



(51) International Patent Classification:

H04W 40/22 (2009.01) *H04W* 48/20 (2009.01)
H04W 88/04 (2009.01) *H04L* 12/56 (2006.01)

(21) International Application Number:

PCT/EP2008/064909

(22) International Filing Date:

4 November 2008 (04.11.2008)

(25) Filing Language:

English

(26) Publication Language:

English

(71) Applicant (for all designated States except US): **NOKIA SIEMENS NETWORKS OY** [FI/FI]; Karaportti 3, FIN-02610 Espoo (FI).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **WANG, Haifeng** [FI/CN]; Room 101, Num 15, Lane 69, GuBei Road, Shanghai 200051 (CN). **CHEN, Xia** [CN/CN]; Road Changxue 109, Town Shuitou, County Pingyang, Zhejiang, Wenzhou 325400 (CN). **XIA, Xiaomei** [CN/CN]; Petrochemical Complex, 3rd room, 3rd floor, No. 75 Residential Building, Hubei, Jingmen 480000 (CN).

(74) Agent: **KOLSTER OY AB**; Iso Roobertinkatu 23, P.O. Box 148, FIN-00121 Helsinki (FI).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— of inventorship (Rule 4.17(iv))

Published:

— with international search report (Art. 21(3))

(54) Title: RELAYED TRANSMISSION IN COMMUNICATION SYSTEM

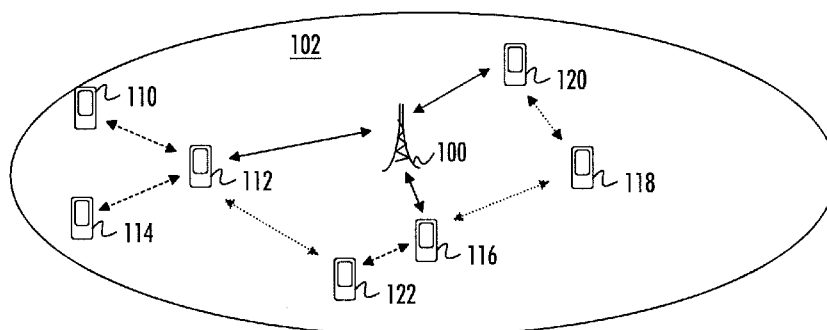


Fig 1

(57) Abstract: A method, apparatus, and computer program for controlling relayed communications in a wireless communication system are provided. Assignment of relay terminals to source terminals requesting for a relayed connection to a destination node is carried out in a centralized manner on the basis of relay status information received from candidate relay terminals. The relay status information received from a given candidate relay terminal indicates which source terminals the candidate relay terminal is capable of serving and in which radio communication resources. The assignment of a relay terminal-source terminal pair is carried out with the primary criterion that radio communication resources available for a relayed connection of one or more terminal devices, for which the assignment has not yet been carried out, are not pre-empted.



Relayed Transmission in Communication System

Field

The invention relates to the field of radio telecommunications and, particularly, to relayed transmissions in a radio telecommunication system.

5 Background

Next-generation wireless communication systems support significantly higher data rates than current systems. The need for high data rates imposes power implications particularly in the uplink, wherein limited battery power resources are used for the transmission. Therefore, it is
10 envisaged that the next-generation wireless communication systems utilize relay-based multi-hop networks in the uplink, wherein a transmission of a given user terminal (a source terminal) is relayed to a serving base station through another user terminal (a relay terminal). Such a solution extends the radio range of the user terminals and reduces the effects of shadowing, for example.

15 A problem related to the relayed transmissions is how to efficiently allocate relay terminal(s) to the source terminals, i.e. how to perform the source-relay pairing. Prior art studies have concentrated on examining scenarios where a single terminal needs a relayed transmission. This is not a practical approach, because in a real radio environment, a cell of the wireless
20 communication system may serve multiple user terminals in need of the relayed transmission and multiple relay terminals providing relayed connections.

Brief description

According to an aspect of the present invention, there is provided a
25 method as specified in claim 1.

According to another aspect of the present invention, there is provided an apparatus as specified in claim 11.

According to another aspect of the present invention, there is provided an apparatus as specified in claim 21.

30 According to yet another aspect of the present invention, there is provided a computer program product embodied on a computer readable distribution medium as specified in claim 22.

Embodiments of the invention are defined in the dependent claims.

List of drawings

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

Figure 1 illustrates relayed communication in a cell of a cellular telecommunication system;

Figure 2 illustrates a generalized process for assigning relay terminals to source terminals requesting a relayed connection;

Figure 3 illustrates the structure of an apparatus carrying out the assignment process of Figure 2;

Figure 4 illustrates a relay utilization optimization procedure according to an embodiment of the invention;

Figure 5 illustrates an embodiment of the optimization procedure based on the process of Figure 4;

Figure 6 illustrates another embodiment of the optimization procedure based on the process of Figure 4;

Figure 7 illustrates another embodiment of the relay utilization optimization procedure; and

Figure 8 illustrates yet another embodiment of the relay utilization optimization procedure.

Description of embodiments

Figure 1 illustrates a general concept of communications according to embodiments of the invention, wherein relayed communication connections are provided between a base station 100 and terminal devices in poor channel conditions in a cell 102 where the base station 100 serves the terminal devices with wireless communication connections. The relayed connections are established via relay terminals having a good channel environment with both the base station 100 and one or more terminal devices for which the relayed connection is established. In Figure 1, solid lines indicate direct communication connections with the base station 100, dashed lines indicate relayed connections, and dotted lines indicate relayed connections that are not established for a reason.

Referring to Figure 1, terminal devices 112, 116, and 120 are relay terminals providing other terminal devices 110, 114, 122, 118 (referred to as source terminals from now on) with a relayed communication connection to the base station. The establishment of the relayed connection may start with the

source terminal broadcasting a request for a relayed connection and a quality-of-service (QoS) requirement for the connection. Candidate relay terminals detecting the request then determine whether or not they are capable of serving the source terminal by determining whether or not they are able to
5 meet the QoS requirement for the connection. If a given relay terminal is capable of meeting the QoS requirement, the relay terminal may report to the base station 100 the identity of the source terminal and information that it is capable of providing the source terminal with the relayed connection. Then, the base station may pair the source terminal with a relay terminal capable of
10 providing the relayed connection and configure the source terminal and the selected relay terminal to establish the relayed connection.

Referring to Figure 1, the source terminals 110, 114, 122, 118 have broadcasted the request for a relayed connection and the QoS requirements for their connection requests. A first candidate relay terminal 112 detects the
15 requests broadcasted by the source terminals 110, 114, and 122. Upon detecting the QoS requirements from the received requests, the first candidate relay terminal 112 estimates its capabilities of providing the relayed connections. The estimation may comprise estimation of channel state information of a communication channel between the base station and the first
20 candidate relay terminal 112 and a communication channel between the first candidate relay terminal 112 and each source terminal 110, 114, 122. From the estimated channel state information, the first candidate relay terminal 112 may estimate its capacity to support the relayed connections. Then, the first candidate relay terminal 112 sends capacity information to the base station
25 100 and receives assignment information indicating the source terminals to which it should provide the relayed connection.

Similarly, a second candidate relay terminal 116 detects the request broadcasted by the source terminals 122, 118 and sends its capacity information to the base station. A third candidate relay terminal 120 also
30 detects the request broadcasted by the source terminal 118 and sends its capacity information to the base station 100. In this case, source terminals 110 and 114 are assigned to the first candidate relay terminal 112 and the source terminal 122 is assigned to the second candidate relay terminal 116. The first candidate relay terminal 112 may have determined that it is not capable of
35 meeting the QoS requirement of the source terminal 122 or all source terminals 110, 114, 122, and the base station may have decided to assign the

source terminal 122 to the second candidate relay terminal 116. Neither the second nor third candidate source terminal is able to provide the source terminal 118 with the relayed connection, for example, because of a high QoS requirement and/or poor channel conditions associated with the source
5 terminal 118.

