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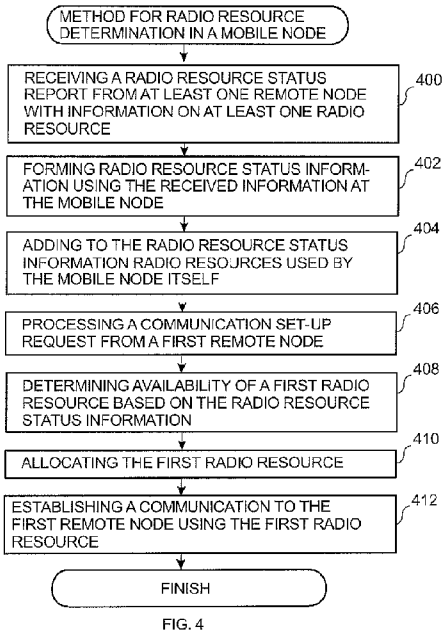


FIG. 4

(57) Abstract: The invention relates to a method and apparatus. In the method is a mobile node receives radio resource status reports from remote nodes, the first radio resource status report comprises information radio resource usage status. In the mobile node is formed radio resource status information. To the radio resource status information may be added information on usage of radio resources by the mobile node. A communication establishment request is received from a first remote node and an available radio resource is determined based on information comprised in the radio resource status information report. Thereupon, from the mobile node is establishing a communication to the first remote node using the available radio resource.

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AN APPARATUS AND A METHOD FOR RADIO RESOURCE DETERMINATION A MOBILE COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

Field of the invention:

The invention relates to mobile communications networks, device-to-device communication between end-user devices, and an apparatus and a method for radio resource determination in a mobile communication system.

Description of the Related Art:

The field of data communications has been in turmoil during the recent years. New technologies are being introduced while old technologies are being dismantled. Particularly, the data rates in wireless mobile communication systems have been increasing in the recent years rapidly. Long-Term Evolution (LTE) standardized by the 3G Partnership Project (3GPP) represents a significant leap forward in wireless mobile communication systems. One of the main objectives of the LTE is the providing of downlink data rates of at least 100 Mbps and uplink date rates of at least 50 Mbps. In order to be able to increase the data rates it should be possible to deploy new frequency bands into usage or to use existing frequency band more effectively via the use of more limited transmission power. One option of increasing the data rates is via the unloading of traffic from licensed frequency bands agreed for LTE. A significant amount of traffic may be unloaded from the licensed frequency bands if the traffic actually destined to a device that may be accessed with direct Device-to-Device (D2D) communications is implemented in the form of unlicensed band

device-to-device traffic. A significant amount licensed frequency band may also be made available, if device-to-device communication is used instead of communication via a base station, since device-to-device communication may use reduced power, which enables the reuse of the same frequencies nearer than in the case of communication via a base station. Device-to-device communications also enable the introduction of proximity based services and applications. The services and applications are based on the awareness of two devices are close to each other. The awareness of proximity may generate a demand to exchange data between the devices. Certain amount of traffic currently served by licensed bands is further inherently replaceable with unlicensed frequency band device-to-device traffic based on the proximity of devices within a single company or a single flat.

The possibility for device-to-device communication between end-user terminals has been discussed in LTE standardization. The use of device-to-device communication provides certain advantages. Firstly, it allows the saving of uplink and downlink radio resources, for example, Orthogonal Frequency Multiple Access (OFDMA) or Single-Carrier Frequency Domain Multiple Access (SC-FDMA) resource blocks to be freed and thereby increases the overall capacity available for users that cannot harness device-to-device communication for their own purposes, for example, if they are downloading files from a distant server. Secondly, device-to-device communication may take place within frequency bands having a transmission power upper limit such as TV channels adjacent to an operational TV channel in TV White Spaces (TVWS). Thirdly, device-to-device communication may be used to increase the coverage area of a base station cell to areas where it would otherwise not reach, for example, to tunnels, caves and buildings not equipped with base stations.

This is achieved by the use of chains of end-user devices that end to a device which is actually within the coverage area of a base station cell. Fourthly, the use of the use of device-to-device communication requires less transmission power compared to normal uplink transmission and that in turn reduces battery drainage. Fifthly, in some cases device-to-device communication may provide better radio channel quality, which in turn leads to improved Quality of Service (QoS) for users.

Device-to-device operation may be designed to be fully controlled by a base station, for example, a Long-Term Evolution (LTE) E-UTRAN Node B (eNB). The device-to-device operation comprises the discovery of devices, the establishment of links between the devices and the allocation of radio resources. However, if there is a large number of devices capable of device-to-device operation, full control of the operation by the base station may cause a significant burden for the base station due to the signaling required for radio resource management and device-to-device communication routing. Moreover, in some cases, a device capable of device-to-device communication initially has no desired remote device to connect to and the device requires information of all potential peers in its vicinity. The discovery of other devices requires a specific channel that other devices may tune to. However, radio resource selection and allocation becomes a problem in device-to-device communication when a base station or any other radio access network node such as a radio network controller is not performing a centralized management of radio resources. Different mobile nodes not communication directly may use same radio resources so that their transmissions disturb each other and cause interference. Another issue to be considered is that a device may communicate with multiple remote devices and a resource selected

for communicating with a further remote device must not be simultaneously used by the device and the other remote devices.

It would be beneficial to be able to coordinate the use of the radio resources directly between devices performing device-to-device communication.

SUMMARY OF THE INVENTION:

According to an aspect of the invention, the invention is a method, comprising: processing, in a mobile node, at least one incoming radio resource status report from at least one remote node, the at least one incoming radio resource status report comprising availability status information regarding at least one radio resource; forming, in the mobile node, radio resource status information from the availability status information; updating the radio resource status information based on usage of radio resources for active communication in the mobile node; processing, in the mobile node, a communication establishment request from a first remote node; determining an available radio resource based on information comprised in the radio resource status information; and establishing a communication to the first remote node using the available radio resource.

According to a further aspect of the invention, the invention is 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 perform: processing at least one incoming radio resource status report from at least one remote node, the at least one incoming radio resource status report comprising availability status information regarding at least one radio resource; forming radio resource status information to the at least one memory from the availability

status information; updating the radio resource status information in the at least one memory based on usage of radio resources by the apparatus for active communication; processing a communication establishment request from a first remote node; determining an available radio resource based on information comprised in the radio resource status information in the at least one memory; and establishing a communication to the first remote node using the available radio resource.

According to a further aspect of the invention, the invention is a mobile node comprising the apparatus.

According to a further aspect of the invention, the invention is an apparatus comprising: means for processing, at the apparatus, at least one incoming radio resource status report from at least one remote node, the at least one incoming radio resource status report comprising availability status information regarding at least one radio resource; means for forming radio resource status information from the availability status information; means for updating the radio resource status information based on usage of radio resources for active communication by the apparatus; means for processing a communication establishment request from a first remote node; means for determining an available radio resource based on information comprised in the radio resource status information; and means establishing a communication to the first remote node using the available radio resource.

According to a further aspect of the invention, the invention is a mobile node comprising the apparatus.

According to a further aspect of the invention, the invention is a computer program comprising code adapted to cause the following when executed on a data-processing system: processing, in a mobile node,

at least one incoming radio resource status report from at least one remote node, the at least one incoming radio resource status report comprising availability status information regarding at least one radio resource; forming, in the mobile node, radio resource status information from the availability status information; updating the radio resource status information based on usage of radio resources for active communication in the mobile node; processing, in the mobile node, a communication establishment request from a first remote node; determining an available radio resource based on information comprised in the radio resource status information; and establishing a communication to the first remote node using the available radio resource.

According to a further aspect of the invention, the invention is a computer program product comprising the computer program.

In one embodiment of the invention, the least one remote node comprises the first remote node. The first remote node may send a single incoming radio resource status report. The report may be comprised in a single message together with the communication establishment request.

In one embodiment of the invention, the radio resource status reports may be sent on a channel or a radio resource on which also communication set-up requests from the at least one remote node are received.

In one embodiment of the invention, the radio resource status reports may be sent on a channel or a radio resource for the discovery of the at least one remote node.

In one embodiment of the invention, the radio resource status reports may be sent on a channel or a radio resource reserved for the radio resource status reports.

In one embodiment of the invention, the availability status information on the at least one radio resource is a list indicating the at least one radio resource as available. The radio resource in the list may be ordered in increasing order based on noise level or channel quality on the radio resource.

In one embodiment of the invention, the availability status information on the at least one radio resource is a list indicating the at least one radio resource as reserved.

In one embodiment of the invention, the availability status information on the at least one radio resource comprises for each radio resource an indicator indicating whether the radio resource is available or reserved.

In one embodiment of the invention, the availability status information on the at least one radio resource comprises a first part for radio resources used by the remote node sending the radio resource status report for communication and a second part for radio resources used by other remote nodes for communication. In one embodiment of the invention, the second part may not contain information on radio resources for which the mobile node has sent a radio resource status report to the remote node sending the radio resource status report or radio resources used by the mobile node for communication with the remote node sending the radio resource status report.

In one embodiment of the invention, the step of determining an available radio resource based on information comprised in the radio resource status information comprises determining from the radio resource status information that all radio resources are allocated, determining from the radio resource status information a radio resource used by the mobile node to communicate with a second remote node, and allocating a part of the radio resource used by the mobile

node to communicate with the second remote node as the available radio resource.

In one embodiment of the invention, the radio resource status information comprises information whether at least one reserved radio resource is used by the mobile node for device-to-device communication.

In one embodiment of the invention, the part of the radio resource is selected using a predefined pattern defining partitioning of the radio resource between a first device-to-device communication and a second device-to-device communication.

In one embodiment of the invention, the method further comprises receiving a message comprising the at least one incoming radio resource status report and the communication establishment request.

In one embodiment of the invention, the method further comprises receiving a first message comprising the at least one incoming radio resource status report and receiving a second message comprising the communication establishment request.

In one embodiment of the invention, the method further comprises transmitting an outgoing radio resource status report comprising the radio resource status information. Before the transmitting of the outgoing radio resource status report, from the radio resource status information may be removed information on radio resources regarding which a radio resource status report has been received from the remote node from to which the radio resource status report is sent. Before the transmitting of the outgoing radio resource status report, from the radio resource status information may be removed information on radio resources indicated as used by the remote node to which the report is sent.

