discovery procedure where resources for discovery signal transmission are allocated on a per UE specific basis. The Type 2 is broken down in to Type 2A and Type 2B.

Type 2A: Resources are allocated for each specific transmission instance of discovery signals.

Type 2B: Resources are semi-persistently allocated for discovery signal transmission.

Telecommunication systems may thus need to support a discovery function, enabling network nodes and/or devices to discover each other directly.

It is noted that the above discussed issues are not limited to any particular communication environment and station apparatus but may occur in any appropriate system.

Embodiments of the invention aim to address one or several of the above issues.

Summary

- 5 In a first aspect there is provided a method comprising: obtaining signal pattern information at a node, said information comprising a codeword; and using said information for configuring said node for reception of at least two copies of a signal from a further node.

10 In some embodiments, the method comprises combining said at least two copies of said received signal.

In some embodiments, the method comprises using said information for configuring said node for transmission of at least two copies of a signal to a further node.

- 15 In some embodiments, the method comprises determining transmit and receive timeslots at said node in accordance with said obtained signal pattern information.

In some embodiments, the signal comprises a discovery signal.

- 20 In some embodiments, the obtaining signal pattern information comprises receiving said signal pattern information.

In some embodiments said discovery signal pattern comprises one of: Type 1; Type 2; Type 2A; Type-2B pattern information.

- 25 In some embodiments said node and said further node comprise user equipment.

30 In a second aspect there is provided a computer program comprising computer executable instructions which when run on one or more processors perform the method of the first aspect.

In a third aspect there is provided a method comprising: determining at least one codeword; indicating the at least one codeword to at least one node for configuring of a signal pattern at said at least one node; wherein said determining comprises using a block code to obtain said

at least one codeword; and wherein said at least one codeword is configured to enable said at least one node to receive at least two copies of a signal.

In some embodiments, the method comprises selecting said block code to use.

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In some embodiments, said indicating the at least one codeword comprises sending the at least one codeword to the at least one node.

In some embodiments, a look-up table is used to obtain said at least one codeword.

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In some embodiments, said obtaining said at least one codeword comprises generating said at least one codeword.

In some embodiments, said selecting said block code comprises determining a Hamming distance of said block code.

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In some embodiments, said block code comprises a BCH code.

In some embodiments, said block code comprises a constant weight code.

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In some embodiments, said block code comprises an error correcting code.

In some embodiments, said determining comprises comparing weights of a plurality of codewords of said block code.

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In some embodiments, said determining comprises using said weights to organize said plurality of codewords in to sets.

In some embodiments, the method comprises determining a modified block code by removing one or more codewords from said block code.

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In some embodiments, the determining at least one codeword comprises using a Kronecker product of said block code.

In some embodiments, said signal comprises a discovery signal.

In some embodiments, said discovery signal pattern comprises one of: Type 1; Type 2; Type-2A; Type-2B discovery signal pattern.

5

In some embodiments said at least one node comprises a user equipment.

In some embodiments the method is carried out at a base station.

- 10 In a fourth aspect there is provided a computer program comprising computer executable instructions which when run on one or more processors perform the method of the third aspect.

- 15 In a fifth aspect there is provided an apparatus comprising: at least one processor; and at least one memory including computer program code; the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to: obtain signal pattern information, said information comprising a codeword; and use said information for configuring reception of at least two copies of a signal from a node.

- 20 In some embodiments, the apparatus is configured to combine said at least two copies of said received signal.

In some embodiments, said apparatus is configured to use said information for configuring transmission of at least two copies of a signal to a node.

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In some embodiments, said apparatus is configured to determine transmit and receive timeslots in accordance with said received signal pattern information.

In some embodiments, the signal comprises a discovery signal.

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In some embodiments, the apparatus is configured to receive said signal pattern information.

In some embodiments said discovery signal pattern comprises one of: Type 1; Type 2; Type 2A; Type-2B pattern information.

In some embodiments said apparatus and said node comprise user equipment.

5 In a sixth aspect there is provided an apparatus comprising means for obtaining signal pattern information, said information comprising a codeword; and means for using said information for configuring reception of at least two copies of a signal from a node.

In some embodiments, the apparatus comprises means for combining said at least two copies of said received signal.

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In some embodiments, said apparatus comprises means for using said information for configuring transmission of at least two copies of a signal to a node.

15 In some embodiments, said apparatus comprises means for determining transmit and receive timeslots in accordance with said received signal pattern information.

In some embodiments, the signal comprises a discovery signal.

20 In some embodiments, the apparatus comprises means for receiving said signal pattern information.

In some embodiments said discovery signal pattern comprises one of: Type 1; Type 2; Type 2A; Type-2B pattern information.

25 In some embodiments said apparatus and said node comprise user equipment.

30 In a seventh aspect there is provided an apparatus comprising: at least one processor; and at least one memory including computer program code; the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to: determine at least one codeword; indicate the at least one codeword to at least one node for configuring of a signal pattern at said at least one node; wherein said determining comprises using a block code to obtain said at least one codeword; and wherein said at least one codeword is configured to enable said at least one node to receive at least two copies of a signal.

In some embodiments, said apparatus is configured to select said block code to use.

5 In some embodiments, the apparatus is configured to send the at least one codeword to the at least one node.

In some embodiments, the apparatus is configured to use a look-up table to obtain said at least one codeword.

10 In some embodiments, the apparatus is configured to generate the at least one codeword.

In some embodiments, said selecting said block code comprises determining a Hamming distance of said block code.

15 In some embodiments, said block code comprises a BCH code.

In some embodiments said block code comprises a constant weight code.

20 In some embodiments said block code comprises an error correcting code.

In some embodiments, said apparatus is configured to compare weights of a plurality of codewords of said block code as part of said determining.

25 In some embodiments, said apparatus is configured to use said weights to organize said plurality of codewords in to sets.

In some embodiments, the apparatus is configured to determine a modified block code by removing one or more codewords from said block code.

30 In some embodiments, the apparatus is configured to use a Kronecker product of said block code for determining said at least one codeword.

In some embodiments, said signal comprises a discovery signal.

In some embodiments, said discovery signal pattern comprises one of: Type 1; Type 2; Type-2A; Type-2B discovery signal pattern.

In some embodiments said at least one node comprises a user equipment.

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In some embodiments said apparatus comprises a base station.

In an eighth aspect there is provided an apparatus comprising: means for determining at least one codeword; means for indicating the at least one codeword to at least one node for
10 configuring of a signal pattern at said at least one node; wherein said means for determining comprises means for using a block code to obtain said at least one codeword; and wherein said at least one codeword is configured to enable said at least one node to receive at least two copies of a signal.

15 In some embodiments, said apparatus comprises means for selecting said block code to use.

In some embodiments, the apparatus comprises means for sending the at least one codeword to the at least one node.

20 In some embodiments, the apparatus comprises means for using a look-up table to obtain said at least one codeword.

In some embodiments, the apparatus comprises means for generating the at least one codeword.

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In some embodiments, said means for selecting said block code comprises means for determining a Hamming distance of said block code.

In some embodiments, said block code comprises a BCH code.

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In some embodiments said block code comprises a constant weight code.

In some embodiments said block code comprises an error correcting code.

In some embodiments, said apparatus comprises means for comparing weights of a plurality of codewords of said block code as part of said determining.

5 In some embodiments, said apparatus comprises means for using said weights to organize said plurality of codewords in to sets.

In some embodiments, the apparatus comprises means for determining a modified block code by removing one or more codewords from said block code.

10 In some embodiments, the apparatus comprises means for using a Kronecker product of said block code for determining said at least one codeword.

In some embodiments, said signal comprises a discovery signal.

15 In some embodiments, said discovery signal pattern comprises one of: Type 1; Type 2; Type-2A; Type-2B discovery signal pattern.

In some embodiments said at least one node comprises a user equipment.

20 In some embodiments said apparatus comprises a base station.

In a ninth aspect there is provided a method comprising: receiving discovery signal pattern information at a node; wherein the pattern information configures at least two patterns for bidirectional discovery with discovery message combining capability; and using said
25 information for configuring said node for reception of at least two copies of a discovery signal from a further node.

In some embodiments, the method comprises combining said at least two copies of said received discovery signal.

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In some embodiments, the method further comprises receiving information for configuring said node for discovery signal transmissions according to one of the said at least two patterns.

In some embodiments, the method further comprises determining transmit and receive timeslots at said node in accordance with said received discovery signal pattern information.

- 5 In a tenth aspect there is provided a computer program comprising computer executable instructions which when run on one or more processors perform the method of the ninth aspect.

- 10 In an eleventh aspect there is provided an apparatus comprising: at least one processor; and at least one memory including computer program code; the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to: receive discovery signal pattern information; wherein the pattern information configures at least two patterns for bidirectional discovery with discovery message combining capability; and use said information for configuring said node for reception of at least two copies of a discovery signal from a further node.

In some embodiments, the apparatus is configured to combine said at least two copies of said received discovery signal.

- 20 In some embodiments, the apparatus is configured to receive information for configuring said node for discovery signal transmissions according to one of the said at least two patterns.

In some embodiments, the apparatus is configured to determine transmit and receive timeslots at said node in accordance with said received discovery signal pattern information.

- 25 In a twelfth aspect there is provided an apparatus comprising: means for receiving discovery signal pattern information; wherein the pattern information configures at least two patterns for bidirectional discovery with discovery message combining capability; and means for using said information for configuring said node for reception of at least two copies of a discovery signal from a further node.