As mentioned above, optimal assignment of the relay terminals for the source terminals is a challenge, because inefficient assignment results in inefficient utilization of the candidate relay terminals and outage of source terminals. In the description, a candidate relay terminal refers to a relay
10 terminal before the assignment or pairing of the relay terminal and a source terminal. According to an embodiment of the invention, the relay terminals are assigned to source terminals with a primary criterion that a maximum number of source terminals requesting the relayed connection is served. Figure 2 illustrates a flow diagram of a process for assigning relay terminals. The
15 process may be implemented in a centralized manner in a network element controlling the relayed connections, for example the base station or a controller of the base station. To be precise, the process may be executed in a control unit of such a network element.

Referring to Figure 2, the process starts in block 200. In block 202,
20 the control unit receives relay status information from each candidate relay terminal. The relay status information comprises identifiers of the source terminals the relay terminal has detected requesting for a relayed connection and radio communication resources available for the relayed connection with each terminal device the candidate relay terminal device is capable of serving.

In block 204, the control unit assigns a relay terminal and radio
25 communication resources for each terminal device according to a criterion that maximizes the number of terminal devices served with the relayed connection. The criterion is satisfied so that a terminal device is primarily assigned with a relay terminal and radio communication resources, wherein the assigned radio
30 communication resources do not pre-empt the radio communication resources available for a relayed connection of one or more terminal devices, for which the assignment has not yet been carried out. In an embodiment, a relay terminal and radio resources are assigned to a given source terminal amongst one or more candidate relay terminals indicating in the relay status information
35 that they are capable of serving the first terminal device. Then, a relay terminal and radio communication resources are assigned to each subsequent source

terminal from radio resources not yet assigned, wherein the assigned relay terminal is associated with the non-assigned radio communication resources and with the terminal device in the relay status information. This is carried out by not pre-empting radio resources of another non-assigned source terminal, unless it is the only option to assign a relay terminal and radio resource to the source terminal.

In block 206, the control unit configures the assigned relay terminals to establish a relayed connection with the source terminal(s) assigned to each relay terminal. The establishment of the relayed connection may comprise establishment of a device-to-device communication connection between the relay terminal and a given source terminal and linking the device-to-device connection to a connection between the relay terminal and the base station to provide the relayed connection between the source terminal and the base station through the relay terminal. The establishment of the device-to-device connection also comprises negotiation of the radio resources allocated to the device-to-device connection. The process ends in block 208.

Figure 3 illustrates the structure of an apparatus for carrying out the method of Figure 2. The apparatus may be realized by a processing unit in the network element controlling the relayed connections in a radio access network of a mobile communication system. The processing unit may be implemented by a digital signal processor executing the method under the instructions contained in a computer program executed in the processor. Alternatively, the processing unit may be realized by an application-specific integrated circuit. Naturally, the steps of the process may be distributed to multiple processing units within the apparatus.

The apparatus may comprise an interface 306 to enable a communication connection with other elements of the network controller and with terminal devices controlled by the network controller. The interface 306 may be understood as a physical interface transferring signals in and out of the apparatus, but it may also be seen as an interface between computer program processing modules. The apparatus according to this embodiment carries out the assignment of relay terminals, so it may output, through the interface 306, control information related to the assignment to another processing module configured to process the control information for transmission to the terminal devices. Similarly, the apparatus receives, through the interface 306, the relay status information from the candidate relay terminals to facilitate the

assignment. The relay status information is stored in a memory unit 304. The memory unit may also store a computer program configuring the apparatus to carry out the assignment process.

The apparatus further comprises a relay utilization optimizer 300
5 which carries out the assignment process, i.e. block 204 of Figure 2. The relay utilization optimizer 300 receives the relay status information from the memory unit 304 and executes the assignment optimization procedure with the relay status information as parameters for the procedure. Embodiments of the optimization procedure are described in more detail below. As a result of the
10 optimization procedure, the relay utilization optimizer obtains relay assignment information indicating the selected relay terminals among the candidate relay terminals and source terminals to be served by each selected relay terminal. The relay utilization optimizer outputs the relay assignment information to a relay link controller 302.

15 The relay link controller 302 controls the execution of the assignment with respect to the terminal devices. In practice, the relay link controller 302 receives the assignment information from the relay utilization optimizer 300 and configures the selected relay terminals to establish the relayed connections to source terminals according to the assignment
20 information, i.e. carries out block 206 of Figure 2. With respect to a given selected relay terminal, the relay link controller 302 communicates to the relay terminal one or more source terminals the relay terminal is assigned to serve and instructs the relay terminal to establish a relayed connection between the source terminals and the base station currently communicating with the relay
25 terminal. The communication between the relay link controller 302 and the relay terminal may be carried out through the base station.

Figures 4 to 8 disclose embodiments for carrying out the relay optimization procedure of block 204 of Figure 2. Before describing the optimization procedure in more detail, let us consider two embodiments of the
30 relay status information used as a parameter in the optimization procedure. As mentioned above in connection with Figure 1, candidate relay terminals monitor relay connection requests broadcasted by the source terminals in need of a relayed connection and determine whether or not they are able to meet the requested QoS requirements. Let us assume that a total of N_f radio
35 resources, for example frequency bands, are available for N_s source nodes and N_R candidate relay nodes. When determining its capability of meeting the

QoS requirement requested by a source terminal, a candidate relay terminal may determine channel status information (CSI) related to a radio channel between the candidate relay terminal and the source terminal (h_{SRf}) and a radio channel between the candidate relay terminal and a destination node (the base station) (h_{RBf}).

Accordingly, the candidate relay terminal may judge independently for each source node whether it can meet the QoS requirements of the source node and on which radio resources the QoS requirements are met. As criteria for meeting the requirements on a given radio resource f_m , the candidate relay node may estimate channel gain, signal-to-noise ratio (SNR), capacity, etc. of the radio resource f_m . For example, if the candidate relay terminal operates in a decode-and-forward mode, the candidate relay terminal R_j may estimate achievable capacity C for a given radio resource f_m and source node S_i from the CSI, i.e. from h_{SRf} and h_{RBf} as:

$$C(i, j, m) = \log \left(1 + \min \left(\rho_{S_i} |h_{S_i R_j f_m}|^2, \rho_{R_j} |h_{R_j B f_m}|^2 \right) \right) \quad (1)$$

where ρ_{S_i} and ρ_{R_j} are the transmitting powers of the source node and the candidate relay node, respectively. On the other hand, if the candidate relay terminal uses amplify-and-forward relay mode, the candidate relay terminal may estimate the achievable capacity as:

$$C(i, j, m) = \log \left(1 + \frac{\rho_{S_i} |h_{S_i R_j f_m}|^2 + \rho_{R_j} |h_{R_j B f_m}|^2}{1 + \rho_{S_i} \rho_{R_j} |h_{S_i R_j f_m}|^2 |h_{R_j B f_m}|^2} \right) \quad (2)$$

Then, the candidate relay node may compare the estimated achievable capacity with the QoS requirements of the source node and determine, whether or not the achievable capacity is equal to or greater than the QoS requirement. If it is either equal to or greater than the QoS requirement, the candidate relay terminal determines that it is able to serve the source terminal with the corresponding radio resource. Otherwise, the candidate relay terminal determines that it is not able to serve the source terminal in the corresponding radio resource. The same estimation may be carried out for all the radio resources available to find out the radio resources with which the candidate relay terminal is capable of serving the source terminals. This procedure may be carried out for all source terminals whose relay connection request the candidate relay terminal receives.

Each candidate relay terminal reports to the serving base station (or another network element carrying out the assignment of the relay terminals) their relay status information comprising an indication which source terminals each candidate relay terminal is capable of serving and with which radio resources. Each candidate relay terminal may simply indicate with a simple 'yes' or 'no' for each pair of a radio resource and a source terminal which pairings it can support. Alternatively, each candidate relay terminal may provide an achievable capacity value for each pair of a radio resource and a source terminal so the base station may know which pairings are the most optimal for each candidate relay terminal. Tables 1 and 2 illustrate these two embodiments of the relay status information.