In one embodiment of the invention, the method further comprises receiving the communication establishment request from the second remote node.

In one embodiment of the invention, the method further comprises removing from the radio resource status information such radio resources for which signal level does not exceed a predefined threshold value in the mobile node.

In one embodiment of the invention, the method further comprises performing spectrum sensing in the available radio resource before the establishing of the communication to the first remote node using the available radio resource.

In one embodiment of the invention, the information on the at least one radio resource used by at least one reporting remote node comprises for each radio resource an identifier of the radio resource as at least one of a frequency range identifier and a time slot identifier.

In one embodiment of the invention, the radio resources comprised in the radio resource status information are for device-to-device communication.

In one embodiment of the invention, the mobile node comprises at least one of a handset, a chipset, a mobile device and a mobile terminal.

In one embodiment of the invention, the communication to the third remote node uses orthogonal frequency division multiple access or single carrier frequency division multiple access.

In one embodiment of the invention, the radio resource comprises at least one single carrier frequency division multiple access resource element which may be on adjacent subcarriers or on adjacent symbols. The resource elements may be seen as elements in a resource grid.

In one embodiment of the invention, the radio resource comprises at least one orthogonal frequency division multiple access resource element which may be on adjacent subcarriers or on adjacent symbols. The

resource elements may be seen as elements in a resource grid.

In one embodiment of the invention, the radio resource comprises at least one orthogonal frequency division multiplexing resource element which may be on adjacent subcarriers or on adjacent symbols.

In one embodiment of the invention, the radio resource comprises at least one frequency range.

In one embodiment of the invention, the radio resource comprises at least one time interval within at least one frequency range.

In one embodiment of the invention, the radio resource may comprise at least one of a channel, a frequency band, a frequency range, a subcarrier, a carrier, a timeslot and a slot.

In one embodiment of the invention, the at least one radio resource report from the at least one remote node comprises at least one identifier for a radio resource. The identifier for the radio resource may also have associated with it status indicating whether the radio resource is available or not.

In one embodiment of the invention, the radio resource status information in the mobile node may comprise at least one identifier for a radio resource. The identifier for the radio resource may also have associated with it status indicating whether the radio resource is available or not.

In one embodiment of the invention, the radio resource status information for radio resources used by the mobile node for active communication may comprise at least one identifier for a radio resource. The identifier for the radio resource may also have associated with it status indicating whether the radio resource is available or not.

In one embodiment of the invention, the processing of the communication establishment request from the first remote node comprises receiving the communi-

cation establishment request at the mobile node, for example, by a receiver of the mobile node.

In one embodiment of the invention, the communication establishment request may be comprised in same message together with the at least one at least one radio resource report.

In one embodiment of the invention, the communication establishment request may comprise at least one radio resource report among the at least one radio resource report. In this case the first remote node may be comprised among the at least one remote node.

In one embodiment of the invention, the determining of the available radio resource based on information comprised in the radio resource status information comprises retrieving information on all radio resources usable from a memory of the mobile node or the apparatus and checking whether among the usable radio resources is any radio resource not among radio resources listed as not available by way of being comprised in the radio resource status information or mentioned as not available in the radio resource status information. By usable radio resources may be meant radio resources for device-to-device communication and/or radio resources excluded from use due to excessive noise level not caused by the mobile node or the remote nodes sending radio resource availability status reports.

In one embodiment of the invention, radio resource sensing comprises finding a radio signal in the radio resource due to the fact that it has a noise level that is below a predefined threshold level for an allowed noise level. The noise may comprise both transmissions from other systems and background noise such as Gaussian noise.

In one embodiment of the invention, the mobile node comprises at least one of a handset, a chipset, a mobile device and a mobile terminal.

In one embodiment of the invention, the mobile node comprises a Long-Term Evolution (LTE) User Equipment.

In one embodiment of the invention, the remote node is a remote mobile node, for example an LTE User Equipment (UE). The remote node may also be a desktop, a desk computer or a server.

In one embodiment of the invention, the symbols are OFDMA or Single Carrier Frequency Division Multiple Access (SC-FDMA) symbols.

In one embodiment of the invention, the mobile node comprises a Long-Term Evolution (LTE) User Equipment.

In one embodiment of the invention, the at least one processor of the apparatus, for example, of the mobile node may be configured to perform any of the method steps disclosed hereinabove.

In one embodiment of the invention, the transmission and reception steps may be performed by at least one radio frequency circuit.

In one embodiment of the invention, the device-to-device communication may be a connection, for example, a transport layer connection, such as, for example, a TCP connection or a Stream Control Transmission Protocol (SCTP) connection. The communication may also be a flow of individual packets, for example, a flow of UDP packets. The flow of UDP packets may represent, for example, a media component associated with a multimedia session. In one embodiment of the invention, the communication may be set-up or established on any protocol layer, for example, it may be established, for example, also on Point-To-Point Protocol (PPP) layer or on a logical link layer.

In one embodiment of the invention, the base station comprises an OFDMA radio network node or an SC-FDMA radio network node.

In one embodiment of the invention, the at least one Radio Frequency (RF) circuit in the mobile node may also be referred to as at least one circuit.

In one embodiment of the invention, the at least one Radio Frequency (RF) circuit in the base station node may also be referred to as at least one circuit.

In one embodiment of the invention, the mobile node such as a User Equipment (UE) comprises a mobile station or generally a mobile terminal. In one embodiment of the invention a user of a mobile terminal is identified using a subscriber module, for example, User Services Identity Module (USIM) or a Subscriber Identity Module (SIM). The combination of Mobile Equipment (ME) and a subscriber module may be referred to as a mobile subscriber. A mobile subscriber may be identified using an IMSI. An IP address may be allocated or associated with a mobile subscriber.

In one embodiment of the invention, the apparatus is a mobile terminal, for example a, mobile handset.

In one embodiment of the invention, the apparatus is a semiconductor circuit, a chip or a chipset.

In one embodiment of the invention, the base station node is configured to be used in a 4G system such as, for example, LTE Evolved Packet System (EPS).

In one embodiment of the invention, a radio resource, for the transmission or for the device-to-device transmission may be a particular channel, a given number of symbols on a given number of subcarriers, a given number of subcarriers within a symbol time, a number of resource elements, or a number of resource blocks. The radio resource location in terms of frequency and time may be indicated by the base station.

In one embodiment of the invention, the computer program is stored on a computer readable medium.

The computer readable medium may be, but is not limited to, a removable memory card, a removable memory module, a magnetic disk, an optical disk, a holographic memory or a magnetic tape. A removable memory module may be, for example, a USB memory stick, a PCMCIA card or a smart memory card.

In one embodiment of the invention, the computer program product is stored on a computer readable medium. The computer readable medium may be, but is not limited to, a removable memory card, a removable memory module, a magnetic disk, an optical disk, a holographic memory or a magnetic tape. A removable memory module may be, for example, a USB memory stick, a PCMCIA card or a smart memory card.

In one embodiment of the invention, any of the at least one processor of the apparatus may perform any of the method steps hereinbefore, for example, indicated to be performed by the mobile node.

The embodiments of the invention described hereinbefore may be used in any combination with each other. Several of the embodiments may be combined together to form a further embodiment of the invention. A method, a base station, an apparatus, a computer program or a computer program product to which the invention is related may comprise at least one of the embodiments of the invention described hereinbefore.

It is to be understood that any of the above embodiments or modifications can be applied singly or in combination to the respective aspects to which they refer, unless they are explicitly stated as excluding alternatives.

The benefits of the invention are related to reduced signaling load at a base station by the virtue of disseminating radio resource availability information between devices such as mobile nodes.

BRIEF DESCRIPTION OF THE DRAWINGS:

The accompanying drawings, which are included to provide a further understanding of the invention and constitute a part of this specification, illustrate embodiments of the invention and together with the description help to explain the principles of the invention. In the drawings:

Fig. 1 illustrates a number of mobile nodes performing device-to-device communication on a number of radio resources in one embodiment of the invention;

Fig. 2A illustrates a first part of a device-to-device communication establishment between two mobile nodes using information received in radio resource usage reports from other mobile nodes in one embodiment of the invention;

Fig. 2B illustrates a second part of a device-to-device communication establishment between two mobile nodes using information received in radio resource usage reports from other mobile nodes in one embodiment of the invention;

Fig. 3 illustrates a number of mobile nodes performing device-to-device communication on a number of radio resources and reporting available radio resources in radio resource usage reports in one embodiment of the invention;

Fig. 4 is a flow chart illustrating a method for available radio resource determination in a mobile node in one embodiment of the invention;

Fig. 5 is a flow chart illustrating a method for radio resource splitting in one embodiment of the invention; and

Fig. 6 illustrates an apparatus in one embodiment of the invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS:

Reference will now be made in detail to the embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

Figure 1 illustrates a number of mobile nodes performing device-to-device communication on a number of radio resources in one embodiment of the invention.

In Figure 1 there is illustrated the time and frequency domains 170 for a frequency band 172 allocated for device-to-device communication. The frequency band comprises radio resources referred to as S1, S2 and S3. In Figure 1 the radio resources are illustrated to be separate in the frequency domain by way of Frequency Division Multiple Access (FDMA). However, the use of FDMA is just for illustrative purposes. Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), Orthogonal Frequency Multiple Access (OFDMA) or Single-Carrier Frequency Domain Multiple Access (SC-FDMA) may be used as well for the separation of the radio resources. In the case of OFDMA or SC-FDMA the radio resource may comprise, for example, resource blocks or resource elements. The number of radio resources is just for illustrative purposes. The radio resources may be paired so that S1, S2 and S3 represent or comprise two transmission directions, one for both communication parties. In addition to band 172 there may be a separate band for the other transmission direction, which is not shown for clarity purposes. This allows full duplex transmission. For example, in the case of OFDMA or SC-FDMA the Frequency Division Duplex (FDD) mode of operation may be used. The radio resources may also be unpaired and half-duplex mode of operation may be used. In the case of OFDMA or SC-FDMA the Time Division Duplex (TDD) may also be used.

