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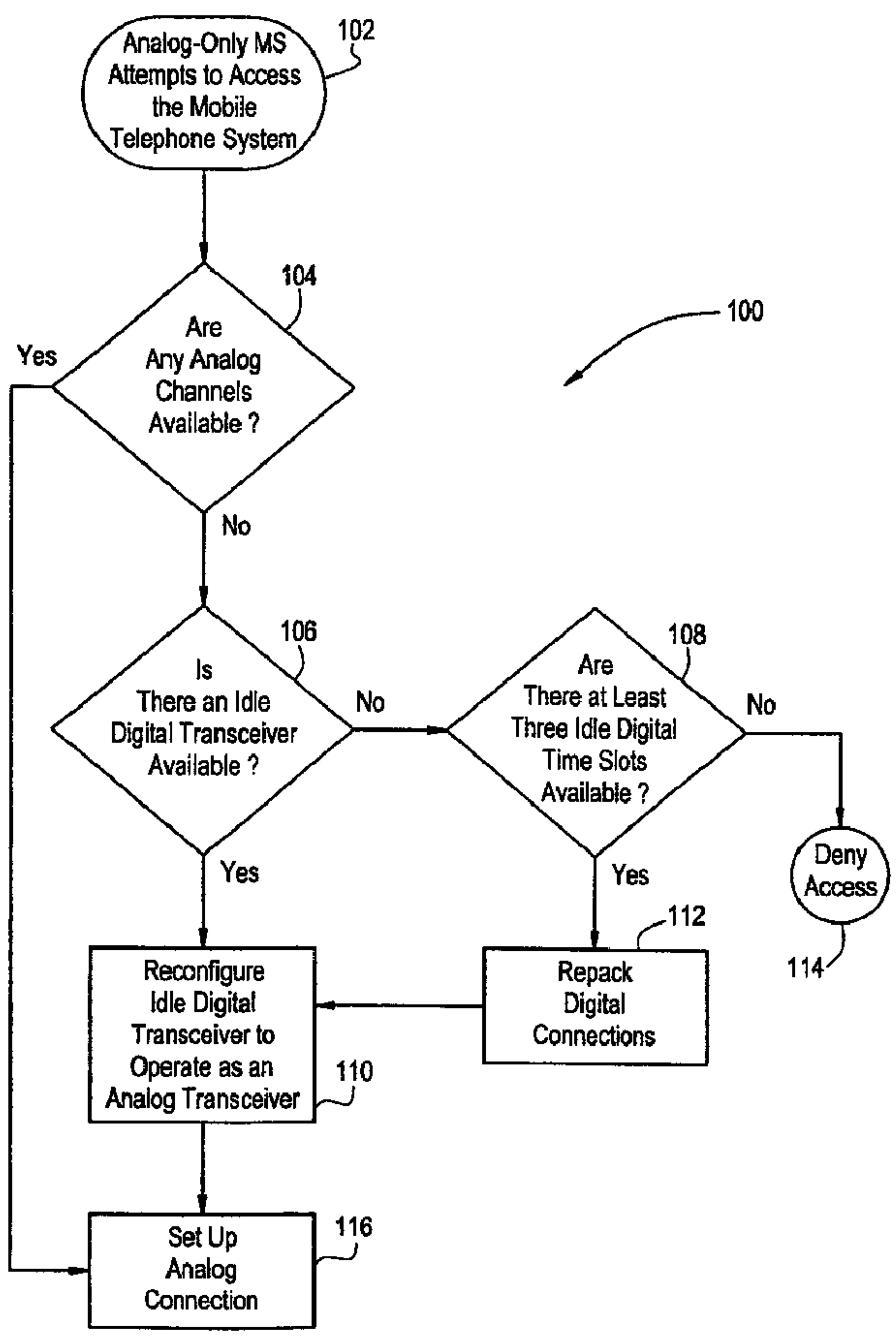
(54) Title: ADAPTIVE DUAL-MODE TRANSCEIVER CONFIGURATION



(57) Abrégé/Abstract:
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(57) Abrégé(suite)/Abstract(continued):
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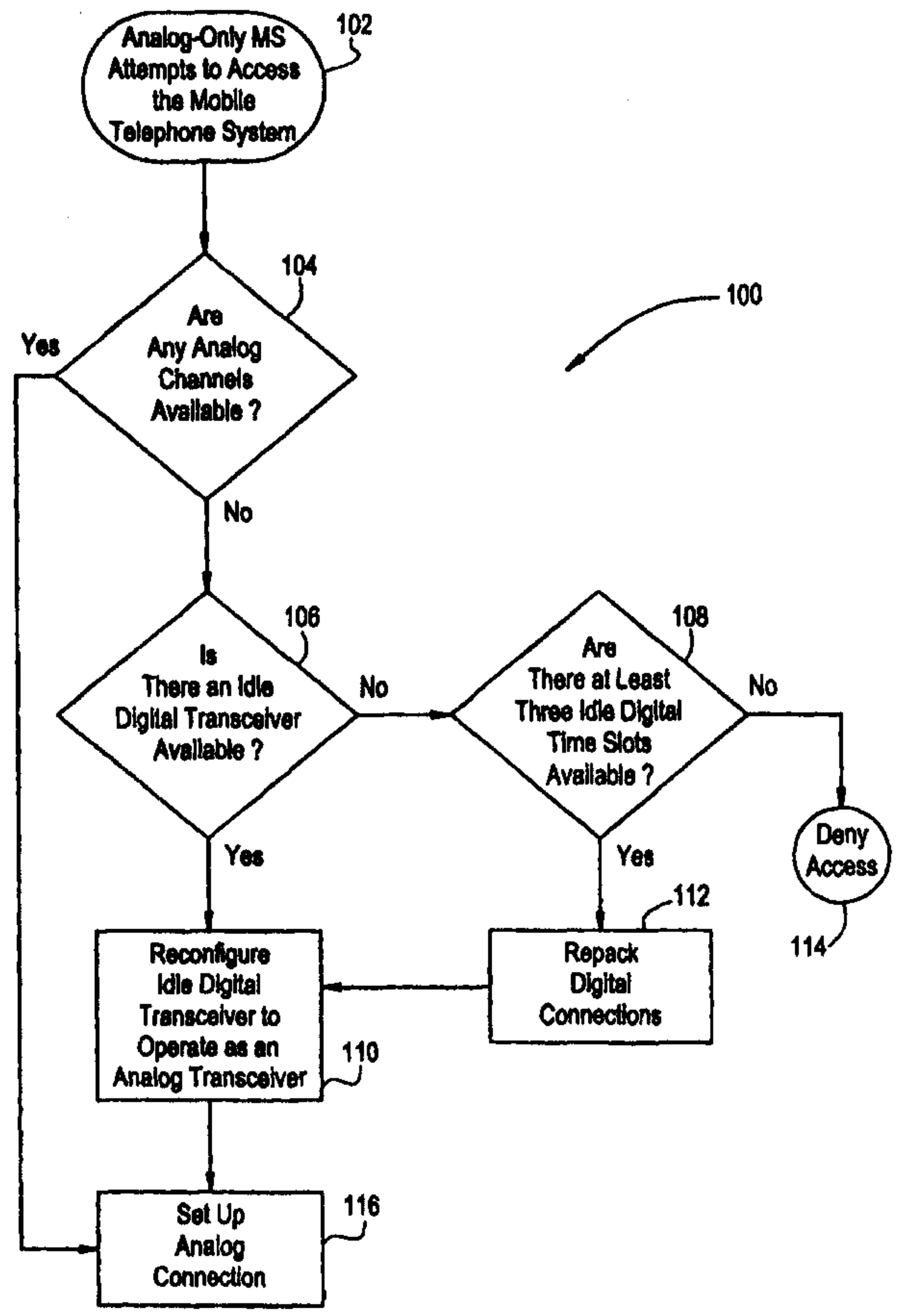
(54) Title: ADAPTIVE DUAL-MODE TRANSCEIVER CONFIGURATION

(57) Abstract

A system and method for automatically reconfiguring a multi-mode transceiver in a mobile telecommunications system for adapting to changes in traffic for two or more modes of operation. Upon receiving a request (202, 302) to set up a communication channel having a digital or analog mode of operation and determining (204, 304) that the said channels are available, an idle transceiver (206, 306) operating under an alternate mode of operation is automatically reconfigured (214, 310) to operate in the requested mode so as to provide the requested communications channel. In the alternative, historical traffic statistics are stored and are used by a traffic estimator (50) for periodically calculating an optimal distribution between analog and digital transceivers. The optimal distribution for maximizing system resource utilization and revenue is implemented by reconfiguring the multi-mode transceivers in accordance with the calculated distribution.



