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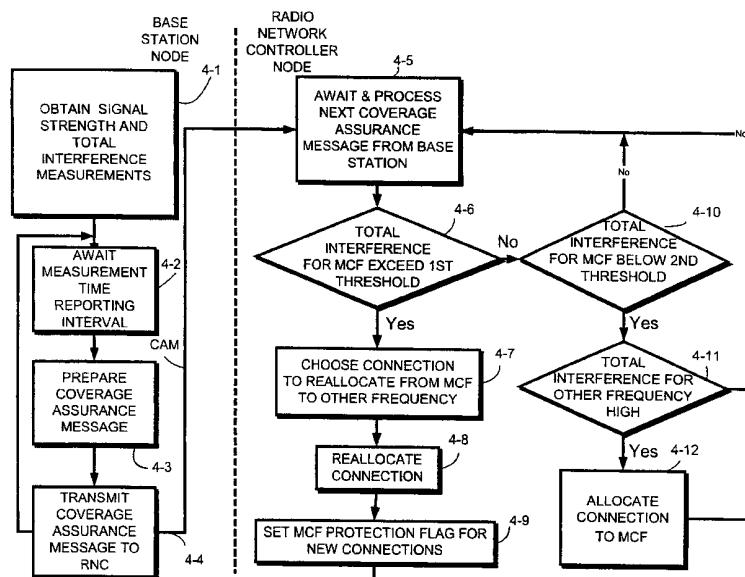
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(54) Title: CELL BREATHING REDUCTION IN A CELLULAR NETWORK



(57) Abstract: Traffic is allocated between plural radio frequencies utilized at a base station (22) of a cellular telecommunications system (18) according to a cell size strategy for a cell served by the base station. The traffic can be allocated between the plural frequencies to maintain a cell size as having a predetermined coverage (e.g., to maximize cell size or maintain the cell size as having a predetermined geographical minimum), thereby reducing effects of cell breathing. One of the plural frequencies utilized at the base station is selected as a maximum coverage frequency (MCF). The invention encompasses interference controlled, connection controlled, and traffic controlled modes for keeping the maximum coverage frequency available for connections with user equipment units (20) situated proximate a constant perimeter of the cell.

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CELL BREATHING REDUCTION IN A CELLULAR NETWORK

BACKGROUND**1. FIELD OF THE INVENTION**

5 The present invention pertains to cellular telecommunications, and particularly to maintaining sufficient cell size in a cellular telecommunications system.

2. RELATED ART AND OTHER CONSIDERATIONS

Cellular telecommunications systems employ a wireless link (e.g., air interface) between the (mobile) user equipment and a base station (BS). The base station has 10 transmitters and receivers for radio connections with numerous mobile user equipment units. The mobile user equipment units can take the form of cellular telephones or laptop computers with mobile termination, for example. The effective geographical transmission/reception range of a base station defines a cell served by that base station. Thus, in a sense, the cell is the territory in which a user equipment unit can be located 15 and still remain in radio communication over the air interface with the associated base station.

In a cellular telecommunications network, the base stations are preferably situated so that the cells served thereby are slightly overlapping proximate their perimeters or at least contiguous, thereby permitting a user equipment unit to move 20 from one cell to another cell and remain within the telecommunications network. For example, when a user equipment unit participating in a mobile connection (e.g., telephone call) moves from a first cell served by a first base station to a second cell served by a second base station, in some technologies a handoff or handover of the mobile connection occurs. As a result of the handoff or handover, the mobile 25 connection is handled through the second base station rather than the first station as formerly.

Radio coverage is a very important characteristic for all cellular telecommunication systems. Cell size is a major factor in obtaining good geographical coverage. The cell size is dependent upon the maximum allowed path loss between the user equipment unit and the base station. The greater the maximum allowed path loss, 5 the further a user equipment unit can move away from the base station and still receive a sufficient signal. This means that if the maximum allowed path loss is increased, then the cell size is increased. Conversely, if the maximum allowed path loss is decreased, then the cell size is reduced.

There are a variety of multiple access techniques for cellular telecommunications 10 systems which permit cellular telecommunications resources to be available to large numbers of users. One multiple access technique which has gained recent interest is code division multiple access (CDMA). In a code division multiple access (CDMA) mobile telecommunications system, the information transmitted between a base station and a particular mobile station is modulated by a mathematical code (such as spreading 15 code) to distinguish it from information for other mobile stations which are utilizing the same radio frequency. Thus, in CDMA, the individual radio links are discriminated on the basis of codes. Various aspects of CDMA are set forth in Garg, Vijay K. et al., *Applications of CDMA in Wireless/Personal Communications*, Prentice Hall (1997). Typically the same base band signal with suitable spreading is sent from several base 20 stations with overlapping coverage. The mobile terminal can thus receive and use signals from several base stations simultaneously.

In general, a CDMA base station attempts to maintain a sufficient Signal to 25 Interference Ratio (SIR) in communications with each mobile station that it currently serves. To this end, a base station measures the received signal from each of the mobile stations in order to determine the Signal to Interference Ratio (SIR). For each mobile station, the SIR is compared with a target value SIR. If the SIR measured for a particular mobile station is less than the target value SIR, the base station commands the mobile station to increase its power in order that a stronger signal can be received at the base station. On the other hand, if the SIR determined for the particular station is 30 greater than the target value SIR, the base station requests the mobile station to decrease its power. Thus, a power control loop is established between the base station and the mobile station, with an uplink aspect of the power control loop involving the mobile

station transmitting to the base station and with the base station, upon receiving the signal from the mobile station and comparing the SINR for the station with the target SIR, providing power control commands to the mobile station as a downlink aspect of the power control loop. An example CDMA power loop control system is disclosed in 5 United States Patent Application Serial No. 08/916,440, entitled "Signaling Method for CDMA Quality Based Power Control", which is incorporated herein by reference.

Thus, in a CDMA system, when the number of active user equipment units increase in a cell, then the interference level also increases in the cell. Unfortunately, this increased interference level has a negative impact upon the maximum allowed path 10 loss. That is, the increased interference level will also decrease cell size. The reduction of cell size due to an increased interference level produces an effect in a CDMA system commonly referred to as "cell breathing".

The overall effect of cell breathing is that the cell size is reduced when the traffic is increased. Providing more cells (e.g., a more dense population of base stations) is 15 one way of compensating for this undesirable reduction of cell size. However, there is expense and overhead in providing and operating additional base stations. Moreover, the provision of more cells may still result in varying cell coverage, e.g., cell breathing with respect even to the new cells.

What is needed, therefore, and an object of the present invention, is a technique 20 to reduce the effect of cell breathing in a telecommunications system.

BRIEF SUMMARY OF THE INVENTION

Traffic is allocated between plural radio frequencies utilized a base station of a cellular telecommunications system according to a cell size strategy for a cell served by the base station. The traffic can be allocated between the plural frequencies utilized at 25 the base station to maintain a cell size as having a predetermined coverage (e.g., to maximize cell size or maintain the cell size has having a predetermined geographical minimum), thereby reducing effects of cell breathing.

In accordance with aspects of the invention, the base station is operated so that at least one of its plural frequencies can be utilized as far away as a geographically

constant cell perimeter. In this regard, one of the plural frequencies utilized at the base station is selected as a maximum coverage frequency. The interference on the maximum coverage frequency is limited so that at least the maximum coverage frequency can be utilized throughout the cell, even to the constant cell perimeter.

5 In one mode of the invention, known as the interference controlled mode, the total interference on the maximum coverage frequency is limited so that the maximum coverage frequency can be utilized at the furthermost extent of the cell. In this mode, total interference on the maximum coverage frequency is measured and, if the total interference exceeds a predetermined threshold, (1) one or more connections carried by
10 the maximum coverage frequency is released (handed over) to another one of the plural frequencies, and/or (2) newly requesting connections are required to be carried on the other frequency(ies). In one example embodiment of this mode, the total interference measurement for the maximum coverage frequency is made at the base station. The base station transfers its total interference measurement for the maximum coverage
15 frequency to its radio network controller (RNC). The radio network controller (RNC) compares the total interference for the maximum coverage frequency to a constant coverage threshold value for the base station. If the total interference for the maximum coverage frequency is within a first predetermined interval of the constant coverage threshold value, the radio network controller (RNC) realizes that the maximum
20 coverage frequency requires protection. For such protection, a resource allocation unit in the radio network controller (RNC) can either (1) transfer existing connections from the maximum coverage frequency to the other frequency(ies), or (2) require that new connections utilize the frequency(ies) other than the maximum coverage frequency. Should the total interference for the maximum coverage frequency fall below a second
25 predetermined interval of the constant coverage threshold value, the radio network controller (RNC) can suspend protection efforts for the maximum coverage frequency.