In Figure 1 there are mobile nodes 150, 152, 154, 156, 158 and 160. The coverage areas of the

transmission from mobile nodes 150, 152, 154, 156, 158 and 160 are 150A, 152A, 154A, 156A, 158A and 160A, respectively. The coverage area 160A illustrated in Figure 1 may represent, for example, the area where the transmission from mobile node 160 may be received by another mobile node so that the level of a transmitted signal exceeds a predefined threshold value. The threshold value may represent a signal-to-noise ratio which allows the receiving of data such as remote mobile node discovery messages from mobile node 160 to be received by other mobile nodes such as mobile node 154. The threshold value may represent a signal-to-noise ratio or a power level which may disturb transmissions by other mobile nodes on same radio resource.

In Figure 1 mobile node 160 performs device-to-device communication with mobile node 154, as illustrated with double headed arrow 100. The device-to-device communication 100 is performed using radio resource S1. The device-to-device communication may be, for example, TDD communication on radio resource S1. Similarly, mobile node 156 and mobile node 158 perform device-to-device communication over radio resource S2, as illustrated with double-headed arrow 101. Due to the fact that mobile node 156 knows that it is communicating with mobile node 158 using radio resource S2, it sends a radio resource usage report to mobile node 150 as illustrated with arrow 103, the radio resource usage report comprises information on the radio resource S2 as being unavailable. The radio resource usage reports may also be called radio resource status reports. The radio resource usage reports may comprise a list of radio resources and their availability status. The radio resources may be listed in the reports on several granularity levels, depending on the size of radio resource allocations. The radio resource usage reports may also associate a bit value indicating allocation status with each radio resource. The

radio resource usage reports may also rank radio resources from best to worse or vice versa based on noise levels detected in them. In one embodiment of the invention, a number of best or worse radio resources may be omitted from the radio resource report. The radio resource usage reports may be sent on a channel that mobile nodes use for the discovery of remote mobile nodes. The channel may be called a Discovery Channel (DC). The radio resource usage reports may be sent on a channel reserved for radio resource usage or radio resource availability status reports. The radio resource usage reports may be sent on a channel or a radio resource where also communication set-up requests from remote nodes such as remote mobile nodes are received. Due to the fact that mobile node 154 knows that it is communicating with mobile node 160 using radio resource S1, it sends a radio resource usage report to mobile node 152 as illustrated with arrow 104, the radio resource usage report comprises information on the radio resource S1 being unavailable. When mobile node 152 requests an establishment of device-to-device communication with mobile node 150, mobile node 152 may indicate information on all radio resources that mobile node 152 knows to be in use. The knowledge on the use of radio resources is based on radio resource usage reports already received by mobile node 152 and radio resources used by mobile node 152 in communication with other possible mobile nodes. In the case of Figure 1 this is radio resource S1. The request for establishment of device-to-device communication from mobile node 152 to mobile node 150 may comprise separately information on radio resources used by other mobile nodes, that is, radio resources, the information of which has been received in radio resource usage reports from other mobile nodes than mobile node 150, and information on radio resources used by mobile node 154. Based on radio resource usage

reports received by mobile node 150 and the radio resource usage information that may be received in the request for establishment of device-to-device communication from mobile node 152, mobile node 150 determines that the radio resource S3 in frequency band 172 is available. Mobile node 150 may also perform radio resource sensing, for example, spectrum sensing in the sub-band of radio resource S3 to determine that the radio resource S3 does not have a signal or a noise exceeding a predefined threshold value. The threshold value may be set to a value that enables device-to-device communication between mobile node 150 and mobile node 152 with a sufficient signal level, that is, sufficient signal-to-noise ratio. The sufficient signal-to-noise ratio may depend on the available modulation and coding rate for the device-to-device communication. The availability status may also change after the receiving of the radio resource usage report, for example, if the availability status is received indirectly via an intermediate mobile node. If radio resource S3 is available, mobile node 150 establishes the device-to-device communication using radio resource S3. Due to the fact that radio resource S3 is being used by mobile node 152, it reports the use radio resource S3 in a radio resource usage report to mobile node 154, as illustrated with arrow 106. Due to the fact that mobile node 154 receives the report from mobile node 152, which itself uses radio resource S3, there is a danger of interference for device-to-device communications between mobile node 154 and other mobile nodes than mobile node 152. Therefore, mobile node 154 reports the radio resource S3 as used in radio resource usage report illustrated with arrow 107 to mobile node 160. The radio resource usage report may be sent during or after the device-to-device communication illustrated with arrow 100, provided that no fresher radio resource reports that indicate radio

resource S3 as available have been received. Mobile node 160, when receiving radio resource usage report 107, may decide whether it must report radio resource S3 as not available in its radio resource usage reports to further mobile nodes (not shown), based on, for example, whether it also receives a radio resource usage report indicating radio resource S3 as used from mobile node 152, whether it receives remote node discovery messages from mobile node 152, or whether radio resource sensing of radio resource S3 reveals a signal level that may cause potential interference for possible device-to-device communications to which mobile node 160 is a party.

Figure 2A illustrates a first part of a device-to-device communication establishment between two mobile nodes using information received in radio resource usage reports from other mobile nodes in one embodiment of the invention.

In Figure 2A there is illustrated the time and frequency domains 270 for a frequency band 272 allocated for device-to-device communication. The frequency band comprises radio resources referred to as S1 and S2. In Figure 2A the radio resources are illustrated to be separate in the frequency domain by way of Frequency Division Multiple Access (FDMA). However, the use of FDMA is just for illustrative purposes. Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), Orthogonal Frequency Multiple Access (OFDMA) or Single-Carrier Frequency Domain Multiple Access (SC-FDMA) may be used as well for the separation of the radio resources.

In Figure 2A there are mobile nodes 250, 252, 254, 256, 258 and 260. The coverage areas of the transmission from mobile nodes 250, 252, 254, 256, 258 and 260 are 250A, 252A, 254A, 256A, 258A and 260A, respectively. The coverage area 260A illustrated in Figure 2A may represent, for example, the area where the

transmission from mobile node 260 may be received by another mobile node so that the level of a transmitted signal exceeds a predefined threshold value. As illustrated with arrow 200, mobile node 258 and mobile node 256 are engaged in device-to-device communication over radio resource S2. As illustrated with arrow 201, mobile node 256 and mobile node 252 are engaged in device-to-device communication over radio resource S1. As illustrated with arrow 202, mobile node 260 and mobile node 254 are engaged in device-to-device communication over radio resource S2. Mobile node 254 sends a radio resource usage report, which may also be called, a radio resource status report that indicates radio resource S2 as used, as illustrated with arrow 203. Mobile node 256 sends a radio resource usage report that indicates radio resource S2 as used to mobile node 252, as illustrated with arrow 204. Mobile node 252 sends a radio resource usage report that indicates radio resources S1 and S2 as used to mobile node 250, as illustrated with arrow 205. This is due to the fact that mobile node 252 has received radio resource report 204 from mobile node 256 where radio resource S2 was indicated as used and that mobile node 252 performs device-to-device communication over S1 with mobile node 256. The device-to-device communication over S2 may cause interference at mobile node 252, since it is within the coverage area of the transmitter of mobile node 256, as determined, for example, from the reception of radio resource report 204 from mobile node 256. The device-to-device communication over S1 may cause interference at both mobile node 250 and mobile node 252, since mobile node 250 is within the coverage area of the transmitter of mobile node 252.

Mobile node 250 desires to establish device-to-device communication with mobile node 252. Mobile node 250 sends a set-up message to mobile node 252, as illustrated with arrow 206, the set-up message may

comprise information on all radio resources that mobile node 250 knows to be in use, that is, radio resources S1 and S2. The knowledge on the use of radio resources is based on radio resource usage reports already received by mobile node 250. If there were additionally radio resources presently used by mobile node 250 in communicating with other mobile nodes (not shown) mobile node 250 would also report them. When receiving the set-up message 206, mobile node 252 determines that there no whole radio resources available on the largest granularity level, that is, the whole S1 or the whole S2. Mobile node 205 may not select radio resource S2 for the new device-to-device communication with mobile node 250, since radio resource S2 is reported to be used by mobile node 256, the coverage area of which spans mobile node 252. The coverage area may be determined based on, for example, the receiving of remote mobile node discovery messages on a Discovery Channel (DC), radio resource sensing of radio resource S2 reported to be used in the mobile node that received the report, or the receiving of radio resource usage reports that indicate that radio resource S2 is being used by the reporting mobile node. Mobile node 252 decides to allocate a part of radio resource S1 that it uses in communication with mobile node 256 for the new device-to-device communication with mobile node 250. The part is illustrated in Figure 2B with reference S1/1. The part may be half of the radio resource or any other fraction. The fraction may depend on a desired bandwidth or QoS parameter from mobile node 250 in set-up message 205 and a desired bandwidth or QoS parameter associated with the existing device-to-device communication illustrated with arrow 201. The channel or radio resource for communicating between mobile node 252 and mobile node 256 is downgraded in terms of the bandwidth due the allocation. The downgraded channel or radio resource for

communicating between mobile node 252 and mobile node 256 is illustrated in Figure 2B with reference S1/2. A channel or radio resource already split may be further split by a mobile node to establish a further device-to-device communication. Mobile node 252 may ensure that a splitting does not cause a fragmentation of radio resources to a level that would increase the size of the allocation status information in the radio resource usage report message to a degree that would consume too much bandwidth. There may be a predefined limit for the splitting in the mobile nodes to guard against too much fragmentation of radio resources. The radio resource status reports may be sent on the Discovery Channel (DC) or on any other channel or radio resource. The radio resource status reports may be sent using a channel or radio resource that also carries communication establishment requests. A radio resource status report may be sent together in a single message with a communication establishment request.

Figure 2B illustrates a second part of a device-to-device communication establishment between two mobile nodes using information received in radio resource usage reports from other mobile nodes in one embodiment of the invention.