With reference to Table 1, a first candidate relay terminal R_1 transmits to the base station the leftmost part of the relay status information, i.e. the matrix below R_1 , a second candidate relay terminal the second leftmost part of the matrix, etc. '1' indicates that the candidate relay terminal is capable of serving the source terminal on that row with a radio resource in that column. '0' denotes that the candidate relay terminal is incapable of serving the source terminal on that row with a radio resource in that column. For example, the first candidate relay terminal is capable of meeting the QoS requirements of a source terminal S_2 with radio resources f_1 and f_2 . The serving base station then constructs an allocation matrix of Table 1 from the relay status information received from the candidate relay terminals. The allocation matrix of Table 1 is actually a three-dimensional matrix, wherein the dimensions are defined by the source terminals S_i , the candidate relay terminals R_j and the radio resources f_m .

	R_1						R_2						...	R_{Nr}					
	f_1	f_2	f_3	f_4	...	f_{Nf}	f_1	f_2	f_3	f_4	...	f_{Nf}	...	f_1	f_2	f_3	f_4	...	f_{Nf}
S_1	1	0	0	0	...	0	1	1	0	0	...	0	...	1	0	0	0	...	0
S_2	1	1	0	0	...	0	1	1	0	0	...	0	...	0	0	0	0	...	0
S_3	1	1	0	0	...	0	0	0	0	0	...	0	...	1	1	0	0	...	0
S_4	1	1	1	1	...	0	0	1	0	1	...	0	...	0	0	0	1	...	0
:	:	:	:	:	...	:	:	:	:	:	...	:	...	:	:	:	:	...	:
S_{Ns}	0	0	0	0	...	0	0	0	0	1	...	1	...	0	1	0	0	...	0

(Table 1)

Table 2 below is similar in the sense that '0' refers to incapability of meeting the QoS requirements. However, each candidate relay terminal now transmits achievable capacity for a given pair of source terminal and radio resource it can serve, i.e. the QoS requirements it can meet. The achievable capacity may be quantized to a specified word length. As an alternative to transmitting the estimated achievable capacity, another channel quality indicator may be used. In both embodiments, the relay status information may also comprise information on a traffic type requested by each source terminal, e.g. voice, streaming data, messaging, e-mail. The traffic type may be indicated as QoS classes known in the art: conversational, streaming, interactive, background. This may also be taken into account in the assignment of relay terminals by assigning to a source terminal requesting a high priority service, e.g. voice service, a relay terminal and radio resource having the highest achievable capacity.

15

	R_1						R_2						...	R_{Nr}					
	f_1	f_2	f_3	f_4	...	f_{Nf}	f_1	f_2	f_3	f_4	...	f_{Nf}	...	f_1	f_2	f_3	f_4	...	f_{Nf}
S_1	C	0	0	0	...	0	C	C	0	0	...	0	...	C	0	0	0	...	0
	11						11	12					...	11					
S_2	C	C	0	0	...	0	C	C	0	0	...	0	...	0	0	0	0	...	0
	21	22					21	22					...						
S_3	C	C	0	0	...	0	0	0	0	0	...	0	...	C	C ₃	0	0	...	0
	31	32											...	31	2				
S_4	C	C	C	C	...	0	0	C	0	C ₄	...	0		0	0	0	C	...	0
	41	42	43	44				42		4							44		
:	:	:	:	:	...	:	:	:	:	:	...	:		:	:	:	:	...	:
S_{Ns}	0	0	0	0	...	0	0	0	0	C _N	...	C _{Ns}		0	C _N	C _N	0	...	0
										s4		Nf			s2	s3			

(Table 2)

Let us now consider the embodiments of the relay optimization procedure with reference to Figures 4 to 8. Figure 4 illustrates a relay optimization procedure which optimizes the number of served source terminals. The procedure may be carried out by the relay utilization optimizer 300 on the basis of relay status information received from the memory unit 304. The procedure starts in block 400. In block 402, the allocation matrix is constructed from the received relay status information. The constructed

allocation matrix may have the form of Table 1 or 2 depending on the specifications of the system for reporting and processing the relay status information.

Then, the source terminals are assigned to the candidate relay
5 terminals in a sequential order in blocks 404 and 406. In block 404, the procedure checks the allocation matrix for radio resources that can be allocated to only one source-relay terminal pair. Referring to Table 1, only candidate relay terminal R_1 is able to utilize radio resource f_3 , and it may use that radio resource to provide source terminal S_4 with a relayed connection.
10 Accordingly, candidate relay terminal R_1 is selected as a relay terminal to provide source terminal S_4 with the relayed connection by using the radio resource f_3 . Similarly, other radio resources are checked whether they can also be used by a single source-relay pair. Thereby, it is ensured that these pairs having exclusive possibility to use a certain radio resource are not allocated to
15 other radio resources that may be allocated to other pairs.

In block 406, a relay terminal is allocated to the rest of the source terminals as possible. This is carried out by assigning a source-relay pair and radio resource from the allocation matrix in such manner that the radio resources of any other non-assigned source terminal is not pre-empted, unless
20 that is the only option. Multiple source terminals may be assigned to a single relay terminal. When all the source terminals are assigned with a relay terminal and radio resource, or when there are no radio resources (satisfying the QoS requirement) to be allocated to non-assigned source terminal(s), the process ends in block 408.

Figure 5 illustrates the embodiment of Figure 4 in more detail in a case where the allocation matrix is in the form of Table 1. The process starts in block 500. Block 402 is similar to that of Figure 4. In block 502, the procedure checks the allocation matrix for rows with p non-zero elements. p is initialized as 1. In other words, the procedure checks the allocation matrix for rows with
30 one non-zero element in the first iteration. The idea is to find source terminals that can only be allocated to a single radio resource. In block 504, it is checked if the elements found in 502 are in the same column. If not, the process moves to block 508, wherein it is determined that each source terminal associated with the elements found in 502 may be assigned with a relay terminal. As a
35 consequence, each source terminal is assigned with the radio resource and relay terminal associated with the found element.

However, if the elements are in the same column in block 504, the process moves to block 506, where it is determined that all the source terminals cannot be served, and one of the rows is selected. As a consequence, the source terminal of the selected row is assigned with the
5 radio resource and relay terminal associated with the found element of the source terminal.

From blocks 506 and 508, the process proceeds to block 510, where the indices of the selected elements, i.e. source-relay terminal pairs and assigned radio resources, are memorized. Additionally, the columns of the
10 selected rows are nulled, because the corresponding source terminal has already been assigned with a relay terminal. Moreover, columns of the selected elements are also nulled, because that radio resource has already been assigned.

In block 512, it is determined whether or not there is at most one
15 element left in each row. If yes, the remaining source-relay pairs and radio resources may be allocated as in blocks 504 to 508, and the process ends in block 516, because all the source terminals are assigned with a relay terminal. If there are one or more rows with a higher number of elements than one, p is incremented in block 514, and the process returns to block 502 to search for
20 rows with two non-zero elements. If at least part of the found non-zero elements is in the same column, each row may keep a random non-zero element from a different column such that no two rows keep the element in the same column to avoid a collision in the radio resource. On the other hand, if the elements are all in different columns, each row may keep one of the
25 elements, and the elements may be selected in such manner that radio resources of a non-assigned source terminal are not pre-empted, unless necessary. In this manner, the procedure assigns the radio resources and relay terminals to the source terminals.

Figure 6 illustrates an embodiment in which the allocation matrix of
30 Table 2 is used. The procedure itself is very similar to that of Figure 5, and the only difference is in the selection of the found elements. The process starts in block 600, and blocks 402, 502, and 504 are the same as described above. In the first iteration, if the elements are not in the same column in block 504, the process moves to block 604, where each row may keep its element, as in
35 Figure 5. If the elements are in the same column in block 504, the process moves to block 602, where a row having the highest value of the element (the

best achievable capacity) keeps its element. This optimizes the capacity of the system.