30 In another mode, known as the connection controlled mode, the available frequencies are ordered in a list. The plural frequencies on the ordered list are ranked in a preferred order of usage with the maximum coverage frequency being the one that is used last (i.e., a least preferred frequency). In the connection controlled mode, when there is a new connection, the system tries to allocate according to the ordered list with the maximum coverage frequency being utilized only as a last resort. For the

connection controlled mode, there is also the possibility also to limit the number of connections.

In yet another mode, known as the traffic controlled mode, the amount of traffic occurring on each frequency is monitored and used as an estimate of the load or 5 interference on each frequency. High traffic connections can be allocated to frequencies other than the maximum coverage frequency.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features, and advantages of the invention will be apparent from the following more particular description of preferred embodiments as 10 illustrated in the accompanying drawings in which reference characters refer to the same parts throughout the various views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

Fig. 1 a schematic view of an embodiment of a telecommunications system which utilizes the present invention.

15 Fig. 2A is a diagrammatic view of a cell.

Fig. 2B is a diagrammatic view of a conventionally operated cell in a heavy traffic situation.

Fig. 2C is a diagrammatic view of the cell of Fig. 2B operated in accordance with a mode of the present invention rather than conventionally.

20 Fig. 3 is a schematic view of selected components of a base station node and a radio network controller (RNC) node, included in the telecommunications system of Fig. 1, according to an embodiment of the present invention.

Fig. 4 is a flowchart showing example basic steps performed in accordance with an interference controlled mode of the present invention.

Fig. 5 is a diagrammatic view of an example format of a coverage assurance message according to an embodiment of the invention.

Fig. 6 is a diagrammatic view of a resource allocation table used for a connection controlled mode of the invention.

5 Fig. 7 is a flowchart showing example basic steps performed in accordance with a connection controlled mode of the present invention.

Fig. 8 is a flowchart showing example basic steps performed in accordance with a traffic controlled mode of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

10 In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular architectures, interfaces, techniques, etc. in order to provide a thorough understanding of the present invention. However, it will be apparent to those skilled in the art that the present invention may be practiced in other embodiments that depart from these specific details. In other instances, detailed 15 descriptions of well known devices, circuits, and methods are omitted so as not to obscure the description of the present invention with unnecessary detail.

20 Fig. 1 shows a telecommunications network 18 in which a user equipment unit 20 communicates with one or more base stations 22 over air interface (e.g., radio interface) 23. Base stations 22 are connected by terrestrial lines (or microwave) to radio 20 network controller (RNC) 24 [also known as a base station controller (BSC) in some networks]. The radio network controller (RNC) 24 is, in turn, connected through a control node known as the mobile switching center 26 to circuit-switched telephone networks (PSTN/ISDN) represented by cloud 28. In addition, radio network controller (RNC) 24 is connected to Serving GPRS Support Node (SGSN) 25 and through 25 backbone network 27 to a Gateway GRPS support node (GGSN) 30, through which connection is made with packet-switched networks (e.g., the Internet, X.25 external networks) represented by cloud 32.

As understood by those skilled in the art, when user equipment unit 20 participates in a mobile telephonic connection, signaling information and user information from user equipment unit 20 are transmitted over air interface 23 on designated radio channels to one or more of the base stations 22. The base stations have 5 radio transceivers which transmit and receive radio signals involved in the connection or session. For information on the uplink from the user equipment unit 20 toward the other party involved in the connection, the base stations convert the radio-acquired information to digital signals which are forwarded to radio network controller (RNC) 24. The radio network controller (RNC) 24 orchestrates participation of the plural base 10 stations 22 which may be involved in the connection or session, since user equipment unit 20 may be geographically moving and handover may be occurring relative to the base stations 22. On the uplink, radio network controller (RNC) 24 picks frames of user information from one or more base stations 22 to yield a connection between user equipment unit 20 and the other party, whether that party be in PSTN/IDSN 28 or on the 15 packet-switched networks (e.g., the Internet) 32.

In the illustrated embodiment, since plural mobile stations served by base station 22 can utilize the same radio frequencies, code division multiple access techniques are employed to distinguish between the various mobile stations. In fact, unless otherwise 20 noted, as used herein the term "channel" refers to CDMA channel, which for any mobile station is defined in terms of an RF frequency and a particular code sequence.

Fig. 2A shows a cell C served by a representative one of the base stations (which is identified simply as base station 22). The base station 22 and cell C are designed so that, under reasonable traffic conditions, a frequency utilized by base station 22 (either 25 downlink or uplink frequency) is effective for connections with user equipment units located at a nominal radius $R_{NOMINAL}$ from base station 22. As shown in Fig. 2A, cell C has a nominal perimeter $P_{NOMINAL}$. The "MS's in Fig. 2A represent locations of active user equipment units (e.g., mobile stations) in cell C.

Fig. 2B illustrates a heavy traffic situation for cell C as conventionally operated. 30 In accordance with conventional operation, there may be only one frequency utilized for each directional link with respect to base station 22 (e.g., only one frequency for the uplink and only one frequency for the downlink), or (if multiple frequencies are provided) no coordination between the multiple frequencies for sake of cell coverage.

Fig. 2B shows cell C having many more user equipment units MSs being shown than in Fig. 2A. In view of the interference occasioned by the increased traffic in cell C as shown in Fig. 2C, the frequency utilized by base station 22 is effective only to a distance $R_{EFFECTIVE}$ shown in Fig. 2B ($R_{EFFECTIVE} < R_{NOMINAL}$). In essence, the 5 conventional operation and cell breathing of cell C has reduced the coverage area of cell C, e.g., reduced the coverage area of base station 22. Consequentially, user equipment units MS positioned at a radius from base station 22 greater than $R_{EFFECTIVE}$ shown in Fig. 2B cannot be served by base station 22 under these heavy traffic conditions.

The present invention reduces effects of cell breathing in a manner illustrated, 10 for example, in Fig. 2C. In particular, in accordance with the present invention plural radio frequencies are utilized by base station 22 for each directional link (e.g., plural frequencies for the uplink and plural frequencies for the downlink). As explained below, one of the plural frequencies is designated as a maximum coverage frequency. 15 In essence, interference on the maximum coverage frequency is limited by allocation of traffic, when necessary, to another of the radio frequencies. The limiting of traffic (e.g., by reallocation to other frequency(ies)) keeps the maximum coverage frequency useable at the cell perimeter (assuming sufficient available channels). Thus, as shown in Fig. 2C, the cell C as operated by the present invention has a maximum geographical 20 cell perimeter P_{MAX} (P_{MAX} being greater than $R_{EFFECTIVE}$). In order to reserve the maximum coverage frequency for use at perimeter P_{MAX} , traffic may be allocated so that the maximum coverage frequency is allocated to user equipment units in the outer ring region as shown in Fig. 2C. Other frequency(ies) are allocated to the remaining user 25 equipment units (as shown by the inner ring region, which now has a radius smaller than $R_{EFFECTIVE}$ of Fig. 2B). Implementation of the frequency allocation scheme of the present invention is described in more detail below.

Fig. 3 shows in more detail components, pertinent to the present invention, of an example base station 22 node and an example radio network controller (RNC) 24 node. 30 Base station 22 is connected by a physical link 40 to radio network controller (RNC) 24. Physical link 40 is typically a terrestrial or microwave line. In the illustrated embodiment, link 40 carries data and signaling packets between base station 22 and radio network controller (RNC) 24. Packets directed from base station 22 to radio network controller (RNC) 24 are said to form an uplink 42 between base station 22 and

radio network controller (RNC) 24; packets directed from radio network controller (RNC) 24 to base station 22 are said to form an downlink 44 between base station 22 and radio network controller (RNC) 24.

As shown in Fig. 3, base station 22 includes radio transceiver 50₁ and radio transceiver 50₂; node controller 52; and, network interface 54. Base station 22 serves cell C. In accordance with CDMA techniques, a particular user equipment unit 20 in the cell is able to decode only the portion of the signal transmitted (from either transceiver 50₁ or transceiver 50₂) which has been encoded by the code known to that particular station. Similarly, the information transmitted by each user equipment unit 20 to base station 22 is encoded with a unique code particular to that user equipment unit and recognizable by base station 22 as being attributed to that station. The portion of a signal over which the code associated with a particular user equipment unit enables that user equipment unit to transmit or receive information relative to base station 22 is known as a “channel” for that station.

In base station 22, controller 52 conducts the coding and decoding of signals applied to and received from radio transceiver 50. The signals encoded by controller 52 are primarily those obtained over link 40 from radio network controller (RNC) 24. The signals decoded by controller 52 are primarily those destined for radio network controller (RNC) 24 over link 40. Network interface 54 is connected between controller 52 and link 40 in order to accommodate the transmission of signals between base station 22 and radio network controller (RNC) 24.