ADAPTIVE DUAL-MODE TRANSCEIVER CONFIGURATION

BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates to the configuration of multi-mode transceivers in a mobile telecommunications system, and in particular to the adaptive configuration of multi-mode transceivers to maximize the amount of served traffic.

Description of Related Art

With the availability of both digital and analog modulation modes in the mobile telecommunications environment, many operators of mobile telecommunications systems currently offer separate analog and digital mobile telecommunications services and/or dual-mode mobile telecommunications services. To operate in this environment, a mobile phone must include circuitry for transmitting and receiving digital and/or analog communications signals. In addition, to simultaneously support both digital and analog communications and/or to support dual-mode communications, the mobile telecommunications system must include separate digital and analog transceivers at each base station. In some cases, the system operator might even want to support more than two different modes. For example, the telecommunications system could support 800 MHZ analog, 800 MHZ digital, and 1900 MHZ digital communications. Generally, a large number of each type of transceiver is required to handle peaks in telecommunications traffic for each of the modes of operation. In some cases, however, analog and digital traffic peaks may not occur at the same time and, as a result, a significant portion of the transceivers will be idle at any given time.

Operators of mobile telecommunications systems normally want to limit the number of transceivers in the system to avoid having a large percentage of the transceivers in an idle state for extended periods. This is because idle transceivers do not produce revenue, yet they represent a significant capital investment and also cause increased maintenance and other overhead costs. On the other hand, if too few transceivers are provided, calls will sometimes be blocked (i.e., attempted calls will fail because the system is congested), particularly during periods of peak usage. Blocked calls also represent lost revenue because they reduce the amount of air time used by customers of the mobile telecommunications system. Moreover, blocked calls can cause dissatisfaction among customers, thereby causing customers to cancel or not renew their mobile telecommunication service agreements.

Mobile telecommunication systems operators must therefore attempt to balance these competing concerns by providing a sufficient number of transceivers to avoid substantial call blocking during peak usage periods while simultaneously minimizing the average number of idle transceivers. Generally, the appropriate number of each type of transceiver is determined by selecting an acceptable grade of service, which defines the probability that the selected number of transceivers will be congested at any particular time. The selected grade of service for each type of transceiver is typically somewhere between 2% and 5%, representing a corresponding 2% to 5% probability that the digital and/or analog side of the system will be congested.

An additional concern with the availability of each type of transceiver can also arise because, as usage patterns change over time, additional digital or analog transceivers are often necessary. For example, if cellular telephone users begin to change from analog to digital systems, the mobile telecommunications system operator must provide additional digital transceivers to keep up with additional demand on the digital side of the system. The acquisition of these additional digital transceivers can be expensive, while the reduced demand for analog mobile service can render many of the analog transceivers unnecessary and obsolete.

To permit greater flexibility, dual-mode transceivers that can operate under either an analog or a digital mode of operation can be used. These transceivers can be converted from an analog to a digital mode of operation or vice versa, or the transceivers can be converted between and among 800 MHZ analog, 800 MHZ digital, and 1900 MHZ digital modes of operation. This capability reduces the number of transceivers that must be purchased to keep up with changes in demand for mobile communication services because the transceivers can be converted from a mode of operation that has lower usage to a mode of operation having higher usage. Currently, however, the conversion of a transceiver from one mode to another requires manual reconfiguration. As a result, reconfiguration of transceivers generally is not responsive to intermittent fluctuations in demand and does not facilitate rapid responses to changes in mobile telecommunications usage patterns. Moreover, it is often difficult to determine the optimal distribution of transceiver resources between the different modes of operation, particularly when the selected configuration is only occasionally changed after extended periods of time.

There is a need, therefore, for a mobile telecommunications system that automatically responds to short-term and long-term fluctuations in demand for different modes of operation and that provides for an efficient allocation of transceiver resources between multiple modes of operation. Preferably, such a system would maximize the amount of traffic served by a particular number of transceivers and would minimize the number of transceivers needed to maintain an acceptable level of served traffic.

SUMMARY OF THE INVENTION

The present invention comprises a system and method for automatically reconfiguring a multi-mode transceiver to increase the amount of served traffic in a mobile telecommunications system. A multi-mode transceiver is programmable to operate in one of a plurality of modes of operation, including for supporting analog and digital traffic channels, analog and digital control channels, and location and verification devices. By adaptively configuring the transceivers in the system, the amount of served traffic can be maximized.

In one embodiment, an idle multi-mode transceiver operating in a first mode of operation is reconfigured to operate in a second mode of operation in response to a request to set up a communication channel requiring the second mode of operation. This embodiment involves reconfiguration upon seizure. Generally, the reconfiguration is performed only if no channels supporting the second mode of operation are otherwise available and if at least one other transceiver is available. In another aspect of the invention, however, even if no transceivers are currently idle, digital traffic can sometimes be repacked to clear all traffic from a particular transceiver. This repacking procedure thereby frees up a transceiver, which can be reconfigured into an alternate mode of operation.

In a second embodiment, historical traffic patterns are used to predict future traffic demands. By configuring the transceivers to operate according to the predicted traffic demands, greater amounts of traffic can be served. In accordance with this embodiment, traffic data is gathered and stored in a database. Using the stored traffic data, a traffic estimator calculates an optional distribution of the available multi-mode transceivers between the analog and various digital modes of operation. By periodically recalculating the optional distribution using more recent traffic data and by implementing the calculated distribution in an appropriate cell, the served traffic can be maximized. Implementation of the optimal distribution can be effectuated on a continually adjusting basis, wherein a calculated distribution from an immediately preceding data collection period is periodically implemented. Optionally, implementation is effectuated on a time of the day and day of the week basis that involves a more detailed and extensive data storage and calculation procedure.

In another embodiment, the historical traffic pattern configuration is combined with the reconfiguration at seizure method. In this embodiment, the transceivers are initially configured based on historical traffic patterns. Modification of the initial configuration through reconfiguration at seizure is permitted to account for unexpected peaks or for inaccuracies in the expected traffic estimates. In addition, reconfiguration of transceivers to provide additional control channels or verification devices is also permitted to account for increased demands on control and verification channels.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, reference is made to the following detailed description taken in conjunction with the accompanying drawings wherein:

FIGURE 1 is a block diagram of a dual-mode mobile telecommunications system for implementing reconfiguration of transceivers upon seizure in accordance with the present invention;

FIGURE 2 is a flow diagram of a method for reconfiguring a transceiver at seizure responsive to an analog-only mobile station in accordance with the present invention;

FIGURE 3 is a diagram of a base station having a plurality of selectively reconfigurable dual-mode transceivers in accordance with the present invention;

FIGURE 4 is a flow diagram of a method for reconfiguring a dual-mode transceiver at seizure responsive to an analog-preferred mobile station in accordance with the present invention;

FIGURE 5 is a flow diagram of a method for reconfiguring a transceiver at seizure responsive to either a digital-only or a digital-preferred mobile station in accordance with the present invention; and

FIGURE 6 is a block diagram of a mobile telecommunications system for reconfiguring transceivers based on historical traffic patterns in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Reference is now made to the Drawings wherein like reference characters denote like or similar parts throughout the various Figures. Referring now to FIGURE 1, there is illustrated a dual-mode mobile telecommunications system 10. The system 10 includes a plurality of mobile switching centers (MSCs) 20 that are interconnected by telecommunications trunks 22. Although only three MSCs 20 are shown, it will be understood that the mobile telecommunications system 10 typically includes a much larger number of MSCs 20. At least one of the MSCs 20 is connected to a public switched telephone network (PSTN) 12 via a telephone line 24. Each MSC 20 is further connected to a plurality of base stations (BSs) 30 by lines 26.

The base stations 30 in the dual-mode telecommunications system 10 include a plurality of multi-mode capable transceivers 34 (see FIGURE 3), some of which are configured to operate in a digital mode while others are configured to operate in an analog mode of operation. The use of both types of transceivers permits customers to access the system 10 using either an analog or digital mobile phone 40 or using a dual-mode mobile phone 40. Traffic signals between the transceivers and the mobile phones 40 are carried via radio links 32. Generally, each analog transceiver is capable of transmitting and receiving one channel of analog telecommunications traffic signals. Each D-AMPS digital transceiver (i.e., in systems operating under the IS-136 protocol) is capable of transmitting and receiving three channels of digital telecommunications traffic signals by dividing the channel into three time slots, and each GSM digital transceiver is capable of transmitting and receiving eight channels of digital telecommunications traffic signals by dividing the channel into eight time slots.