In further iterations, where k is higher than one, each row keeps its biggest non-zero element in block 604. In block 602, a non-zero element is selected for each row such that no rows have the element in the same column and the sum of the selected non-zero element values is maximized. However, it is primarily ensured that the radio resources of other non-assigned source terminals are not pre-empted. In other words, the maximization of the sum is secondary to that. The process ends in block 606.

Figure 7 illustrates another embodiment of the optimization procedure. This embodiment maximizes the number of served source terminals, but also minimizes the number of relay terminals. As a consequence, relay terminals most suitable for relaying, e.g. laptops, and fixed relays, are utilized for relaying to the extent possible, and other relay terminals, e.g. mobile phones, can be used for other purposes. This also reduces the signaling links related to the relaying and, as a consequence, the amount of overall signaling, because relay configuration signaling related to multiple source terminals may be bundled into one signaling link. Referring to Figure 7, the process starts in block 700.

In block 702, the number of source terminals each candidate relay terminal can serve is calculated. Before block 702, the allocation matrix has been constructed from the received relay status information. The number of source terminals each candidate relay terminal can serve may be calculated from the amount of rows having at least one non-zero element in different columns in the allocation matrix with respect to the candidate relay terminal in question. In practice, the calculation of the number of servable source terminals is determined by taking into account the radio resource allocation, i.e. that no servable source terminal is assigned with the same radio resource as another servable source terminal.

In block 704, a candidate relay terminal capable of serving the highest number of source terminals is selected for assignment. In block 706, the source terminals which the relay terminal selected in block 704 is capable of serving are assigned to the selected relay terminal. Radio resources are also allocated to the source terminals. Additionally, the assigned source terminals are deleted from the allocation matrix, and the radio resources already allocated to the source terminals are also disabled for all the remaining

source/relay terminals so that the same radio resource will not be allocated to two links.

Then, the process moves to block 708, where it is checks whether or not there are source terminals and candidate relay terminals still
5 unassigned. If there are no source terminals unassigned, the process assumes that all the relay requests have been handled, and the process ends in block 710. If there are no unassigned candidate relay terminals, the process assumes that all the relay link capacity is already in use and no more relay links can be assigned even if there were unassigned source terminals.
10 However, if there are unassigned source terminals and relay terminals, the process returns to block 702, where the number of unassigned source terminals each unassigned relay terminal can serve is calculated by taking into account only the available (unassigned) radio resources. In this manner the process continues, until all the source terminals and/or relay terminals are
15 assigned and the process ends in block 710.

Accordingly, the candidate relay terminals are assigned as relay terminals in the descending order of the number of terminal devices each candidate relay terminal is able to serve simultaneously until a maximum number of terminal devices that can be served simultaneously by all candidate
20 relay terminals is reached. The process of Figure 7 may use either form of the allocation matrix, i.e. that of Table 1 or 2. However, the use of the allocation matrix of Table 1 results in less uplink signaling because of the short word length for the indication service capability, i.e. the elements of the matrix.

Figure 8 illustrates another embodiment of the relay utilization
25 optimization process. The process starts in block 800. This process preferably utilizes the allocation matrix of Table 2 to effectively optimize the capacity as well as the number of served source terminals. The allocation matrix may be constructed before proceeding to block 802. In block 802, all combinations of k candidate relay terminals are processed so as to find out the maximum
30 number of servable source terminals. In this embodiment, k is initialized as 1. In the first iteration, the candidate relay terminal capable of serving the highest number of source terminals is selected. In this embodiment, the calculation of the number of servable source terminals is determined by taking into account the radio resource allocation, i.e. that no servable source terminal is assigned
35 with the same radio resource as another servable source terminal. In block 804, sub-matrices of the allocation matrix associated with the selected relay

terminals are combined into one sub-matrix. In the first iteration, this step is omitted, because only the sub-matrix of one relay terminal is in use. The sub-matrix refers to a matrix constructed from the relay status information received from the relay terminal(s) selected in block 802 (see Tables 1 and 2 for a sub-matrix below each $R_1, R_2, \dots R_{N_r}$). The combination of multiple sub-matrices is described later in connection with the next iteration.

In block 806, it is determined whether or not the selected relay terminal can serve all the source terminals. This is carried out by analyzing the combined sub-matrix to find out if a radio resource can be allocated to each source terminal, i.e. whether there is a non-zero element in different columns of the combined sub-matrix for every source terminal. If the relay terminal can serve every source terminal, the process proceeds to block 810 where the source terminals and radio resources are assigned to the relay terminal, and the process ends in block 814, because all the source terminals have been allocated. If the relay terminal cannot serve all the source terminals, the process moves from block 806 to block 808 where it is checked whether or not k is at maximum. The maximum value for k is N_R , i.e. the total number of candidate relay terminals. If k is at maximum, the process moves to block 810 where the source terminals that can be served by the selected relay terminal are assigned to the relay terminal. If k is not at maximum, k is incremented in block 812 and the process returns to block 802. Now, k is 2.

In the second iteration, all combinations of 2 candidate relay terminals are processed to find out the maximum number of source terminals, that two relay terminals can serve. The two candidate relay terminals that together can serve the highest number of source terminals are selected. In block 804, the sub-matrices of the selected relay terminals are combined into one sub-matrix. The combination of the sub-matrices is carried out by selecting for each element of the combined sub-matrix the corresponding element from the two sub-matrices that has the highest value. In other words, the relay terminal providing the highest achievable capacity for a given source terminal and radio resource is selected for that pair of source terminal and radio resource. Naturally, it is also memorized which of the selected relay terminals occupies which element of the combined sub-matrix. The size of the combined sub-matrix is naturally the same as the size of the sub-matrix of each relay terminal, that is S_{N_s} rows and f_{N_f} columns. The combination of the sub-matrices is carried out so as to optimize the achievable capacity.

In block 806, it is determined whether the selected relay terminals can serve all the source terminals, and the process moves either to block 808 or 810 on the basis of the result. In block 810, the source terminals are assigned to the relay terminals on the basis of the combined sub-matrix. In this manner, the procedure continues until all the source terminals can be assigned or the available relay terminals run out (k reaches its maximum value). As can be seen, this process optimizes the number of served source terminals, minimizes the number of relay terminals, and optimizes the achievable capacity.

10 In the embodiment described above, k was initialized as 1. However, k may be initialized as two, if it is determined that no single candidate relay terminal can serve all the source terminals or a sufficient number of source terminals. The sufficient number of source terminals may be predetermined by setting a threshold number. Analogously, k may be initialized as a higher number, if it is determined that no two (or three, four, etc.) candidate relay terminals together can serve all or a sufficient number of source terminals.

The processes or methods described in Figures 2 and 4 to 8 may also be carried out in the form of a computer process defined by a computer program. The computer program may be in source code form, object code form, or in some intermediate form, and it may be stored in some sort of carrier, which may be any entity or device capable of carrying the program. Such carriers include a record medium, computer memory, read-only memory, electrical carrier signal, telecommunications signal, and software distribution package, for example. Depending on the processing power needed, the computer program may be executed in a single electronic digital processing unit or it may be distributed amongst a number of processing units.

The optimization procedure may be carried out in a mobile telecommunication system for source and relay terminals located in a geographically limited area, e.g. in a cell of the system. Basically, the present invention is not dependent on the radio interface technology. Accordingly, the present invention is applicable to current mobile communication systems, e.g. UMTS (Universal Mobile Telecommunication System) or any of its evolution versions and WiMAX (Worldwide Interoperability for Microwave Access). The present invention is also applicable to all types of duplexing schemes, e.g.

time-division duplexing, frequency-division duplexing, and code division duplexing.

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

Claims

1. A method for controlling relayed communications in a wireless communication system, comprising:

receiving, from each of a plurality of candidate relay terminal
5 devices that are candidates for providing other terminal devices with a relayed communication connection, relay status information identifying the terminal devices and radio communication resources available for and associated with each terminal device which the candidate relay terminal device is capable of providing with the relayed communication connection; and
10 assigning a relay terminal and a radio communication resource to each terminal device with a criterion that the number of terminal devices served with the relayed connection is maximized, wherein a terminal device is primarily assigned with a relay terminal and radio communication resources that do not pre-empt radio communication resource available for a relayed
15 connection of one or more terminal devices, for which the assignment has not yet been carried out.