In some embodiments, the apparatus comprises means for combining said at least two copies of said received discovery signal.

In some embodiments, the apparatus comprises means for receiving information for configuring said node for discovery signal transmissions according to one of the said at least two patterns.

- 5 In some embodiments, the apparatus comprises means for determining transmit and receive timeslots at said node in accordance with said received discovery signal pattern information.

Brief description of drawings

- 10 Figure 1 shows a schematic diagram of a system where certain embodiments can be implemented;

Figure 1A illustrates an example of a group of communication devices making device-to-device transmissions;

Figure 2 illustrates an example apparatus for use at a user equipment;

- 15 Figure 3 illustrates an example of apparatus for use at a network transceiving entity;

Figure 4 shows a flowchart according to an embodiment;

Figure 5 shows a flowchart according to an embodiment;

Figure 6 shows a flowchart according to an embodiment;

Figure 7 shows different frame types;

- 20 Figure 8 shows a logical resource space;

Figure 9 shows an example discovery pattern for a UE;

Figure 10 shows example codewords;

Figure 11 is a table showing UE Tx and Rx opportunities.

- 25 Detailed description

In the following certain exemplifying embodiments are explained with reference to a wireless or mobile communication system serving mobile communication devices. Before explaining in detail the exemplifying embodiments, certain general principles of a wireless
30 communication system, access systems thereof, and communication devices are briefly explained with reference to Figures 1 and 2 to assist in understanding the technology underlying the described examples.

A non-limiting example of the recent developments in communication system architectures is the long-term evolution (LTE) of the Universal Mobile Telecommunications System (UMTS) that is being standardized by the 3rd Generation Partnership Project (3GPP). Other examples of a radio access system include those provided by base stations of systems that are based on technologies such as wireless local area network (WLAN) and/or WiMax (Worldwide Interoperability for Microwave Access).

In system 10 communication devices 1 can be provided wireless access to a wider communication system via access points 2, for example base stations or similar wireless transmitter and/or receiver nodes providing wireless access for users. Figure 1 also shows devices 3 that act as relay nodes between the access points 2 and user devices 1. The communication devices 1 and 3 may comprise any suitable device capable of wireless communication of data, for example a mobile phone, laptop, tablet etc. Communication devices are typically controlled by at least one appropriate controller apparatus so as to enable operation thereof. The control apparatus can typically be provided with memory capacity and at least one data processor. The control apparatus and functions may be distributed between a plurality of control units.

Figure 1A illustrates an example of a group of communication devices (UE) 8a to 8d communicating with each other by device-to-device (D2D) transmissions under the assistance of a first network via an eNB 2a of the network.

Figure 2 shows a schematic view of an example of user equipment 8 that may be used for communicating with the eNBs 2 or other UEs 8 of Figure 1A via a wireless interface. In addition to D2D communications, the user equipment (UE) 8 may be used for various tasks such as making and receiving phone calls, for receiving and sending data from and to a data network and for experiencing, for example, multimedia or other content.

The UE 8 may be any device capable of at least sending or receiving radio signals to or from the UEs and eNBs 2 of Figure 1. Non-limiting examples include a mobile station (MS), a portable computer provided with a wireless interface card or other wireless interface facility, personal data assistant (PDA) provided with wireless communication capabilities, or any combinations of these or the like. The UE 8 may communicate via an appropriate radio interface arrangement of the UE 8. The interface arrangement may be provided for example

by means of a radio part and associated antenna arrangement 205. The antenna arrangement may be arranged internally or externally to the UE 8, and may include a plurality of antennas capable of operating in a multi-layer transmission scheme.

5 The UE 8 may be provided with at least one data processing entity 203 and at least one memory or data storage entity 217 for use in tasks it is designed to perform. The data processor 203 and memory 217 may be provided on an appropriate circuit board 219 and/or in chipsets.

10 The user may control the operation of the UE 8 by means of a suitable user interface such as key pad 201, voice commands, touch sensitive screen or pad, combinations thereof or the like. A display 215, a speaker and a microphone may also be provided. Furthermore, the UE 8 may comprise appropriate connectors (either wired or wireless) to other devices and/or for connecting external accessories, for example hands-free equipment, thereto.

15

Figure 3 shows an example of apparatus for use at a network transceiving entity, such as a base station or eNB 2a of Figure 1A. The apparatus comprises a radio frequency antenna array 301 configured to receive and transmit radio frequency signals; radio frequency interface circuitry 303 configured to interface the radio frequency signals received and
20 transmitted by the 8-antenna array 301 and the data processor 306. The radio frequency interface circuitry 303 may also be known as a transceiver. The apparatus also comprises an interface 309 via which it can send and receive information to and from one or more other network nodes. The data processor 306 is configured to process signals from the radio frequency interface circuitry 303, control the radio frequency interface circuitry 303 to
25 generate suitable RF signals to communicate information to the UE 8 via the wireless communications link, and also to exchange information with other network nodes via the interface 309. The memory 307 is used for storing data, parameters and instructions for use by the data processor 306.

30 It will be appreciated that the apparatus shown in each of Figures 2 and 3 described above may comprise further elements which are not directly involved with the embodiments of the invention described hereafter.

In the following examples the different nodes forming the network of, for example, Figure 1 and Figure 1A can discover each other directly over the air. Examples describe use of specific discovery patterns and groups of discovery patterns applicable to nodes operating in a frame based system. In addition to discovery in traditional access point-to-user equipment (AP2UE) links, support is provided also for other link types, such as device-to-device (D2D) communication and wireless backhauling. Time division duplexing (TDD) is considered as a feasible solution for the service discovery for half duplex nodes. D2D and discovery may also use TDD technology in the case of FDD (Frequency Division Duplexing) devices. Scenarios where a node cannot transmit and receive at the same time on the spectrum of interest are assumed. Hence, the following examples concentrate on half-duplex technology.

The herein described patterns can be used for comprehensive bidirectional communication where all nodes are able to listen to each other. The proposed scheme can support network topologies containing network elements of different hierarchies which require mono-directional discovery function among network nodes, e.g. from higher towards lower hierarchy levels.

The discovery patterns can be built on top of a frame based communication arrangement. The network nodes can be assumed to be synchronized with each other.

The flowchart of Figure 4 shows general principles of operation where specific discovery patterns or Tx/Rx patterns are employed to enable network nodes, or devices, configured to form e.g. a tree topology, to discover each other directly over the air. Discovery of devices in a network of devices can be controlled by providing different discovery patterns of transmission and/or reception phases for different devices in the network for transmission and reception of discovery information between the devices, see block 32. Prior to allocation of the discovery patterns discovery resources (e.g. frequency/time/code) are made available at 30.

A network entity that is responsible for allocating the discovery patterns can also control the reservation / assigning of those resources for the devices that are a part of the discovery. For example, for D2D an appropriate controlling network entity may comprise an eNB or another access point in control of allocation of discovery patterns. Generally speaking, the control can

be logically provided by a network node on the highest hierarchy level in a certain geographical area.

The discovery patterns are delivered to relevant devices in the network at 32.

5

The flowchart of Figure 5 shows operation at an eNB, according to an example. At block 50, the eNB keeps a record of discovery pattern use by UEs under its control and/or in its vicinity. This information may be stored in memory. At block 52 the eNB uses this information for determining discovery signals patterns for those UEs, which it then allocates to the UEs.

10

The flowchart of Figure 6 is viewed from the perspective of a UE. At block 60, the UE receives an allocation to use a pattern. Then, at block 62 the UE sends/receives discovery signals according to the pattern. In other words the UE applies the allocated discovery signal pattern.

15

In accordance with a possibility discovery patterns are generated in advance and described in relevant specifications. An eNB / AP may manage the usage of the discovery patterns in accordance with the specifications. The delivery of an available discovery pattern can be based e.g. on tabulation in a relevant specification listing available discovery patterns. There may also be a predefined pattern index for each pattern.

20

The specification may also define discovery patterns corresponding to at least one group, or in more general terms, grouping of the patterns.

25

The usage/management of the discovery patterns may be provided in a similar fashion to reference signal usage in LTE. One approach is to use dedicated e.g. higher layer signalling, e.g. radio resource control (RRC) or medium access control (MAC), to assign discovery pattern or index of pattern for a certain node in the network. Assignment of discovery patterns can also be automated and derived also from a predefined parameter (e.g. UE-ID) and predefined criteria (e.g. type of node). Allocation of discovery resources (frequency/time/code) can be a part of broadcasted system information or beaconing signalling. Alternatively, they can be conveyed to the UE using dedicated signalling.

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At 34 the devices can use the patterns for discovery of other devices in the network. This can comprise transmitting or receiving information using predetermined discovery resources in accordance with the dedicated discovery pattern of transmission and reception phases allocated from a set of different discovery patterns.

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Use of transmission and/or reception phases for the device discovery can be based on arranging the discovery patterns in different groups. Patterns in a first group can be used to enable bi-directional communication of information between relevant devices allocated to said first group and patterns in a second group can be used to enable mono-directional communication of information between relevant devices allocated to the second group and devices allocated to said first group. More detailed examples of the use of the grouping are given below.