In addition to configuring the transceivers to operate as digital or analog traffic channels, one or more of the transceivers can also be configured to operate as an analog control channel, a digital control channel, or a location and verification module (LVM). Analog and digital control channels are used to send control messages, such as mobile pages, call set-up requests, registration messages, handover requests, and other non-traffic information, between the base stations 30 and the mobile phones 40. An LVM is used to verify location data received from the mobile station 40 for performing mobile-assisted handover. To perform mobile-assisted handover, the mobile station 40 periodically transmits data relating to the received signal strength of signals from base stations 30 in neighboring cells. If, based on this data, it is determined that signals from the neighboring cell are stronger than those from the current cell, a handover to a neighboring cell is normally appropriate. To ensure that the mobile station 40 is actually in the cell to which handover is planned, however, an LVM is used to verify the approximate location of the mobile station 40 by attempting to detect uplink signals transmitted by the mobile station 40. If the location is confirmed, then the handover procedure is allowed to proceed.

Depending on the number of transceivers configured to transmit and receive a particular type of signal (i.e., analog, D-AMPS digital, or GSM digital traffic channel, analog or digital control channel, or LVM), congestion of the available channels for those signals can sometimes occur, particularly during periods of peak usage. In accordance with one aspect of the present invention, an idle transceiver can be automatically reconfigured upon seizure of the transceiver device. This reconfiguration can be accomplished by loading a different type of modulation and control software at the base station 30 and at the MSC 20. To change from analog to digital, for example, requires a digital signal processing software change.

If a particular type of channel is requested but none are available, the system 10 will attempt to select an idle transceiver and, if one is available, will reconfigure it to operate according to the requested type of channel. For example, if a mobile station 40 requests an 800 MHZ D-AMPS digital voice channel but no 800 MHZ D-AMPS time slots are available, the system 10 will attempt to locate an idle analog channel or another type of idle digital channel, such as a 1900 MHZ digital channel. This search for an idle analog channel can include searching among the transceivers in the same base station 30, the same cell, or even in other neighboring cells. If an idle analog channel is available, the system 10 will reconfigure it to operate as three digital voice channels. One of these digital voice channels can then be used by the requesting mobile station 40. This procedure can similarly be performed to reconfigure an idle channel of any type (e.g., analog voice channel, 1900 MHZ D-AMPS digital channel, GSM digital channel, etc.) to any type of requested channel. Furthermore, the procedure is applicable regardless of whether the request to set-up a communication channel is initiated by the mobile station 40, is initiated by the MSC 20, the PSTN 12, or another mobile station 40, or is the result of an attempted handover.

Reference is now made to FIGURE 2, wherein there is shown a flow diagram of a method 100 for reconfiguring a transceiver at seizure responsive to an analog-only mobile station (MS) 40. The method 100 is initiated by an analog-only mobile station 40 attempting to access the mobile telecommunications system 10 at step 102. At step 104, it is determined if any analog traffic channels are available. If at least one analog traffic channel is available, then no reconfiguration is necessary, and a call is set up over the available analog traffic channel at step 116. If no analog traffic channels are available, then the system 10 attempts to execute the necessary reconfiguration so as to provide an additional analog traffic channel. Thus, at step 106, it is determined if an idle digital configured transceiver is available. If so, the digital configured transceiver is reconfigured to operate as an analog traffic channel at step 110, and a call is set up over the available analog traffic channel at step 116. If there are no idle digital configured transceivers, it is next determined at step 108 if there are at least three idle digital time slots available in the base station. If not, then reconfiguration is not possible because the system 10 is congested, and the attempted access is denied at step 114. However, if at least three digital time slots are available in the cell, then the digital configured connections can be rearranged so as to clear all traffic from one of the digital configured transceivers at step 112. This repacking process is discussed in greater detail below in connection with the multiple transceivers shown in FIGURE

3. The cleared digital configured transceiver is then reconfigured to operate in the analog mode at step 110, and a call is set up over the available analog traffic channel at step 116.

Referring now to FIGURE 3, there is illustrated a base station 30 in accordance with the present invention. The base station 30 includes a plurality of multi-mode transceivers 34 for transmitting signals to and receiving signals from mobile stations 40 in the mobile telecommunication system 10. Each of the transceivers 34 is connected to an antenna 38 via a wire 39. Although the transceivers 34 are illustrated as being attached to a single antenna, it is also possible to attach the transceivers to separate antennas 38. As illustrated in FIGURE 3, three of the transceivers 34(1), 34(2), & 34(4) are currently configured to operate as digital transceivers in a D-AMPS system. Thus, each of these transceivers 34(1), 34(2), & 34(4) include three digital telecommunications channels 35. In this particular example, two of the digital channels 35 are in use and one digital channel 35 is idle for each of the digital transceivers 34(1), 34(2), & 34(4). The remaining transceiver 34(3) is operating in the analog mode. Thus, this analog configured transceiver 34(3) has only a single analog telecommunications channel 36.

In the situation illustrated in FIGURE 3, no idle transceivers 34 are currently available. Thus, no analog channels are currently available nor can a digital transceiver by immediately reconfigured to the analog mode. As discussed in connection with FIGURES 2, 4, and 5, however, digital connections can sometimes be reallocated among the available digital time slots to completely clear all traffic from one or more digital configured transceivers 34. In this example, for instance, the two digital connections that are currently supported by two of the channels of one digital configured transceiver 34(2) can be handed-over (as generally indicated at 42) to the idle channels in the other two digital configured transceivers 34(1) & 34(4). Typically, the calls on the transceiver carrying the least amount of traffic are handed-over since it is normally desirable to minimize the number of handovers. Upon completion of the repacking process, all of the channels for one digital configured transceiver 34(2) will then be idle, and the digital configured transceiver 34(2) can be reconfigured to operate as an analog configured transceiver 34 or other type of transceiver, thereby providing an additional analog traffic channel, digital traffic channel, or control channel and permitting greater utilization of the available resources.

Although a digital channel having three time slots is used as an example, it will be understood that any channel having multiple slots can be repacked to provide an idle transceiver for reconfiguration. Thus, a GSM configured transceiver can be repacked and reconfigured to have another mode of operation. Furthermore, it is possible to repack and reconfigure an 800 MHZ digital-configured transceiver to operate as a 1900-MHZ digital-configured transceiver or vice versa, or to repack and reconfigure an 800 MHZ digital-configured transceiver or a 1900 MHZ digital-configured transceiver to operate in an analog mode.

Referring now to FIGURE 4, there is shown a flow diagram of a method 200 for reconfiguring a transceiver at seizure responsive to an analog-preferred mobile station (MS) 40. The method 200 is initiated by an analog-preferred mobile station 40 attempting to access the mobile telecommunications system 10 at step 202. An analog-preferred mobile station 40 is a dual-mode device that will select an analog channel if it is available. At step 204, it is determined if any analog traffic channels are available. If at least one analog configured transceiver 34 is available, then no reconfiguration is necessary, and an analog call connection is set up at step 220. If no analog configured transceivers 34 are available, the system 10 attempts to reconfigure an idle digital configured device to provide an additional analog traffic channel. Therefore, at step 206, it is determined if an idle digital configured transceiver 34 (FIGURE 3) is available. Idle in this connection means that all three of its digital channels are available. If so, the digital configured transceiver is reconfigured to operate in the analog mode at step 214, and an analog call connection is set up at step 220. If there are no idle digital configured transceivers it is next determined at step 208 if there are at least three idle digital time slots available in the base station (or eight idle time slots in the case of a GSM system). If so, the connections over the digital channels are repacked at step 216, as discussed above in connection with FIGURE 3 by transferring these connections to idle channels for other digital configured transceivers. The cleared digital configured transceiver 34 is reconfigured to operate in the analog mode at step 214, and an analog call connection is set up at step 220.

If it is determined at step 208, however, that there are not at least three idle digital time slots (or eight idle time slots in the case of a GSM system), the system 10 is too congested to provide analog service. Because the mobile phone 40 is a dual-mode phone (i.e., it is capable of digital operation), however, it might still be possible to set up a digital call connection. Therefore, at step 210, it is determined if any digital time slots are available. If so, then a digital call connection is set up at step 218. If no digital time slots are available, the system 10 is completely congested on both the analog and digital sides, and the attempted access is denied at step 212.

Referring now to FIGURE 5, there is shown a flow diagram of a method 300 for reconfiguring a transceiver at seizure responsive to either a digital-only or digital-preferred mobile station (MS) 40. At step 302, the digital mobile station 40 attempts to access the mobile telecommunications system 10. At step 304, it is determined if any digital time slots are available. If one or more digital channels are available, then no reconfiguration is necessary, and a call is set up over the available digital traffic channel at step 312. If, on the other hand, no digital traffic channels are available, it is determined if an idle analog configured transceiver is available at step 306. If not, then the system 10 is entirely congested, and the attempted access if denied at step 308. If there is an analog configured transceiver that is idle, however, the analog configured transceiver is reconfigured to operate in the digital mode at step 310, and a digital call connection is set up at step 312.