Figure 2B is continuation for Figure 2A. In Figure 2B there is illustrated the time and frequency domains 270 for a frequency band 272 allocated for device-to-device communication. The frequency band comprises radio resources referred to as S1/1, S1/2 and S2. In Figure 2B the radio resources are illustrated to be separate in the frequency domain by way of Frequency Division Multiple Access (FDMA). However, the use of FDMA is just for illustrative purposes. Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), Orthogonal Frequency Multiple Access (OFDMA) or Single-Carrier Frequency Domain Multi-

ple Access (SC-FDMA) may be used as well for the separation of the radio resources.

As illustrated with arrow 201, mobile node 258 and mobile node 256 are engaged in device-to-device communication over radio resource S1/1. As illustrated with arrow 207, mobile node 252 and mobile node 250 are engaged in device-to-device communication over radio resource S1/2.

The embodiments of the invention described hereinbefore in association with Figures 1, 2A and 2B may be used in any combination with each other. Several of the embodiments may be combined together to form a further embodiment of the invention.

Figure 3 illustrates a number of mobile nodes performing device-to-device communication on a number of radio resources and reporting available radio resources in radio resource usage reports in one embodiment of the invention.

In Figure 3 there is illustrated the time and frequency domains 370 for a frequency band 372 allocated for device-to-device communication. The frequency band comprises radio resources referred to as S1 and S2. In Figure 3 the radio resources are illustrated to be separate in the frequency domain by way of Frequency Division Multiple Access (FDMA). However, the use of FDMA is just for illustrative purposes. Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), Orthogonal Frequency Multiple Access (OFDMA) or Single-Carrier Frequency Domain Multiple Access (SC-FDMA) may be used as well for the separation of the radio resources.

In Figure 3 there are mobile nodes 350, 352, 354, 356, 358 and 360. The coverage areas of the transmission from mobile nodes 350, 352, 354, 356, 358 and 360 are 350A, 352A, 354A, 356A, 358A and 360A, respectively. The coverage area 360A illustrated in Figure 3 may represent, for example, the area where the

transmission from mobile node 360 may be received by another mobile node so that the level of a transmitted signal exceeds a predefined threshold value. As illustrated with arrow 300, mobile node 358 and mobile node 356 are engaged in device-to-device communication over radio resource S2. As illustrated with arrow 301, mobile node 356 and mobile node 352 are engaged in device-to-device communication over radio resource S1. As illustrated with arrow 302, mobile node 360 and mobile node 354 are engaged in device-to-device communication over radio resource S2. Mobile node 354 sends a radio resource usage report, which may also be called, a radio resource status report that indicates radio resource S1 as unused, as illustrated with arrow 303. The radio resource status report may comprise information on all radio resources known not to be used in mobile node 354. The radio resource status report may also comprise information on radio resources ranked among a predefined number of radio resources having the best quality in terms of at least one of low noise and determined ongoing transmissions on the radio resource. The quality may be determined using radio resource sensing by mobile node 354, or any other reporting mobile node. Mobile node 352 sends a radio resource usage report that indicates no radio resources as available to mobile node 350, as illustrated with arrow 304, due to the fact that mobile node 352 performs device-to-device communication with mobile node 356 using radio resource S1 and mobile node knows radio resource S2 to be unavailable, for example, from a radio resource status report from mobile node 356 or by radio resource sensing performed by mobile node 352. Mobile node 350 desires to establish device-to-device communication with mobile node 352. Mobile node 350 sends a set-up message to mobile node 352, as illustrated with arrow 305, the set-up message may comprise information on all radio resources that mobile node

350 knows to be available. In this case the list is empty. The knowledge on the use of radio resources is based on radio resource usage reports concerning available radio resources already received by mobile node 350. If there were additionally radio resources presently known to be available by mobile node 350, mobile node 350 would also report them. When receiving the set-up message 305, mobile node 352 determines that there no whole radio resources available on the largest granularity level, that is, the whole S1 or the whole S2. Mobile node 352 may not select radio resource S2 for the new device-to-device communication with mobile node 350, since radio resource S2 is not reported to be available by any mobile node. Mobile node 352 decides to allocate a part of radio resource S1 that it uses in communication with mobile node 356 for the new device-to-device communication with mobile node 350. The part is illustrated in Figure 2B with reference S1/1. The part may be half of the radio resource or any other fraction. The fraction may depend on a desired bandwidth or QoS parameter from mobile node 350 in set-up message 305 and a desired bandwidth or QoS parameter associated with the existing device-to-device communication illustrated with arrow 301. The channel or radio resource for communicating between mobile node 352 and mobile node 356 is downgraded in terms of the bandwidth due the allocation.

Figure 4 is a flow chart illustrating a method for available radio resource determination in a mobile node in one embodiment of the invention.

At step 400 a mobile node receives an incoming radio resource status report from at least one remote node, the at least one incoming radio resource status report comprises information on at least one radio resource used by at least one actively communicating remote node.

In one embodiment of the invention, the actively communicating remote node may comprise, for example, the remote node sending the status report or a remote node communicating with a remote node sending a radio resource status report to the remote node that sent the radio resource status report to the mobile node.

In one embodiment of the invention, the information may comprise a usage or an allocation status for each of the at least one radio resource.

At step 402 the mobile node forms a radio resource status information from the information on the at least one radio resource.

At step 404 the mobile node adds to the radio resource status information radio resource usage information for radio resources used by the mobile node for active communication. The mobile node may also update the radio resource status information based on radio resource usage information for radio resources used by the mobile node for active communication, for example, if the radio resource status information comprises information on available radio resources.

At step 406 the mobile node processes a communication establishment request from a first remote node. The communication establishment request may be comprised together in a single message with a radio resource status report from a remote node.

At step 408 the mobile node determines an available radio resource based on information comprised in the radio resource status information.

At step 410 the mobile node may allocate the available radio resource. The allocation may mean that the mobile node marks the radio resource as used in a memory of the mobile node, for example, in the radio resource status information, or in a temporary data structure that is used to update, for example, at a

later instance of the execution of step 404, the radio resource status information.

At step 412 the mobile node establishes a communication to the first remote node using the available radio resource.

In one embodiment of the invention, the mobile node may form a radio resource usage report comprising the radio resource status information and send it to a remote node known to the mobile node, from which a radio resource status report has not been received with information equivalent to the radio resource status information in the mobile node.

In one embodiment of the invention, the mobile node may filter from radio resource status information each radio resource for which the signal level does not exceed a predefined threshold level at the mobile node receiver and which is not used by the mobile node itself. The signal level may be determined by the mobile node, for example, by receiver measurement, that is, radio resource sensing or by being able to decode the first radio resource report at a receiver of the mobile node at step 402 or by being able to decode a discovery message from a remote node using the radio resource at a receiver of the mobile node.

Figure 5 is a flow chart illustrating a method for radio resource splitting in a mobile node in one embodiment of the invention.

At step 500 the mobile node sets up a device-to-device communication to a second remote node.

At step 502 the mobile node determines that all radio resources are reserved. The determination may be performed based on radio resource status reports from remote nodes and the radio resources used by the mobile node, for example, for the device-to-device communication with the second remote node.

At step 504 the mobile node determines, that is, selects a radio resource used to communicate with the second remote node.

At step 506 the mobile node decides to split the radio resource used to communicate with the second remote node to two new radio resources, one for the first remote node and the other for the second remote node.

At step 508 the mobile node allocates a first new radio resource for communication with the second mobile node.

At step 510 the mobile node allocates the second new radio resource for communication with the first mobile node. The mobile node determines this as the available radio resource of step 408 in Figure 4. The steps 502 - 510 may be part of step 408 of Figure 4.

The embodiments of the invention described hereinbefore in association with Figures 1, 2A, 2B, 3, 4 and 5 may be used in any combination with each other. Several of the embodiments may be combined together to form a further embodiment of the invention.

Figure 6 is a block diagram illustrating an apparatus in one embodiment of the invention. In Figure 6 there is an apparatus 600, which is, for example, a mobile node, user equipment, a handset, a cellular phone, a mobile terminal, an Application Specific Integrated Circuit (ASIC), a chip or a chipset. Apparatus 600 may correspond to a mobile node illustrated in Figures 1, 2A, 2B, 3, 4 and 5. The internal functions of apparatus 500 are illustrated with a box 602. Apparatus 600 may comprise at least one antenna 610. There may be multiple input and output antennas. In association with apparatus 600 there is Radio Frequency (RF) circuit 612. RF circuit 612 may be also any circuit or may be referred to as circuit 612 or circuitry 612. RF circuit 612 may also comprise a baseband circuit 612.

RF circuit 612 is communicatively connected to at least one processor 614. Connected to processor 614 there may be a first memory 620, which is, for example, a Random Access Memory (RAM). There may also be a second memory 622, which may be a non-volatile memory, for example, an optical or magnetic disk. There may also be a User Interface (UI) 616 and a display 618. In memory 620 there may be stored software relating to functional entities 632 and 634. A protocol stack entity 632 communicates with RF circuit 612 to perform device-to-device communication related signaling and user data transmission and reception. Protocol stack entity 632 receives radio resource usage reports, sends radio resource usage reports and sends request to perform device-to-device communication to remote nodes. Protocol stack entity 632 also comprises protocol functionalities related to user plane device-to-device transmission. Protocol stack entity 632 may comprise, for example, an internet protocol stack and a link layer protocol stack for remote device discovery and radio resource usage reporting. Radio resource manager entity 634 keeps track of radio resources used by remote nodes and mobile node 600 based on radio resource usage reports received via protocol stack entity 632. Radio resource manager entity 634 determines radio resources available and allocates a radio resource for device-to-device communication to a remote node. Radio resource manager entity 634 may also decide to split part of an already used radio resource for a new device-to-device communication as explained in association with Figures 2A and 2B, 3, 4 and 5. RF circuit 612 may comprise a transmitter for SC-FDMA and a receiver and a transmitter for OFDMA. RF circuit 612 may also comprise a receiver for SC-FDMA. RF circuit 512 may also comprise a transmitter and a receiver circuit for WLAN transmission or reception. As used in this application, the term 'circuitry' and 'circuit'

refers to all of the following: (a)hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and (b) to combinations of circuits and software (and/or firmware), such as (as applicable): (i) to a combination of processor(s) or (ii) to portions of processor(s)/software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and (c) to circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present. This definition of 'circuitry' applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term "circuitry" would also cover an implementation of merely a processor (or multiple processors) or portion of a processor and its (or their) accompanying software and/or firmware. The term "circuitry" would also cover, for example and if applicable to the particular claim element, a baseband integrated circuit or applications processor integrated circuit for a mobile phone or a similar integrated circuit in server, a cellular network device, or other network device.

