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(54) Title: METHOD OF FREEING A VOICE CHANNEL IN A RADIO TELECOMMUNICATIONS NETWORK

(57) Abstract

A method is disclosed of freeing a voice channel in a congested first cell (Cell B) in a cellular telecommunication system upon demand and without dropping an ongoing call. The method begins by identifying a second cell (Cell D) that neighbors the congested first cell, identifying a first mobile station (M2) operating on a voice channel in the congested first cell near the boundary of the second cell, and forcing a handoff of the first mobile station from the congested first cell to the second cell, thereby freeing the voice channel. If the second cell is also congested, the method identifies a third cell (Cell E) neighboring the second cell and identifies a second mobile station (M3) operating in the second cell near the boundary of the third cell. The method then forces a handoff of the second mobile station from the second cell to the third cell, thereby freeing a second voice channel located in the second cell. Finally, the method forces a handoff of the first mobile station from the congested first cell to the second cell, utilizing the second voice channel, thereby freeing the first voice channel in the congested first cell.

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METHOD OF FREEING A VOICE CHANNEL IN A RADIO TELECOMMUNICATIONS NETWORK

BACKGROUND OF THE INVENTION

Technical Field of the Invention

This invention relates to radio telecommunication systems and, more particularly, to a method of accelerating handoff to free a voice channel in a radio telecommunications network.

Description of Related Art

In existing cellular radio telecommunications networks, mobile subscribers operating mobile stations may roam from a first cell to a second cell while engaged in a telephone call. The call may be handed off from the first cell to the second cell if there is sufficient signal strength in the second cell, and if there is an available voice channel in the second cell. If there is not sufficient signal strength or an available voice channel in the second cell, the call may be dropped when signal strength from the first cell becomes too weak to maintain the call.

Similarly, when a mobile station attempts to access the cellular system to originate a call, and all voice channels are being utilized in the cell in which the mobile station is located, access may be denied. In some existing cellular systems, a method known as directed retry may improve the chances for successfully accessing the cellular system. When there is no voice channel available when a mobile station attempts to access the cellular system, the system attempts to access a designated neighbor cell. Only if the designated neighbor cell cannot be accessed, is system access denied.

Although there are no known prior art teachings of a solution to the aforementioned deficiency and shortcoming such as that disclosed herein, U.S. Patent

Number 4,670,899 to Brody et al. (Brody) discusses subject matter that bears some relation to matters discussed herein. Brody discloses a system and method for balancing the load of calls between cells in a cellular mobile radio telephone system. The channel utilization of each cell is periodically determined, and the system attempts to hand-off calls from cells with higher voice channel occupancy levels to adjacent cells with lower voice channel occupancy levels. Cells with higher voice channel occupancy levels may be blocked so that handoffs are not allowed to those cells. Also, cells with higher voice channel occupancy levels may be directed to preserve voice channels for incoming handoffs by denying voice channels to mobile transceivers initiating new calls. Thus, at predetermined intervals, Brody attempts to rebalance the voice channel occupancy load to more evenly distribute the loading throughout the cellular system.

If a cell becomes completely congested during the predetermined time interval of Brody, however, handoffs and system accesses are denied. Brody does not teach or suggest a system that is capable of rebalancing the load, and freeing a voice channel in response to a request, or in real time as needed. Thus, review of the foregoing reference reveals no disclosure or suggestion of a method such as that described and claimed herein.

In order to overcome the disadvantage of existing solutions, it would be advantageous to have a method of freeing a voice channel in a congested cell in response to a request, or in real time as needed, without dropping an ongoing call. The present invention provides such a method.

SUMMARY OF THE INVENTION

In one aspect, the present invention is a method of freeing a voice channel in a congested first cell in a cellular telecommunication system upon demand and without dropping an ongoing call. The method comprises the steps of identifying a second cell neighboring the congested first cell, identifying a mobile station operating in the congested first cell, and forcing a handoff of the mobile station from the congested first cell to the second cell, thereby freeing the voice channel.

In another aspect, the present invention is a method of freeing a first voice channel in a congested first cell in a cellular telecommunication system upon demand and without dropping an ongoing call. The method begins by identifying a second cell neighboring the congested first cell, identifying a third cell neighboring the second cell, identifying a first mobile station operating in the congested first cell, and identifying a second mobile station operating in the second cell. These steps are followed by determining whether the second cell is congested, forcing a handoff of the second mobile station from the second cell to the third cell upon determining that the second cell is congested, thereby freeing a second voice channel located in the second cell. Finally, the method forces a handoff of the first mobile station from the congested first cell to the second cell, utilizing the second voice channel, thereby freeing the first voice channel in the congested first cell.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood and its numerous objects and advantages will become more apparent to those skilled in the art by reference to the following drawing, in conjunction with the accompanying specification, in which:

FIG. 1 is an illustrative drawing of several contiguous cells and mobile stations in a cellular radio telecommunication system in which the present invention has been implemented;

FIG. 2 is an illustrative drawing of several contiguous cells and mobile stations in a cellular radio telecommunication system in which a recursive enhancement to the present invention has been implemented;

FIGS. 3A-3B are a flow chart illustrating the steps performed by the present invention during an accelerated handoff procedure; and

FIGS. 4A-4B are a flow chart illustrating the steps performed by the present invention during a recursive accelerated handoff procedure.

DETAILED DESCRIPTION OF EMBODIMENTS

FIG. 1 is an illustrative drawing of several contiguous cells and mobile stations in a cellular radio telecommunication system in which the present invention has been implemented. The cells are labeled as Cell A through Cell E. Two illustrative mobile stations operating within the cells are labeled as M1 and M2.

As a mobile station roams out of the coverage area of a cell, measurements of signal strengths of neighboring cells must be taken to assess whether the mobile station should reselect a particular neighboring cell for service ("cell reselection" in the idle mode) or be handed off to one of the neighboring cells ("handoff" in the busy mode). Location, Presence Verification, and Handoff are three procedures required to hand over an ongoing call from cell to cell while maintaining high signal quality as a mobile station moves around in a cellular network. The purpose of the Location function is to find a cell with the best radio reception characteristics for a specific mobile station. The purpose of the Presence Verification function is to verify the presence of the mobile station in the selected cell prior to handoff. The purpose of the Handoff function is to safely transfer an ongoing call from one cell to another that, according to the Location function and the Presence Verification function, is better suited to handle the call. Handoffs can also be conducted within the same cell to another channel or to and from an overlaid cell such as between a pico cell and an overlaid macrocell.

For mobile stations in the busy (on-call) operating mode, there are two alternative methods of performing the Location function and identifying when a handoff should be initiated. One method utilizes mobile assisted handoff (MAHO), and the mobile station performs the Location function.