In each of the methods discussed above, reconfiguration is controlled by the MSC 20 and is dependent upon the receipt of a request to set-up communications over a particular type of channel that is currently not available. Referring again to FIGURE 1, a request to set-up communications over a particular type of traffic channel is transmitted by the mobile station 40 over a control channel and received by the MSC 20. For incoming calls, it is possible to store the preferred mode of operation for the mobile station 40 at the MSC 20 or elsewhere in the system 10, so that the MSC 20 generates the necessary channel assignment without having to query the mobile station 40. Requests for additional control channels or verification channels, on the other hand, are normally generated by the MSC 20 itself based on increased demand for control or verification channels. Then, to reconfigure a selected transceiver, the MSC

20 initiates loading of a different type of modulation and control software at the base station 30 and at the MSC 20.

Preferably, in accordance with the reconfiguration at seizure procedure, each transceiver remains in its last configuration until another reconfiguration command is received. In other words, if a digital configured transceiver is reconfigured into the analog mode to provide service for a requested analog call connection, the transceiver will remain in the analog configuration even after the call connection terminates. The analog configured transceiver will change back to the digital mode only if a reconfiguration command is later received to switch the transceiver into the digital configuration. As a result, the transceivers for a particular base station 30 or cell will tend to stabilize at or near an optimal distribution between digital and analog modes of operation and further will dynamically respond to changes in traffic patterns. Once the system stabilizes, a reduced amount of time and processing resources are expended on reloading software in the MSC 20 and the base station 30 to reconfigure the transceivers.

In the above discussion, reconfiguration is only performed when a requested mode of operation is completely saturated (i.e., at 100% of capacity). In some cases, however, especially where a verification device or digital control channel (DCCH) becomes highly loaded, it is often desirable to trigger the reconfiguration before the point of saturation is reached to avoid denying access to the system 10 or losing verification or control data. Depending upon the value or state of a configuration parameter, the system 10 reconfigures either an analog or a digital configured transceiver to operate as a second DCCH, a second verification device, or some other mode of operation. Furthermore, the reconfiguration is triggered once a predetermined traffic threshold is reached - 90% of capacity, for instance. In the alternative, the threshold parameter for the DCCH can be measured by the number of mobile requests and acknowledges (uplink signals) and the number of system requests or acknowledges (downlink signals). When either the uplink or downlink exceeds a certain threshold, an idle transceiver is reconfigured to a DCCH. Similarly, for an LVM, if the number of system requests exceeds a predefined threshold, the system automatically reconfigures an idle digital or analog transceiver as an LVM.

After a second DCCH or second verification device has been configured on a particular multi-mode transceiver, the transceiver will generally remain in that configuration until the load on the LVM or DCCH falls below some threshold. At that point, the transceiver is reconfigured to an analog or digital traffic mode. Normally, to prevent rapid oscillations between operation as a DCCH or LVM and operation as an analog or digital traffic channel in connection with load variations near the threshold, the threshold for converting back to a traffic channel is lower than the threshold for the initial conversion to a second DCCH or second LVM. For example, a transceiver might be reconfigured to a LVM or DCCH at 90% of capacity, but will not go back to a digital or analog traffic mode until the load falls below 70% of the capacity of one transceiver. The likelihood of rapid oscillations can further be reduced by averaging the LVM or DCCH traffic during a window of five to ten seconds, for instance, rather than reconfiguring based upon instantaneous load levels.

In another embodiment of the invention, the transceivers are periodically reconfigured based on historical traffic patterns. In this embodiment, the distribution of available transceivers between digital and analog configurations is calculated to maximize the amount of served traffic, thereby maximizing revenue system utilization, and presumably customer satisfaction. Referring now to FIGURE 6, there is illustrated a mobile telecommunications system 14 for reconfiguring transceivers based on historical traffic patterns. During ordinary operating conditions, each base station 30 reports event data to the MSC 20 (as generally indicated at 52). This event data generally comprises traffic statistical data, such as a time stamp for each call connection and a length of each call. The MSC 20 in turn sends the event data to a traffic estimator 50 (as generally indicated at 53). The traffic estimator 50 stores this data in a database 56 and uses the stored data to calculate optimal transceiver configurations on a per call basis. Based on the calculations performed by the traffic estimator 50, reconfiguration commands are periodically sent to the MSC 20 (as generally indicated at 54). These commands are then forwarded to the appropriate base stations 30 (as generally indicated at 55), where transceivers are reconfigured according to the received commands. In some cases, prior to sending out reconfiguration commands, operator approval or confirmation might be required. This confirmation can be obtained via a user interface 60. The user interface 60 can also be used to notify the operator if preselected blocking thresholds are exceeded, thereby providing notice to the operator that additional transceivers are necessary, or to simply inform the operator of traffic estimates and recommendations for numbers of devices, separate and apart from the implementation of reconfiguration processes.

Prior to calculating the optimal transceiver distribution, it is first necessary to calculate certain usage statistics using the stored event data. In particular, the amount of offered traffic measured in erlangs is needed for each modulation mode (i.e., 800 MHZ digital, 1900 MHZ digital and/or analog). The estimated offered traffic (Off. Traff.) in a particular cell for a specific modulation mode is equal to the mean holding time (MHT) of calls in that cell that use the specific modulation mode times the number (n) of attempted accesses per second for that modulation mode. Thus,

$$\text{Off. Traff.} = \text{MHT} * n$$

The mean holding time is the average time that a mobile call connection lasts in the particular cell for the specific modulation mode after being successfully designated on voice channel. Generally, the mean holding time does not take into account dropped calls. "Attempted accesses" refers to any attempt to originate, terminate, or handover a call involving a mobile station 40. Each of these values can be derived from data stored in the traffic database 56.

Once the offered traffic estimate is obtained and the total number of reconfigurable transceivers is known, the optimal configuration distribution can be determined by calculating the total expected served traffic for various possible configurations. The expected served traffic (T_e) is calculated for each modulation mode for a selected number of channels (N_{ch}) by subtracting from the estimated offered traffic (Off. Traff.) the probability (p) that blocking will occur for the estimated offered traffic and the given number of channels times the estimated offered traffic (Off. Traff.). Accordingly,

$$T_e = \text{Off. Traff.} - (p * \text{Off. Traff.})$$

The expected served traffic for each modulation mode can then be added together to obtain a total expected served traffic. The probability that blocking will occur is typically determined in a cellular system using an Erlang B table to model subscriber behavior. As will be appreciated by those skilled in the art, however, any appropriate probability function can be used including Poisson or Erlang C distributions, depending upon the system parameters.

To illustrate the served traffic calculation, it is assumed that there are 10 transceivers in a cell and that the offered traffic estimate for the cell is calculated to be 5 erlang of analog traffic and 3 erlang of digital traffic. If it is first assumed that the system is configured to have 6 analog transceivers (6 analog channels) and 4 D-AMPS digital transceivers (12 digital channels), the served analog traffic is expected to be approximately 4.0 erlang calculated using a B-erlang table and the expected served digital traffic is about 3.0, for a total expected served traffic of about 7.0 erlangs. Next, the expected served traffic is calculated for 7 analog and 3 digital transceivers (i.e., 7 analog channels and 9 digital channels). The expected served traffic is approximately 4.25 for analog and 3.0 for digital, giving a total of 7.25 erlangs. Thus, a larger amount of traffic is expected to be served by the 7/3 distribution than the 6/4 distribution. For an 8 analog and 2 digital transceiver configuration, the expected served traffic is approximately 4.6 for analog and 2.9 for digital, for a total of about 7.5 erlangs. Therefore, the 8/2 distribution is expected to serve about 7.5 erlangs of the estimated 8 erlangs of total offered traffic. Additional calculations would normally be carried out for each possible distribution. However, in this example, the 8/2 distribution turns out to be the optimal configuration and would therefore be expected to generate the highest amount of revenue. In accordance with the invention, the traffic estimator would generate a command to configure 8 of the 10 transceivers as analog and the remaining 2 as digital.

The frequency of reconfigurations based on historical traffic patterns can be selected by the system operator depending on the desired resolution of the reconfigurations. Preferably, the resolution is between five minutes and one week, although other periods can also be used. In one embodiment, traffic pattern data is collected during an evaluation window. The collected data is used to calculate a preferred configuration, which is applied during an application window. While the application window is running, a subsequent evaluation window can be performed. The evaluation window and the application window can be for the same length of time or for different time periods and can be concurrent or offset from one another. As an example, the evaluation window in a particular system might be a 15 minute period followed by a five minute idle period, so that the evaluation window repeats at 20 minute intervals. The application window in this example could coincide with the 20 minute interval, during which a preferred configuration from a previous evaluation window is applied. Changes in demand would thereby be substantially accounted for within 20 minutes. More or less frequent reconfigurations can be used depending primarily upon the expected rate of traffic pattern changes.