Radio network controller (RNC) 24 has its own network interface 60 connected to link 40. Network interface 60 is connected within radio network controller (RNC) 24 to diversity handoff (DHO) unit 62, node controller 64, and resource allocation unit (RAU) 66. Of considerable interest to the present invention are the functions performed by resource allocation unit (RAU) 66, which can include (for example) a microprocessor.

It should be noted, in passing, that the functions of radio network controller (RNC) 24 can also be performed by a type of node referred to as base station controller (BSC) or mobile switching center (MSC). Moreover, the radio network controller (RNC) 24 is typically connected to a plurality of base stations for performing operations

such as those above-described. In addition, radio network controller (RNC) 24 is usually connected to one or more other radio network controllers comprising the mobile telecommunications network. At least one of the radio network controllers of the mobile telecommunications network is connected to or forms part of a gateway to the 5 wired portion of the public switched telephone network (PSTN).

Diversity handoff (DHO) unit 62 performs numerous functions, including but not limited to assisting the transition which occurs when a mobile station travels or roams into a cell handled by another base station. In addition, diversity handoff (DHO) unit 62 computes a target signal to interference/noise ratio (TSNR) for each base station for 10 which radio network controller (RNC) 24 is responsible.

The resource allocation unit (RAU) 66 of the embodiment of Fig. 3 includes a resource allocation table 100. The resource allocation table 100 has a list or table of potential radio frequency resources, and reflects the status (already allocated or available) for each resource. The resources on the resource allocation table 100 are 15 grouped by uplink and downlink. In the particular example of resource allocation table 100 shown in Fig. 3, the resource allocation table 100 includes two frequencies for the uplink and a corresponding two frequencies for the downlink. In other words, for this particular case there is one regular frequency pair and one maximum coverage frequency (MCF) pair. For each frequency the resource allocation table 100 has plural 20 records, and in particular a record for each channel of the frequency. Thus, there are i number of records in resource allocation table 100 corresponding to i number of channels for the uplink regular frequency; i number of records in resource allocation table 100 corresponding to i number of channels for the downlink regular frequency; k number of records in resource allocation table 100 corresponding to k number of 25 channels for the uplink maximum coverage frequency; and k number of records in resource allocation table 100 corresponding to k number of channels for the downlink maximum coverage frequency. Each record includes a status indication from which resource allocation unit (RAU) 66 can determine if the channel has already been allocated to a connection or remains available for a new connection. In addition, for 30 each channel which has already been allocated to a connection, the record includes a connection identifier.

For sake of simplification, the resource allocation table 100 of Fig. 3 is shown as having only two uplink frequencies and two downlink frequencies. It should be apparent that a greater number of uplink frequencies and two downlink frequencies can be employed.

5 As will become more evident below, in the embodiment of Fig. 3 the total interference on the maximum coverage frequency (MCF) is limited so that the maximum coverage frequency is available for use by user equipment units proximate the maximum perimeter P_{MAX} of the cell (see Fig. 2C). Fig. 4 shows various basic steps or operations performed by base station 22 and radio network controller (RNC) 24 in
10 connection with the Fig. 3 example embodiment of the invention.

At step 4-1, various signal measurements are performed by base station 22. In this regard, when a connection involving a user equipment unit is in progress, the strength (i.e., received power) of the signal on the uplink from the user equipment unit to base station 20 is monitored by base station 20. Preferably, the strength of the signal
15 on the uplink from the user equipment unit to base station 20 is monitored essentially continuously by base station 20. In this regard, radio transceiver 50 is interrogated by controller 52 with respect to each channel (e.g., each user equipment unit) to ascertain the received power of the signal. For each uplink frequency, controller 52 thus knows the received power for all user equipment units served by the uplink frequency of base
20 station 20. For each frequency, including the maximum coverage frequency (MCF), the total interference is also measured. The person skilled in the art will appreciate that there are a number of ways that total interference for a frequency can be measured or ascertained, such as, e.g., using the total received power as an estimate of total
25 interferences. Thus, at step 4-1 the controller 52 determines, with respect to each uplink frequency, both a signal strength for each channel and a total interference for the uplink frequency.

In passing, it is also noted that, with respect to each user equipment unit, controller 52 also determines a signal to interference/noise ratio (SIR).

At step 4-2 controller 52 of base station 22 waits for a measurement time
30 reporting interval. When it is time to report a measurement, at step 4-3 the controller 52 of base station 22 prepares a coverage assurance message (CAM). An example format

of a coverage assurance message (CAM) is illustrated in Fig. 5. The coverage assurance message (CAM) begins with a header 5-1, which identifies, e.g., the type of message as being a coverage assurance message (CAM). The header is followed by a field 5-2 which declares the number of frequencies reported in the coverage assurance message (CAM). Field 5-3 declares the total interference for the uplink maximum coverage frequency. Field 5-4 states the number of channels active for the maximum coverage frequency. Fields 5-5-1 through 5-5-j give the signal strength for each of the active channels for the maximum coverage frequency. Similarly, field 5-6 declares the total interference for the uplink regular frequency (REGF). Field 5-7 states the number of channels active for the uplink regular frequency (REGF). Fields 5-8-1 through 5-8-q give the signal strength for each of the active channels for the uplink regular frequency (REGF). The values for total interference for each frequency, as well as the signal strength values for fields 5-5-1 through 5-5-j and fields 5-8-1 through 5-8-q, are obtained from step 4-1.

The format of the coverage assurance message (CAM) as illustrated in Fig. 5 would have a value of “2” in the number of frequencies field 5-2 in order to reflect utilization on the uplink of both the maximum coverage frequency and the other uplink frequency (herein known as the regular frequency). It will be readily understood that, when resource allocation table 100 has more than two uplink frequencies, the coverage assurance message (CAM) also includes information for a corresponding number of more than two uplink frequencies.

At step 4-4 the base station 22 is shown as transmitting the coverage assurance message (CAM) to radio network controller (RNC) 24 over link 40. Thereafter, the controller 52 of base station 22 returns to step 4-2 to determine if it is time to report new measurement results (which are being essentially continuously taken at step 4-1). Upon expiration of a further measurement time reporting interval, a further coverage assurance message (CAM) will be prepared and transmitted, all as understood with respect to the foregoing discussion of step 4-3 and step 4-4.

In Fig. 4, a broken line delineates steps performed by base station 22 (on the left of the broken line) and steps performed by radio network controller (RNC) 24 (on the right of the broken line). The transmission of the coverage assurance message (CAM) is reflected by the arrow labeled “CAM”.

Step 4-5 of Fig. 4 shows radio network controller (RNC) 24 awaiting, and then processing (e.g., decoding), the coverage assurance message (CAM) received from base station 22. Remaining functions performed by radio network controller (RNC) 24, and particularly by resource allocation unit (RAU) 66, with respect to the coverage assurance message (CAM) are illustrated as steps 4-6 through 4-12 in Fig. 4.

At step 4-6 the resource allocation unit (RAU) 66 determines whether the total interference value for the maximum coverage frequency is exceeds a predetermined interference first threshold. As understood from Fig. 5, the total interference value for the maximum coverage frequency is obtained from field 5-3 of the coverage assurance message (CAM). If the interference first threshold is exceeded, step 4-7 through step 4-9 are performed.

At step 4-7, the resource allocation unit (RAU) 66 chooses an existing connection to be reallocated from the maximum coverage frequency to the other frequency (the regular frequency). In performing step 4-7, the resource allocation unit (RAU) 66 can note, from the records in resource allocation table 100, the connection identifier of an allocated channel for the uplink maximum coverage frequency, and change the connection from the maximum coverage frequency to a channel of the regular frequency. Such reallocation is accomplished by resource allocation unit (RAU) 66 at step 4-8. In addition, anticipating that addition of further connections would also cause the total interference level for the maximum coverage frequency to exceed the interference threshold, at step 4-9 the resource allocation unit (RAU) 66 sets a MCF protection flag. As long as the MCF protection flag is set, all requests for new connections must be allocated a channel of the regular frequency. In other words, when the MCF protection flag is set, the maximum coverage frequency cannot be used for new connections.

If the interference first threshold is not exceeded at step 4-6, the resource allocation unit (RAU) 66 determines at step 4-10 whether the total interference value for the maximum coverage frequency is below a predetermined interference second threshold. If the total interference value for the maximum coverage frequency is below the predetermined interference second threshold, the resource allocation unit (RAU) 66 can determine whether further connections should be added to the maximum coverage

frequency. In such case, resource allocation unit (RAU) 66 performs step 4-11 and step 4-12.