When a mobile station begins operating on a digital traffic channel, the mobile station measures the quality of the radio link connection by measuring the bit error rate and the received signal strength on its assigned channel. The mobile station also measures the signal quality of channels in neighboring cells listed in a measurement order from the base station. The channels listed in the measurement order (the MAHO list) may be updated and downloaded to each mobile station as needed. The MAHO list may be customized for each mobile station according to predetermined criteria. The mobile stations periodically measure the received signal strength of each channel listed in the MAHO list and return the MAHO measurements to the base station. The base station receives channel quality messages of its neighboring cells and compares the channels with each other. The base station considers received signal strength and propagation path loss (transmitted power level minus received signal strength). Parameters in the base station determine whether a request for handoff should be sent to the Mobile Switching Center (MSC).

The other Location method, referred to as the classical location method, does not utilize MAHO, and the Location function is performed by assessing radio link quality in the serving base station and its neighboring base stations. The serving base station measures the quality of the radio link connection by measuring the received signal strength on the serving channel. The serving base station then considers received signal strengths and propagation path loss (transmitted power level minus received signal strength). Parameters in the base station are then utilized to determine whether a request for handoff should be sent to the MSC. The MSC then requests measurements of the serving channel from neighbor cells and outer cells, each of which have signal strength receivers for this purpose. The MSC then ranks the neighbor cells and outer cells to build a candidate list for handoff. A distant cell is normally not a candidate cell that is included on the MAHO list. For example, from Cell A, Cell B may be a candidate on the MAHO list, but Cell C or Cell D would not.

In cellular systems that do not utilize MAHO, location and verification devices are installed in each base station. The location and verification devices are capable of independently measuring the signal strength on each frequency operated by the base station and its neighbor cells.

Presence Verification is performed following the Location process and prior to handoff in order to verify the presence of the mobile station in the cell which has been designated as the best candidate cell for handoff. Presence Verification is performed in the base station of a neighboring cell on order from the serving MSC. When operating on a digital traffic channel, the base station in the candidate cell for handoff is given the mobile station's old channel number, rate, time slot, and digital verification color code (DVCC), and is ordered to verify the mobile station's presence on the old channel. A final signal strength measurement of the mobile station's signal is made in the candidate handoff cell utilizing its location and verification device, and if the signal strength exceeds a predetermined threshold, the handoff is initiated. When operating on an analog voice channel, signal strength is measured on the voice channel for the serving channel Supervisory Audio Tone (SAT). The verification information is reported to the MSC.

Presence verification may be performed with or without the use of MAHO to perform the Location function. Presence Verification measurements are made by the location and verification devices in the base station of the candidate handoff cell.

The above description of the Location, Presence Verification, and Handoff functions described handoff within the coverage area of a single MSC. Handoffs may also be performed across exchange boundaries between a cell in one MSC and an outer cell in another MSC. In addition to performing the Location, Presence Verification, and Handoff functions, cellular networks supporting inter-exchange handoffs for mobile stations must exchange outer cell information between the MSCs involved. The standard protocol for inter-exchange signaling is IS-41, which is hereby incorporated by reference herrein. When an inter-exchange handoff is performed between MSCs, known IS-41 messages are utilized to carry required information between the exchanges for handoff of the call. These messages may include a handoff measurement request (HandMeasReq) message, a facilities directive (FacDir) message, a Handoff Back (HandBack) message, and a handoff-to-third (HandThird) message.

The handoff measurement request message is utilized to request locating measurements for outer cells in the classical location method, in order to assess the best candidate outer cell for handoff. The same message is also utilized to request Presence Verification information in neighbor outer cells, in order to verify the presence of the mobile station in those cells and assess the best candidate outer cell. If the serving MSC determines that the handoff is to be made to an outer cell in a neighboring MSC, then a voice channel is requested.

When a mobile call in progress must be dropped, or a mobile call access must be denied due to voice channel congestion in a particular cell, a voice channel may be made available using the method of the present invention.

In essence, the present invention "bumps" another mobile station utilizing a voice channel and utilizes the freed voice channel to service the call which is about to be dropped or denied access. Service is maintained to the bumped mobile station by forcing it to handoff to another cell which has an idle voice channel earlier than dictated by the existing location and handoff mechanism (i.e., accelerated handoff).

Referring again to FIG. 1, M1 is roaming from Cell A to Cell B, but there is not an idle voice channel in Cell B. Therefore, the method of the present invention accelerates (forces) the handoff of M2 from Cell B to either Cell C or Cell D in order to free a voice channel for M1 in Cell B. The case of call access is similar. If an idle mobile station is located in Cell A and attempts to access the cellular system there, the present invention may accelerate the handoff of M2 from Cell B to either Cell C or Cell D in order to free a voice channel in Cell B for the idle mobile station to access the system as a directed retry call. Alternatively, the freed voice channel in Cell B may be utilized to accelerate handoff of a mobile station in Cell A, thereby freeing a voice channel in Cell A, which may be utilized to service the new call.

For digital cellular systems, the system already has the list of candidate cells with their respective MAHO signal measurements. For analog systems, signal strength measurements must be obtained periodically from neighboring cells for each mobile station. Otherwise, implementation of the present invention is similar. The present invention selects a candidate cell that has sufficient signal strength for service (SS_SUFF), but not enough to trigger handoff (SS_HANDOFF). The method may also select cells with SS_HANDOFF, but to which handoff was not triggered due to, for example, controls to prevent oscillating handoffs. In addition, the method may utilize a third signal strength threshold value to represent the minimum signal strength required for accelerated handoff (SS_AHOFF). The SS_AHOFF value is set between SS_SUFF and SS_HANDOFF. When SS_AHOFF is set equal to SS_SUFF, accelerated handoff is permitted as long as there is sufficient signal strength for service to be maintained. When SS_AHOFF is set equal to SS_HANDOFF, accelerated handoff is effectively disabled. Thus, the system operator may utilize the SS_AHOFF threshold to enable or disable accelerated handoff, and to control the amount of degradation allowed during accelerated handoff.

The selection of the mobile station to bump may be made by scanning all mobile stations within the congested cell and selecting the one with the highest received signal strength or MAHO measurement entry. There may be some degradation in voice quality for the mobile station that is forced to handoff, but this degradation can be limited to an arbitrarily small amount by adjusting the SS_AHOFF threshold value as described above.

An Accelerated Handoff To Free Voice Channel (AHFVC) function is architecturally part of a Voice Channel Selection (VCS) function. Table 1 below illustrates VCS's place in call origination, call termination, and handoff cases.