In an alternative embodiment, the preferred configuration can be determined based on the time and the day of the week. Because call data is stored in the database 56, it is possible to calculate the appropriate distribution of analog and digital transceivers using stored data for traffic patterns exhibited during corresponding historical periods. Generally, traffic patterns on weekdays will differ significantly from night or weekend traffic. Therefore, the configuration can be tailored to the historical demand for analog and digital traffic channels. For example, based on expected served traffic calculations, the system 14 might be programmed to have a 50% analog and 50% digital distribution on a Monday morning between 9:00 a.m. and 10:00 a.m., while on Sunday morning the preferred distribution might be 70% analog and 30% digital. Furthermore, although a one-hour resolution is illustrated, the resolution of the reconfigurations can be as small as five minutes or as large as 24 hours in a preferred embodiment. It should also be noted that the distribution can often vary depending on the location of the cell. A cell that is near a major highway, for instance, may exhibit different traffic patterns than a cell in an urban area.

As an additional alternative, reconfiguration at seizure can also be utilized in connection with the historical traffic pattern configuration embodiment. Thus, reconfiguration at seizure can be applied to handle unexpected peaks in traffic. Preferably, however, such a reconfiguration at seizure is conditioned on a determination that the other modulation mode is below a certain percentage of the expected offered traffic according to the traffic estimator calculation. In this situation, for example, at a given time there might not be any digital channels available. Prior to reconfiguring an idle analog transceiver, however, the system 14 would be required to determine if the analog traffic is below 80%, for instance, of its expected value. In contrast to the pure reconfiguration at seizure method, however, reconfigured transceivers are returned to the state recommended by the traffic estimator in the mixed method. The number of requests for reconfiguration at seizure can be used to provide an error estimate for the historical traffic pattern configuration. Moreover, it is also possible to automatically increase the resolution of reconfiguration calculations in the traffic pattern embodiment if the number of intervening reconfiguration requests exceeds some threshold value. For example, if the system is receiving three reconfiguration requests per second and the resolution of the evaluation window is one hour, it might be desirable to shorten the evaluation window. Thus, when this occurs the system can be programmed to automatically change the evaluation window to a shorter time period, such as five minutes.

Although a preferred embodiment of the method and apparatus of the present invention has been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it is understood that the invention is not limited to the embodiment disclosed, but is capable of numerous rearrangements, modifications, and substitutions without departing from the spirit of the invention as set forth and defined by the following claims.

WHAT IS CLAIMED IS:

1. A method for configuring a plurality of multi-mode transceivers (34) in a mobile telecommunications system (10), the plurality of multi-mode transceivers serving a particular geographic area, said method comprising the step of pre- configuring the plurality of multi-mode transceivers to individually operate according to one of at least a first mode of operation and a second mode of operation, wherein said method is characterized by the steps of:

measuring an amount of telecommunications traffic accessing the plurality of multi-mode transceivers for each of the first mode of operation and the second mode of operation;

calculating a preferred distribution between at least the first mode of operation and the second mode of operation for the plurality of multi-mode transceivers based on the measured traffic; and

reconfiguring at least one of the plurality of multi-mode transceivers in accordance with said preferred distribution.

2. The method of claim 1 wherein at least one of the plurality of multimode transceivers is configured to have an analog mode of operation.

3. The method of claim 1 wherein at least one of the plurality of multimode transceivers is configured to have a digital mode of operation.

4. The method of claim 1 wherein at least one of the plurality of multimode transceivers is configured to operate as a verification device.

5. The method of claim 1 wherein at least one of the plurality of multimode transceivers is configured to operate as at least one digital control channel.

6. The method of claim 1 wherein the step of measuring the amount of telecommunications traffic comprises:

measuring a number of accesses during a selected time period; and

measuring a holding time of each access for each of the first and second modes of operation.

7. The method of claim 1 further comprising the step of calculating an expected amount of served traffic for each of the first and second modes of operation using the measured traffic and an estimate of a probability of blocking.

8. The method of claim 1 wherein said step of measuring the amount of telecommunications traffic is performed periodically and during selected time periods and the preferred distribution is calculated using data from a prior one of said periodic measurements.

9. The method of claim 1 wherein said calculation of the preferred distribution is based on historical traffic data measured during a predetermined recurring time period.

10. The method of claim 1 further comprising the steps of:

detecting that an amount of traffic over a digital control channel exceeds a selected threshold; and

reconfiguring one of said plurality of multi-mode transceivers to operate as a digital control channel.

11. The method of claim 1 further comprising the steps of:

detecting that an amount of traffic for a verification device exceeds a selected threshold; and

reconfigurlng one of said plurality of multi-mode transceivers to operate as a verification device.

12. The method of claim 1, further comprising the steps of:

receiving a call set-up request for a mobile station having the first mode of operation, said call set-up request received subsequent to the step of reconfiguring;

determining that no multi-mode transceivers having said first mode of operation are available;

determining that a particular multi-mode transceiver having the second mode of operation is idle; and

reconfiguring said particular multi-mode transceiver from said second mode of operation to said first mode of operation to handle a call connection initiated in response to said call set-up request.

13. The method of claim 12 further comprising the step of determining that an amount of traffic using said second mode of operation in the plurality of multimode transceivers is below a selected threshold prior to reconfiguring said particular multi-mode transceiver.

14. The method of claim 12 further comprising the step of reconfiguring said particular multi-mode transceiver to said second mode of operation after termination of said call connection.

15 A mobile telecommunications system (10), comprising:

a mobile switching center (MSC) (20);

a plurality of multi-mode transceivers (34(1), 34(2), 34(4) connected to said MSC, a first group of said multi-mode transceivers configured to operate in a first mode and a second group of said multi-mode transceivers (34(3) configured to operate in a second mode, said system characterized by:

a traffic estimator (50) for receiving traffic data from the MSC and calculating a preferred distribution for said first and second groups of multi-mode transceivers between said first mode of operation and said second mode of operation.

16. The system of claim 15 further comprising a command link (54, 55) connecting the traffic estimator and each of the plurality of multi-mode transceivers for reconfiguring the multi-mode transceivers in accordance with the preferred distribution.

17. The system of claim 16 further comprising a database (56) coupled to the traffic estimator for storing said traffic data.

18. The system of claim 17 wherein said traffic data includes information about a number of attempted accesses and holding time information for the first mode and the second mode.

19. The system of claim 17 wherein said database stores historical traffic data according to time and date.

20. The system of claim 15 wherein the traffic estimator calculates the preferred distribution to maximize an expected amount of served traffic.

21. The system of claim 20 wherein the expected amount of served traffic is calculated for the first mode of operation and the second mode of operation using an estimate of the amount of offered traffic and an estimate of the probability of blocking.

22. A method for configuring a multi-mode transceiver (34) in a mobile telecommunications system (10) having a plurality of transceivers, said multi-mode transceiver operating according to a first mode of operation, comprising the step of monitoring (52) a level of traffic on a communications channel in said telecommunications system, said communications channel having a second mode of operation, said method characterized by the step of:

reconfiguring said multi-mode transceiver to operate as a second communications channel if said level of traffic exceeds a first threshold.