At step 4-11, resource allocation unit (RAU) 66 checks the total interference value for the other frequency (e.g., the regular frequency). In the Fig. 3 embodiment, 5 this total interference value is obtained from field 5-6 of the coverage assurance message (CAM) of Fig. 5. If it is determined at step 4-11 that the total interference value for the other frequency (e.g., the regular frequency) is high, then at step 4-12 resource allocation unit (RAU) 66 allocates a connection from the regular frequency to the maximum coverage frequency. The allocation is performed by consulting the 10 resource allocation table 100, and determining therefrom a connection which can be transferred from the regular frequency to the maximum coverage frequency.

In the event that the total interference value for the maximum coverage frequency is below the predetermined interference second threshold (see step 4-10), or should the total interference for the regular frequency not be high (see step 4-11), and 15 upon completion of any of step 4-9 and step 4-12, the resource allocation unit (RAU) 66 returns to step 4-5 to await the next coverage assurance message (CAM) issued by base station 22.

Thus, the steps of Fig. 4 depict an interference controlled mode of operation of 20 resource allocation unit (RAU) 66, wherein the total interference on the uplink maximum coverage frequency is limited to be below the interference first threshold (see step 4-6).

Insofar as the downlink is concerned, coverage is primarily determined by the 25 available Multiple Carrier Power Amplifier (MCPA) output power. A MCPA can be viewed as a common amplifier that serves a number of mobile units and thus is a pooled resource. The MCPA facilitates allocating a higher power to a mobile further away and a lower power for a mobile closer to the base station so long as the total allocated power does not exceed the MCPA power. This has the overall effect that at all reasonable loads the coverage will be uplink limited. Accordingly, interference increase does not have the same effect as on the uplink.

Furthermore, most commonly each uplink frequency will have its corresponding downlink frequency, and one therefore often talks about a frequency allocation with the implicit meaning of one uplink frequency and the corresponding downlink frequency. Regarding the interference controlled mode, only the uplink interference has been 5 included, so for that mode the most natural is to have a maximum coverage frequency based on the uplink measurements and together with this use the corresponding downlink frequency.

In accordance with another mode of the invention, known as the connection controlled mode, the maximum coverage frequency (MCF) is used only as a last resort 10 for allocation to a new connection. In the connection controlled mode, the resource allocation table 100 is conceptualized as being an ordered list of frequencies. Fig. 6 shows another example of resource allocation table, particularly resource allocation table 600 which can be utilized with the resource allocation unit (RAU) 66 and other components shown in Fig. 3. For purposes of illustration, resource allocation table 600 15 is shown as having four uplink frequencies and four downlink frequencies. As reflected by arrow 602 in Fig. 6, the plural frequencies on the ordered list are ranked in preferred order of usage with the maximum coverage frequency being a least preferred frequency. In general, in the connection controlled mode, a new connection is allocated to a least preferred one of the plural frequencies having an available channel.

20 Fig. 7 shows basic steps performed by resource allocation unit (RAU) 66 of radio network controller (RNC) 24 for the connection controlled mode of the invention. In particular, step 7-1 shows resource allocation unit (RAU) 66 waiting for a request for a new connection. When a request for a new connection is received, at step 7-2 resource allocation unit (RAU) 66 checks through resource allocation table 600, checking 25 frequencies, in order, from the most preferred (e.g, frequency 1) to the least preferred (i.e., the maximum coverage frequency), looking for the first frequency that can be used for the new connection, and choosing this first frequency for this connection. Thus, the maximum coverage frequency is the most conserved frequency, and therefore utilized to reach user equipment units which are situated proximate the maximum perimeter P_{MAX} 30 of the cell (see Fig. 2C).

Additionally, by not allowing more than a predetermined number of connections on the most conserved frequency, a more controlled (e.g., constant radius) service area for the cell can be obtained.

In accordance with yet a further mode of the invention, known as the traffic controlled mode, the amount of traffic occurring on each frequency is monitored by the radio network controller (RNC) 22 and used as an estimate of the load or interference on each frequency. In an example of the traffic controlled mode illustrated in Fig. 8, substantially all of the steps are performed by radio network controller (RNC) 24. As reflected by step 8-1, the radio network controller (RNC) 24 obtains traffic measurements for each frequency. The person skilled in the art will appreciate that there are several ways for the RNC to obtain traffic measurements for a frequency, such as (for example) adding the number of connections in a sector (with a weighting factor for the case in which there are different types of connections). As a next step (step 8-6), the radio network controller (RNC) 24 determines if the total traffic for the maximum coverage frequency (MCF) exceeds a first threshold, in similar manner to the interference determination of step 4-6 for the interference controlled mode. If the first threshold is exceeded at step 8-6, step 8 - 7 through step 8-9 are performed for the respective purposes of choosing a connection to reallocate from the maximum coverage frequency to another frequency, performing the actual reallocation (step 8-8), and setting the MCF protection flag (step 8-9), all before looping back to step 8-1. If the first traffic threshold is not exceeded at step 8-6, the radio network controller (RNC) 24 determines at step 8-10 whether the total traffic for the maximum coverage frequency is below a second threshold. If the determination at step 8-10 is positive, and if it is further determined at step 8-11 that the total traffic for the other frequency is high, a connection is allocated to the maximum coverage frequency at step 8-12.

Although not particularly stated herein, the person skilled in the art will realize that more than two uplink frequencies and more than two downlink frequencies can be employed at a given base station 22. In fact, as well known in the art, multiple frequencies can be employed for sectorized base stations. The present invention is applicable even to sectorized base stations, there being a maximum coverage frequency for each sector. The maximum coverage frequency can be the same or different for each sector.

It should be noted, in connection with the setting of the MCF protection flag at step 4-9, that for requests for certain important connections (e.g., such as a request for an emergency connection [e.g., 911]), the resource allocation unit (RAU) 66 can override the setting of the MCF protection flag and reallocate yet other connections in order to accommodate the emergency connection.

Thus, in accordance with the present invention, having an appropriate allocation of traffic between the available plural frequencies utilized by the base station reduces cell breathing tendencies of the cell. Moreover, as explained above, the appropriate allocation of traffic between the different plural frequencies utilized at a base station can be made both when a new radio resource is to be allocated in a cell (e.g., a new connection is requested), as well as a reallocation of existing traffic from the maximum coverage frequency to another frequency when cell conditions so require. As a consequence of the allocation (or reallocation), some frequency(ies) may carry more traffic so that other frequency(cies) [e.g., the maximum coverage frequency] can have reduced interference levels and thereby be used throughout the cell.

As exemplified above, the allocation of traffic in accordance with the present invention can be made according to differing strategies. One such strategy is to maximize the cell size, i.e., to minimize the interference level at the maximum coverage frequency. Another strategy can be to try to keep the cell size as constant as possible. These two strategies were merely examples, other strategies are within the purview of the present invention. These traffic allocation strategies can, of course, be combined with other mechanisms in order to reduce further the effect of cell breathing.

Various embodiments described herein and illustrated in the drawings are only examples. For example, the network of Fig. 1 may or may not include GPRS nodes. There is also the possibility that there may be no separate physical radio network controller (RNC) node, e.g., the functionality of the radio network controller (RNC) may instead be incorporated or otherwise included in another node such as the mobile switching center (MSC). Moreover, as noted above, the embodiment of base station node 22 and radio network controller (RNC) node 24 described herein, e.g., with reference to Fig. 3, are merely examples. Other node architectures and functionalities occur in differing embodiments.

While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within 5 the spirit and scope of the appended claims.

WHAT IS CLAIMED IS:

1 1. A method of operating a cellular telecommunications system (18)
2 characterized by allocating traffic between plural radio frequencies utilized at a base
3 station (22) according to a cell size strategy for a cell served by the base station.

1 2. The method of claim 1, comprising allocating traffic between the plural
2 frequencies utilized at the base station (22) to maintain a cell size as having a
3 predetermined coverage (P_{max}).

1 3. The method of claim 1, comprising allocating traffic between the plural
2 frequencies utilized at the base station to maximize cell size.

1 4. The method of claim 1, further comprising:
2 designating one of the plural frequencies as a maximum coverage frequency
3 (MCF);
4 measuring total interference on the maximum coverage frequency; and,
5 when the total interference on the maximum coverage frequency exceeds an
6 interference first threshold, releasing a connection carried by the maximum coverage
7 frequency to another one of the plural frequencies.

1 5. The method of claim 1, further comprising:
2 designating one of the plural frequencies as a maximum coverage frequency
3 (MCF);
4 measuring total interference on the maximum coverage frequency; and,
5 when the total interference on the maximum coverage frequency exceeds an
6 interference first threshold, requiring another one of the plural frequencies to carry a
7 newly requested connection.

1 6. The method of claim 1, further comprising:
2 designating one of the plural frequencies as a maximum coverage frequency
3 (MCF);
4 limiting a number of connections allocated to the maximum coverage frequency
5 whereby the maximum coverage frequency is utilizable proximate an edge of the cell.