CALL PHASE	MESSAGE SOURCE	MESSAGE DESTINATION	DESCRIPTION
MS Originatio n	MS -- System	System -- MS	ORIGINATION (VOICE CHANNEL SELECTION) DESIGNATE VC
MS Terminatio n	System MS -- System	MS System -- MS	PAGE PAGE RESPONSE (VOICE CHANNEL SELECTION) DESIGNATE VC
Handoff	System MS -- System	MS System -- MS	MEASUREMENT CHANNELS CHANNEL MEASUREMENTS (VOICE CHANNEL SELECTION) HANDOFF

Table 1: Voice Channel Selection Function in Various Call Phases

The AHFVC function is a common module utilized during VCS in all of the above call phases.

The AHFVC function is applied in each cell and is divided into two components: a background component which continuously executes, and a demand component which is only executed when an accelerated handoff is to be performed. A major part of the background component is involved in MAHO processing to determine when mobile station handoffs are to be initiated. As described above, mobile stations measure received signal strength from channels on the MAHO list provided to them in the measurement order, and return the MAHO measurements to the base station. At any given time, in a given cell, the MAHO measurements provided by the served mobile stations may be represented by a table such as Table 2 below. The entries P_{11} through P_{MN} represent exemplary power level measurements in dBm taken by each mobile station for each neighboring cell in its respective MAHO list.

	$NCELL_1$	$NCELL_2$	• • •	$NCELL_J$	• • •	$NCELL_N$
MS_1	P_{11}	P_{12}				P_{1N}
MS_2	P_{21}	P_{22}		P_{2J}		
MS_3	P_{31}					
• • •						
MS_I	P_{I1}			P_{IJ}		P_{1N}
• • •						
MS_M	P_{M1}					P_{MN}

Table 2: MAHO Measurements Within a Cell

Table 2 shows the N neighboring cells for a given cell serving M mobile stations. The entry P_{IJ} represents the received signal strength measured by the I^{th} mobile station (MS_I) on the J^{th} neighboring cell ($NCELL_J$). If a neighboring cell is not measured by a mobile station, its corresponding power level is entered in the table as $-\infty$. By utilizing the MAHO measurements of Table 2, the background component of the AHFVC function may identify the mobile station with the maximum received signal strength for each neighboring cell by determining the maximum entry for each column, as shown by the following:

$$MAX\text{-}level_J = MAX_{I:1-M}(P_{IJ})$$

The mobile station which achieves the highest received signal strength reading for a neighboring cell (for example $NCELL_J$) is the ideal candidate for accelerated handoff to $NCELL_J$. Such a mobile station is termed:

CAND-AH$_J$: Candidate for accelerated handoff to cell j.
Therefore, if P_{IJ} = *MAX-level*$_J$,
CAND-AH$_J$ = MS_I.

Given the MAX-*level* for each neighboring cell, $NCELL_1$ to $NCELL_N$, the background component of the AHFVC function forms an ordered list of neighboring cells, all of which meet the SS_AHOFF criterion for accelerated handoff, and all of which are sorted in descending order according to the value of the MAX-*level* for the cell:

Sorted-Neighbor-list = {$Cell_A$, $Cell_B$, $Cell_C$, ...}, where
MAX-level$_A$≥*MAX-level*$_B$≥*MAX-level*$_C$≥ ...

The demand component of the AHFVC function is executed when an accelerated handoff is required. The output of this component is the identity of mobile stations and neighboring cells to which the identified mobile stations should be forced to handoff. A list of neighboring cells that are to be excluded from consideration is input to the demand component. If a formerly idle mobile station is attempting to access the system in a congested cell, the list of excluded cells may contain cells in which directed retry has already been attempted and failed. For mobile stations requiring handoff to a congested cell, the list of excluded cells may contain cells in which voice channel congestion has already been encountered.

Given the Sorted-Neighbor-list derived by the background component, and the exclusion list, the demand component computes a difference list by subtracting the exclusion list from the Sorted-Neighbor-list. The result is a sorted list of neighboring cells to which a handoff may be attempted:

AHFVC-list = *Sorted-Neighbor-list* - *Exclusion list;* with

$$|AHFVC\text{-}list| \leq |Sorted\text{-}Neighbor\text{-}list|$$

In an exemplary situation, the first accelerated handoff candidate cell may be $NCELL_J$ in the full list of neighboring cells of Table 2. Then, the ideal mobile station to be forced to handoff is:

$$CAND\text{-}AH_J = MS_I.$$

Therefore, a handoff is attempted for MS_I in $Cell_J$. If the handoff is successful, then a voice channel is freed. If the handoff is not successful, the second cell in the *AHFVC-list* is tried next. This process continues until there is a successful handoff or the *AHFVC-list* is exhausted.

In the case of an analog system, as discussed above, the mobile stations do not provide channel measurements to the system. Instead, each base station includes a signal strength receiver to monitor the signal levels of voice channel frequencies used in neighboring cells. When the signal quality of a mobile station in the serving cell falls below a predetermined threshold, the system polls the neighboring cells to provide their measurements of the signal level received on the voice channel serving the mobile station. The neighboring cell with the highest received signal strength represents the best candidate cell for handoff. Handoff may also be attempted to neighboring cells of lower received signal strength if the preferred cell is unable to accept the call due to voice channel congestion.

In order to implement the present invention, a cell must periodically poll its neighboring cells for the received signal strength values for each of its served mobile stations. This polling is similar to the construction of a MAHO list, except that the channel measurements are uplink, and are provided by the system rather than the mobile stations. The periodic signal strength values are then utilized to compile Table 2.

FIG. 2 is an illustrative drawing of several contiguous cells and mobile stations in a cellular radio telecommunication system in which a recursive enhancement to the present invention has been implemented. Recursion refers to the ability to repeatedly apply the AHFVC function in each cell where a voice channel is needed, creating a recursive chain of handoffs. When mobile station M1 begins to roam from Cell A to Cell B, handoff to Cell B is requested. If there is not an available voice channel in Cell B, the AHFVC function identifies mobile station M2 for accelerated handoff, and identifies Cell C and Cell D as candidate cells for handoff. If both Cell C and Cell D are congested, the AHFVC function is recursively applied to the most promising candidate (i.e., the first element of the *AHFVC-list*). In the example shown in FIG. 2, this candidate is Cell D. The AHFVC function then identifies mobile station M3 for accelerated handoff, and identifies Cell E as the candidate cell for handoff. If a voice channel is available in Cell E, the handoff of mobile station M3 to Cell E is then attempted. If successful, a voice channel is made available in Cell D. This voice channel is then used for the handoff of mobile station M2 from Cell B to Cell D. This handoff, in turn, frees a voice channel in Cell B which is utilized for the handoff of mobile station M1 from Cell A to Cell B.