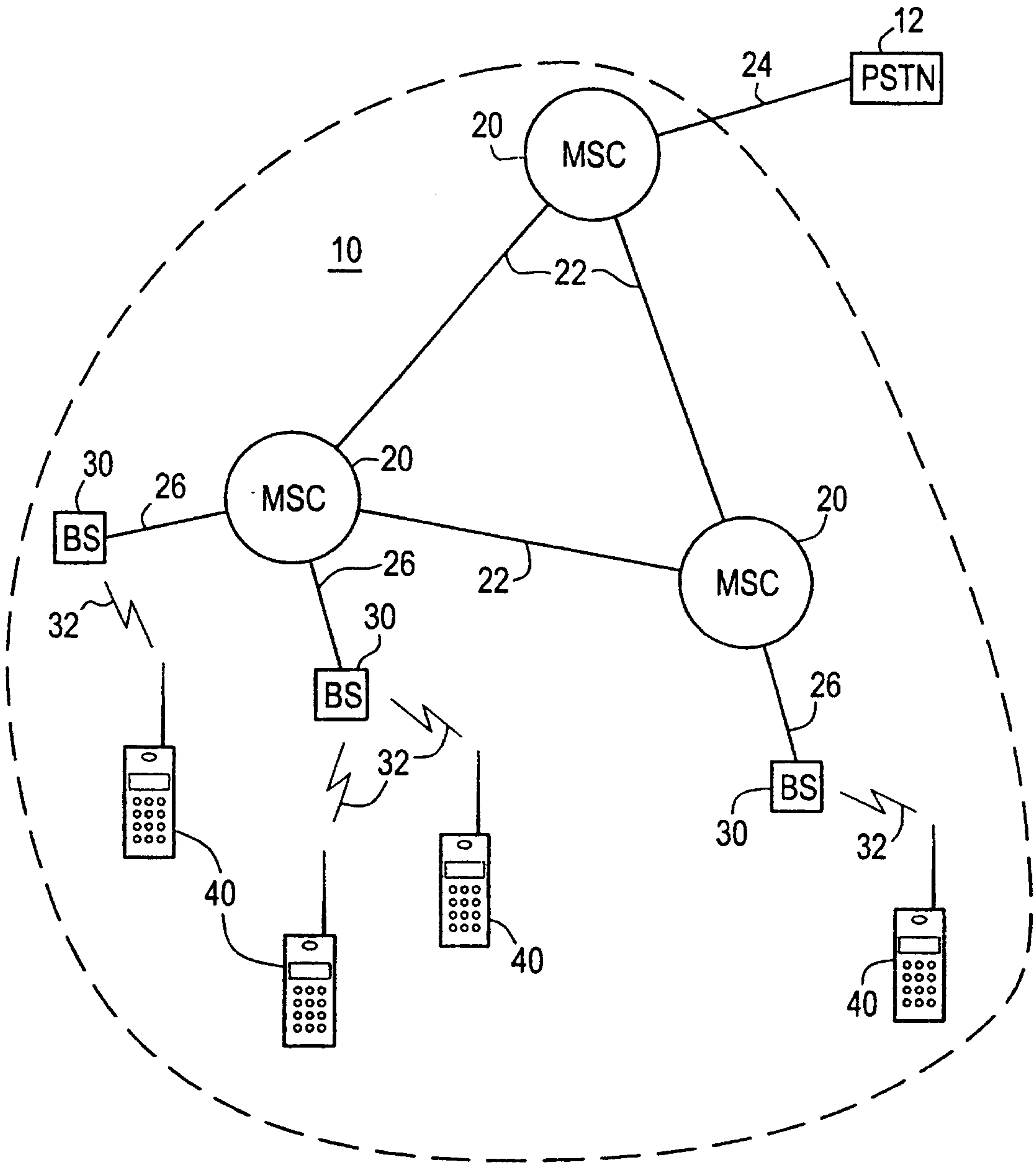
23. The method of claim 22 wherein said second mode of operation comprises operating as a verification device.

24. The method of claim 22 wherein said second mode of operation comprises operating as a control channel.

25. The method of claim 22 further comprising the step of reconfiguring said multi-mode transceiver to said first mode of operation if said level of traffic falls below a second threshold, said second threshold lower than said first threshold.

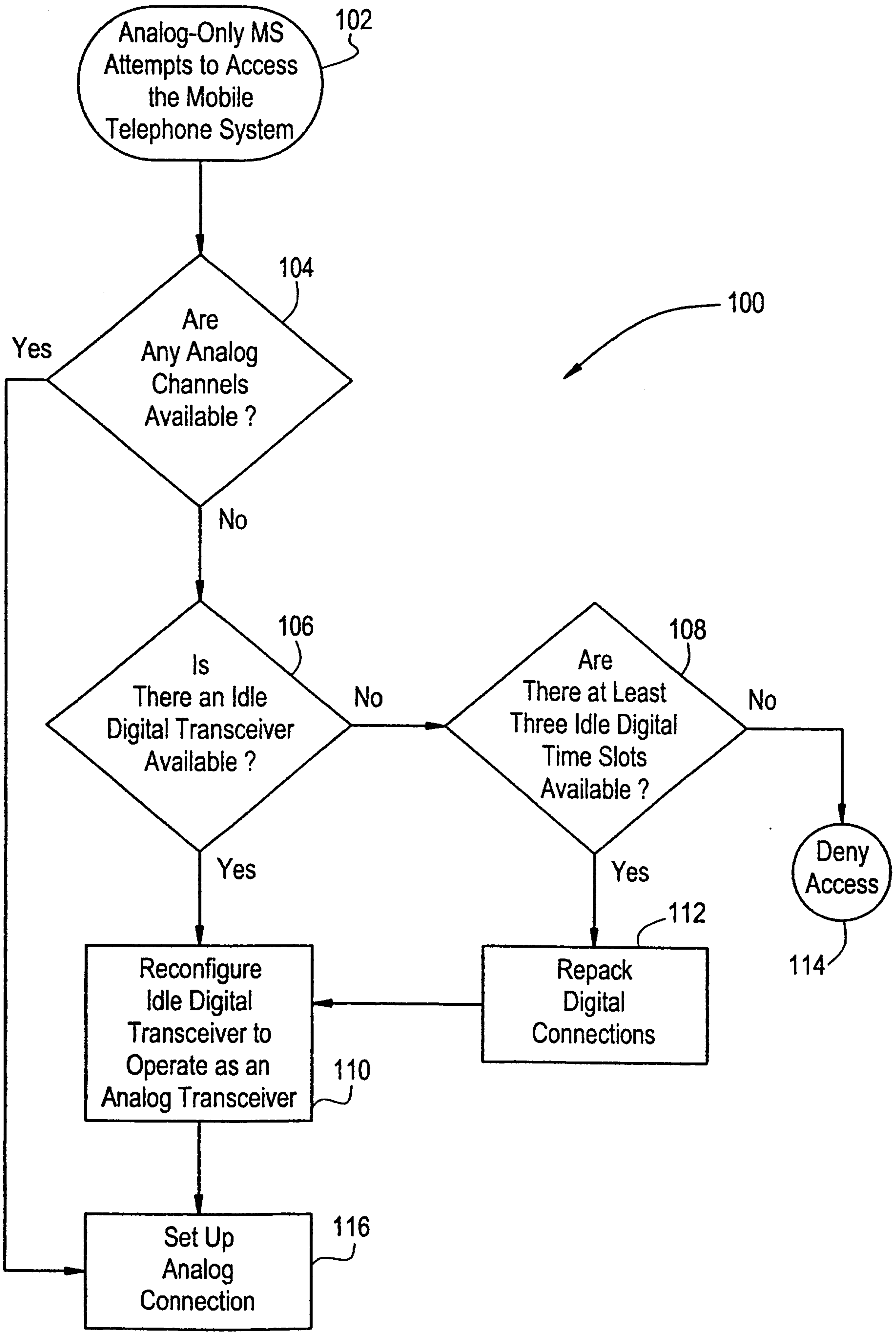
26. The method of claim 22, wherein the step of monitoring the level of traffic for each of the first and second modes of operation comprises determining an average level of traffic during a time window.