1 7. The method of claim 1, further comprising:

2 designating one of the plural frequencies as a maximum coverage frequency

3 (MCF);

4 maintaining an ordered list (100) of the plural frequencies, the plural frequencies
5 on the ordered list being ranked in preferred order of usage with the maximum coverage
6 frequency being a least preferred frequency;

7 allocating to a new connection a least preferred one of the plural frequencies

8 having an available channel.

1 8. The method of claim 1, further comprising:

2 designating one of the plural frequencies as a maximum coverage frequency

3 (MCF);

4 limiting an amount of traffic allocated to the maximum coverage frequency

5 whereby the maximum coverage frequency is utilizable proximate an edge of the cell.

1 9. The method of claim 1, further comprising:

2 designating one of the plural frequencies as a maximum coverage frequency

3 (MCF);

4 determining total traffic on the maximum coverage frequency; and,

5 when the total traffic on the maximum coverage frequency exceeds a first traffic

6 threshold, requiring another one of the plural frequencies to carry a connection.

1 10. A cellular telecommunications system (18) characterized by:

2 a base station (22) which utilizes plural radio frequencies for serving a cell;

3 a resource allocation unit (66) which allocates traffic between the plural radio

4 frequencies according to a cell size strategy for a cell served by the base station.

1 11. The apparatus of claim 10, wherein the resource allocation unit (66)

2 allocates traffic between the plural frequencies utilized at the base station to maintain a

3 cell size as having a predetermined coverage P_{max}).

1 12. The apparatus of claim 10, wherein the resource allocation unit allocates

2 traffic between the plural frequencies utilized at the base station to maximize cell size.

1 13. The apparatus of claim 10, wherein one of the plural radio frequencies is
2 designated as a maximum coverage frequency (MCF), wherein the base station
3 measures total interference on the maximum coverage frequency; and further
4 comprising

5 a node (24) which releases a connection carried by the maximum coverage
6 frequency to another one of the plural frequencies when the total interference on the
7 maximum coverage frequency exceeds a predetermined threshold.

1 14. The apparatus of claim 13, wherein the node which releases the connection
2 carried by the maximum coverage frequency is a radio network controller (RNC).

1 15. The apparatus of claim 10, wherein one of the plural radio frequencies is
2 designated as a maximum coverage frequency (MCF), wherein the base station
3 measures total interference on the maximum coverage frequency; and further
4 comprising

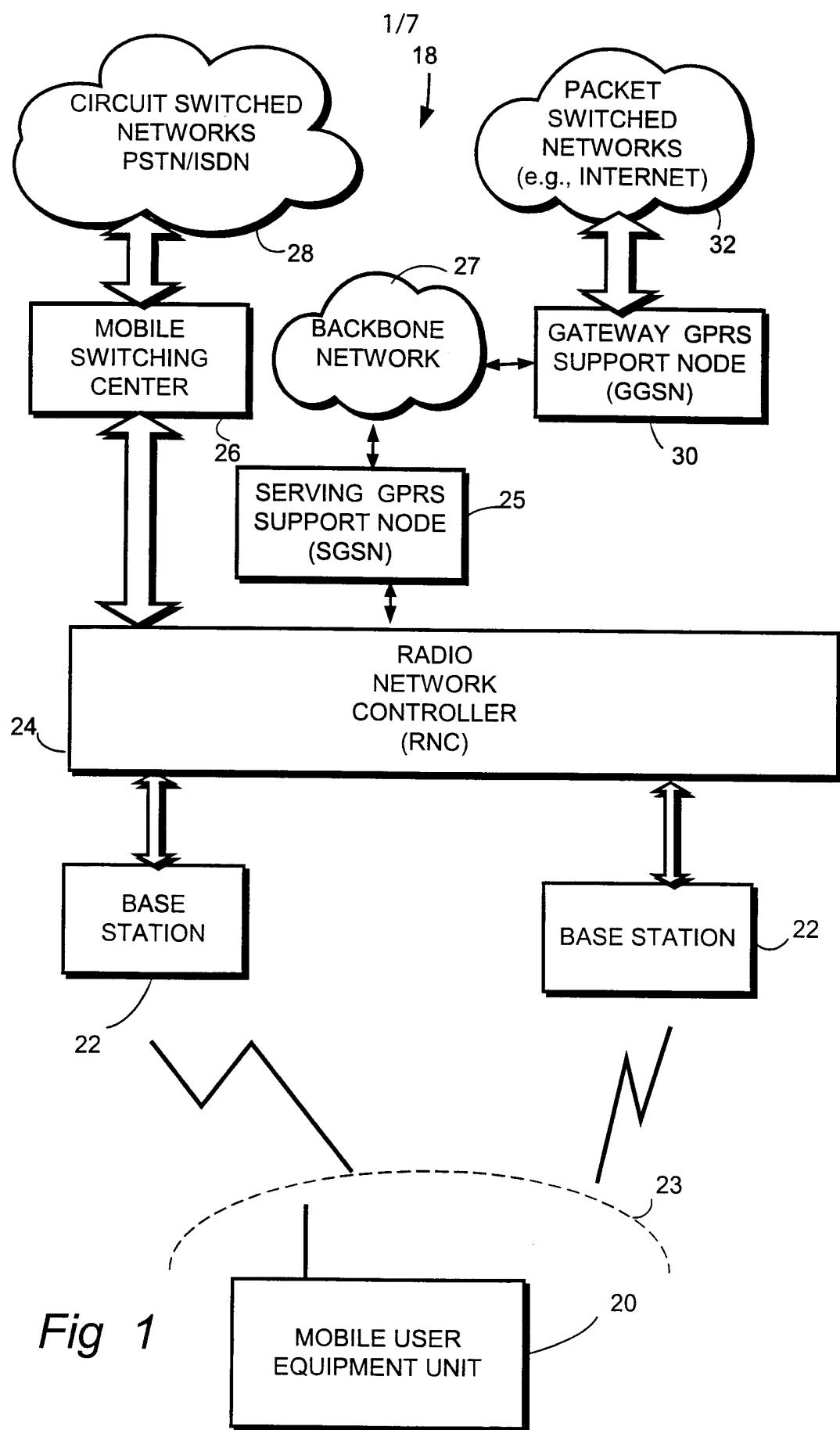
5 a node (24) which requires another one of the plural frequencies to carry a newly
6 requested connection when the total interference on the maximum coverage frequency
7 exceeds a predetermined threshold.

1 16. The apparatus of claim 15, wherein the node which requires another one of
2 the plural frequencies to carry a newly requested connection is a radio network
3 controller (RNC).

1 17. The apparatus of claim 10, wherein one of the plural radio frequencies is
2 designated as a maximum coverage frequency (MCF), wherein the resource allocation
3 unit (66) limits a number of connections allocated to the maximum coverage frequency
4 whereby the maximum coverage frequency is utilizable proximate an edge of the cell.

1 18. The apparatus of claim 17, wherein the resource allocation unit maintains an
2 ordered list (100) of the plural frequencies, the plural frequencies on the ordered list
3 being ranked in preferred order of usage with the maximum coverage frequency being a
4 least preferred frequency, and wherein the resource allocation unit allocates to a new
5 connection a least preferred one of the plural frequencies having an available channel.

1 19. The apparatus of claim 10, wherein one of the plural radio frequencies is
2 designated as a maximum coverage frequency (MCF), wherein the resource allocation
3 unit determines total traffic on the maximum coverage frequency, and wherein when the
4 total traffic on the maximum coverage frequency exceeds a traffic threshold, the
5 resource allocation unit requires another one of the plural frequencies to carry a
6 connection.