10

The specific Tx/Rx patterns and groups of such patterns can be defined to allow for a desired communication arrangement to network nodes that are configured to form e.g. a mesh, D2D or a self-backhauling network using half-duplex TDD technology.

15

An example for possible frame types for communications in the system of Figure 1 and 1A is shown in Figure 7. For simplicity, guard periods (GP) are not shown in the subframes of Figure 7 between the different subframe portions. However, it can be assumed that GP is present when switching between transmission (Tx) and reception (Rx) phases, either way. Guard period allows flexible allocation of different control frame types for consecutive subframes.

20

In a traditional network topology, nodes can be divided between different types. In this example two types, A (access point; AP) and B (user equipment; UE), are considered. Conventionally communication is possible between A and B (A-B) but not for A-A (AP2AP) or B-B (UE2UE) whereas the latter is now enabled. The corresponding control frame types are shown in Figure 4 as type a/b for A-B, and type c/d for A-A and B-B, respectively.

25

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The data part 44 of the subframe 40 can be used either for transmission or reception. The two Tx/Rx portions 42, 43 are available in the control part 41 of each TDD subframe 40. In conventional arrangements this means that a single subframe does not allow mutual communications between more than two kinds of nodes. Having multiple frames grouped

together allows more nodes in the system, as then there are more than two Tx/Rx portions to be used for the discovery patterns. These do not necessarily need to be consecutive but could be distributed in time over multiple subframes.

- 5 In accordance with an example the control frame types shown in Fig. 7 are varied over time in a coordinated and predefined manner to facilitate seamless control connection among all network nodes in a system.

10 It should be noted that the frame structure shown in Fig 7. is by way of example only. It's equally possible to provide Tx/Rx opportunities with the granularity of one LTE subframe. In this scenario, a node can either transmit or receive during the subframe and discovery patterns are generated by concatenating a plurality of those subframes together. Further, there can be gaps between D2D transmissions including D2D discovery, for example transmission to/from cellular network, guard time for the switching between Tx and Rx at a device, can intersperse the D2D discovery subframes.

The discovery patterns and groups of discovery patterns may be defined by a relevant standard, or otherwise agreed beforehand. Some discovery patterns may be ruled out from a group of acceptable patterns according to a pre-defined criterion, e.g. a criterion related to latency involved in the discovery. This can be made e.g. by applying limitations on the number of consecutive Tx/Rx phases for acceptable discovery patterns. Thus, patterns with more than a predefined number of consecutive Tx or Rx indications can be ruled out from a set of acceptable discovery patterns.

- 25 Some embodiments relate to Type 2B discovery procedures, supporting bi-directional, discovery with predictable latency for those UEs configured to apply it. Some properties of the embodiments include scalability, small overhead and a reasonable signalling burden.

Figure 8 shows an example logical or physical resource space 500 which may be used for Type 2B discovery. Logical resource space can be realized by means of different physical layer arrangements. A physical discovery resource can be e.g. 1-2 PRBs in frequency (domain of parallel resources) and one subframe in time (domain of serial resources). Each logical resource is represented by a box 502. The resource space consists of N parallel resources 504. In this example N=6. The resource space also consists of consecutive groups

of M serial resources 506. The number of serial resources (M) equals the pattern length. In this example the pattern length (M) = 8. That is there are eight serial resources available for a discovery pattern. A physical discovery resource where the logical resource is conveyed can be, for example, 1 to 2 Physical Resource Blocks (PRBs) in frequency and one subframe in time.

Figure 9 shows an example of a Type 2B discovery pattern from a UE's point of view. The pattern defines the time instants (e.g. subframes) when the UE transmits the predefined discovery signal on the predefined resource(s). The baseline assumption is during the time instants when the UE is not transmitting it will listen to other UEs' discovery signals. On the other hand, when the UE is transmitting it cannot listen to other UEs' discovery signals. This restriction is called a half duplex constraint. In Figure 9 the logical resource space 600 comprises logical resource blocks 602. The pattern length is 8, as shown at 606. The logical resource blocks 602 containing a "0" represent a resource from which a UE is receiving, or is in a condition to receive, discovery signals from other UEs. The logical resource blocks containing a "1" represent a resource where the UE transmits, or is in a condition to transmit, discovery signals to other UEs. The blocks in the same column as a Tx resource box are empty because they are not used for Tx and cannot be used for Rx because of the half-duplex constraint. In this example, it's assumed that UE utilizes the same parallel resources all the time when transmitting. However, it can also vary from transmission to transmission or from pattern length to pattern length. The variation may include a deterministic hopping pattern to randomize the interference properties among D2D (discovery) UEs and/or between D2D (discovery) and cellular data transmission.

It has previously been suggested to use a scheme to arrange UEs' Tx/Rx opportunities. In that scheme, one Rx opportunity from any other UE is guaranteed at a UE. The size of discovery message is fixed (e.g. 104 bits). For example, each square shown in Figure 8 would contain 104 bits of information, and each square is for one or two PRBs. Receiving multiple copies of the same message may provide the following benefits:

1. Frequency/time diversity (if multiple copies are located at different frequency locations/different TTIs)
2. Robustness to interference as the interference experienced at different frequency/time can be different.

3. Adoption to different link budget requirements. For example, configurable repetition would allow the same discovery channel design (fixed coding and fixed PRB size) to be used for high pathloss vs low pathloss scenarios.
4. Assume different redundancy versions can be used for multiple copies of the same message, the effective coding rate of the received message can be lower than that from the Chase combining.

Hence, in some cases, it may be appropriate to give a UE multiple opportunities to receive a message from another UE. The receiving UE can then combine the received messages and detect the message and the contents of the message more reliably. Therefore some embodiments relate to facilitating receipt and combining of messages e.g. a discovery signal, in a coordinated and well-structured manner.

Some embodiments more particularly relate to the combining of Type 2B discovery patterns. Some embodiments enable the combining of multiple transmissions of the same packet.

Due to the above-mentioned half duplex constraint, a UE can either transmit or receive at a certain TTI (see Figure 6). If two UEs have information ("message") to share with each other, then the Tx patterns and Rx patterns need to be chosen so each UE has at least one opportunity to transmit its own message and at least one opportunity to receive the message from another UE.

Some embodiments provide a pattern design for Type 2B discovery signals. According to embodiments, a UE may have multiple opportunities to receive a discovery message from another UE, as part of a discovery process. Error correcting codes (ECCs) include block codes, convolutional codes, turbo codes, etc. A convolutional code including a tail-biting convolutional code can be also formulated as a block code with the generator matrix derived from its generator polynomials once the size of input data is fixed. The same can be done for turbo codes. Hence techniques or definitions applicable to a block code can be also used for a code generated from, say, a turbo code with a given input data size. Hence any reference to "block code" in the following does not limit the methods or apparatus provided herein to a narrowly defined "block code". Block codes are used as an initial point in the pattern design. A block code takes an input data of length K and generate output data of length N . A Tx/Rx

pattern can be derived from an error correcting code, and the selection and use of a particular codeword can be signaled by an eNB to a UE.

One example of a block code is the Hamming code, which has a minimum Hamming distance of 3. In some embodiments multiple Tx opportunities and multiple Rx opportunities are enabled by using an error correcting code with a minimum Hamming distance higher than a certain minimum (say 3) to define the Tx/Rx patterns. A Hamming distance between two bit strings of equal length is the number of positions at which the corresponding bits are different (for example, referring to Figure 10, the Hamming distance between cells 702 and 704 is eight). By doing this, a UE m can be guaranteed to receive $t > 1$ copies of a message from UE n in one discovery period (where t denotes the number of minimum copies (NMC)). Given a minimum Hamming distance between two codewords, ideally, the Tx and Rx opportunities are evenly split between them so some embodiments are configured to provide NMC equals, $\left\lfloor \frac{d_{min}}{2} \right\rfloor$, where d_{min} is the minimum Hamming distance among codewords of a block code, where $\lfloor x \rfloor$ stands for the floor operation on x . In the following, we provide embodiments which have this property. As the error correction capability of a block code is given by $t_c = \left\lfloor \frac{d_{min}-1}{2} \right\rfloor$, the error correction capability is a good indication of NMC for those embodiments: the NMC and the error correcting capability are the same if d_{min} is odd; NMC is larger than the error correction capability by 1 if d_{min} is even.

Some embodiments utilise BCH codes. BCH codes form a class of cyclic error-correcting codes that are constructed using finite fields. In an example embodiment shown in Figure 10, a BCH code BCH(N=15, K=5) is used.

BCH(15,5) can correct up to 3 errors ($t_c = 3$), and the minimum Hamming distance is 7.

Reference is now made in more detail to Figure 10 illustrating all the codewords in BCH(15,5). The first codeword and the last codeword are shaded and removed from further discussions as they would imply a UE transmits or receives at all opportunities. The code derived from BCH(15,5) by removing the first and the last codewords is denoted as a Modified-BCH, or M-BCH(15,5). A UE may be signaled by an eNB or may autonomously

choose one. Patterns may be needed in D2D data and/or scheduling assignments for example. Furthermore, in coming releases the D2D may also support unicast traffic. The pattern may also be used for, for example, obtaining channel state information (CSI).