FIG. 1



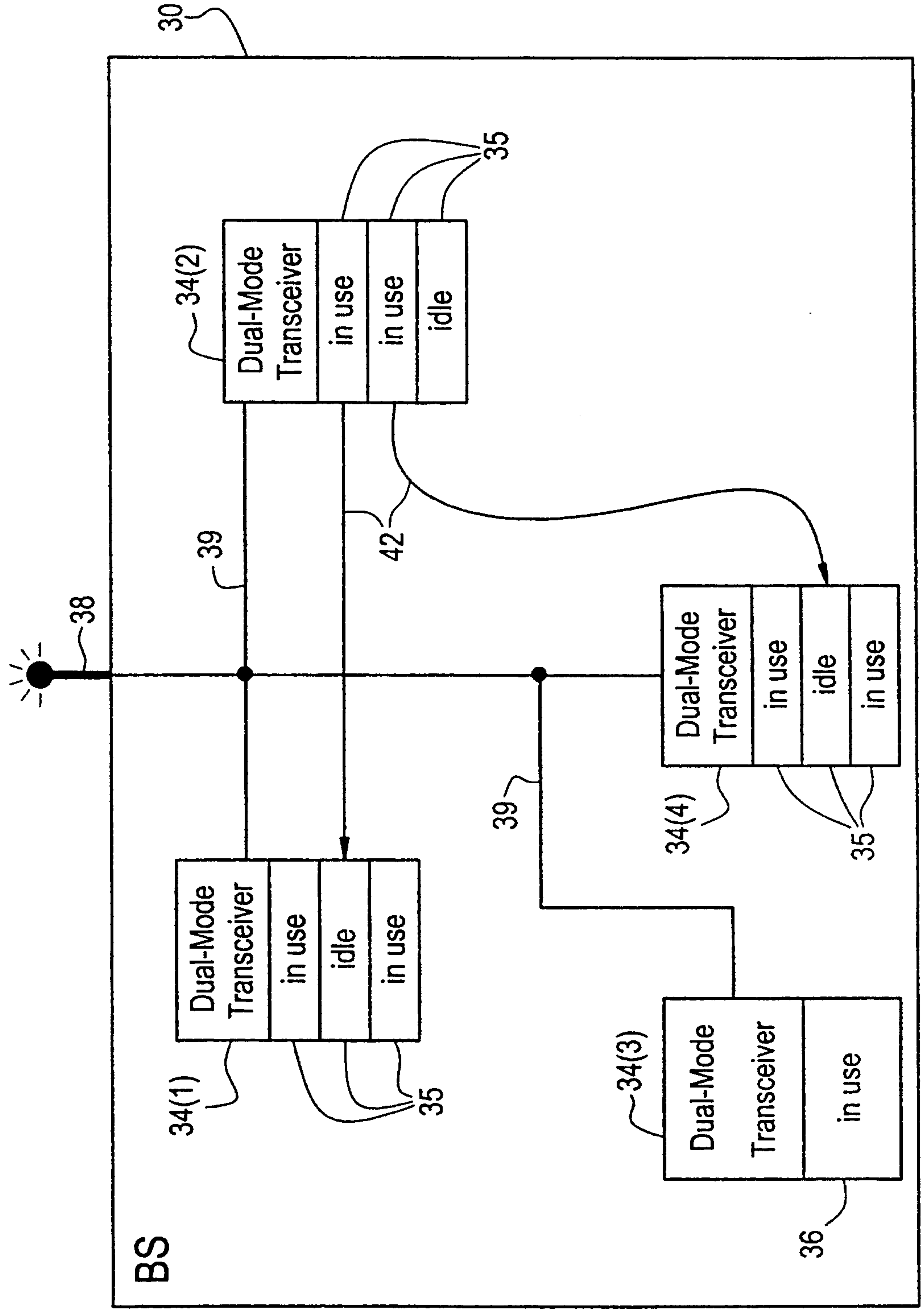
Marks & Clerk

FIG. 2



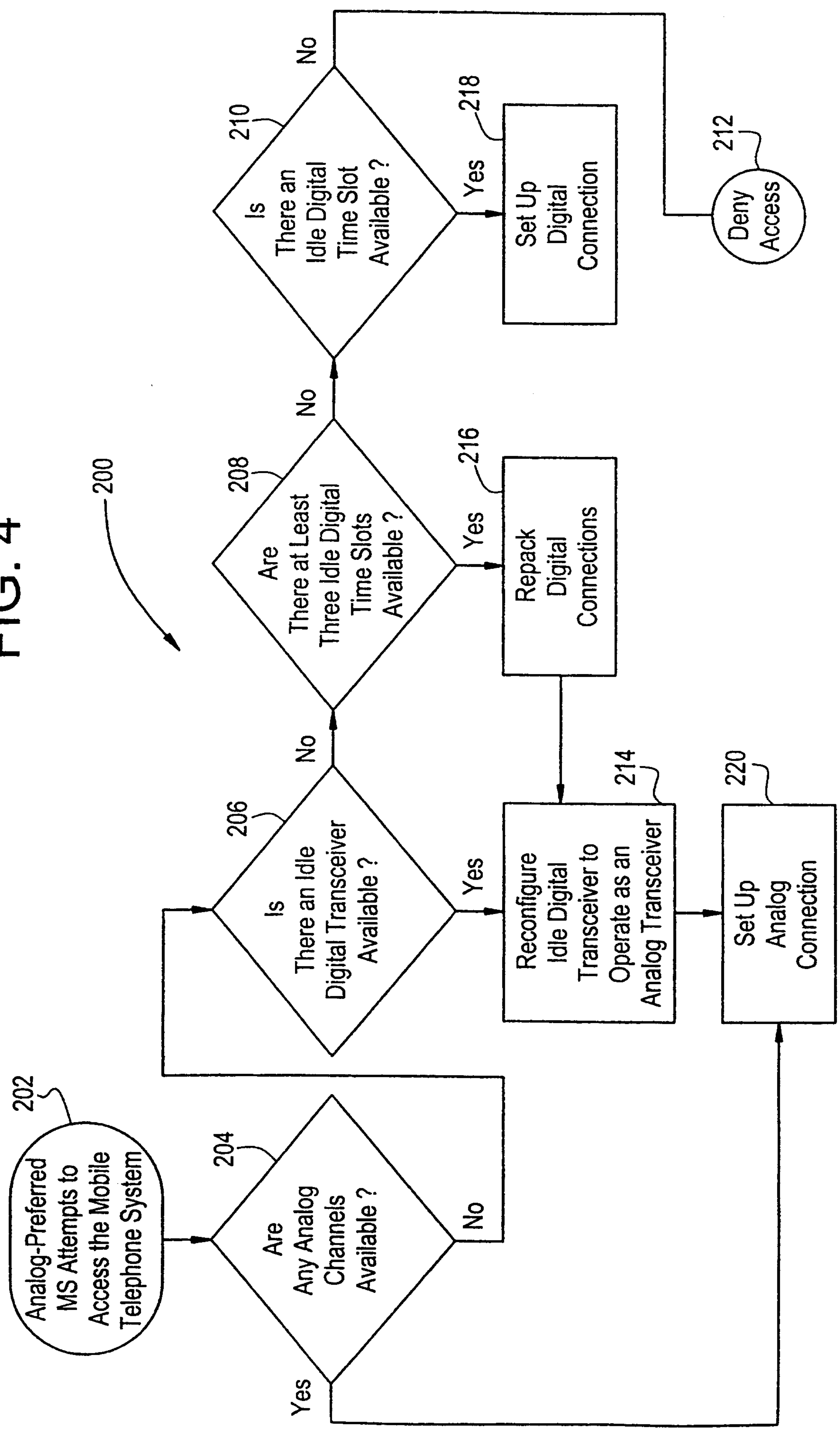
Marks & Clerk

FIG. 3



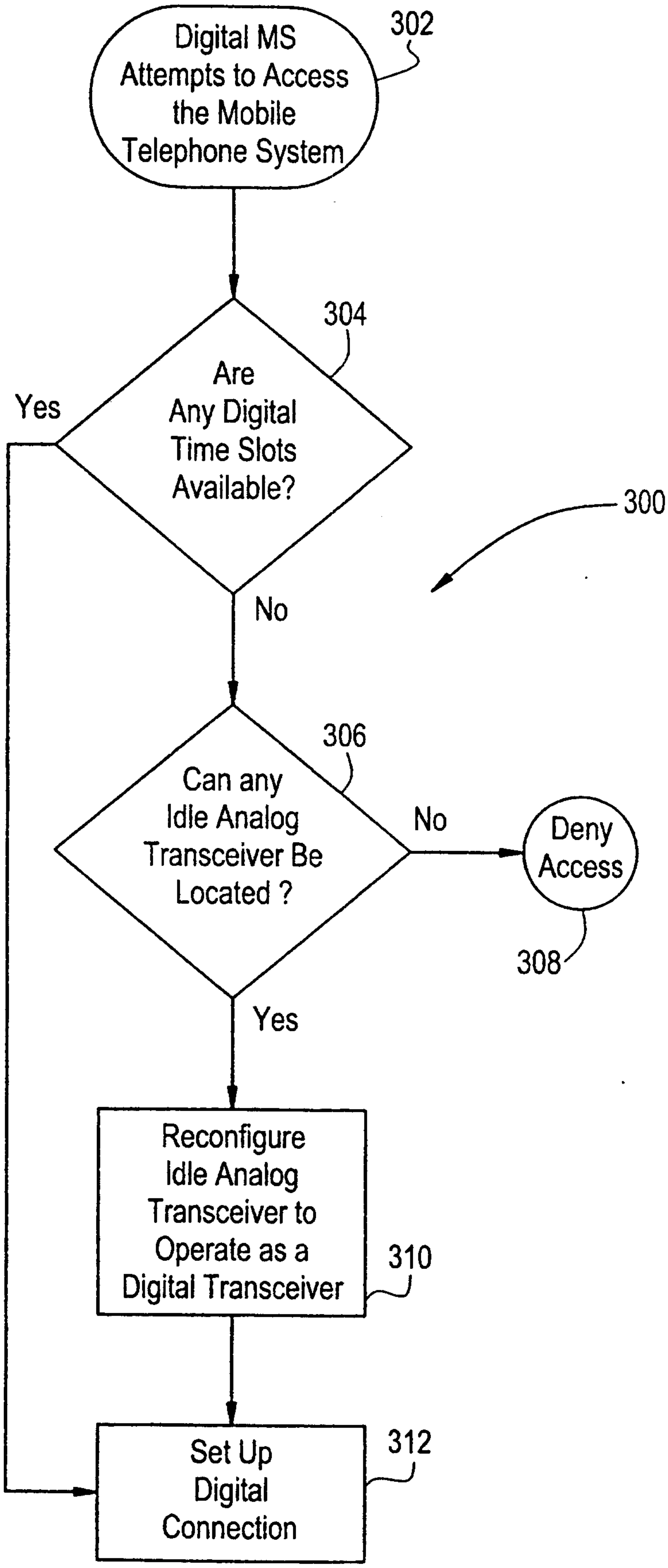
Marks & Clerk

FIG. 4



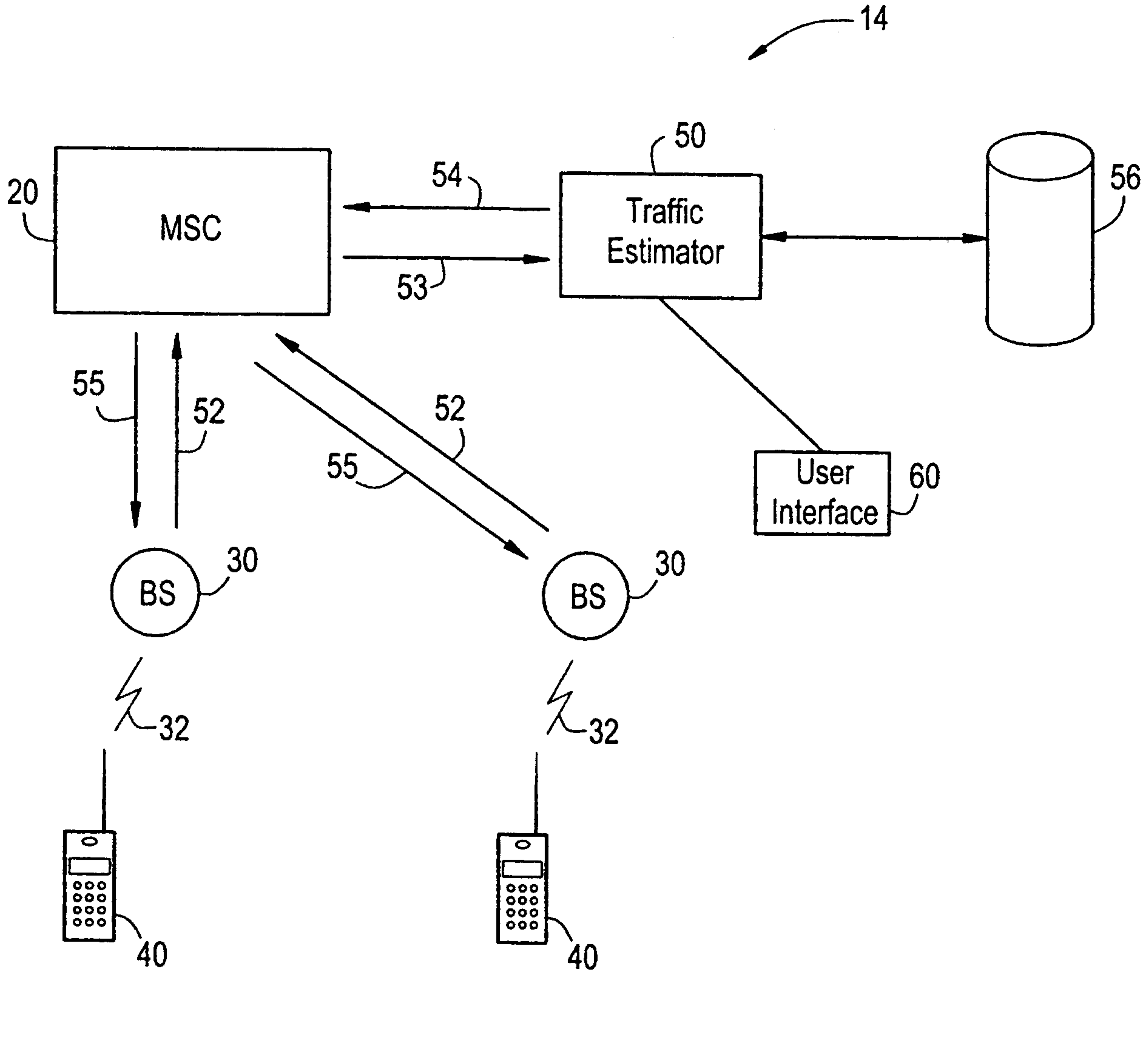
Marks & Clerk

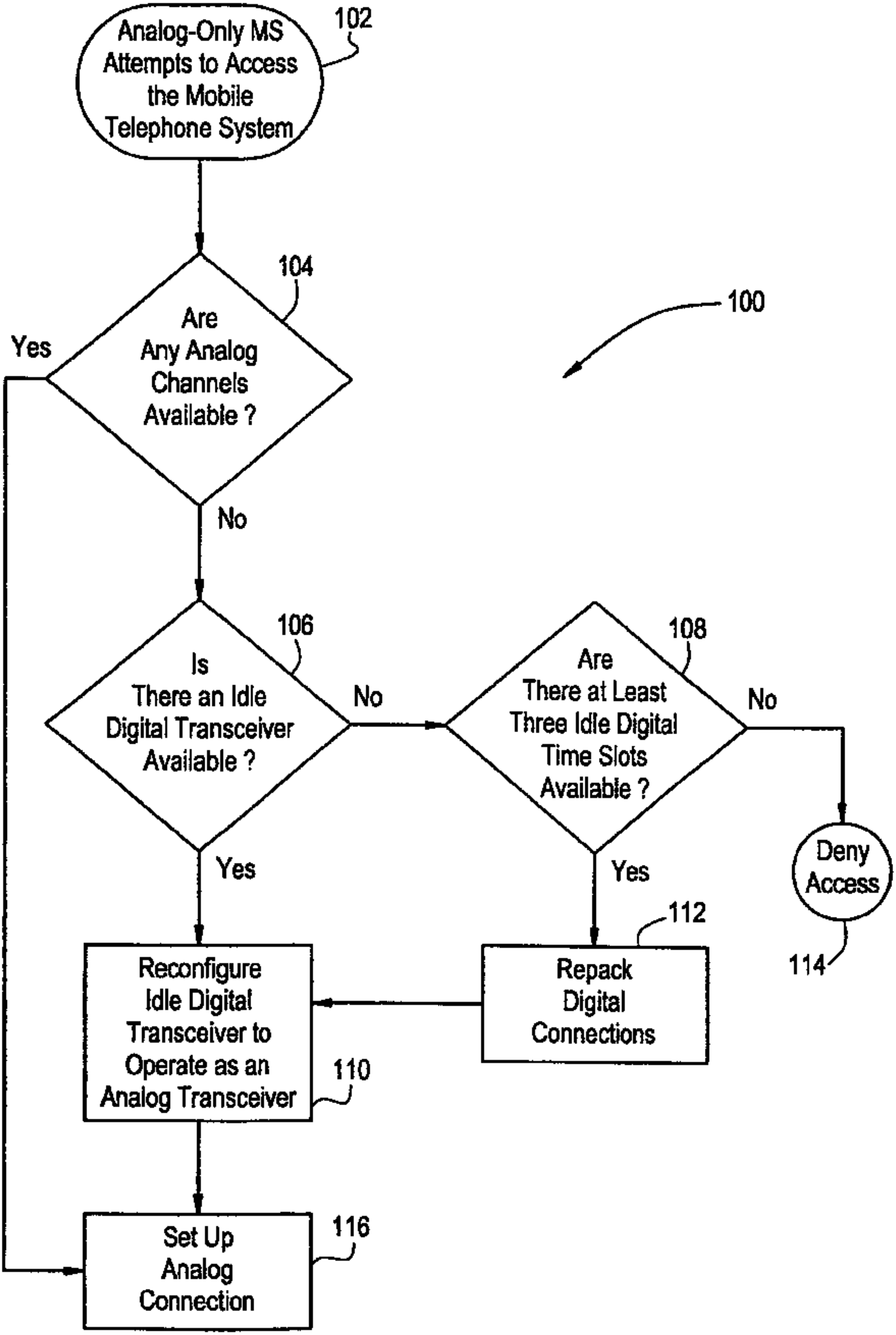
FIG. 5



Marks & Clerk

FIG. 6


14
50
54
20
MSC
Traffic
Estimator
56
53
55
52
52
55
User
Interface
60
BS
30
BS
30
32
32
40
40


Analog-Only MS Attempts to Access the Mobile Telephone System
102
Are Any Analog Channels Available ?
104
100
Yes
No
Is There an Idle Digital Transceiver Available ?
106
No
Are There at Least Three Idle Digital Time Slots Available ?
108
No
Yes
Yes
Deny Access
114
Repack Digital Connections
112
Reconfigure Idle Digital Transceiver to Operate as an Analog Transceiver
110
Set Up Analog Connection
116