When the at least one processor 614 executes functional entities associated with the invention, memory 620 comprises entities such as, any of the functional entities 632 and 634. The functional entities within apparatus 600 illustrated in Figure 6 may be implemented in a variety of ways. They may be implemented as processes executed under the native operating system of the network node. The entities may be implemented as separate processes or threads or so that a number of different entities are implemented by means of one process or thread. A process or a thread may be the instance of a program block comprising a

number of routines, that is, for example, procedures and functions. The functional entities may be implemented as separate computer programs or as a single computer program comprising several routines or functions implementing the entities. The program blocks are stored on at least one computer readable medium such as, for example, a memory circuit, memory card, magnetic or optical disk. Some functional entities may be implemented as program modules linked to another functional entity. The functional entities in Figure 5 may also be stored in separate memories and executed by separate processors, which communicate, for example, via a message bus or an internal network within the network node. An example of such a message bus is the Peripheral Component Interconnect (PCI) bus.

In one embodiment of the invention, the apparatus 600 comprises the at least one processor 614 and at least one memory, such as memory 620, including computer program code, the at least one memory and the computer program code are configured to, with the at least one processor, cause apparatus 600 at least to perform: processing at least one incoming radio resource status report from at least one remote node, the at least one incoming radio resource status report comprising availability status information regarding at least one radio resource; forming radio resource status information to the at least one memory from the availability status information; updating the radio resource status information in the at least one memory based on usage of radio resources by the apparatus for active communication; processing a communication establishment request from a first remote node; determining an available radio resource based on information comprised in the radio resource status information in the at least one memory; and establishing a communication to the first remote node using the available radio resource.

The exemplary embodiments of the invention can be included within any suitable device, for example, including any suitable servers, workstations, PCs, laptop computers, PDAs, Internet appliances, handheld devices, cellular telephones, wireless devices, other devices, and the like, capable of performing the processes of the exemplary embodiments, and which can communicate via one or more interface mechanisms, including, for example, Internet access, telecommunications in any suitable form (for instance, voice, modem, and the like), wireless communications media, one or more wireless communications networks, cellular communications networks, 3G communications networks, 4G communications networks Public Switched Telephone Network (PSTNs), Packet Data Networks (PDNs), the Internet, intranets, a combination thereof, and the like.

It is to be understood that the exemplary embodiments are for exemplary purposes, as many variations of the specific hardware used to implement the exemplary embodiments are possible, as will be appreciated by those skilled in the hardware art(s). For example, the functionality of one or more of the components of the exemplary embodiments can be implemented via one or more hardware devices, or one or more software entities such as modules.

The exemplary embodiments can store information relating to various processes described herein. This information can be stored in one or more memories, such as a hard disk, optical disk, magneto-optical disk, RAM, and the like. One or more databases can store the information regarding cyclic prefixes used and the delay spreads measured. The databases can be organized using data structures (e.g., records, tables, arrays, fields, graphs, trees, lists, and the like) included in one or more memories or storage devices listed herein. The processes described with respect to the exemplary embodiments can include appropriate

data structures for storing data collected and/or generated by the processes of the devices and subsystems of the exemplary embodiments in one or more databases.

All or a portion of the exemplary embodiments can be implemented by the preparation of one or more application-specific integrated circuits or by interconnecting an appropriate network of conventional component circuits, as will be appreciated by those skilled in the electrical art(s).

As stated above, the components of the exemplary embodiments can include computer readable medium or memories according to the teachings of the present inventions and for holding data structures, tables, records, and/or other data described herein. Computer readable medium can include any suitable medium that participates in providing instructions to a processor for execution. Such a medium can take many forms, including but not limited to, non-volatile media, volatile media, transmission media, and the like. Non-volatile media can include, for example, optical or magnetic disks, magneto-optical disks, and the like. Volatile media can include dynamic memories, and the like. Transmission media can include coaxial cables, copper wire, fiber optics, and the like. Transmission media also can take the form of acoustic, optical, electromagnetic waves, and the like, such as those generated during radio frequency (RF) communications, infrared (IR) data communications, and the like. Common forms of computer-readable media can include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, any other suitable magnetic medium, a CD-ROM, CDRW, DVD, any other suitable optical medium, punch cards, paper tape, optical mark sheets, any other suitable physical medium with patterns of holes or other optically recognizable indicia, a RAM, a PROM, an EPROM, a FLASH-EPROM, any other suitable memory

chip or cartridge, a carrier wave or any other suitable medium from which a computer can read.

While the present inventions have been described in connection with a number of exemplary embodiments, and implementations, the present inventions are not so limited, but rather cover various modifications, and equivalent arrangements, which fall within the purview of prospective claims.

The embodiments of the invention described hereinbefore in association with the figures presented and the summary of the invention may be used in any combination with each other. Several of the embodiments may be combined together to form a further embodiment of the invention.

It is obvious to a person skilled in the art that with the advancement of technology, the basic idea of the invention may be implemented in various ways. The invention and its embodiments are thus not limited to the examples described above; instead they may vary within the scope of the claims.

What is Claimed is:

1. A method, comprising:

processing, in a mobile node, at least one incoming radio resource status report from at least one remote node, the at least one incoming radio resource status report comprising availability status information regarding at least one radio resource;

forming, in the mobile node, radio resource status information from the availability status information;

updating the radio resource status information based on usage of radio resources for active communication in the mobile node;

processing, in the mobile node, a communication establishment request from a first remote node;

determining an available radio resource based on information comprised in the radio resource status information; and

establishing a communication to the first remote node using the available radio resource.

2. The method according to claim 1, wherein the availability status information on the at least one radio resource is a list indicating the at least one radio resource as available.

3. The method according to claim 1, wherein the availability status information on the at least one radio resource is a list indicating the at least one radio resource as reserved.

4. The method according to claim 1, wherein the availability status information on the at least one radio resource comprises for each radio resource an indicator indicating whether the radio resource is available or reserved.

5. The method according to claim 1, wherein the availability status information on the at least one radio resource comprises a first part for radio resources used by the remote node sending the radio resource status report for communication and a second

part for radio resources used by other remote nodes for communication.

6. The method according to claim 1, wherein the step of determining an available radio resource based on information comprised in the radio resource status information comprises:

determining from the radio resource status information that all radio resources are allocated;

determining from the radio resource status information a radio resource used by the mobile node to communicate with a second remote node; and

allocating a part of the radio resource used by the mobile node to communicate with the second remote node as the available radio resource.

7. The method according to claim 6, wherein the radio resource status information comprises information whether at least one reserved radio resource is used by the mobile node for device-to-device communication.

8. The method according to claim 6, wherein the part of the radio resource is selected using a predefined pattern defining partitioning of the radio resource between a first device-to-device communication and a second device-to-device communication.

9. The method according to claim 1, wherein the method further comprises:

receiving a message comprising the at least one radio resource status report and the communication establishment request.

10. The method according to claim 1, wherein the method further comprises:

receiving a first message comprising the at least one radio resource status report; and

receiving a second message comprising the communication establishment request.

11. The method according to claim 1, wherein the method further comprises:

transmitting an outgoing radio resource status report comprising the radio resource status information.

12. The method according to claim 1, wherein the method further comprises:

receiving the communication establishment request from the second remote node.

13. The method according to claim 1, wherein the method further comprises:

removing from the radio resource status information such radio resources for which signal level does not exceed a predefined threshold value in the mobile node.

14. The method according to claim 1, the method further comprising:

performing spectrum sensing in the available radio resource before the establishing of the communication to the first remote node using the available radio resource.

15. The method according to claim 1, wherein the information on the at least one radio resource used by at least one reporting remote node comprises for each radio resource an identifier of the radio resource as at least one of a frequency range identifier and a time slot identifier.

16. The method according to claim 1, wherein the radio resources comprised in the radio resource status information are for device-to-device communication.

17. The method according to claim 1, wherein the mobile node comprises at least one of a handset, a chipset, a mobile device and a mobile terminal.

18. The method according to claim 1, wherein the communication to the first remote node uses orthogonal frequency division multiple access or single carrier frequency division multiple access.

19. 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 perform:

processing at least one incoming radio resource status report from at least one remote node, the at least one incoming radio resource status report comprising availability status information regarding at least one radio resource;

forming radio resource status information to the at least one memory from the availability status information;

updating the radio resource status information in the at least one memory based on usage of radio resources by the apparatus for active communication;

processing a communication establishment request from a first remote node;

determining an available radio resource based on information comprised in the radio resource status information in the at least one memory; and

establishing a communication to the first remote node using the available radio resource.

20. A computer program comprising code adapted to cause the following when executed on a data-processing system:

processing, in a mobile node, at least one incoming radio resource status report from at least one remote node, the at least one incoming radio resource status report comprising availability status information regarding at least one radio resource;

forming, in the mobile node, radio resource status information from the availability status information;

updating the radio resource status information based on usage of radio resources for active communication in the mobile node;

processing, in the mobile node, a communication establishment request from a first remote node;

determining an available radio resource based on information comprised in the radio resource status information; and

establishing a communication to the first remote node using the available radio resource.