When the AHFVC function is applied recursively, the neighboring cells must be successively farther away geographically from the first serving cell. This is accomplished with the exclusion list which eliminates cells from the *AHFVC-list* that have been previously considered in the chain. Thus, the exclusion list, forwarded to the next level of recursion, is a union of the exclusion list provided to the demand component of the

AHFVC function along with the *AHFVC-list* of the current level.

FIGS. 3A-3B are a flow chart illustrating the steps performed by the present invention during an accelerated handoff procedure. If the cellular telecommunication system in which the present invention is implemented is a digital system, as determined at step 30, the procedure moves to step 31 where MAHO measurements are collected from the mobile stations being served in a cell of interest. If the cellular system is not digital (i.e., it is analog), the serving cell polls its neighboring cells for the received signal strength (RSS) for the serving cell's served mobile stations at 32. The procedure then moves to step 33 where the background component of the AHFVC fucntion compiles a table of RSS values for the served mobile stations and neighboring cells. At 34, the AHFVC function derives a Sorted-Neighbor-list of ranked candidate cells which meet the SS_AHOFF threshold for accelerated handoff. At 35, an exclusion list is derived from cells that were previously found to be congested when handoff was attempted, and from cells for which directed retry failed to achieve system access. The exclusion list is then input to the demand component of the AHFVC function at step 36. When the demand component is invoked, a check is first made in step 36A to determine whether the Sorted-Neighbor-list is null (i.e., no *MAX-level* entries meet the SS_AHOFF threshold). If so, the AHFVC function cannot continue, and a failure result is returned. At step 37, the demand component of the AHFVC function derives an *AHFVC-list* by subtracting the exclusion list from the Sorted-Neighbor-list. If the *AHFVC-list* is null at step 37A (because the Sorted-Neighbor-list is a subset of the exclusion list), then the AHFVC function cannot continue, and a failure result is returned at step 37B. Otherwise, the procedure then moves to step 38 of FIG. 3B.

At step 38, the procedure sets $i = 1$. At 39, a handoff is then attempted to $Cell_i$ of the *AHFVC-list*. At 41 it is determined whether or not the handoff was successful. If yes, the procedure moves to step 42 where the freed voice channel is returned for use. If the handoff was not successful at 41, the procedure moves to step 43 where it is determined whether or not handoff has been attempted to all of the cells in the *AHFVC-list*. If yes, the procedure moves to step 44 where a failure is returned. If handoff has not been attempted to all of the cells in the *AHFVC-list*, then the procedure moves to step 45 and sets $i = i+1$. The procedure then returns to step 39 and attempts a handoff to the next cell of the *AHFVC-list*. This cycle continues until either a voice channel is freed or handoff is unsuccessfully attempted to all cells of the *AHFVC-list*.

FIGS. 4A-4B are a flow chart illustrating the steps performed by the present invention during a recursive accelerated handoff procedure. If the cellular telecommunication system in which the present invention is implemented is a digital system, as determined at step 40, the procedure moves to step 41 where MAHO measurements are collected from the mobile stations being served in a cell of interest. If the cellular system is not digital (i.e., it is analog), the serving cell polls its neighboring cells for the received signal strength (RSS) for the serving cell's served mobile stations at 42. The procedure then moves to step 43 where the background component of the AHFVC fucntion compiles a table of RSS values for the served mobile stations and neighboring cells. At 44, the AHFVC function derives a Sorted-Neighbor-list of ranked candidate cells which meet the SS_AHOFF signal strength threshold for accelerated handoff. At step 44A, a recursion control counter is set to zero to indicate that no recursion has yet occurred. At 45, an exclusion list is derived from cells that were previously found to be congested when handoff was attempted, and from cells for which directed retry failed to achieve system access. The exclusion list is then input to the demand component of the AHFVC function at step 46. When the demand component is invoked, a check is first made in step 46A to determine whether the Sorted-Neighbor-list is null (i.e., no *MAX-level* entries meet the SS_AHOFF criterion). If so, the AHFVC function cannot continue, and a failure result is returned. At step 47, the demand component of the AHFVC function derives an *AHFVC-list* by subtracting the exclusion list from the Sorted-Neighbor-list. If the *AHFVC-list* is null (because the Sorted-Neighbor-list is a subset of the exclusion list), then the AHFVC function cannot continue, and a failure result is returned at step 47A. Otherwise, the procedure moves to step 48 of FIG. 4B.

At step 48, the procedure sets $i = 1$. At 49, a handoff is then attempted to $Cell_i$ of the *AHFVC-list*. At 51 it is determined whether or not the handoff was successful. If yes, the procedure moves to step 52 where the freed voice channel is returned for use. If the handoff was not successful at 51, the procedure moves to step 53 where it is determined whether or not handoff has been attempted to all of the cells in the *AHFVC-list*. If handoff has not been attempted to all of the cells in the *AHFVC-list*, then the procedure moves to step 54 and sets $i = i+1$. The procedure then returns to step 49 and attempts a handoff to the next cell of the *AHFVC-list*. This cycle continues until either a voice channel is freed or handoff is unsuccessfully attempted to all cells of the *AHFVC-list*.

If handoff has been attempted to all of the cells in the *AHFVC-list* at 53, the procedure moves to step 55 where a check is made to determine whether recursion should be attempted by determining whether the recursion limit has been reached. If the recursion limit has been reached, the procedure moves to step 56 and returns a failure result. Note that if the recursion limit is set to 0, then recursion is disabled, and the AHFVC function returns a failure result. At each level of recursion, the procedure determines whether another level of recursion should be attempted. If the recursion limit has not been reached at step 55, recursion is allowed to continue, and the procedure moves to step 57 where the procedure sets the new exclusion list = (the exclusion list + the *AHFVC-list*). The recursion counter is then incremented in step 58. The procedure then returns to step 46 and performs the AHFVC function in $Cell_1$ (the first element of the *AHFVC-list*).

It is thus believed that the operation and construction of the present invention will be apparent from the foregoing description. While the method, apparatus and system shown and described has been characterized as being preferred, it will be readily apparent that various changes and modifications could be made therein without departing from the spirit and scope of the invention as defined in the following claims.

WHAT IS CLAIMED IS:

1. A method of freeing a voice channel in a congested first cell in a cellular telecommunication system upon demand and without dropping an ongoing call, said method comprising the steps of:

identifying a second cell, said second cell neighboring said congested first cell;

identifying a first mobile station, said first mobile station operating in said congested first cell; and

forcing a handoff of said first mobile station from said congested first cell to said second cell, thereby freeing said voice channel.

2. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 1 wherein said step of identifying a second cell neighboring said congested first cell includes measuring received signal strength between said first mobile station and a plurality of cells neighboring said congested first cell.

3. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 2 wherein said step of measuring received signal strength between said first mobile station and a plurality of cells neighboring said congested first cell includes measuring said received signal strength at said first mobile station.

4. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 2 wherein said step of measuring received signal strength between said first mobile station and a plurality of cells neighboring said congested first cell includes measuring said received signal strength at said plurality of cells neighboring said congested first cell.

5. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 2 wherein said step of identifying a second cell neighboring said congested first cell includes identifying a cell neighboring said congested first cell with the highest measured received signal strength of said plurality of cells neighboring said congested first cell.

6. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 1 wherein said step of identifying a first mobile station operating in said congested first cell includes identifying a first mobile station operating in said congested first cell near a boundary of said second cell.

7. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 6 wherein said step of identifying a first mobile station operating in said congested first cell includes identifying a first mobile station with sufficient received signal strength from said second cell to maintain a call in said second cell.

8. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 1 wherein said step of forcing a handoff of said first mobile station from said congested first cell to said second cell includes forcing said handoff when an occupied voice channel is needed by a second mobile station within said congested first cell.

9. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 8 wherein said step of forcing a handoff of said first mobile station from said congested first cell to said second cell includes forcing said handoff

when said second mobile station attempts to access said cellular telecommunication system within said congested first cell.

10. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 9 further comprising the steps of:

identifying a third cell, said third cell neighboring said second cell;

identifying a third mobile station, said third mobile station operating in said second cell;

forcing a handoff of said third mobile station from said second cell to said third cell; and

directing said second mobile station to access said cellular telecommunication system as a directed retry through said second cell.

11. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 8 wherein said step of forcing a handoff of said first mobile station from said congested first cell to said second cell includes forcing said handoff when said second mobile station roams into said congested first cell during a call.

12. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 8 wherein said step of forcing a handoff of said first mobile station from said congested first cell to said second cell includes forcing said handoff before said cellular telecommunication system automatically performs a handoff of said first mobile station based on predetermined criteria.

13. A method of freeing a voice channel in a congested first cell in a cellular telecommunication

system upon demand and without dropping an ongoing call, said method comprising the steps of:

identifying a second cell, said second cell neighboring said congested first cell, said step of identifying a second cell comprising:

measuring received signal strength between a first mobile station operating in said congested first cell, and a plurality of cells neighboring said congested first cell; and

identifying a cell neighboring said congested first cell with the highest measured received signal strength of said plurality of cells neighboring said congested first cell; and

forcing a handoff of said first mobile station from said congested first cell to said second cell when an occupied voice channel is needed by a second mobile station within said congested first cell, said step of forcing said handoff being performed before said cellular telecommunication system automatically performs a handoff of said first mobile station based on predetermined criteria.

14. A method of freeing a first voice channel in a congested first cell in a cellular telecommunication system upon demand and without dropping an ongoing call, said method comprising the steps of:

identifying a second cell, said second cell neighboring said congested first cell;

identifying a third cell, said third cell neighboring said second cell;

identifying a first mobile station, said first mobile station operating in said congested first cell;

identifying a second mobile station, said second mobile station operating in said second cell;

determining whether said second cell is congested;

forcing a handoff of said second mobile station from said second cell to said third cell upon determining that said second cell is congested, thereby freeing a second voice channel located in said second cell; and

forcing a handoff of said first mobile station from said congested first cell to said second cell, utilizing said second voice channel, thereby freeing said first voice channel in said congested first cell.

15. The method of freeing a first voice channel in a congested first cell in a cellular telecommunication system of claim 14 wherein said step of identifying a third cell neighboring said second cell includes identifying a third cell that does not neighbor said congested first cell.

16. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 14 wherein said step of identifying a second cell neighboring said congested first cell includes measuring received signal strength between said first mobile station and a plurality of cells neighboring said congested first cell.

17. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 16 wherein said step of identifying a second cell neighboring said congested first cell includes identifying a cell neighboring said congested first cell with the highest measured received signal strength of said plurality of cells neighboring said congested first cell.

18. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 14 wherein said step of identifying a first mobile station operating in said congested first cell includes identifying a first mobile station operating in said congested first cell near a boundary of said second cell.

19. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 17 wherein said step of identifying a first mobile station operating in said congested first cell includes identifying a first mobile station with sufficient received signal strength from said second cell to maintain a call in said second cell.

20. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 14 wherein said steps of forcing a handoff of said second mobile station from said second cell, and forcing a handoff of said first mobile station from said congested first cell include forcing said handoffs when an occupied voice channel is needed in said congested first cell by a third mobile station.

21. The method of freeing a voice channel in a congested first cell in a cellular telecommunication system of claim 20 wherein said step of forcing said handoffs when an occupied voice channel is needed in said congested first cell by a third mobile station includes forcing said handoffs before said cellular telecommunication system automatically performs said handoffs based on predetermined criteria.

22. A method of freeing a first voice channel in a congested first cell in a cellular telecommunication system upon demand and without dropping an ongoing call, said method comprising the steps of:

identifying a second cell, said second cell neighboring said congested first cell, said step of identifying a second cell comprising the steps of:

measuring received signal strength between a first mobile station operating in said congested first cell, and a plurality of cells neighboring said congested first cell; and

identifying a cell neighboring said congested first cell with the highest measured received signal strength of said plurality of cells neighboring said congested first cell;

identifying a third cell, said third cell neighboring said second cell, but not neighboring said congested first cell;

identifying a second mobile station, said second mobile station operating in said second cell, said second mobile station having sufficient received signal strength from said third cell to maintain a call in said third cell;

determining whether said second cell is congested;

forcing a handoff of said second mobile station from said second cell to said third cell upon determining that said second cell is congested, thereby freeing a second voice channel located in said second cell, said handoff of said second mobile station being forced before said cellular telecommunication system automatically performs said handoff of said second mobile station based on predetermined criteria; and

forcing a handoff of said first mobile station from said congested first cell to said second cell, utilizing said second voice channel, thereby freeing said first voice channel in said congested first cell, said handoff of said first mobile station being forced before said cellular telecommunication system automatically performs said handoff of said first mobile station based on predetermined criteria.