5 Figure 11 is a table showing Tx and Rx indices for a number of UEs. In this example there are thirty UEs involved, as shown by the thirty rows in the Tx UE index 802. In the Rx UE index 804 seventeen columns are shown. Each numbered column represents a UE which corresponds with a same numbered row in the Tx UE index 802. For example UE 11 in the Tx UE index is the same as UE 11 in the Rx UE index (there could in theory be up to thirty
10 columns in the Rx UE index to correspond with the thirty rows in the Tx UE index, but only seventeen are shown for the purposes of conciseness).

From Figure 8, it can be seen that it is guaranteed that each UE receives at least 3 copies of a message from another UE i.e. NMC equals 3. The 0s in the table are entries for the same UE
15 i.e. a UE will not receive a message transmitted by itself.

In a case where the codewords have a constant weight, the number of minimum copies (NMC) received from another UE is guaranteed by the designed error correction capability. This is discussed in more detail below.

20

In the codewords of M-BCH (15,5) described with respect to Figure 10, the codewords have a weight of 7 or 8, where “weight” refers to the number of 1s (i.e. transmit opportunities). The NMC received from another UE is equal to the designed error correction capability.

25 When codewords do not have constant weights, the NMC does not necessarily equal the designed error correction capability plus one; sometimes it is even less than the designed error correction capability. This can be illustrated by considering the difference between codewords at two locations. In this example we have the following combinations of bit patterns from two codewords (10,01), (00,11). These codewords represent a UE pair (i.e.
30 (UE1 action at TTI n1, UE1 action at TTI n2, UE2 action at TTI n1, UE2 at TTI n2)), and “1” and “0” respectively represent “transmit” and “receive”. In this context TTI is the abbreviation for “Transmission Time Interval”. In other words (10, 01) represents (UE1-Tx UE1-Rx, UE2-Rx UE2-Tx), and (00,11) represents (UE1-Rx UE1-Rx, UE2-Tx UE2-Tx).

Though each bit pattern leads to the same Hamming distance of 2, the first pattern (10,01) is more useful for D2D discovery as it gives each UE opportunity for Tx/Rx; and the second bit pattern implies either all Tx or all Rx. It has been determined by the present inventors that

5 when the weight (i.e. the number of bit 1s) for a first UE equals the weight of another UE, the number of minimum copies received from another UE (NMC) equals the designed error correction capability plus one. And, in general, with an increasing weight difference the NMC goes down. The weight of a codeword may be considered the total number of 1s over a given period (e.g. N).

10

Consider now by way of example another BCH code BCH(N=31, K=11). This code has an error correction capability of 5. The weight (i.e. number of 1s) of its non-zero codewords are 11,12,15,16,19 and 20. The codewords can be divided according to their weights: for example all the codewords of weight 11 are put into one set S_{11} (there are 186 of these

15 codewords), and codewords of weight 12 are put into another set S_{12} (there are 310 of these codewords), and so on. Within each set, the minimum Tx/Rx opportunities are lower-bounded by the designed error correction capability. For example, codewords in S_{11} have NMC at 4, and the minimum Hamming distance at 8. Between codewords from S_{11} and S_{19} respectively, the minimum number of Tx/Rx opportunities is 2, which is less than the

20 designed error correction capability, which is 5. In general, the larger the weight difference between codewords, the larger the gap between the NMC and the designed error correction capability. In some embodiments it is the eNBs responsibility to assign a codeword to a UE to ensure the potential for more than one opportunity for Tx/Rx is realized. In one embodiment, only S_{11} , and S_{12} are used, and codewords from other sets are not assigned to

25 any UEs. From the analysis below, it is also possible to include S_{11} and S_{12} together as their weight difference is just 1.

30

The information in configured subsets may be used by a UE to decide resource mapping. For BCH (15,5) there is only one subset. For BCH (31,11) there are six subsets.

In general, a Kronecker product (an operation on two matrices of arbitrary size resulting in a block matrix) of two Tx patterns can be used to obtain a new Tx pattern. A further

construction can be built with the Kronecker product of the block code based pattern and the combinatorial based pattern. That is a Kronecker product approach can be used to obtain new discovery patterns. This is discussed in more detail below.

- 5 In [3GPP R1-142450, Pattern design and resource allocation for discovery Type 2B, NSN, Nokia, May 2014] a Tx pattern based on the combinatorial design is disclosed. The design provided by $Comb(K_c, N)$ is denoted, where N is the length of the Tx pattern, K_c is the number of chosen indices. Treating the combinatorial design as a binary error correcting code, it can be seen its minimum Hamming distance is 2.

10

For example,

- if the first pattern is [0 1 1] (Comb (2, 3)),
- and the second pattern (from BCH(7,4)) is [0 0 0 1 0 1 1],
- 15 • then the new pattern is given by the product of these two matrices: [0x[0 1 1] 0x[0 1 1] 0x[0 1 1], 1x[0 1 1], 0x[0 1 1], 1x[0 1 1], 1x[0 1 1].

The result of this calculation can give a new transmission pattern.

- 20 In some embodiments, certain parts of UE codewords are compared. For example, a first UE is operating in accordance with a codeword that is 15 bits in length ($N=15$). A second UE is also operating with a codeword that is 15 bits in length. The values for the 1st, 2nd, 3rd...15th entries in the separate codewords can be compared. In a typical scenario, all codewords have the same length. In principle, it's possible to define patterns which have different lengths (e.g.
- 25 length M patterns and length 2M patterns could coexist).

In an embodiment where the codewords are of different weights, all the bits where there are differences can be collected i.e.

30

$$\begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

or

$$\begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

where the first row is for codeword 1 and the second row is for codeword 2.

In this embodiment it is assumed the first codeword's weight is smaller than the second
 5 codeword's: i.e. $w_1 < w_2$. Considering the number of different bits to be F , $F \geq 2t$. If F is
 odd, one bit in difference is removed with the pattern

$$\begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

out (this is allowed as $w_1 < w_2$) from further consideration. This results in $F' = F - 1 \geq 2t$
 different bits. If F is even, let $F' = F$. As F' is even, let $t' = F'/2$, which results in $t' \geq t$.

10 The bits in difference can be divided into pairs:

1. Let M_1 be the number of pairs with pattern

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

15 2. Let M_2 be the number of pairs with pattern

$$\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$$

3. Let M_3 be the number of pairs with pattern

$$\begin{bmatrix} 1 & 1 \\ 0 & 0 \end{bmatrix}$$

20

4. Let M_4 be the number of pairs with pattern

$$\begin{bmatrix} 0 & 0 \\ 1 & 1 \end{bmatrix}$$

Let the weight of the common bit pattern (e.g. the number of occurrences where 1s and 0s
 25 match between the codewords) between codeword 1 and codeword 2 be N_c .

The weight of the first codeword is $w_1 = N_c + M_1 + M_2 + 2M_3$, and the weight of the second word is $w_2 = N_c + M_1 + M_2 + 2M_4$ if F is even; or $w_2 = N_c + M_1 + M_2 + 2M_4 + 1$ if F is odd. $t' = M_1 + M_2 + M_3 + M_4$. As $w_2 > w_1$, we have $M_3 \leq M_4$. When $w_2 = w_1 + 1$, then F cannot be even (otherwise $w_2 - w_1 = 2M_4 - 2M_3 = 1$). F must be odd and $w_2 - w_1 = 2M_4 + 1 - 2M_3 = 1$, results in $M_3 = M_4$. Consequently codeword 1 or codeword 2 each has at least $t' \geq t$ Rx opportunities. From that it can be seen if two codewords' weights are different by 1, then it is guaranteed the NMC is no less than the designed error correcting capability.

10 To give an example, consider two codewords at $N = 19$. Let:

$$w_1 = [0 \ 0 \ 0 \ 0 \ 1 \ 0 \ 1 \ 0 \ 0 \ 1 \ 1 \ 0 \ 1 \ 1 \ 1 \ 0 \ 1 \ 0 \ 1],$$

and

$$w_2 = [0 \ 0 \ 0 \ 1 \ 1 \ 1 \ 1 \ 0 \ 1 \ 0 \ 1 \ 1 \ 0 \ 0 \ 1 \ 1 \ 0 \ 1 \ 0]$$

15 When comparing w_1 and w_2

$$\begin{bmatrix} w_1 \\ w_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 \end{bmatrix}$$

It can be seen that they are different at bits 4,6,9,10,12,13,14,16,17,18,19 (counting from 1).

Consider the bits in difference out and the following pattern is reached:

20

$$\begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 \end{bmatrix}$$

Following the above stated procedure, the first bit in difference can be removed from further

consideration as it is taking the pattern $\begin{bmatrix} 0 \\ 1 \end{bmatrix}$. This reaches the following grouping:

25

$$\begin{bmatrix} 0 & 0 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$$

and $M_1 = 1$, $M_2 = 2$, $M_3 = 1$, $M_4 = 1$.

That is codewords of the block code can be categorised into subsets according to their weights. The eNB may configure the subsets to be used for discovery.