2. The method of claim 1, further comprising: assigning, on the basis of the received relay status information, the terminal devices with a secondary criterion that the number of assigned relay terminals is minimized.

20 3. The method of claim 2, wherein the assignment further comprises: assigning candidate relay terminals to serve the terminal devices by selecting a determined number of relay terminals, checking whether or not the selected relay terminals can serve all the terminal devices needing the relayed connection, and incrementally increasing the number of relay terminals
25 until the maximum number of serviceable terminal devices is reached.

4. The method according to any one of claims 1 to 3, wherein the assignment comprises:

assigning a relay terminal and a radio communication resource to a first terminal device amongst one or more candidate relay terminals indicating
30 in the relay status information a capability to serve the first terminal device;

disabling the assigned radio communication resource from further assignment; and

assigning a relay terminal and radio communication resources to each subsequent terminal device from the radio communication resources not
35 yet assigned, wherein the assigned relay terminal is associated with the non-

assigned radio communication resources and with the terminal device in the relay status information.

5 5. The method according to any one of claims 1 to 3, wherein the relay status information received from each candidate relay terminal indicates the number of terminal devices each candidate relay terminal is able to serve simultaneously, and wherein the assignment further comprises:

10 assigning terminal devices to the candidate relay terminals in a descending order of the number of terminal devices each candidate relay terminal is able to serve simultaneously until a maximum number of terminal devices that can be served simultaneously by all candidate relay terminals is reached.

6. The method of claim 5, wherein the assignment further comprises:

15 assigning terminal devices and radio resources first to a candidate relay terminal capable of serving the highest number of relay terminals;

 disabling the availability of the radio communication resources assigned to the first candidate relay terminal;

20 determining, on the basis of the remaining radio communication resources and the received relay status information of the remaining candidate relay terminals, a candidate relay terminal that is able to serve the highest number of terminal devices;

 assigning terminal devices and radio resources to the determined candidate relay terminal;

25 disabling the availability of the radio communication resources assigned to the determined candidate relay terminal; and

 repeating the determination and subsequent assignment and disabling until the maximum number of terminal devices that can be served simultaneously by all candidate relay terminals is reached or there are no more unassigned candidate relay terminals.

30 7. The method according to any one of claims 1 to 3, wherein the assignment further comprises:

 selecting incrementally a number of candidate relay terminals and determining the number of terminal devices which the selected number of candidate relay terminals are able to server;

35 selecting a higher number of candidate relay terminals and carrying out the determination of the number of serviceable terminal devices, if the

determined number of serviceable terminal devices is lower than a predefined threshold; and

assigning the selected candidate relay terminals to the terminal devices to enable the relayed communications, if the determined number of serviceable terminal devices is higher than a predefined threshold.

8. The method according to any one of claims 1 to 7, wherein the relay status information received from a given candidate relay terminal and comprising the radio communication resources available for and associated with each terminal device indicates for each radio communication resource whether or not the candidate relay terminal is able to serve the terminal device in that radio communication resource.

9. The method according to any one of claims 1 to 8, wherein the relay status information indicates an estimated channel quality indicator for at least those radio communication resources, in which the candidate relay terminal is able to serve the terminal device.

10. The method of claim 9, further comprising: assigning a radio communication resource primarily to the relay terminal that indicates the best channel quality for the radio communication resource.

11. An apparatus for controlling relayed communications in a wireless communication system, comprising:

a controller configured to receive, from each of a plurality of candidate relay terminal devices that are candidates for providing other terminal devices with a relayed communication connection, relay status information identifying the terminal devices and radio communication resources available for and associated with each terminal device which the candidate relay terminal device is capable of providing with the relayed communication connection, and to

assign a relay terminal and a radio communication resource to each terminal device with a criterion that the number of terminal devices served with the relayed connection is maximized, wherein a terminal device is primarily assigned with a relay terminal and radio communication resources that do not pre-empt the radio communication resource available for a relayed connection of one or more terminal devices, for which the assignment has not yet been carried out.

12. The apparatus of claim 11, wherein the controller is further configured to assign, on the basis of the received relay status information, the

terminal devices with a secondary criterion that the number of assigned relay terminals is minimized.

13. The apparatus of claim 12, wherein the controller is further configured to assign the candidate relay terminals to serve the terminal
5 devices by selecting a determined number of relay terminals, check whether or not the selected relay terminals can serve all the terminal devices needing the relayed connection, and incrementally increase the number of relay terminals until the maximum number of serviceable terminal devices is reached.

14. The apparatus according to any one of claims 11 to 13, wherein
10 the controller is further configured to assign a relay terminal and a radio communication resource to a first terminal device amongst one or more candidate relay terminals indicating in the relay status information a capability to serve the first terminal device, to disable the assigned radio communication resource from further assignment, and to assign a relay terminal and radio
15 communication resources to each subsequent terminal device from the radio communication resources not yet assigned, wherein the assigned relay terminal is associated with the non-assigned radio communication resources and with the terminal device in the relay status information.

15. The apparatus according to any one of claims 11 to 13, wherein
20 the relay status information received from each candidate relay terminal indicates a number of terminal devices which each candidate relay terminal is able to serve simultaneously, and wherein the controller is further configured to assign terminal devices to the candidate relay terminals in a descending order of the number of terminal devices which each candidate relay terminal is able
25 to serve simultaneously until a maximum number of terminal devices that can be served simultaneously by all candidate relay terminals is reached.

16. The apparatus of claim 15, wherein the controller is further configured to assign terminal devices and radio resources first to a candidate relay terminal capable of serving the highest number of relay terminals, to
30 disable the availability of the radio communication resources assigned to the first candidate relay terminal, to determine, on the basis of the remaining radio communication resources and the received relay status information of the remaining candidate relay terminals, a candidate relay terminal that is able to serve the highest number of terminal devices, to assign terminal devices and
35 radio resources to the determined candidate relay terminal, to disable the availability of the radio communication resources assigned to the determined

candidate relay terminal, and to repeat the determination and subsequent assignment and disabling until the maximum number of terminal devices that can be served simultaneously by all candidate relay terminals is reached or there are no more unassigned candidate relay terminals.

5 17. The apparatus according to any one of claims 11 to 13, wherein the controller is further configured to select incrementally a number of candidate relay terminals and to determine the number of terminal devices that the selected number of candidate relay terminals are able to server, to select a higher number of candidate relay terminals and to carry out the determination
10 of the number of serviceable terminal devices, if the determined number of serviceable terminal devices is lower than a predefined threshold, and to assign the selected candidate relay terminals to the terminal devices to enable the relayed communications, if the determined number of serviceable terminal devices is higher than a predefined threshold.

15 18. The apparatus according to any one of claims 11 to 17, wherein the relay status information received from a given candidate relay terminal and comprising the radio communication resources available for and associated with each terminal device indicates for each radio communication resource whether or not the candidate relay terminal is able to serve the terminal device
20 in that radio communication resource.

 19. The apparatus according to any one of claims 11 to 18, wherein the relay status information indicates an estimated channel quality indicator for at least those radio communication resources in which the candidate relay terminal is able to serve the terminal device.

25 20. The apparatus of claim 19, the controller is further configured to assign a radio communication resource primarily to the relay terminal that indicates the best channel quality for the radio communication resource.

 21. An apparatus for controlling relayed communications in a wireless communication system, comprising:

30 means for receiving, from each of a plurality of candidate relay terminal devices that are candidates for providing other terminal devices with a relayed communication connection, relay status information identifying the terminal devices and radio communication resources available for and associated with each terminal device that the candidate relay terminal device is
35 capable of providing with the relayed communication connection; and

means for assigning a relay terminal and a radio communication resource to each terminal device with a criterion that the number of terminal devices served with the relayed connection is maximized, wherein a terminal device is primarily assigned with a relay terminal and radio communication
5 resources that do not pre-empt the radio communication resource available for a relayed connection of one or more terminal devices, for which the assignment has not yet been carried out.