FIG.1

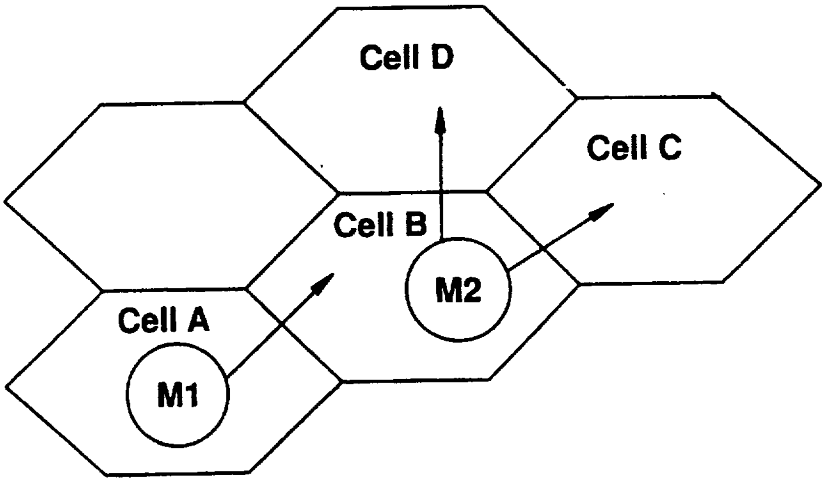

Cell D
Cell C
Cell B
M2
Cell A
M1

FIG.2

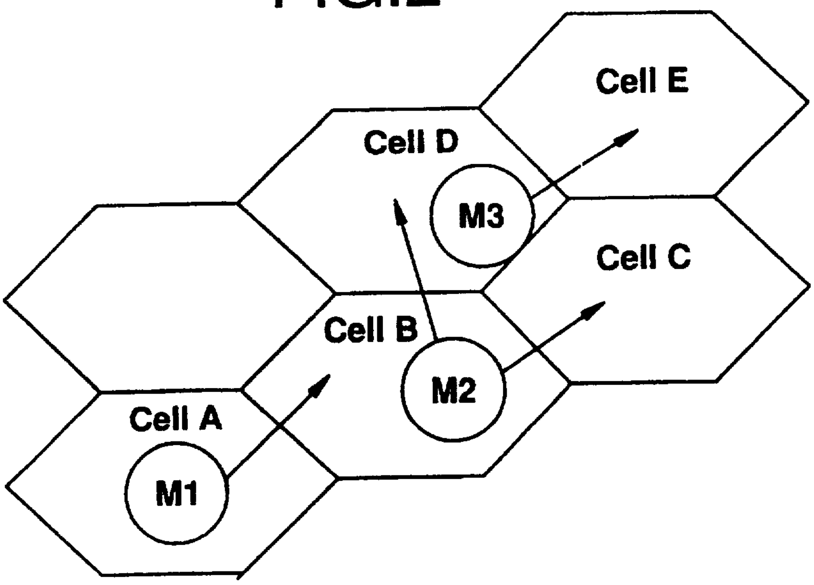
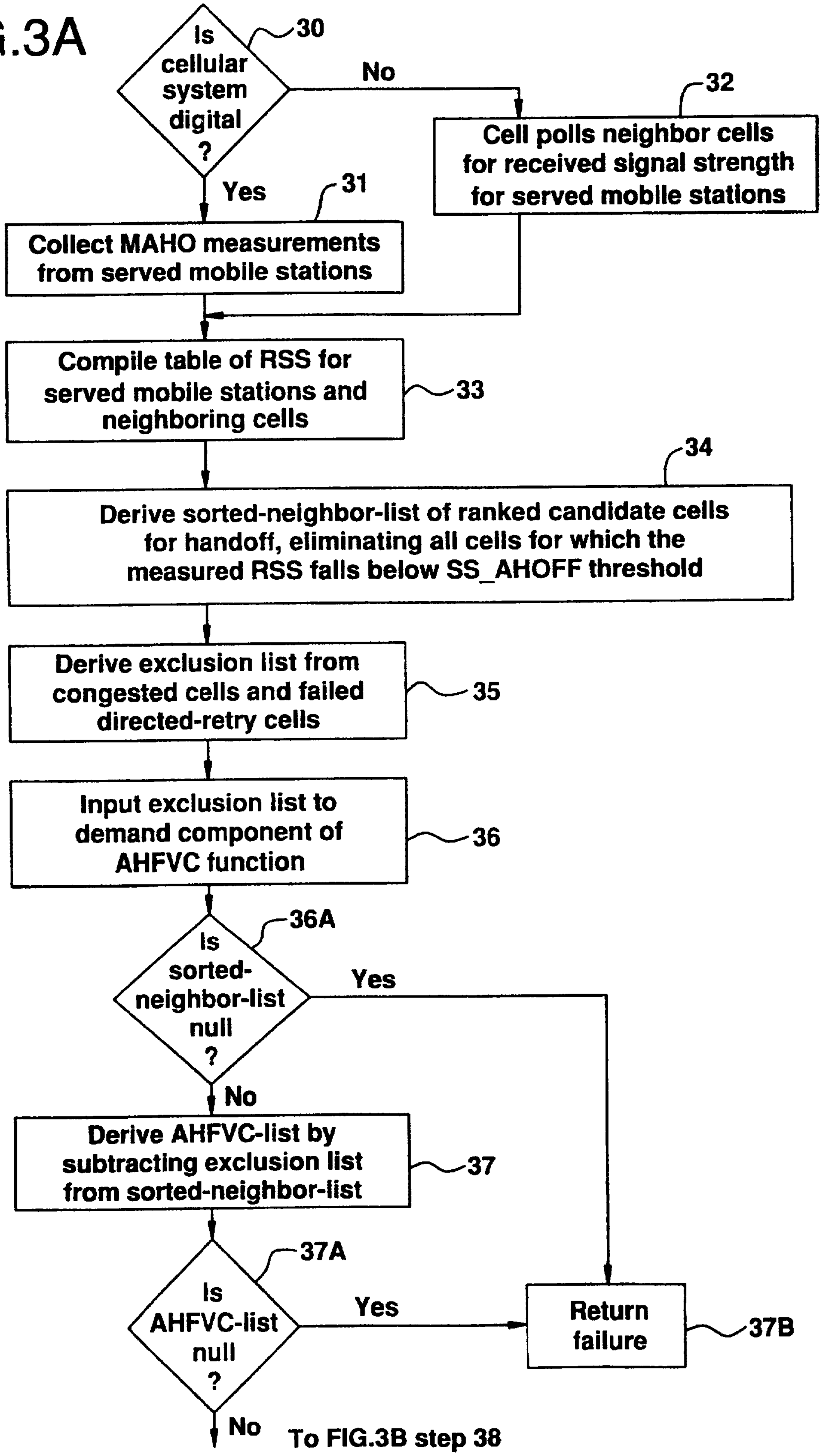

Cell E
Cell D
M3
Cell C
Cell B
M2
Cell A
M1

FIG.3A



Is cellular system digital ?
30
No
32
Cell polls neighbor cells for received signal strength for served mobile stations
Yes
31
Collect MAHO measurements from served mobile stations
Compile table of RSS for served mobile stations and neighboring cells
33
34
Derive sorted-neighbor-list of ranked candidate cells for handoff, eliminating all cells for which the measured RSS falls below SS_AHOFF threshold
Derive exclusion list from congested cells and failed directed-retry cells
35
Input exclusion list to demand component of AHFVC function
36
36A
Is sorted-neighbor-list null ?
Yes
No
Derive AHFVC-list by subtracting exclusion list from sorted-neighbor-list
37
37A
Is AHFVC-list null ?
Yes
Return failure
37B
No
To FIG.3B step 38