21. The computer program according to claim 20, wherein said computer program is stored on a computer readable medium.

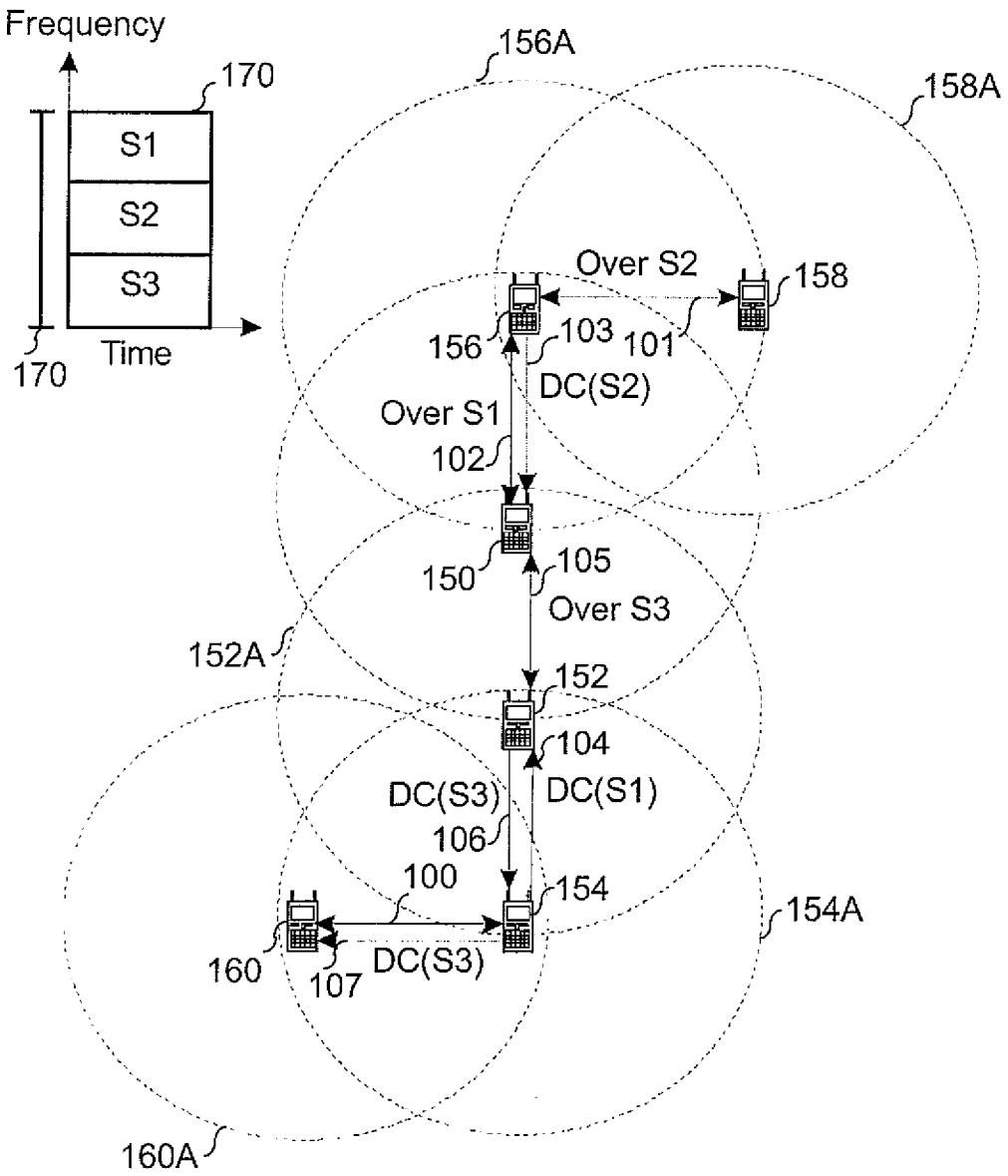

Frequency
170
S1
S2
S3
Time
170
156A
158A
Over S2
158
156
103
101
DC(S2)
Over S1
102
150
105
Over S3
152A
152
104
DC(S3)
DC(S1)
106
100
154
154A
160
107
DC(S3)
160A

FIG. 1

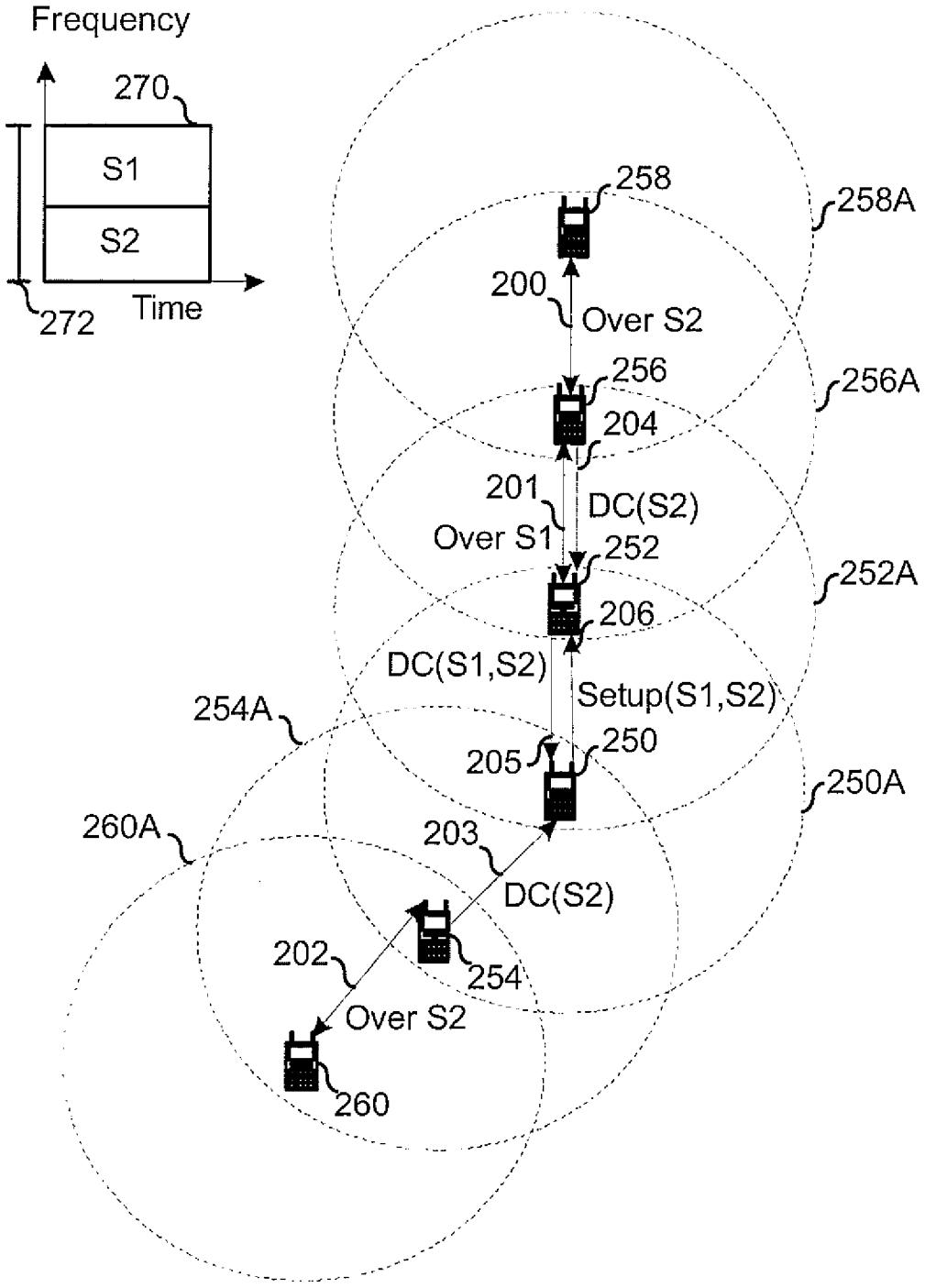

Frequency
270
S1
S2
272
Time
258
258A
200
Over S2
256
256A
204
201
DC(S2)
Over S1
252
252A
206
DC(S1,S2)
Setup(S1,S2)
254A
205
250
250A
260A
203
DC(S2)
202
254
Over S2
260

FIG. 2A

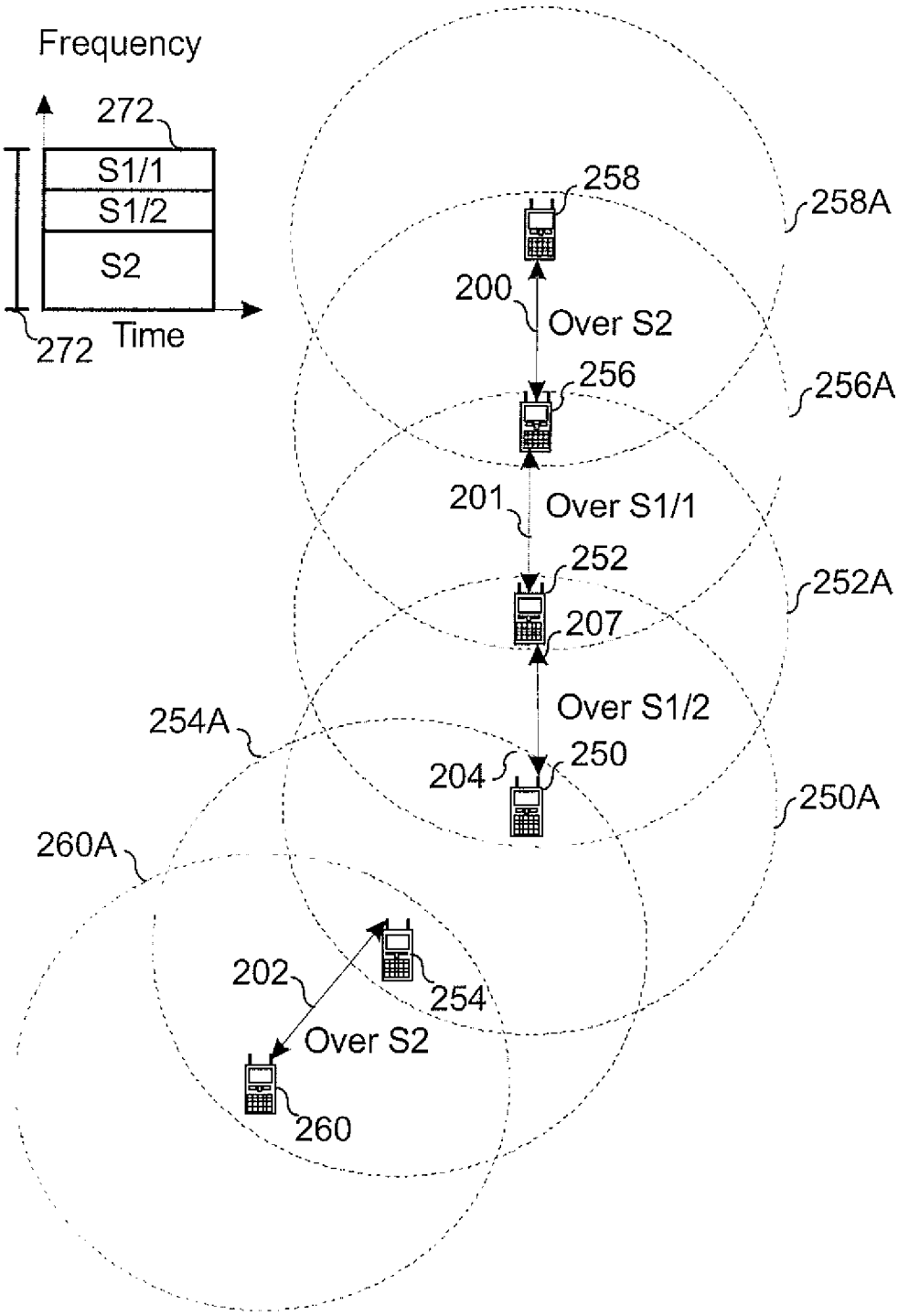

Frequency
272
S1/1
S1/2
S2
Time
272
258
258A
200
Over S2
256
256A
201
Over S1/1
252
252A
207
Over S1/2
254A
250
204
250A
260A
202
254
Over S2
260