22. A computer program product embodied on a distribution medium readable by a computer and comprising program instructions which, when
10 loaded into an apparatus, execute the method according to any preceding claim 1 to 10.

1/4

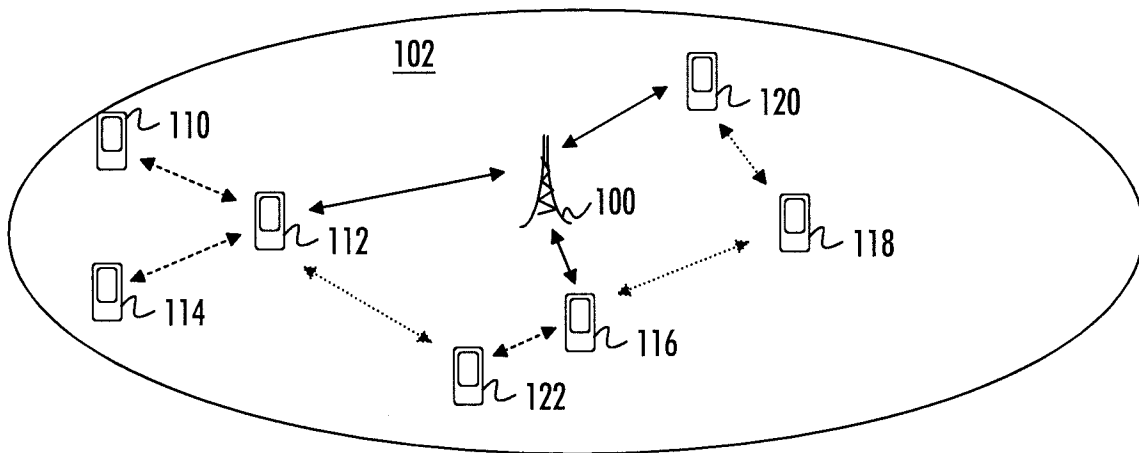


Fig 1

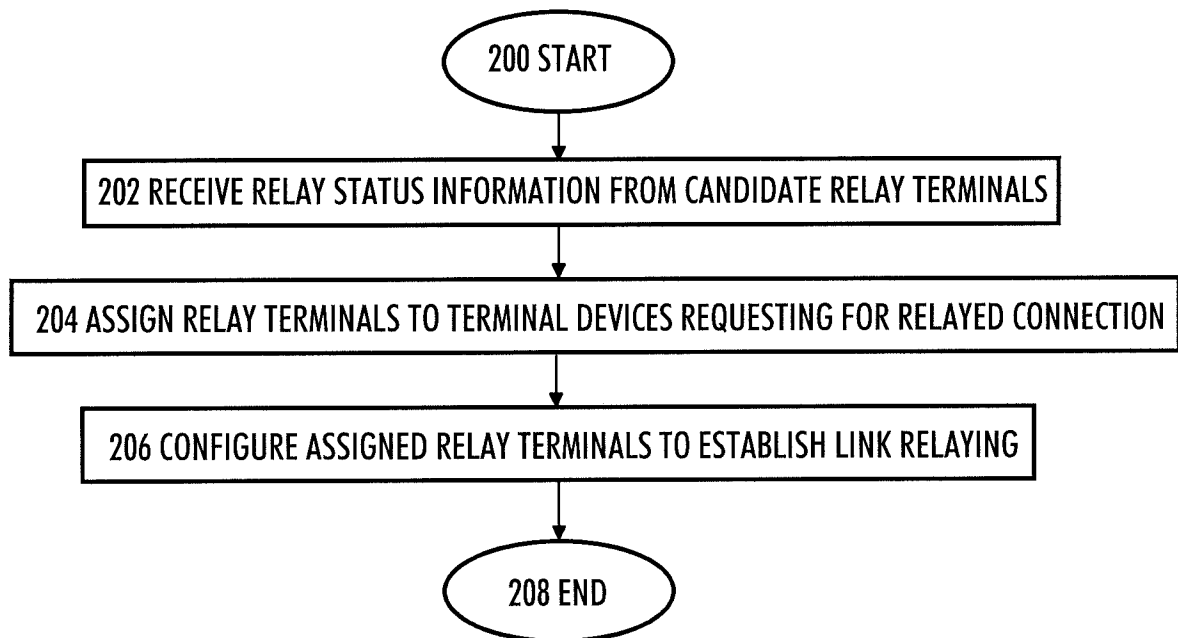


Fig 2

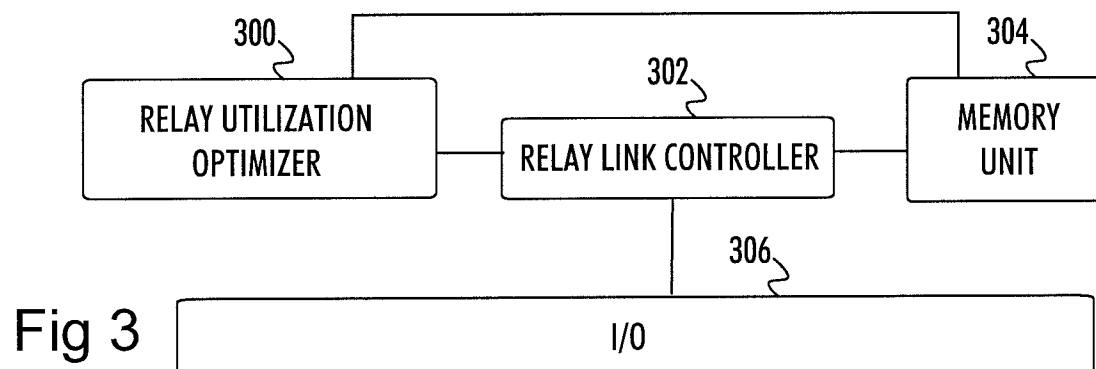
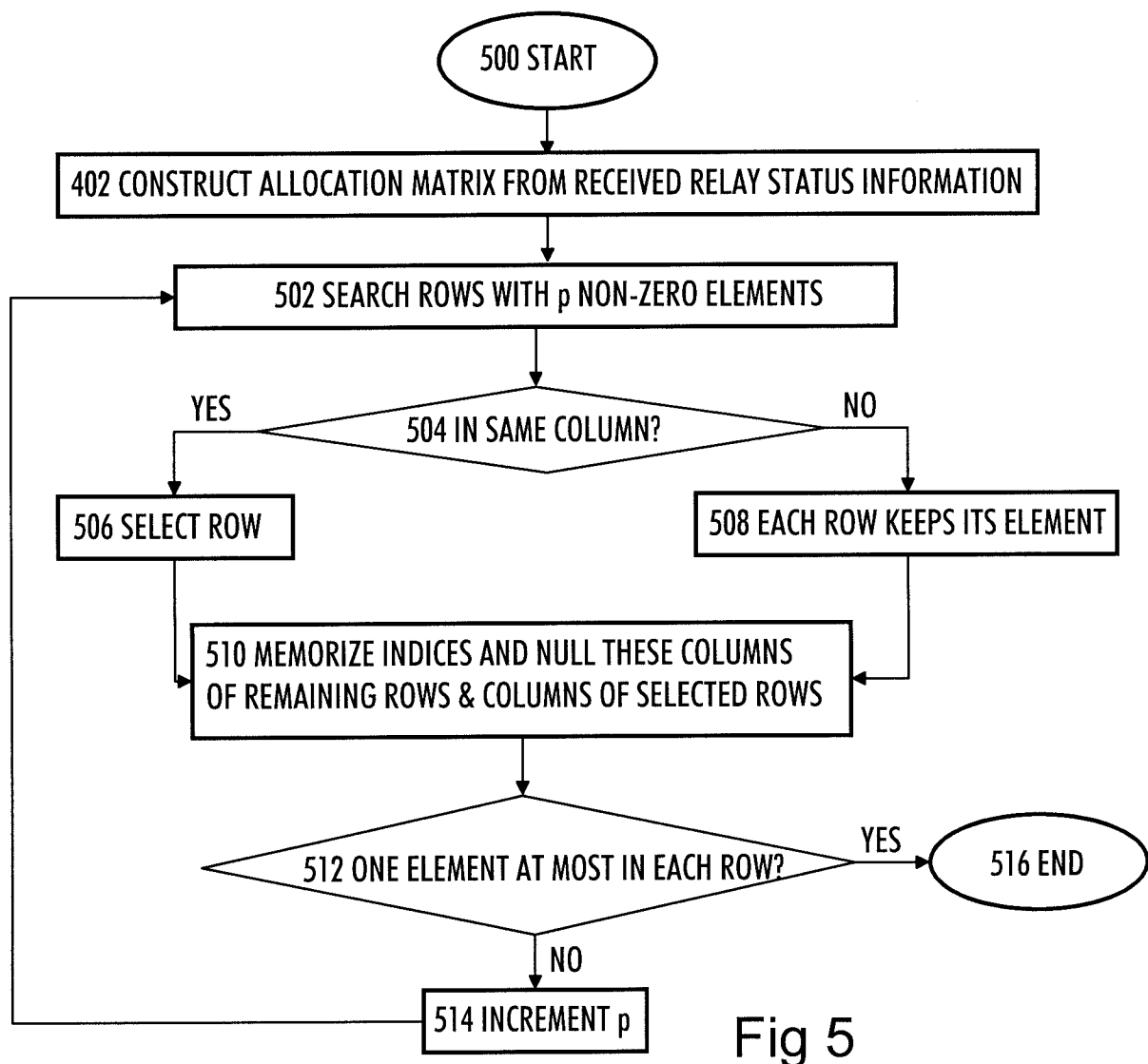
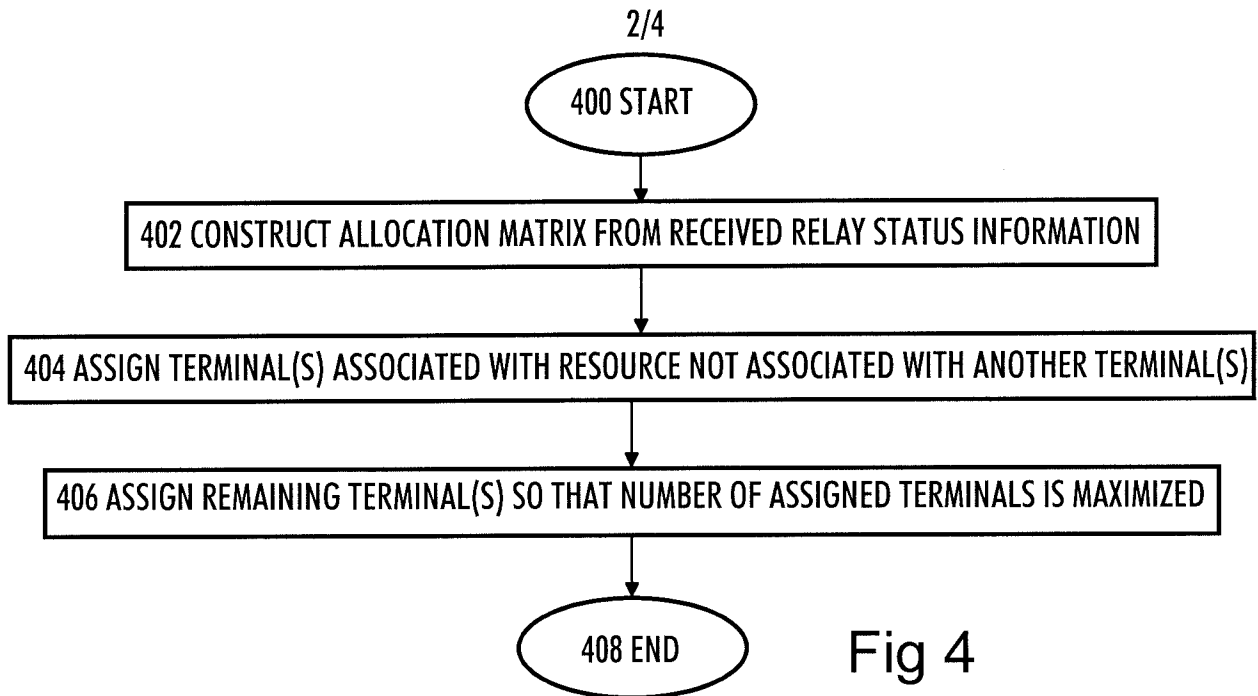