FIG.3B

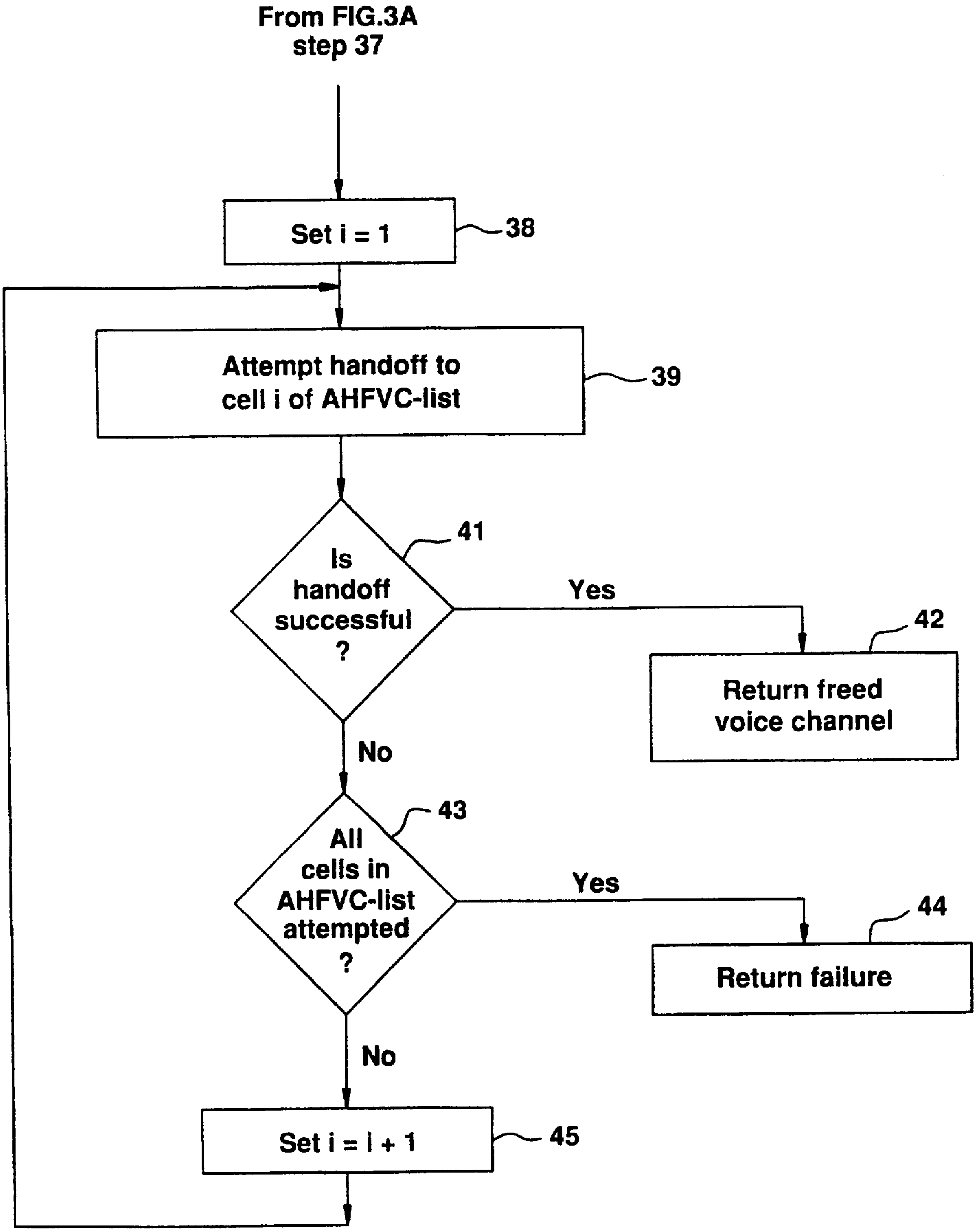
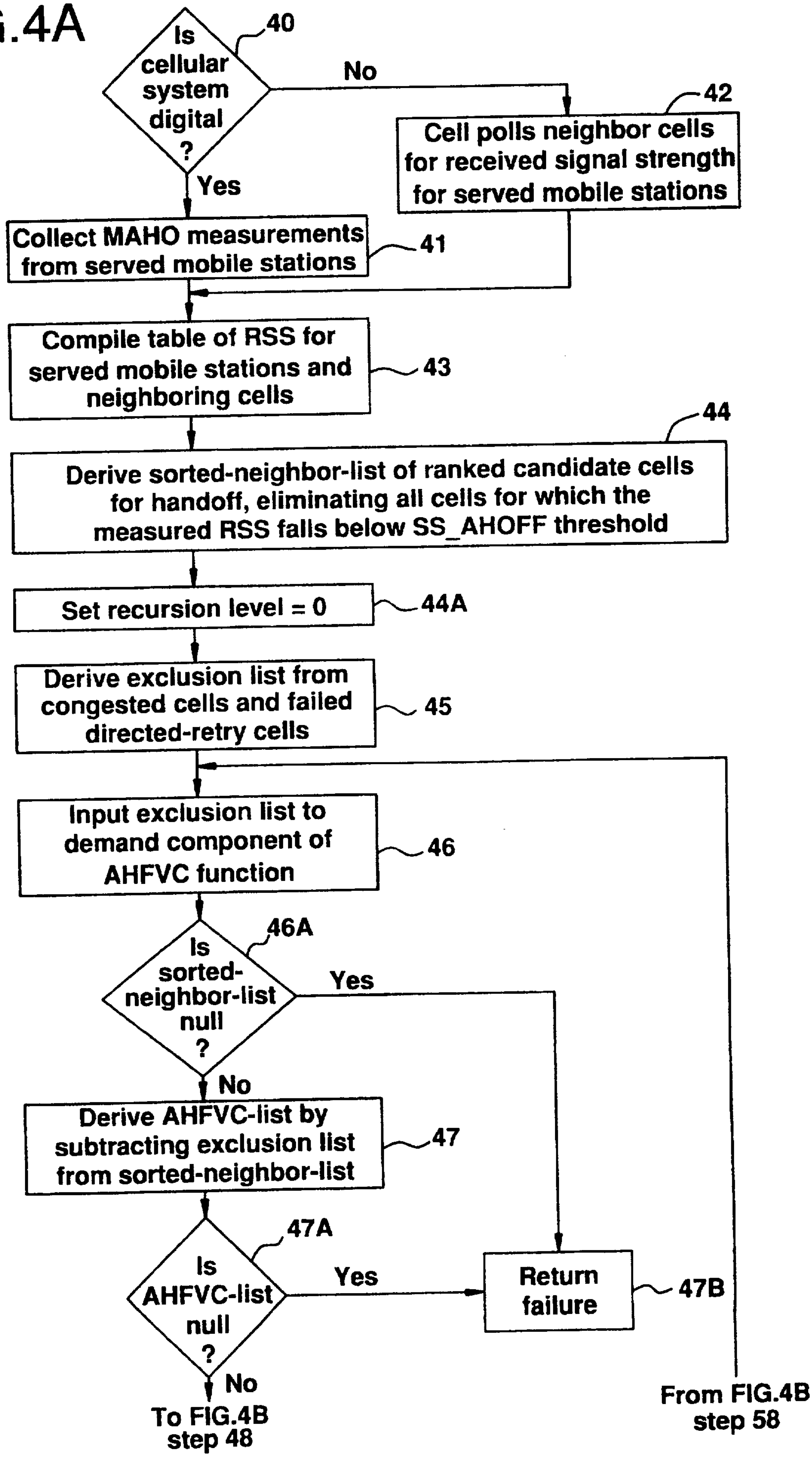
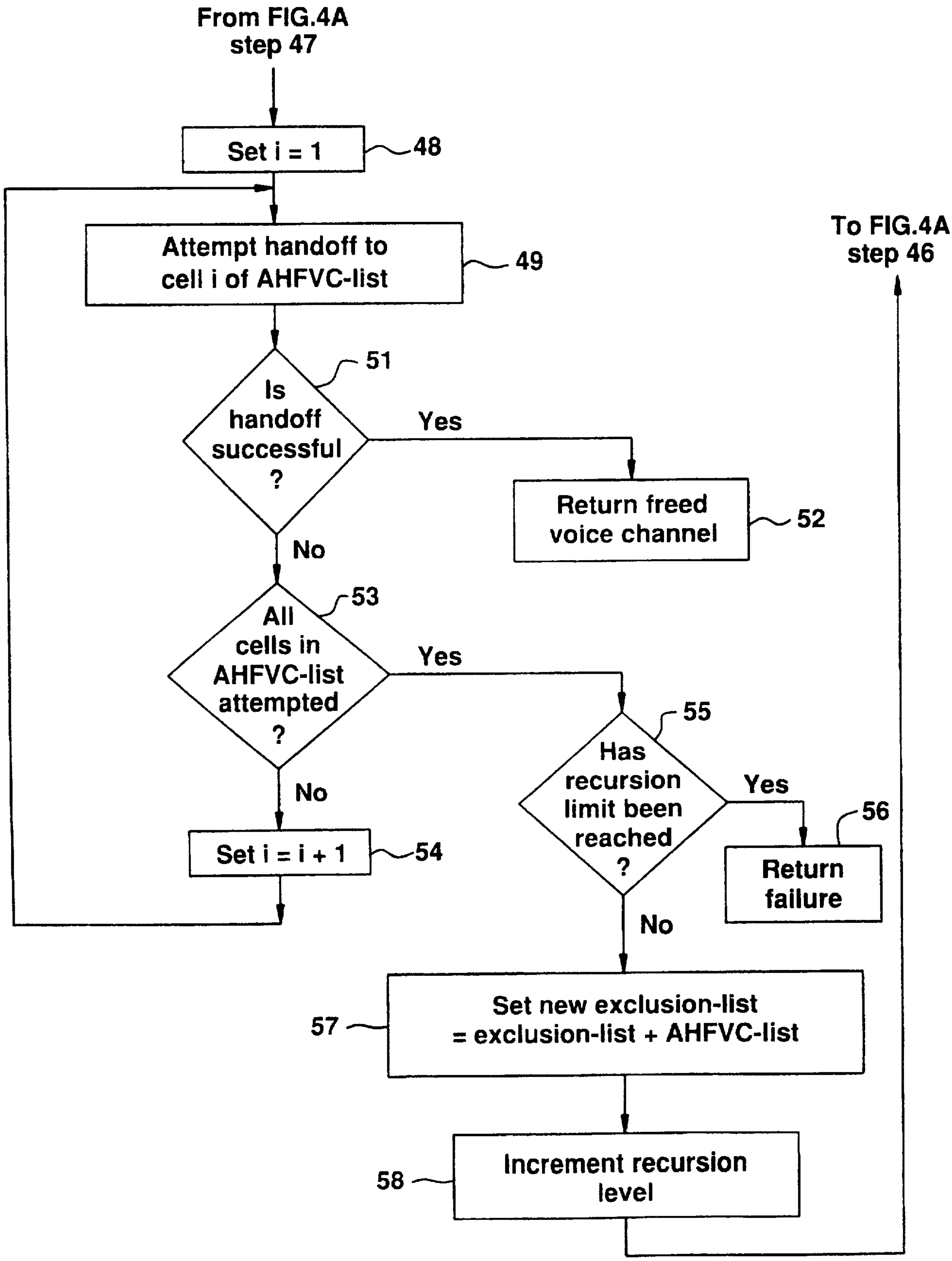