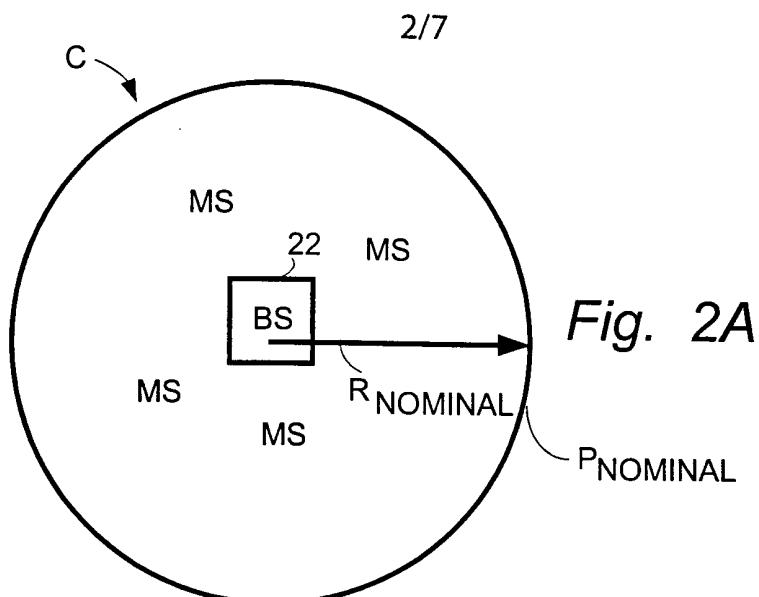


Fig. 2A

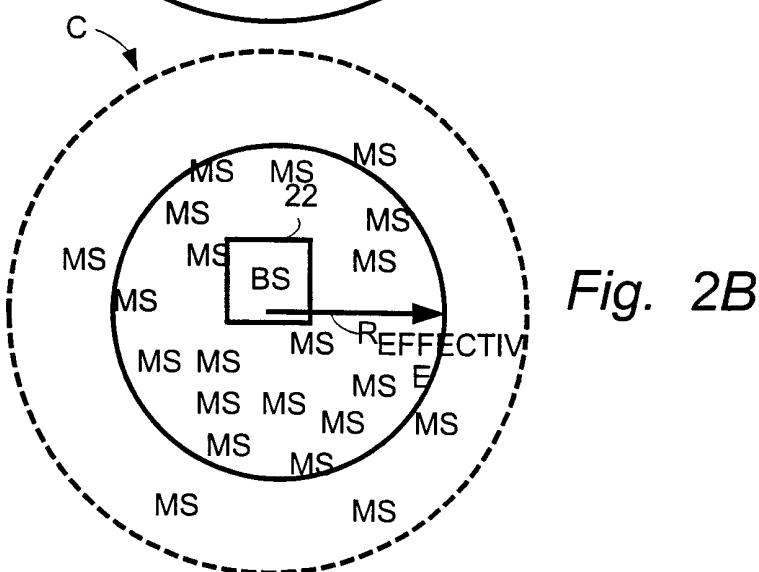


Fig. 2B

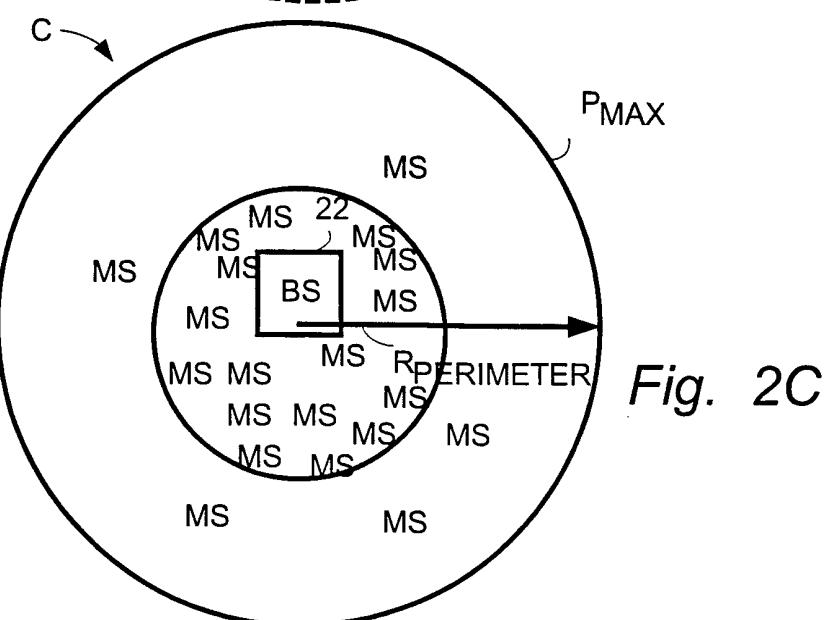


Fig. 2C

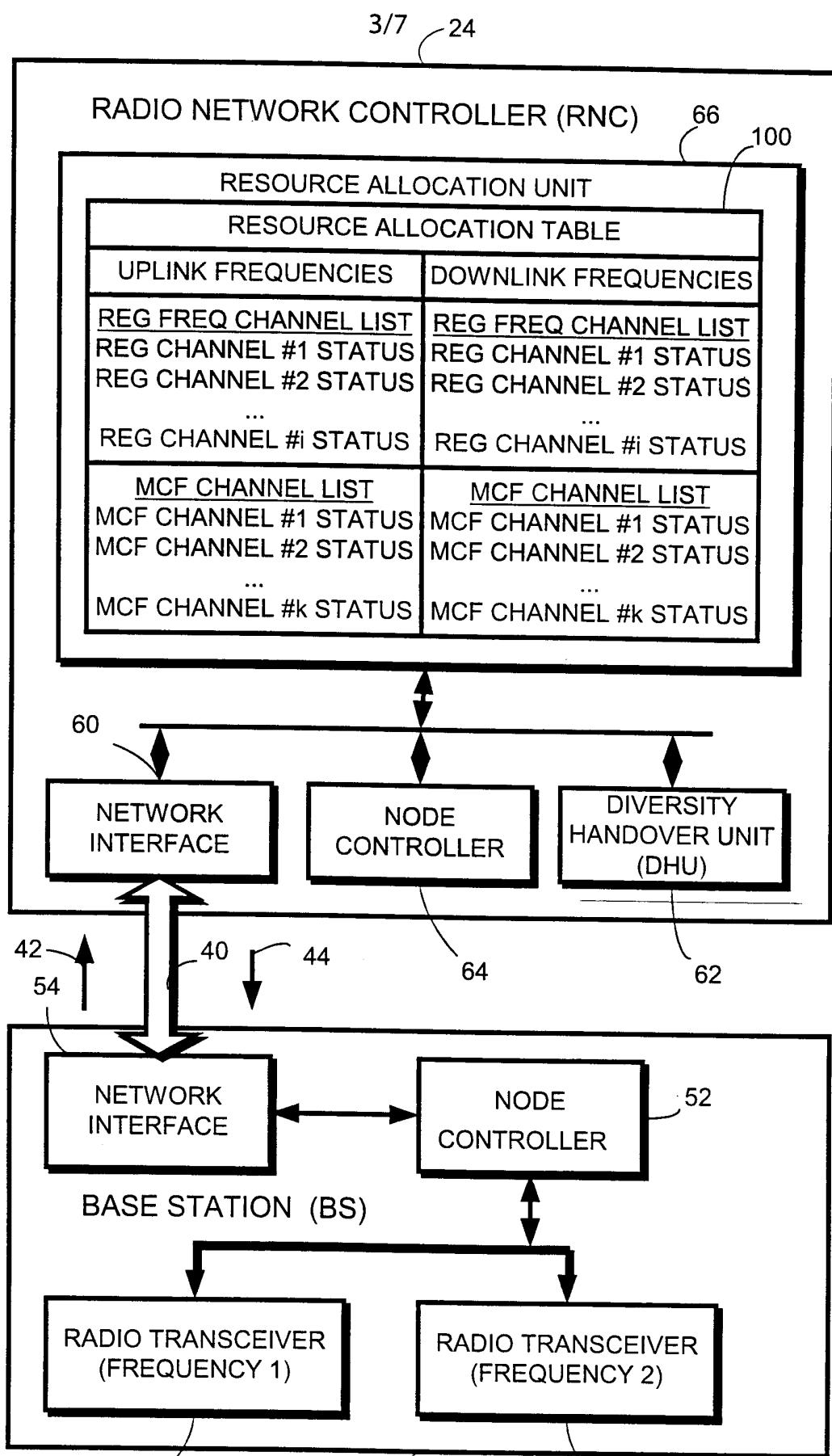


Fig 3

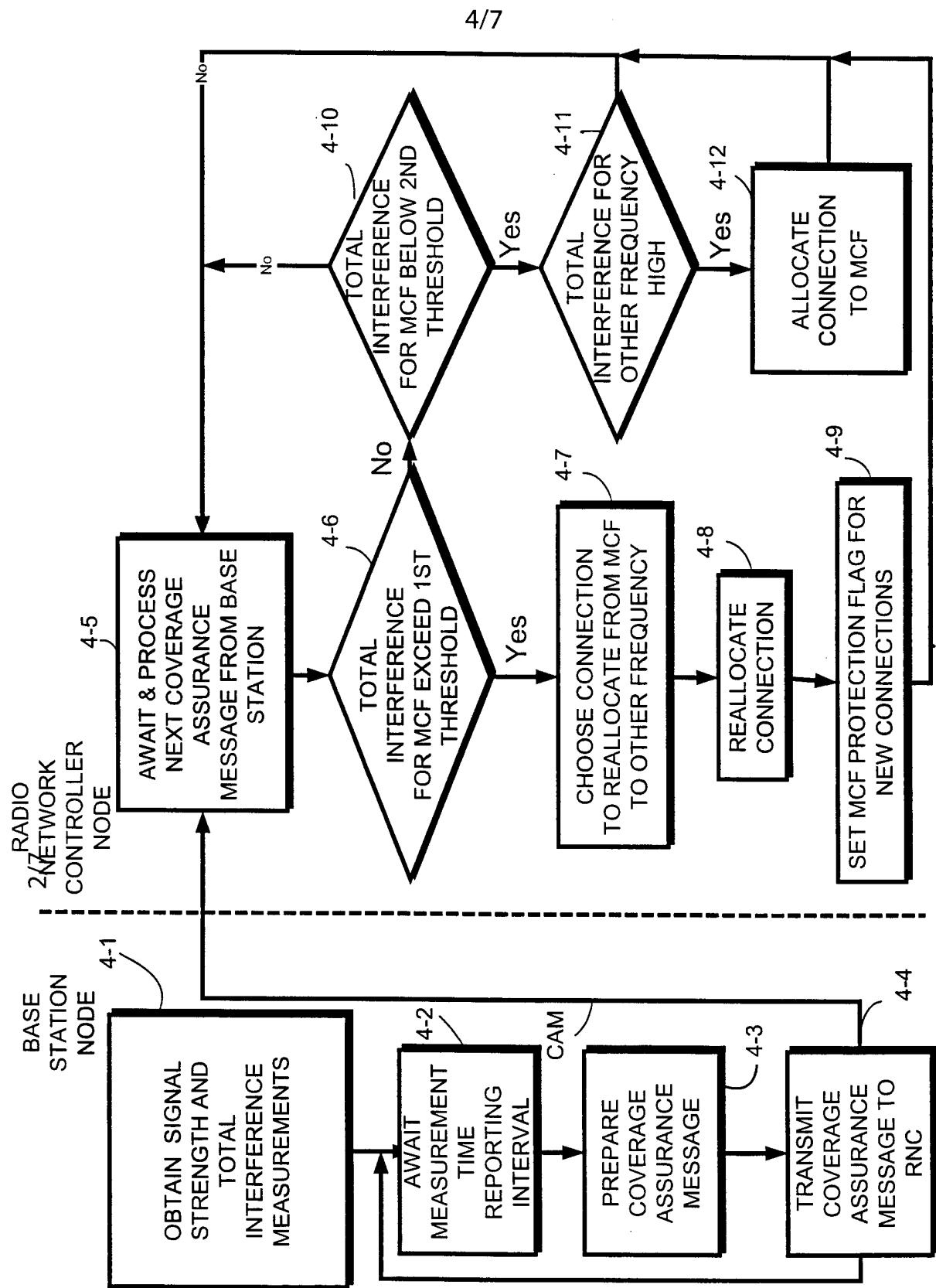
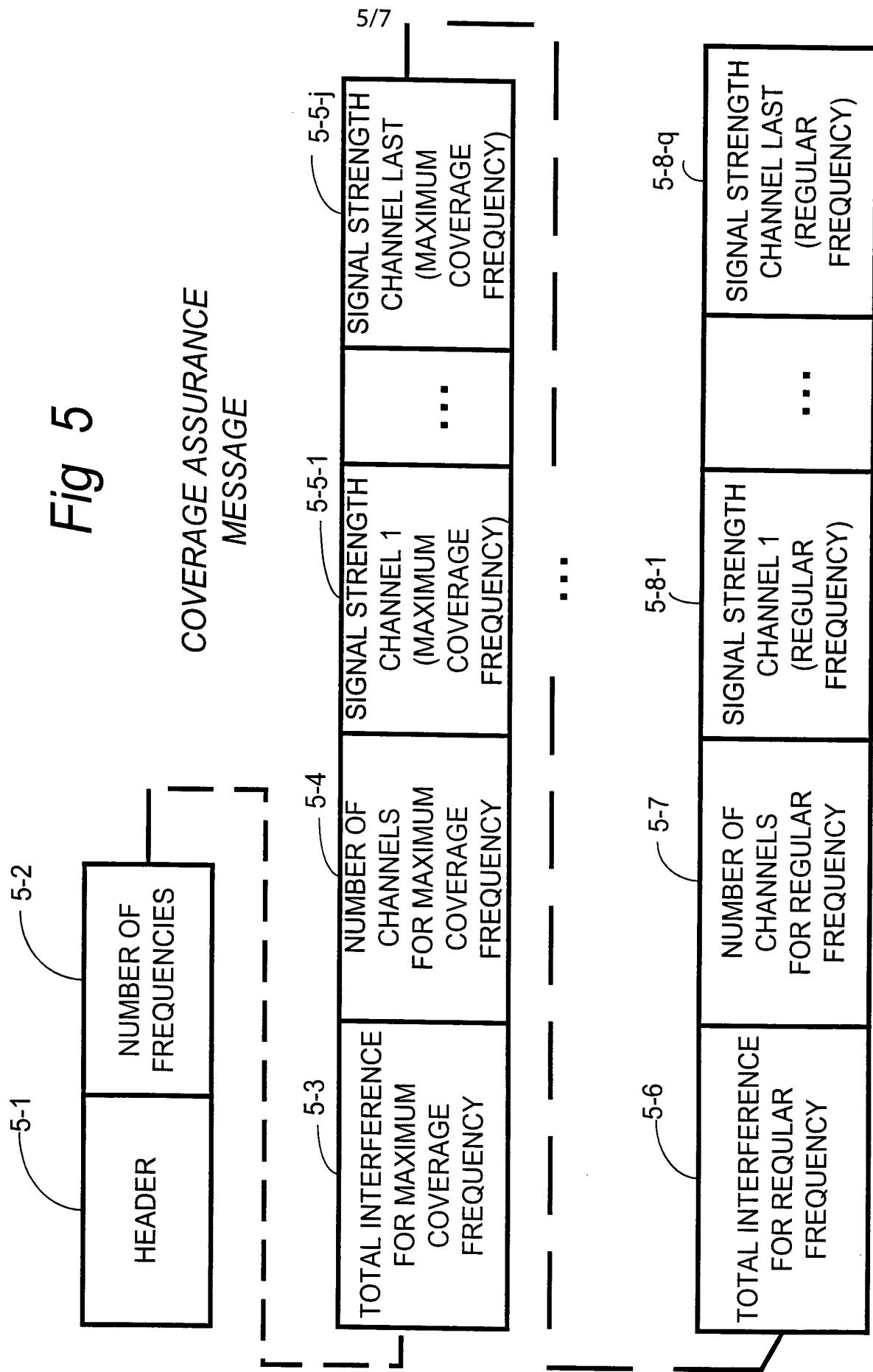


Fig 4

Fig 5

MESSAGE
COVERAGE ASSURANCE



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The table is labeled 600 and has a header 'RESOURCE ALLOCATION TABLE'. It is divided into two main sections: 'UPLINK FREQUENCIES' and 'DOWNLINK FREQUENCIES'. The 'UPLINK FREQUENCIES' section contains four rows: 'UP FREQ 1 CHANNEL LIST' (with rows for CHANNEL #1 STATUS, CHANNEL #2 STATUS, ..., CHANNEL #i STATUS), 'UP FREQ 2 CHANNEL LIST' (with rows for CHANNEL #1 STATUS, CHANNEL #2 STATUS, ..., CHANNEL #i STATUS), 'UP FREQ 3 CHANNEL LIST' (with rows for CHANNEL #1 STATUS, CHANNEL #2 STATUS, ..., CHANNEL #i STATUS), and 'MCF CHANNEL LIST' (with rows for MCF CHANNEL #1 STATUS, MCF CHANNEL #2 STATUS, ..., MCF CHANNEL #k STATUS). The 'DOWNLINK FREQUENCIES' section contains four rows: 'DN FREQ 1 CHANNEL LIST' (with rows for CHANNEL #1 STATUS, CHANNEL #2 STATUS, ..., CHANNEL #i STATUS), 'DN FREQ 2 CHANNEL LIST' (with rows for CHANNEL #1 STATUS, CHANNEL #2 STATUS, ..., CHANNEL #i STATUS), 'DN FREQ 3 CHANNEL LIST' (with rows for CHANNEL #1 STATUS, CHANNEL #2 STATUS, ..., CHANNEL #i STATUS), and 'MCF CHANNEL LIST' (with rows for MCF CHANNEL #1 STATUS, MCF CHANNEL #2 STATUS, ..., MCF CHANNEL #k STATUS). A vertical arrow labeled 602 points downwards from the table.