FIG. 2B

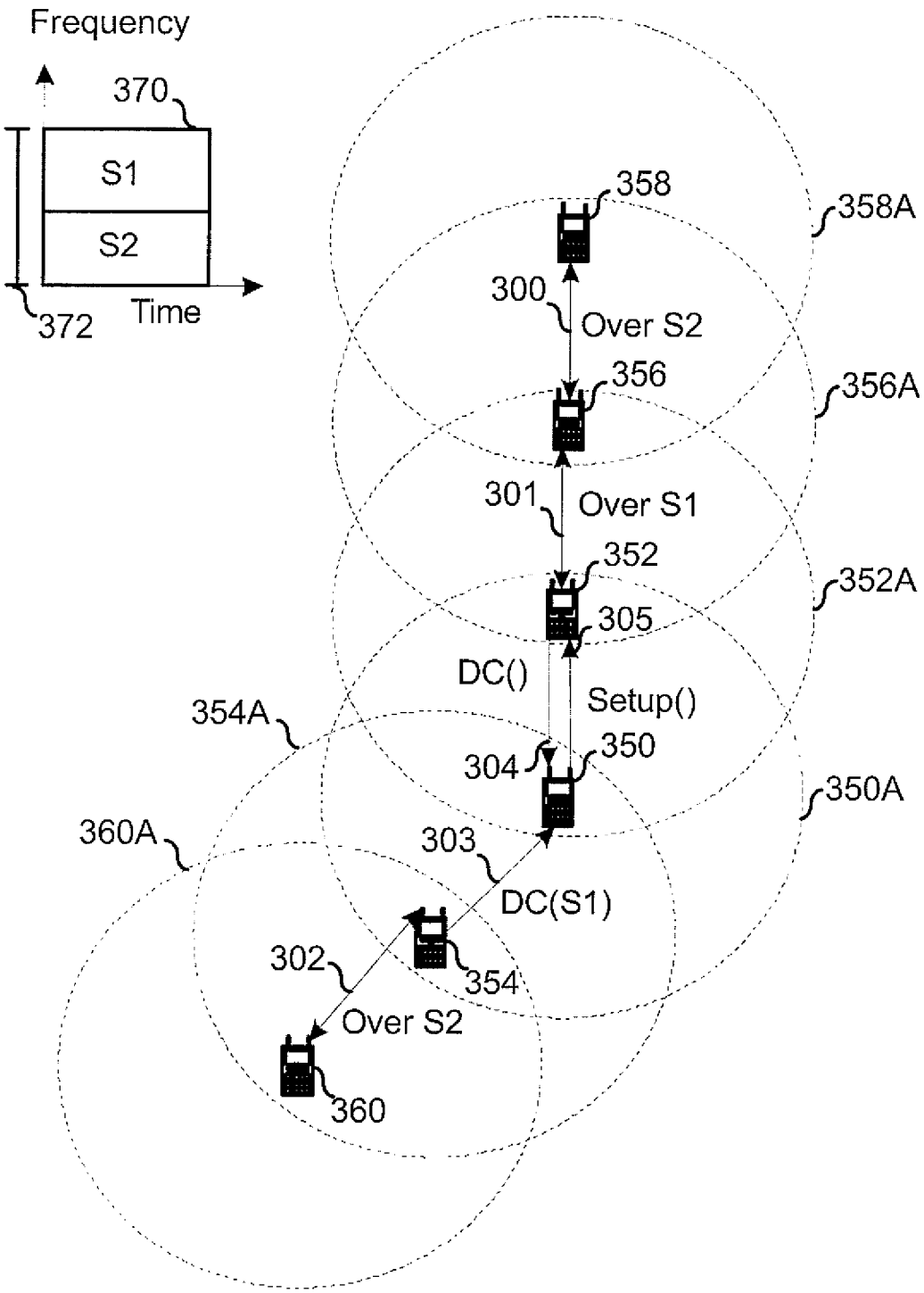

Frequency
370
S1
S2
372
Time
358
358A
300
Over S2
356
356A
301
Over S1
352
352A
305
DC()
Setup()
354A
304
350
350A
360A
303
DC(S1)
302
354
Over S2
360

FIG. 3

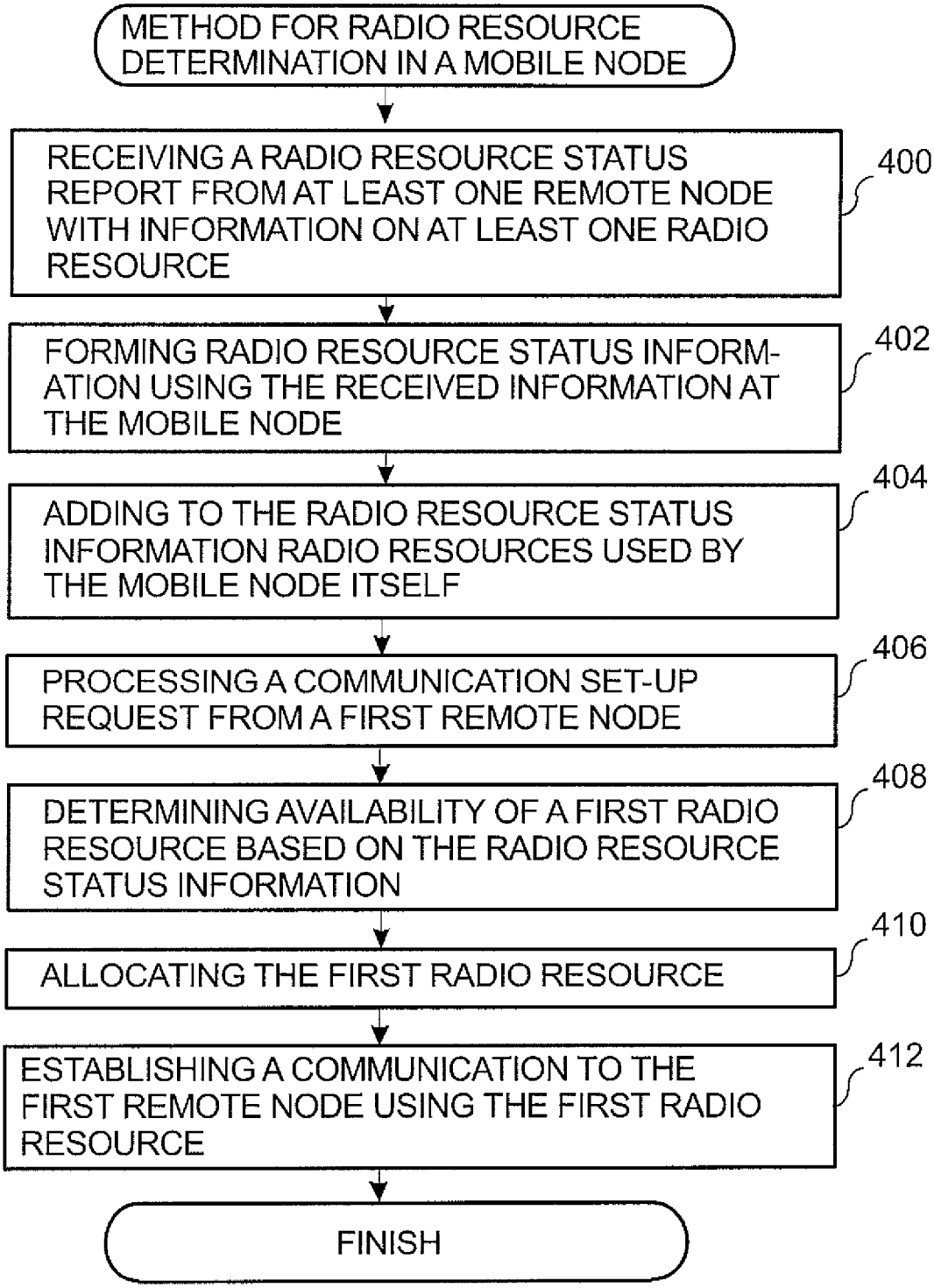

METHOD FOR RADIO RESOURCE DETERMINATION IN A MOBILE NODE
RECEIVING A RADIO RESOURCE STATUS REPORT FROM AT LEAST ONE REMOTE NODE WITH INFORMATION ON AT LEAST ONE RADIO RESOURCE
400
FORMING RADIO RESOURCE STATUS INFORMATION USING THE RECEIVED INFORMATION AT THE MOBILE NODE
402
ADDING TO THE RADIO RESOURCE STATUS INFORMATION RADIO RESOURCES USED BY THE MOBILE NODE ITSELF
404
PROCESSING A COMMUNICATION SET-UP REQUEST FROM A FIRST REMOTE NODE
406
DETERMINING AVAILABILITY OF A FIRST RADIO RESOURCE BASED ON THE RADIO RESOURCE STATUS INFORMATION
408
ALLOCATING THE FIRST RADIO RESOURCE
410
ESTABLISHING A COMMUNICATION TO THE FIRST REMOTE NODE USING THE FIRST RADIO RESOURCE
412
FINISH