5 Therefore it is realised that the Tx/Rx pattern design can be based on constant weight binary codes. A constant weight binary code is either a linear or nonlinear code with the property that each non-zero codeword has the same number of “1”s (the number of “1s” in a codeword is called its weight). There are many ways to construct a constant weight code, e.g. constructions from the Steiner systems, translate of linear codes and Nordstrom Robinson
 10 codes, group code, the Johnson construction, the partitioning constructions, lexicographic codes, etc. A survey on constant weight codes and their construction methods can be found in [“A new table of constant weight codes” by Brouwer, Shearer, Sloane and Smith (pp.1334-1380, IEEE Trans. on Information Theory, November 1990, “A New Table of Constant Weight Codes of Length Greater than 28” by D. H. Smith, L.A. Hughes, S. Perkins, the
 15 Electronic Journal of combinatorics, Volume 13, 2006 and online at <http://www.win.tue.nl/~aeb/codes/Andw.html> (“Bounds for binary constant weight codes”). Due to the rich connection among block codes, design theory, graph theory and many other theories in discrete mathematics, designs motivated from other branches of discrete mathematics may lead to the Tx pattern design as well. Here we identify the application of
 20 constant weight property of the Tx patterns.

In one embodiment, considering the number of codewords to be D , and the length of a given codeword to be N , and the weight of a codeword (in a constant weight code, every non-zero codeword has the same weight) to be W . In D2D discovery, the number of codewords D (Tx
 25 patterns) is prescribed, and the NMC, t , is also prescribed, which determines the number of Rx opportunities in a discovery period. W has the meaning of Tx opportunities (from a power saving and interference generation point of view, the smaller the value of W the better).

30 In general, the following observations are made:

- W the weight of a codeword decides the number of transmissions;
- $N - W$ determines the Rx attempts a UE needs to make;

- t determines the least number of copies from a single UE that another UE is able to receive;
- DW determines the total resources the discovery patterns consume;
- and $\frac{DW}{N}$ determines the required parallel resources.

5

Parallel resources here refers to the number of resources in the frequency domain. Referring back to Figure 8 for example, there are 6 parallel resources and 8 serial resources.

For a given D and t , a small W is preferred (minimizing Tx opportunities from interference point of view and power saving), small N is preferred (Rx power saving and discovery latency), and small DW is preferred (as there may be multiple options, potentially with differing values of D , it is appropriate to compare DW).

In a given embodiment, assuming the code is a cyclic code, then the parallel resources used at any time is $\frac{DW}{N}$,

and then an objective is to find a pair of (W, N) so W/N is small with given lower bounds of D and t .

Considering the total resource used is given by DW , then the objective is to have a small W and meet the requirement of D . Among the construction methods for constant weight codes, the Steiner triple systems and the Steiner quadruple systems are of interest.

A Steiner triple system is an ordered pair (S, T) where S is a finite set of points or symbols and T is a set of 3-element subsets of S called triples, such that every pair of distinct elements of S occurs together in exactly one triple of T . The order of a Steiner triple system (S, T) is size of the set S , denoted by $|S|$ [P.1, “*Design theory*”, by Lindner and Rodger, 2nd edition, CRC Press].

A Steiner quadruple system is an ordered pair (V, B) where V is a finite set of symbols and B is a set of 4-element subsets of V called quadruples with the property that every 3-

element subset of V is a subset of exactly one quadruple in B . $|V|$ is called the order of the Steiner quadruple system [P.208, “*Design theory*”, by Lindner and Rodger, 2nd edition, CRC Press].

5 A Steiner quadruple system at order 8 is given as an example:

With $|V| = 8$, $V = \{0,1,2,3,4,5,6,7,8\}$, and

$B = \{(0,1,2,3), (0,1,4,5), (0,1,6,7), (0,2,4,6), (0,2,5,7),$

$(0,3,4,7), (0,3,5,6), (1,2,4,7), (1,2,5,6), (1,3,4,6),$

$(1,3,5,7), (2,3,4,5), (2,3,6,7), (4,5,6,7)\}$, and each block is mapped to a codeword. For

10 example, $(0,1,6,7)$ is mapped to $[11000011]$.

The Steiner triple systems (STS) provide construction methods for the constant weight codes at $W = 3$ for $N = 6n+1$ or $N = 6n+3$, $n = 1,2,3,\dots$, and the Steiner quadruple systems (SQS) provide construction methods for the constant weight codes at $W = 4$ with

15 $N = 6n+2$ or $N = 6n+4$ for $n = 1,2,3,\dots$.

Jointly, STS and SQS provide construction methods for:

$N = 1,2,3,4,7, 8,9,10,13, 14,15,16,19,20,21,22, 25,26,27, 28,31,32,33,34,37,38, 39,40,43, 44,45,46,49,50,51,52, 55,56,57, 58,61,62,\dots$

20

so they provide a comprehensive coverage for N which may be of practical interest to LTE D2D.

The construction methods (the Bose construction / the Skolem construction / The “ $6n+5$ construction” / the Wilson construction etc for STS, constructions such as the “ $(3v-2u)$ construction for SQS”, etc) are also discussed in [“*Design theory*”, by Lindner and Rodger, 2nd edition, CRC Press].

25

In embodiments where codewords are combined, the combined codewords may be expressed as follows. In one example, let the Tx patterns be:

30

$$\begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_D \end{bmatrix},$$

where c_i are the codewords from an existing error correction code, each of them is a $1 \times N_1$ vector, and D is the number of Tx patterns.

5

One way to provide more Rx opportunities is through repetition, for example:

$$\underbrace{\begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_D \end{bmatrix}}_{\text{in the first period}} \quad \underbrace{\begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_D \end{bmatrix}}_{\text{in the second period}},$$

A UE takes one row of the matrix for Tx pattern: $[c_k \ c_k]$.

10

In some embodiments, a permutation matrix P is used in the second period, which is equivalent to assigning a UE different Tx patterns in those two periods $[c_k \ c_{k'}]$:

$$\underbrace{\begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_D \end{bmatrix}}_{\text{in the first period}} \quad \underbrace{P \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_D \end{bmatrix}}_{\text{in the second period}},$$

15

With either method, a UE gets at least 2 Rx opportunities.

Using the combinatorial design $Comb(k_c = 2, N = 15)$ as an example, with one repetition, this results in $N = 30$, $t = 2$, $W = 4$, $D = 105$. These values are calculated from the given example ($k=2$, $M=15$).

20

In comparison, a constant code with $N = 30, t = 2, W = 3$, which can be built from a Steiner triple system, the number of codewords D is 140, which is larger than 105, the number of codewords provided by $Comb(k_c = 2, N = 15)$

- 5 Therefore it can be appreciated that it is possible in some embodiments to support more discovering UEs with the same overhead and discovery latency using the Steiner triple system.

10 From a Steiner quadruple system of order 15, a constant weight code with $N = 15, t = 2, W = 4$ and $D = 105$ can be constructed. In terms of total resources used, it is the same as the combinatorial design $Comb(k_c = 2, N = 15)$ with one repetition. Yet as the discovery with a SQS of order 15 can be finished in 15 TTIs ($N = 15$), to achieve the same protection, the combinatorial method needs 30 TTIs ($N = 30$). From this comparison it can be appreciated that the SQS method can provide a lower latency for discovery in some cases.

15

In the combinatorial design the number of Rx opportunities between codewords varies. For instance with $Comb(k_c = 3, N = 6)$ it is 1, 2, or 3, the average number being 30/19. By defining a suitable pattern hopping (i.e. extending the code with a permuted codewords), the minimum number of Rx opportunities could be increased to grow at a faster rate than is proportional to the number of added permutations. Based on studies of the patterns from $Comb(k_c = 3, N = 6)$, (20 codewords or patterns in total) improvement is not always straightforward to achieve by finding suitable permutations. For example, with $Comb(k_c = 3, N = 6)$, combining three permutations cannot increase the minimum number of Rx opportunities to 4, and a combination of four permutations is required to increase the minimum number of opportunities to 5. An example of such optimized four permutations of the 20 codewords is :

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20;
 5 16 10 6 17 11 9 3 18 15 1 14 19 8 13 2 12 7 20 4;
 30 17 18 13 16 15 6 9 1 2 20 5 19 3 4 10 14 8 12 11 7;
 10 3 4 16 1 12 5 13 15 7 19 18 11 14 6 9 17 2 8 20.

Following the above table of permutations, a UE may start by transmitting according to the codeword 1, and would continue by transmitting according to the codewords 5, 17 and 10. Similarly, a UE starting with codeword 2, would continue with codewords 16, 18, and 3.

- 5 In some embodiments, a permutation matrix P which can be an identity matrix is used in the second period, and the Tx patterns in the first period and the Tx patterns in the second period may be derived from the same or different block codes, which is equivalent to assigning a UE different Tx patterns in those two periods $[c^{(1)}_k \ c^{(2)}_{k'}]$:

$$10 \quad \underbrace{\begin{bmatrix} c^{(1)}_1 \\ c^{(1)}_2 \\ \vdots \\ c^{(1)}_D \end{bmatrix}}_{\text{in the first period}} \quad P \quad \underbrace{\begin{bmatrix} c^{(2)}_1 \\ c^{(2)}_2 \\ \vdots \\ c^{(2)}_D \end{bmatrix}}_{\text{in the second period}},$$

With this method, a UE gets combined Rx opportunities from the first period and the second period, and $c^{(1)}_k$, $k=1,2,3,\dots,D$, are the codewords of the first block code, and $c^{(2)}_k$, $k=1,2,3,\dots,D$, are the codewords of the second block code. In one example, $c^{(2)}_k$ is the
15 complement of $c^{(1)}_k$ (i.e. replacing 0 with 1 and 1 with 0 in $c^{(1)}_k$)

Some embodiments may be used to maximize coverage and robustness of Discovery Type 2B, and may provide a generic framework for defining discovery patterns having inbuilt support for repetition.