RESOURCE ALLOCATION TABLE	
UPLINK FREQUENCIES	DOWNLINK FREQUENCIES
UP FREQ 1 CHANNEL LIST	DN FREQ 1 CHANNEL LIST
CHANNEL #1 STATUS	CHANNEL #1 STATUS
CHANNEL #2 STATUS	CHANNEL #2 STATUS
...	...
CHANNEL #i STATUS	CHANNEL #i STATUS
UP FREQ 2 CHANNEL LIST	DN FREQ 2 CHANNEL LIST
CHANNEL #1 STATUS	CHANNEL #1 STATUS
CHANNEL #2 STATUS	CHANNEL #2 STATUS
...	...
CHANNEL #i STATUS	CHANNEL #i STATUS
UP FREQ 3 CHANNEL LIST	DN FREQ 3 CHANNEL LIST
CHANNEL #1 STATUS	CHANNEL #1 STATUS
CHANNEL #2 STATUS	CHANNEL #2 STATUS
...	...
CHANNEL #i STATUS	CHANNEL #i STATUS
MCF CHANNEL LIST	MCF CHANNEL LIST
MCF CHANNEL #1 STATUS	MCF CHANNEL #1 STATUS
MCF CHANNEL #2 STATUS	MCF CHANNEL #2 STATUS
...	...
MCF CHANNEL #k STATUS	MCF CHANNEL #k STATUS

Fig 6

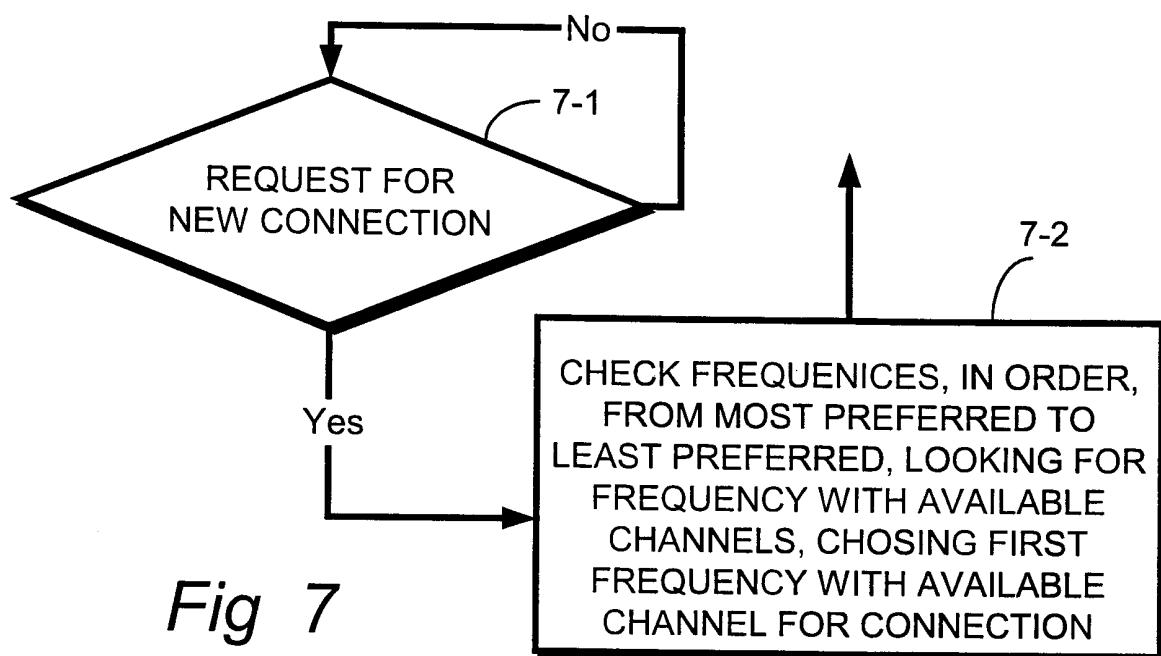
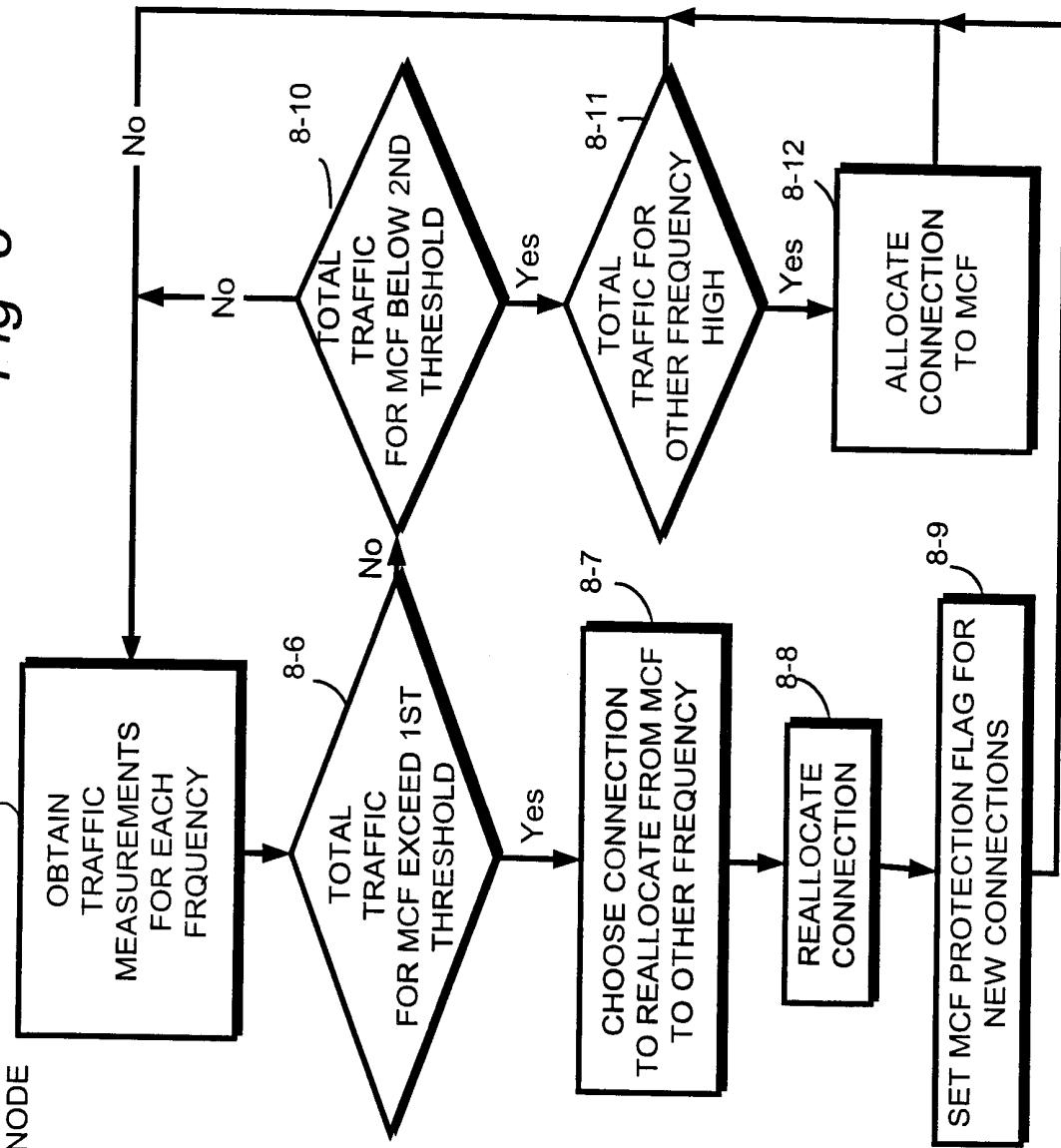


Fig 7

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Fig 8
 RADIO
 NETWORK
 CONTROLLER
 NODE



INTERNATIONAL SEARCH REPORT

Interr. Application No
PCT/SE 00/01654

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04Q/36

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 7 H04Q

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 52364 A (NEXTEL COMMUNICATIONS INC) 19 November 1998 (1998-11-19) page 8, line 5 -page 9, line 17 page 12, line 17 -page 13, line 14	1-3, 10, 11
A	page 19, line 1 - line 15 page 20, line 8 -page 22, line 21 claims 1,15-19 figures 1,3	4-9, 13-19
A	WO 96 37082 A (NOKIA TELECOMMUNICATIONS OY ;POSTI HARRI (FI)) 21 November 1996 (1996-11-21) page 3, line 15 - line 35 page 5, line 2 -page 6, line 19 page 7, line 16 - line 25 figure 2	1-3, 10-12
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Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

* Special categories of cited documents :

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

5 December 2000

Date of mailing of the international search report

12/12/2000

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INTERNATIONAL SEARCH REPORT

Intern 1al Application No
PCT/SE 00/01654

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 98 16029 A (ERICSSON GE MOBILE INC) 16 April 1998 (1998-04-16) -----	

INTERNATIONAL SEARCH REPORT

...formation on patent family members

Internat...ional Application No

PCT/SE 00/01654

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WO 9816029	A 16-04-1998	US 5946625 A		31-08-1999
		AU 4665797 A		05-05-1998
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