FIG. 4

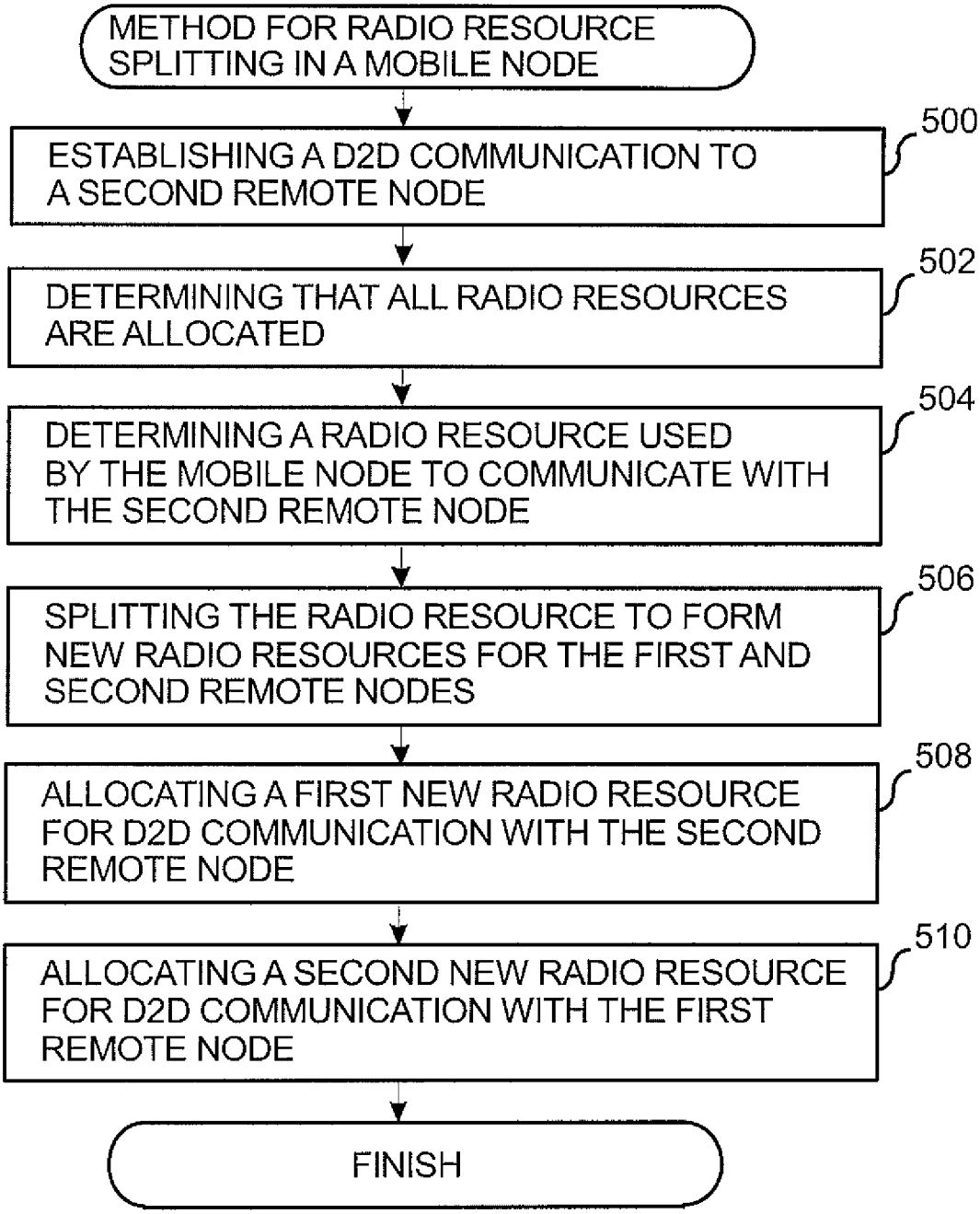

METHOD FOR RADIO RESOURCE SPLITTING IN A MOBILE NODE
ESTABLISHING A D2D COMMUNICATION TO A SECOND REMOTE NODE
500
DETERMINING THAT ALL RADIO RESOURCES ARE ALLOCATED
502
DETERMINING A RADIO RESOURCE USED BY THE MOBILE NODE TO COMMUNICATE WITH THE SECOND REMOTE NODE
504
SPLITTING THE RADIO RESOURCE TO FORM NEW RADIO RESOURCES FOR THE FIRST AND SECOND REMOTE NODES
506
ALLOCATING A FIRST NEW RADIO RESOURCE FOR D2D COMMUNICATION WITH THE SECOND REMOTE NODE
508
ALLOCATING A SECOND NEW RADIO RESOURCE FOR D2D COMMUNICATION WITH THE FIRST REMOTE NODE
510
FINISH

FIG. 5

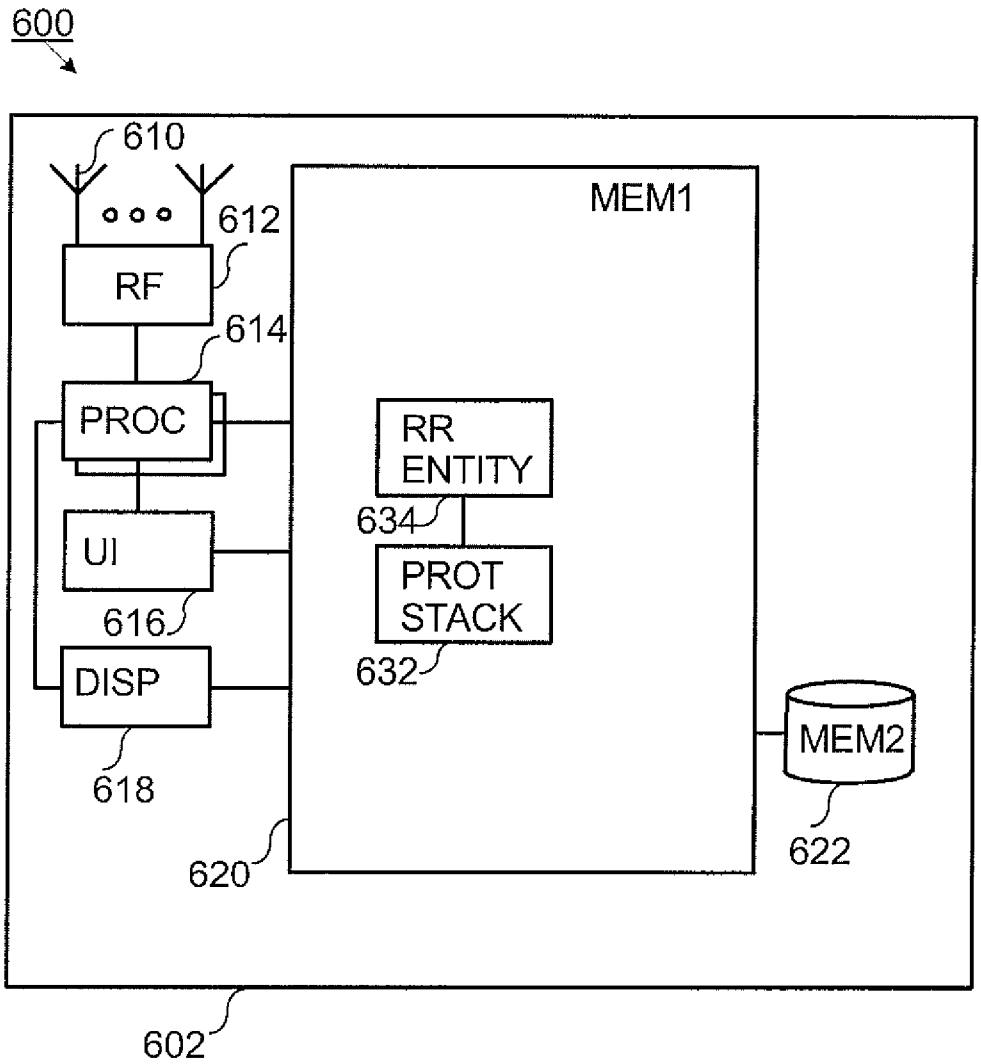

600
610
612
RF
614
PROC
UI
616
DISP
618
620
MEM1
RR
ENTITY
634
PROT
STACK
632
MEM2
622
602

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2012/070839

A. CLASSIFICATION OF SUBJECT MATTER

H04W16/10 (2009.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H04W, H04Q7, H04L12, H04L29

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)

VEN, CPRSABS, CNKI: radio, wireless, communication, resources, D2D, P2P, T2T, device to device, point to point, terminal to terminal, remoter, node, status, state, information, report, message, availability, usage, update, list

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN102246575 A (NOKIA CORP) 16 Nov. 2011(16.11.2011) Paragraphs [0020]-[0046] of the description	1-21
A	WO2011069295 A1 (NOKIA CORP) 16 Jun. 2011 (16.06.2011) Paragraphs [0028]-[0066] of the description	1-21
A	CN102325301 A (UNIV TONGJI) 18 Jan. 2012 (18.01.2012) The whole document	1-21
A	CN101064949 A (POTEVIO INST TECHNOLOGY) 31 Oct. 2007 (31.10.2007) The whole document	1-21

☐ 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

"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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
22 Oct. 2012 (22.10.2012)	**15 Nov. 2012 (15.11.2012)**
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer WANG, Chunyan Telephone No. (86-10)62411355

Form PCT/ISA /210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2012/070839

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN102246575A	16.11.2011	EP2342932A1	13.07.2011
		US2012093098A1	19.04.2012
		KR20110089311A	05.08.2011
		WO2010049801A1	06.05.2010
WO2011069295A1	16.06.2011	US2012243431A1	27.09.2012
CN102325301A	18.01.2012	None	
CN101064949A	31.10.2007	CN100571440C	16.12.2009