20

The following codes provided below are for the Steiner Quadruple System with N=15:

25

```

000000000011110
000000000101101
000000000110011
000000001001011
000000001010101
000000001100110
000000001111000

```

	000000110000110
	000000110011000
	000000111100000
	000001010000101
5	000001010101000
	000001011010000
	000001100000011
	000001100110000
	000001101001000
10	000010010000011
	000010010110000
	000010011001000
	000010100000101
	000010100101000
15	000010101010000
	000011000000110
	000011000011000
	000011001100000
	000011110000000
20	000100010010001
	000100010100010
	000100011000100
	000100100001001
	000100100100100
25	000100101000010
	000101000001010
	000101000010100
	000101001000001
	000110000001100
30	000110000010010
	000110000100001
	001000010001001
	001000010100100
	001000011000010

	001000100010001
	001000100100010
	001000101000100
	001001000001100
5	001001000010010
	001001000100001
	001010000001010
	001010000010100
	001010001000001
10	001100000000110
	001100000011000
	001100001100000
	001100110000000
	001111000000000
15	010000010001010
	010000010010100
	010000011000001
	010000100001100
	010000100010010
20	010000100100001
	010001000010001
	010001000100010
	010001001000100
	010010000001001
25	010010000100100
	010010001000010
	010100000000101
	010100000101000
	010100001010000
30	010101010000000
	010110100000000
	011000000000011
	011000000110000
	011000001001000

	011001100000000
	011010010000000
	100000010001100
	100000010010010
5	100000010100001
	1000000100001010
	1000000100010100
	1000000101000001
	1000010000001001
10	100001000100100
	100001001000010
	1000100000010001
	1000100000100010
	1000100001000100
15	1001000000000011
	1001000000110000
	1001000001001000
	1001011000000000
	1001100100000000
20	1010000000000101
	1010000000101000
	1010000001010000
	1010010100000000
	1010101000000000
25	1100000000000110
	1100000000011000
	1100000001100000
	1100000110000000
	1100110000000000
30	1111000000000000

The following codes provided below are for the Steiner Triple System with N=30:

000000000000000000001100000000010

0000000000000000001010001000000
0000000000000000001100000000100
00000000000000000010010000000100
0000000000000000001010001000000
5 00000000000000000011000000001000
0000000000000000010001001000000
00000000000000000100100000001000
0000000000000000010100010000000
00000000000000000110000000010000
10 0000000000000001000010000001000
0000000000000001000100100000000
0000000000000001001000000010000
0000000000000001010001000000000
0000000000000001100000000000001
15 0000000000000001000001010000000
00000000000000010000100000010000
0000000000000001000100100000000
00000000000000010010000000000001
00000000000000010100000000010000
20 00000000000000011000000000000010
000000000000000100000010000010000
000000000000000100000101000000000
000000000000000100001000000000001
000000000000000100010000000010000
25 000000000000000100100000000000010
000000000000000101000000000100000
000000000000000110000000000000100
00000000000001000000011000000000
00000000000001000000100000000001
30 000000000000010000001000000100000
000000000000010000100000000000010
000000000000010001000000001000000
000000000000010010000000000000100
000000000000010100000000010000000

00000000000011000000000000001000
0000000000010000000010000000001
0000000000010000000100000100000
0000000000010000001000000000010
5 0000000000010000010000001000000
00000000000100001000000000000100
00000000000100010000000010000000
00000000000100100000000000001000
00000000000101000000000100000000
10 00000000000110000000000000010000
00000000001000000000000000110000
00000000001000000000000001001000
00000000001000000000000010000100
00000000001000000000000100000010
15 00000000001000000000001000000001
00000000010000000000000000000011
00000000010000000000000001100000
00000000010000000000000010010000
00000000010000000000000100001000
20 00000000100000000000001000000100
0000000011000000000100000000000
0000000100000000000000000000110
0000000100000000000000000001001
00000001000000000000000011000000
25 0000000100000000000000100100000
00000001000000000000001000010000
000000010100010000000000000000
000000011000000000100000000000
0000001000000000000000000001100
30 0000001000000000000000000010010
0000001000000000000000000100001
00000010000000000000000110000000
00000010000000000000001001000000
0000001001000000001000000000000

00000010100010000000000000000000
00000011000000001000000000000000
000001000000000000000000000011000
0000010000000000000000000000100100
5 00000100000000000000000000001000010
00000100000000000000000010000001
00000100000000000000001100000000
00000100010010000000000000000000
00000100100000000100000000000000
10 00000101000100000000000000000000
00000110000000001000000000000000
00001000000000000000000001010000
00001000000000000000000010001000
00001000000000000000000100000100
15 00001000000000000000001000000010
0000100000000010000000000100000
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00001000100100000000000000000000
00001001000000010000000000000000
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00001100000000000000100000000000
00010000000000000000000000000101
00010000000000000000000010100000
00010000000000000000000100010000
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5 00100000101000000000000000000000
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00100100000000000001000000000000
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10 00110000000000000001000000000000
010000000000000000000000000010100
010000000000000000000000000100010
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15 010000000001000000000100000000
010000000110000000000000000000
010000001000000000001000000000
010000010000001000000000000000
010000100000000000010000000000
20 010001000000010000000000000000
010010000000000000100000000000
010100000000100000000000000000
011000000000000001000000000000
10000000000000000000000000101000
25 10000000000000000000000001000100
100000000000000000000000010000010
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30 100000001000001000000000000000
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100001000000000000100000000000
100010000000010000000000000000

```

1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0
1 0 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0

```

5 It is noted that the described embodiments may be applicable for Type 2 resource allocation i.e. when there is a controlling node like eNB allocating the patterns for the devices, like UEs. The controlling node may ensure that devices in the same area are transmitting and receiving according to different patterns. However, the patterns according to the described embodiments can be utilized also with Type 1 resource allocation when pattern selection is

10 left to the devices. In this case, two nearby devices may occasionally choose to follow the same pattern, which prevents them from detecting each other or may prevent other devices from detecting them. But if such collisions are infrequent enough and only temporary (e.g. devices are changing the pattern after every pattern length), also Type 1 discovery gains may be obtained from the message combining.

15

It is noted that whilst embodiments have been described with reference to LTE, similar principles can be applied to any other communication system or indeed to further developments with LTE. Therefore, although certain embodiments were described above by way of example with reference to certain exemplifying architectures for wireless networks,

20 technologies and standards, embodiments may be applied to any other suitable forms of communication systems than those illustrated and described herein.

The required data processing apparatus and functions of any of the communication devices may be provided by means of one or more data processors. The described functions at each

25 end may be provided by separate processors or by an integrated processor. The data processors may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), application specific integrated circuits (ASIC), gate level circuits and processors based on multi core processor architecture, as non- limiting examples.

30 The data processing may be distributed across several data processing modules. A data processor may be provided by means of, for example, at least one chip. Appropriate memory capacity can also be provided in the relevant devices. The memory or memories may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor based memory devices, magnetic

memory devices and systems, optical memory devices and systems, fixed memory and removable memory.

In general, the various embodiments may be implemented in hardware or special purpose
5 circuits, software, logic or any combination thereof. Some aspects of the invention may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device, although the invention is not limited thereto. While various aspects of the invention may be illustrated and described as block diagrams, flow charts, or using some other pictorial representation, it
10 is well understood that these blocks, apparatus, systems, techniques or methods described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof. The software may be stored on such physical media as memory chips, or memory blocks implemented within the processor, magnetic media such as
15 hard disk or floppy disks, and optical media such as for example DVD and the data variants thereof, CD.

In the above various examples of means for implementing the functionalities are given. However, it is noted that these examples do not provide an exhaustive list of means capable
20 of operating in accordance with the inventive principles described herein.

The foregoing description has provided by way of exemplary and non-limiting examples a full and informative description of the exemplary embodiment of this invention. However, various modifications and adaptations may become apparent to those skilled in the relevant
25 arts in view of the foregoing description, when read in conjunction with the accompanying drawings and the appended claims. However, all such and similar modifications of the teachings of this invention will still fall within the spirit and scope of this invention as defined in the appended claims. Indeed there is a further embodiment comprising a combination of one or more of any of the other embodiments previously discussed.

30

Claims

1. A method comprising:
obtaining signal pattern information at a node, said information comprising a
5 codeword; and
using said information for configuring said node for reception of at least two copies of
a signal from a further node.
2. A method as set forth in claim 1, comprising combining said at least two copies of
10 said received signal.
3. A method as set forth in claim 1 or claim 2, comprising using said information for
configuring said node for transmission of at least two copies of a signal to a further node.
- 15 4. A method as set forth in any preceding claim, comprising determining transmit and
receive timeslots at said node in accordance with said obtained signal pattern information.
5. A method comprising:
determining at least one codeword;
20 indicating the at least one codeword to at least one node for configuring of a signal
pattern at said at least one node;
wherein said determining comprises using a block code to obtain said at least one
codeword;
and wherein said at least one codeword is configured to enable said at least one node
25 to receive at least two copies of a signal.
6. A method as set forth in claim 5, wherein said method comprises selecting said block
code to use.
- 30 7. A method as set forth in claim 5 or claim 6, wherein said determining comprises
comparing weights of a plurality of codewords of said block code.
8. A method as set forth in claim 7, wherein said determining comprises using said
weights to organize said plurality of codewords in to sets.