From FIG.3A
step 37
Set i = 1
38
Attempt handoff to
cell i of AHFVC-list
39
Is
handoff
successful
?
41
Yes
42
Return freed
voice channel
No
All
cells in
AHFVC-list
attempted
?
43
Yes
44
Return failure
No
Set i = i + 1
45

FIG.4A



Is cellular system digital ?
40
No
Yes
Cell polls neighbor cells for received signal strength for served mobile stations
42
Collect MAHO measurements from served mobile stations
41
Compile table of RSS for served mobile stations and neighboring cells
43
Derive sorted-neighbor-list of ranked candidate cells for handoff, eliminating all cells for which the measured RSS falls below SS_AHOFF threshold
44
Set recursion level = 0
44A
Derive exclusion list from congested cells and failed directed-retry cells
45
Input exclusion list to demand component of AHFVC function
46
Is sorted-neighbor-list null ?
46A
Yes
No
Derive AHFVC-list by subtracting exclusion list from sorted-neighbor-list
47
Is AHFVC-list null ?
47A
Yes
Return failure
47B
No
To FIG.4B step 48
From FIG.4B step 58

FIG.4B


From FIG.4A step 47
Set i = 1
48
Attempt handoff to cell i of AHFVC-list
49
Is handoff successful ?
51
Yes
Return freed voice channel
52
No
All cells in AHFVC-list attempted ?
53
Yes
No
Set i = i + 1
54
Has recursion limit been reached ?
55
Yes
Return failure
56
No
Set new exclusion-list = exclusion-list + AHFVC-list
57
Increment recursion level
58
To FIG.4A step 46