Fig 3



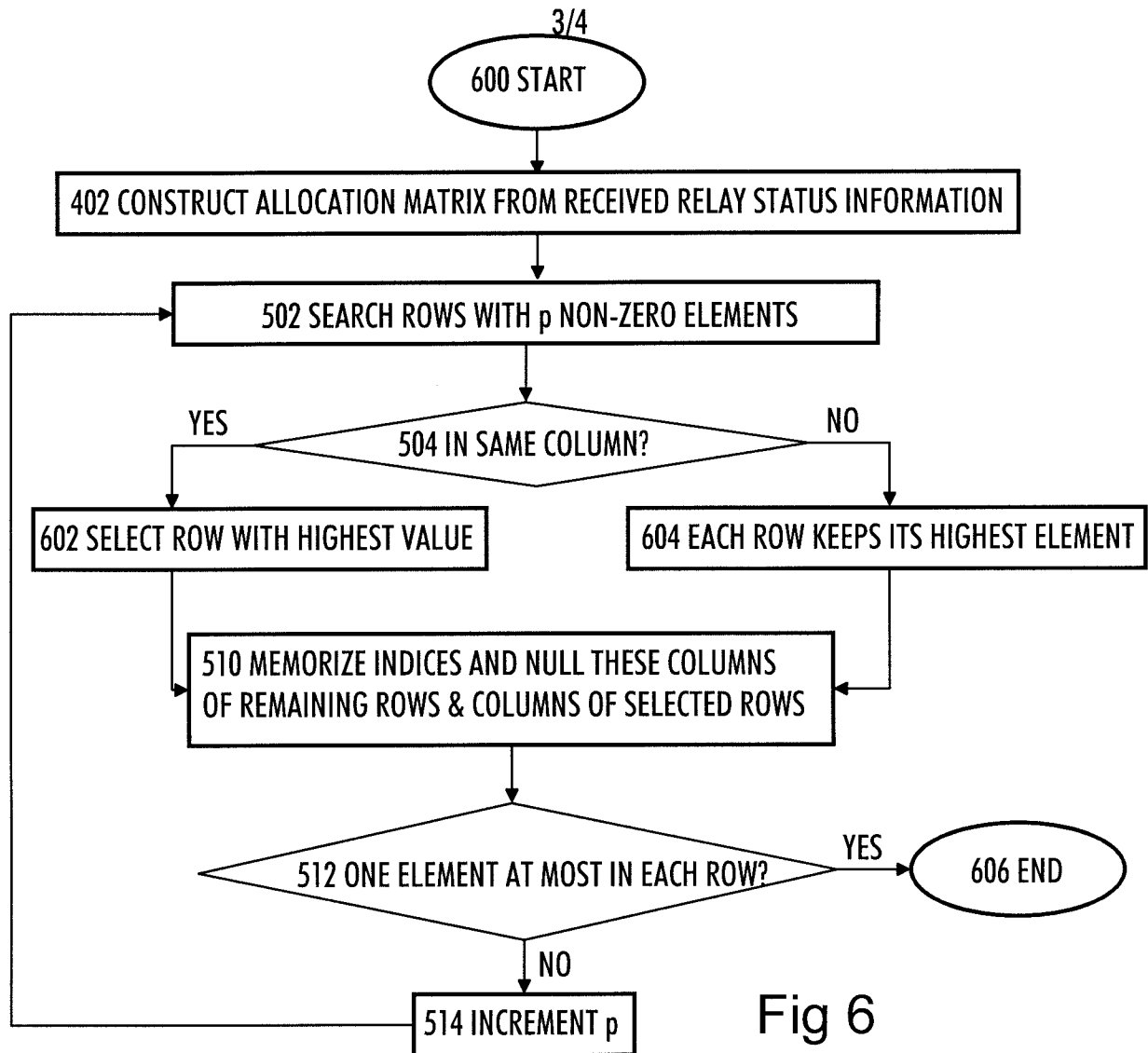


Fig 6

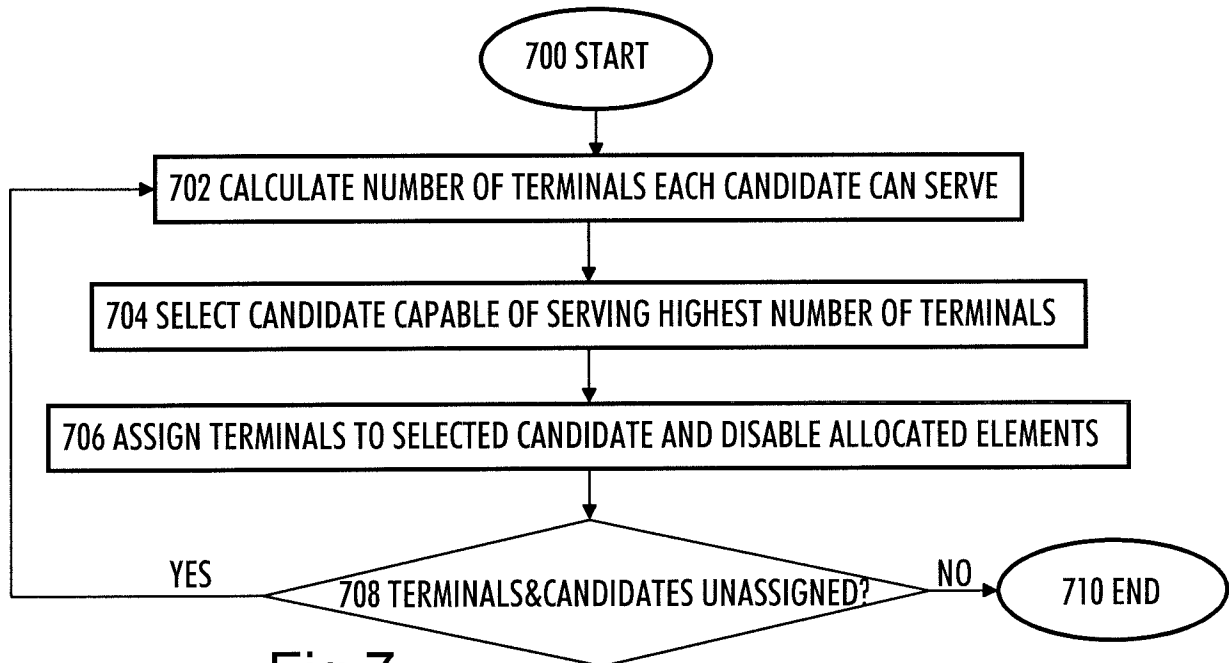


Fig 7

4/4

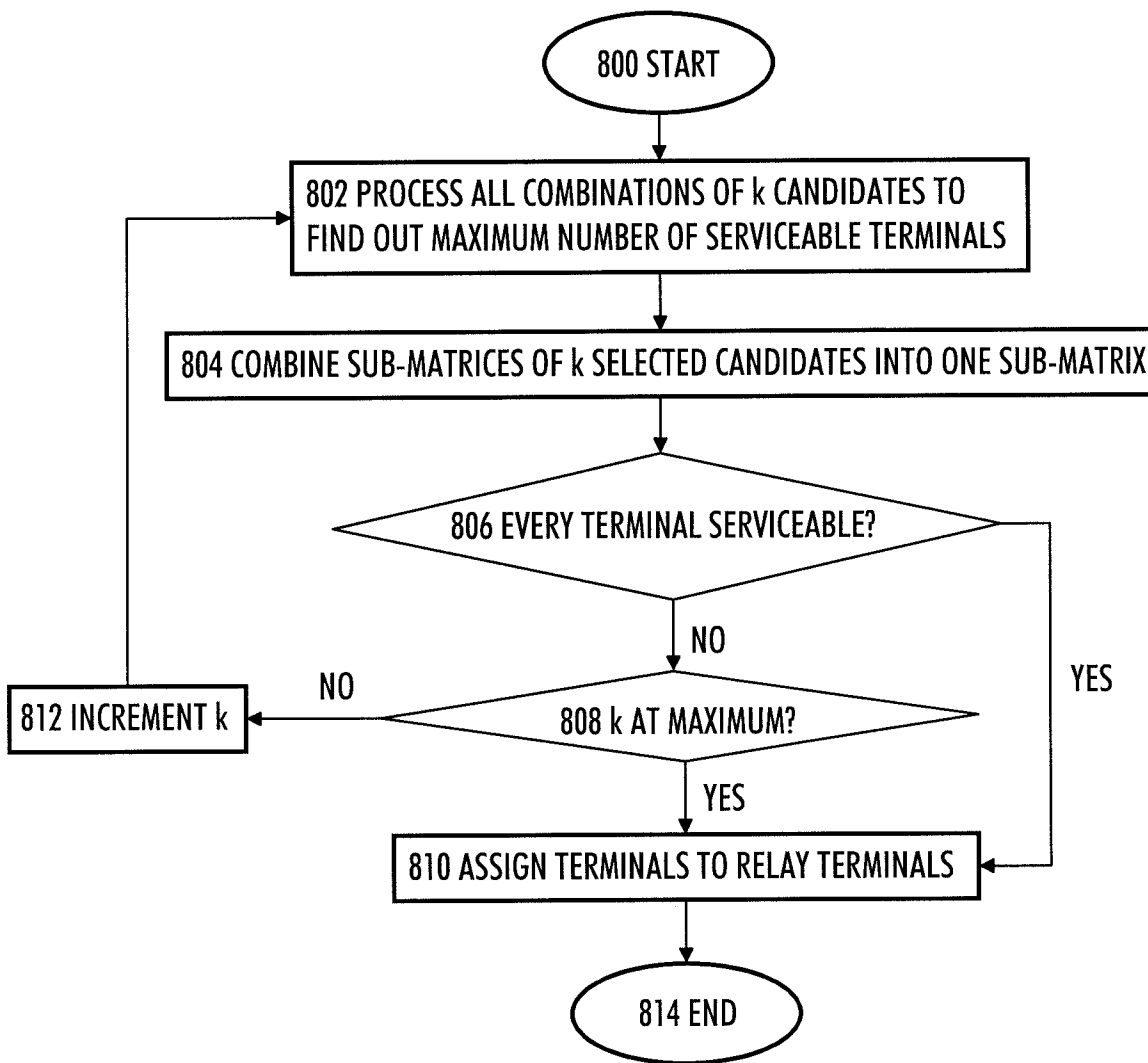


Fig 8

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2008/064909

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W40/22 H04W88/04 H04W48/20
 ADD. H04L12/56

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

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2006/138122 A (INTERDIGITAL TECH CORP [US]; ROY VINCENT [CA]) 28 December 2006 (2006-12-28) paragraphs [0016], [0017] paragraph [0026] - paragraph [0035] figures 1-4 -----	1-22

☐

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 document 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

10 July 2009

Date of mailing of the international search report

21/07/2009

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040,
 Fax: (+31-70) 340-3016

Authorized officer

Engmann, Steffen

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2008/064909

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2006138122 A	28-12-2006	AU 2006259698 A1	28-12-2006
		CA 2611285 A1	28-12-2006
		EP 1891752 A2	27-02-2008
		JP 2008547266 T	25-12-2008
		KR 20080025070 A	19-03-2008
		KR 20080020700 A	05-03-2008
		US 2007010271 A1	11-01-2007