9. A method as set forth in any of claims 5 to 8, comprising determining a modified block code by removing one or more codewords from said block code.

5 10. A method as set forth in any of claims 5 to 9, wherein said determining at least one codeword comprises using a Kronecker product of said block code.

11. A computer program comprising computer executable instructions which when run on one or more processors perform the method of any of claims 1 to 10.

10

12. An apparatus comprising
at least one processor;
and at least one memory including computer program code;
the at least one memory and the computer program code configured to, with the at
least one processor, cause the apparatus at least to:
15 obtain signal pattern information, said information comprising a codeword; and
use said information for configuring reception of at least two copies of a signal from a
node.

20 13. An apparatus as set forth in claim 12, wherein the apparatus is configured to combine said at least two copies of said received signal.

14. An apparatus as set forth in claim 12 or claim 13, wherein said apparatus is
configured to use said information for configuring transmission of at least two copies of a
25 signal to a node.

15. An apparatus as set forth in any of claims 12 to 14, wherein said apparatus is
configured to determine transmit and receive timeslots in accordance with said received
signal pattern information.

30

16. An apparatus comprising
at least one processor;
and at least one memory including computer program code;

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

determine at least one codeword;

5 indicate the at least one codeword to at least one node for configuring of a signal pattern at said at least one node;

wherein said determining comprises using a block code to obtain said at least one codeword;

and wherein said at least one codeword is configured to enable said at least one node to receive at least two copies of a signal.

10

17. An apparatus as set forth in claim 16, wherein said apparatus is configured to select said block code to use.

18. An apparatus as set forth in claim 16 or claim 17, wherein said apparatus is
15 configured to compare weights of a plurality of codewords of said block code as part of said determining.

19. An apparatus as set forth in claim 18, wherein said apparatus is configured to use said weights to organize said plurality of codewords in to sets.

20

20. An apparatus as set forth in any of claims 16 to 19, wherein the apparatus is configured to determine a modified block code by removing one or more codewords from said block code.

25

FIG 1

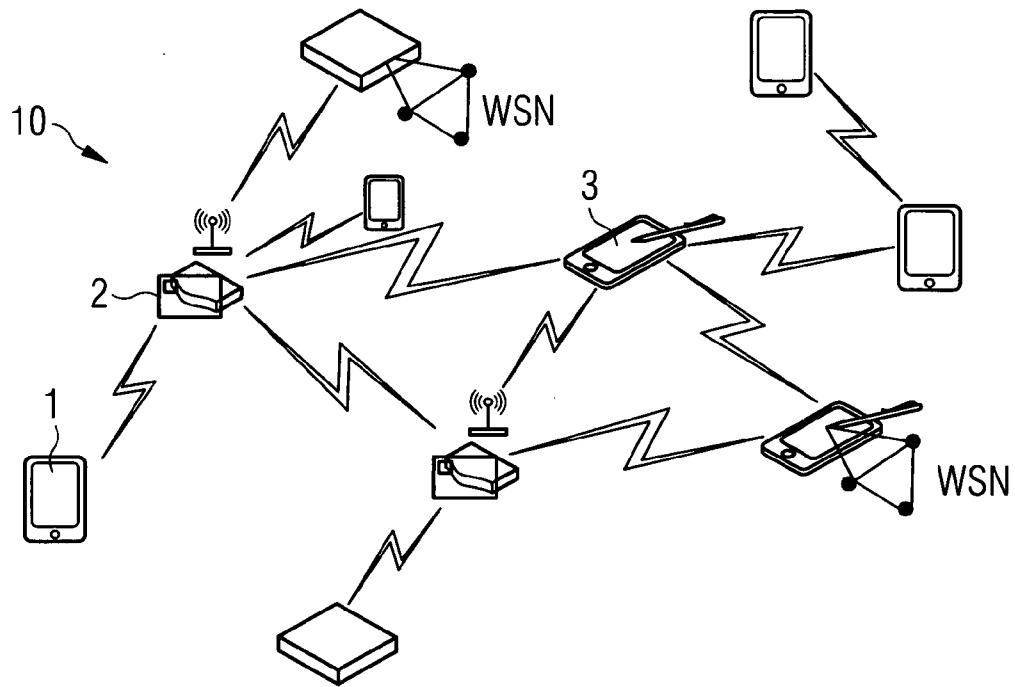
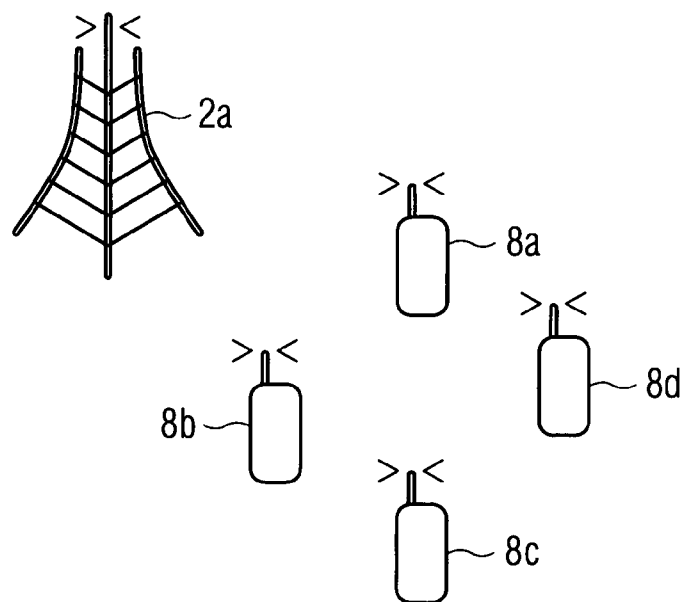


FIG 1A



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FIG 2

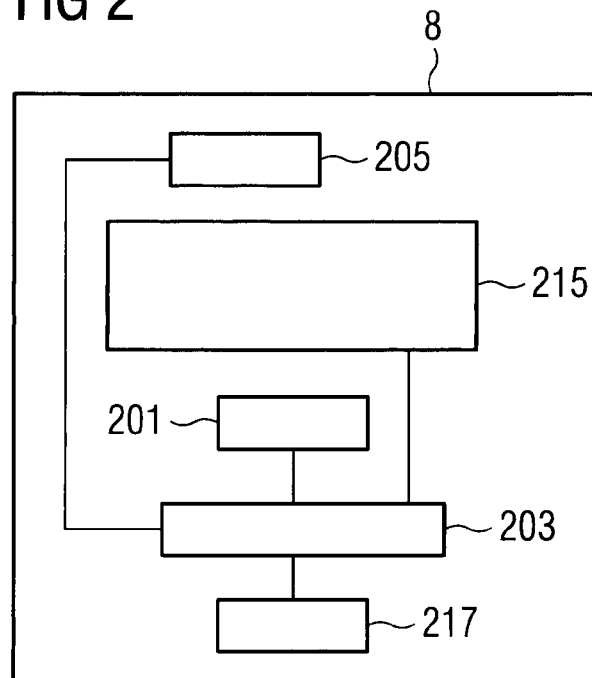
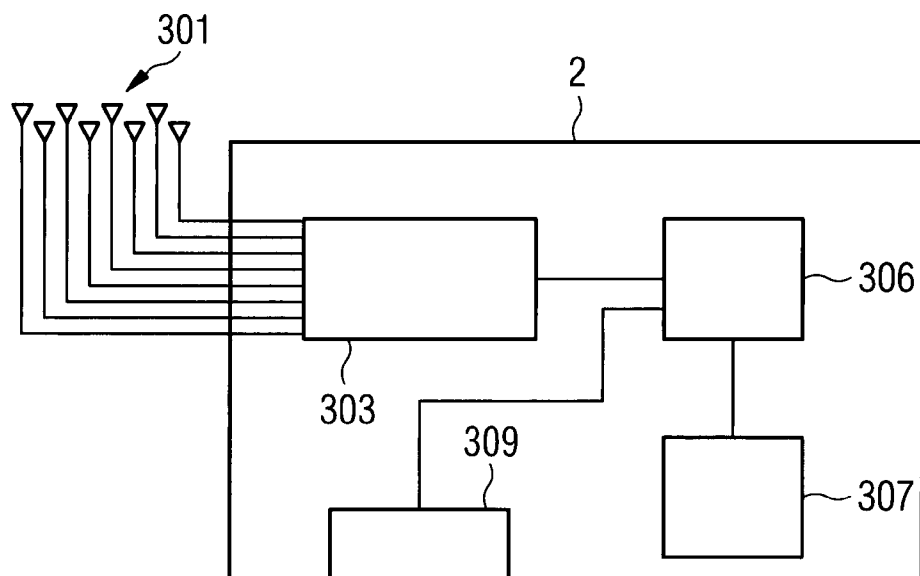


FIG 3



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FIG 4

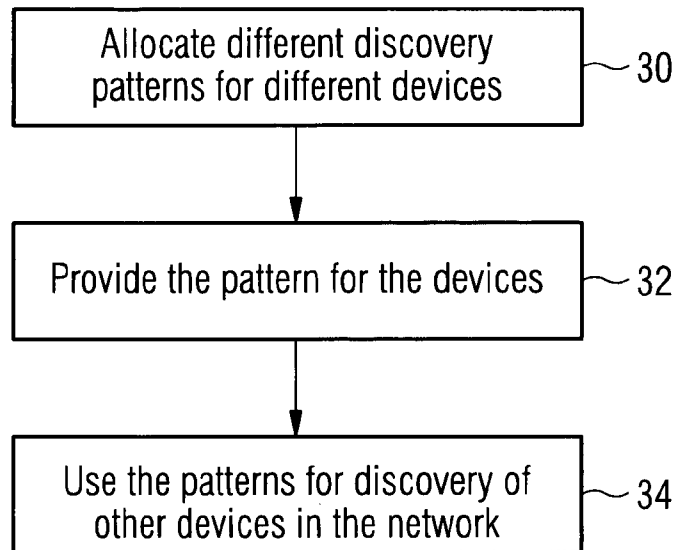


FIG 5

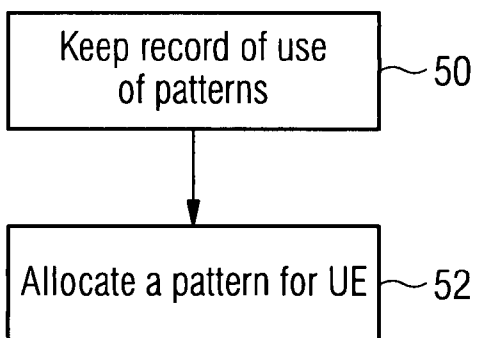
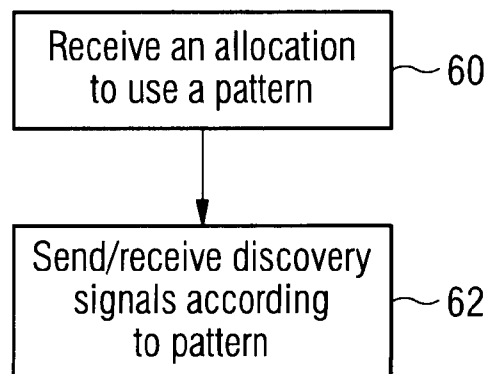


FIG 6



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FIG 7

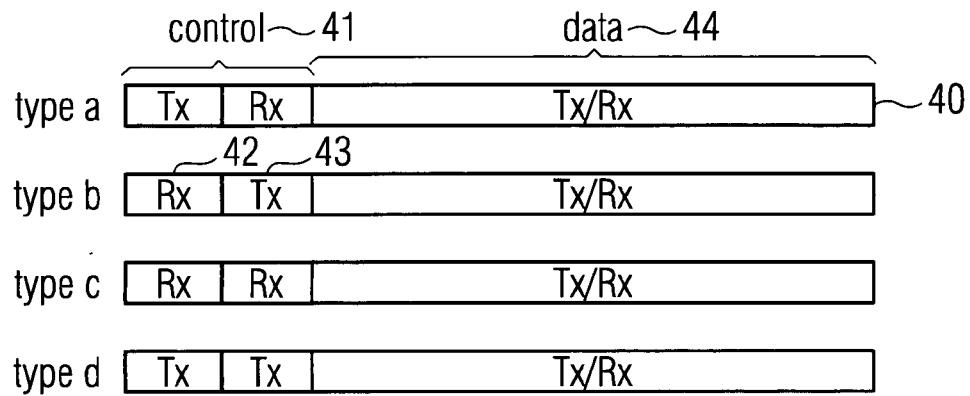


FIG 8

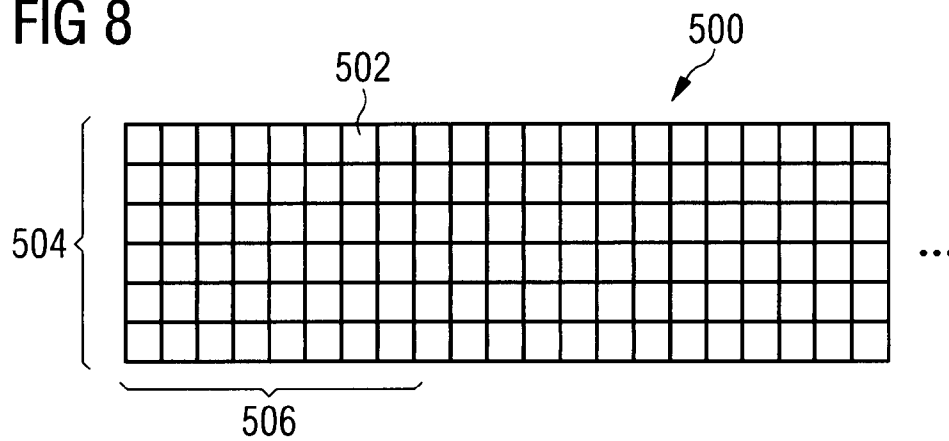
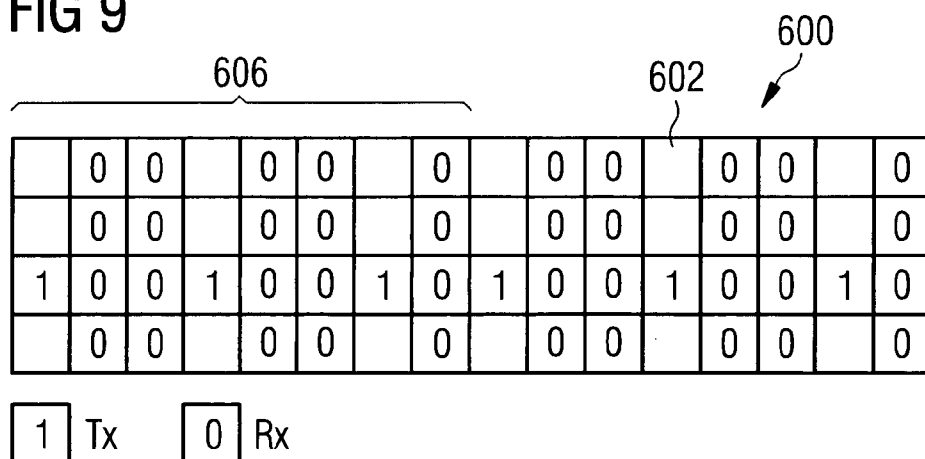


FIG 9



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FIG 10

0000000000000000	
000010100110111	← 702
000101001101110	← 704
000111101011001	
001000111101011	
001010011011100	
001101110000101	
001111010110010	
010001111010110	
010011011100001	
010100110111000	
010110010001111	
011001000111101	
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011100001010011	
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100001010011011	
100011110101100	
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101001101110000	
101011001000111	
101100100011110	
101110000101001	
110000101001101	
110010001111010	
110101100100011	
110111000010100	
111000010100110	
111010110010001	
111101011001000	
111111111111111	

FIG 11

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
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2	4	0	3	3	4	4	3	3	4	4	3	3	4	4	3	4	3
3	4	4	0	4	4	4	4	4	4	4	4	4	4	4	4	4	4
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9	4	4	3	3	4	4	3	3	0	4	3	3	4	4	3	4	3
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13	4	4	3	3	4	4	3	3	4	4	3	3	0	4	3	4	3
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26	4	4	4	4	8	4	4	4	4	4	4	4	4	4	4	4	4
27	4	4	3	7	4	4	3	3	4	4	3	3	4	4	3	4	3
28	4	4	7	3	4	4	3	3	4	4	3	3	4	4	3	4	3
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30	8	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

802 TX UE index

804 RX UE index

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/060524

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W72/00 H04W72/12 H04W74/04 H04L1/00 H04L1/08
H04W8/00

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)

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ASUSTEK: "On the Use of Type 2B Discovery", 3GPP DRAFT; R1-140292 ON THE USE OF TYPE 2B DISCOVERY, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Prague, Czech Republic; 20140210 - 20140214 9 February 2014 (2014-02-09), XP050735842, Retrieved from the Internet: URL: http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN/RAN1/Docs/ [retrieved on 2014-02-09] from page 2, beginning of section 2 to page 3 end of section 2.2; figure 1 ----- -/--	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

16 January 2015

Date of mailing of the international search report

28/01/2015

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Fax: (+31-70) 340-3016

Authorized officer

Courville, Nicolas

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2014/060524

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ASUSTEK: "Type 2B Discovery with Resource Hopping", 3GPP DRAFT; R1-140293 TYPE 2B DISCOVERY WITH RESOURCE HOPPING, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Prague, Czech Republic; 20140210 - 20140214 9 February 2014 (2014-02-09), XP050735843, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/RAN1/Docs/ [retrieved on 2014-02-09] section labelle "3) Deep fade in D2D channel links:" bridging pages 3 and 4 -----	1-20
A	NSN ET AL: "Pattern design and resource allocation for discovery Type 2B", 3GPP DRAFT; R1-142450, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Seoul, Korea; 20140519 - 20140523 18 May 2014 (2014-05-18), XP050789568, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/RAN1/Docs/ [retrieved on 2014-05-18] cited in the application the whole document -----	1-20
A	ASUSTEK: "Resource Hopping Mechanism for Type 2B Discovery", 3GPP DRAFT; R1-142360 RESOURCE HOPPING MECHANISM FOR TYPE 2B DISCOVERY, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; , vol. RAN WG1, no. Seoul, Korea; 20140519 - 20140523 18 May 2014 (2014-05-18), XP050787954, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/RAN1/Docs/ [retrieved on 2014-05-18] page 1 - page 2; figures 1-2 -----	1-20