(54) Title: METHODS, DEVICES AND SYSTEMS RELATING TO RESELECTING CELLS IN A CELLULAR WIRELESS
COMMUNICATIONS SYSTEM
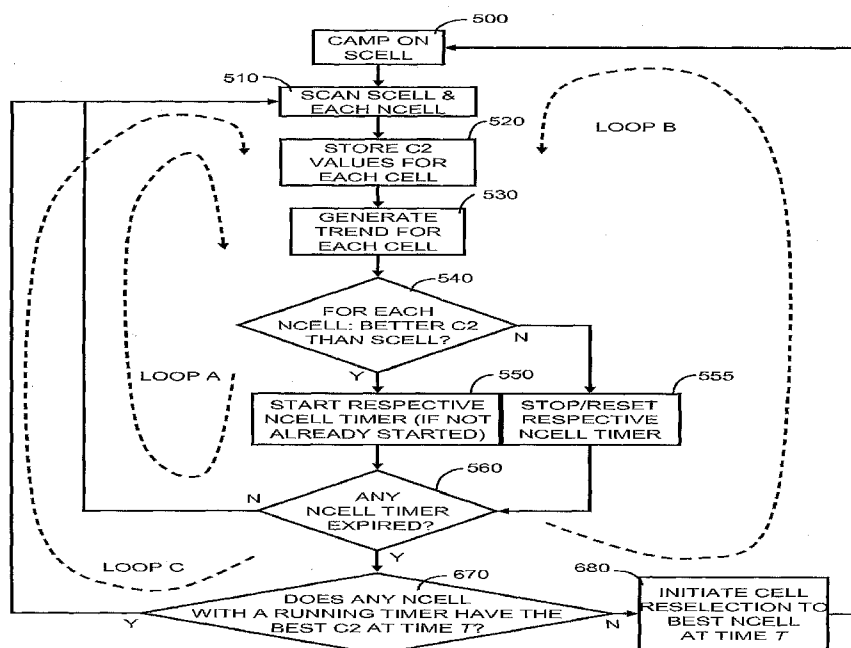
(57) Abstract: Signals of different cells in a cellular wireless communications system are observed during associated intervals to
predict a signal behavior in future. A target cell is selected by observing over time signal characteristics of potential target cells.
Thereafter a target cell is selected by using the observed characteristics to predict which potential target cell will in future satisfy
certain criteria.

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METHODS, DEVICES AND SYSTEMS RELATING TO RESELECTING CELLS IN A CELLULAR WIRELESS COMMUNICATIONS SYSTEM

BACKGROUND

Field

[0001]   The present invention relates generally to methods, devices and systems for reselecting and then handing over a mobile communications device from a first cell to a second cell in a cellular wireless communications system. More particularly, although not exclusively, aspects and embodiments of the invention relate to criteria for selecting a second cell while a mobile station is 'camped' on, or otherwise interacting with and/or controlled by, a first cell. Particular aspects and embodiments of the present invention are well suited for use in a cellular wireless communications system which supports packet switched communications, for example according to the General Packet Radio Service (GPRS) standard, but are not limited to such an application.

Background

[0002]   It is well known that cellular wireless communication systems generally comprise a number (often large) of radio transceivers, or base stations, that define service areas or cells. The schematic diagram in Figure 1 of the accompanying drawings, illustrates a system 100 comprising four base stations 120 defining respective cells 110. The cells typically overlap in order to ensure continuous coverage of service in the service areas. This is desirable for many reasons, not least because cellular systems are designed specifically to accommodate users as they move around within the system. In principle, mobile communications devices 130 interact with various base stations as the devices move through the respective cells 110 of the system 100.

[0003]   One of the goals of a cellular wireless communication system is to enable a mobile communications device, which will be referred to herein for convenience as a "mobile station", to remain connected to the system even when the user is moving through the system from one cell to another. Traditionally, the mobile station has been a so-called "mobile phone" or "cellular phone," although, with advances in technology, a mobile station may be any one or more of a wide range of devices from solely voice devices to solely data devices. A mobile station may be anything from a traditional

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radio pager or mobile phone, though faxes, personal data assistants (PDAs), and music players, to computers, or any combination of these. This list is, of course, far from exhaustive. Indeed, although the term "mobile station" is used herein, the term is also intended to encompass devices that may not be user-operated or even user-operable, for example the device could be a wireless 'data card' or the like, which is within another kind of apparatus.

[0004]   Early cellular systems were circuit switched systems. That it to say, for each call the system created a circuit that reserves a channel for the user for the duration of the call. This is an inefficient use of resources, especially for bursty data. As technology has advanced, newer cellular systems have moved away from circuit switching to packet switching in which bursts of data are sent only when needed. Consequently, cellular systems have become more suitable for the transmission of data, which tends to be transmitted in bursts rather than a continuous stream.

[0005]   As already mentioned each cell in a cellular system is defined and served by a base station. As a mobile station is moved from the service area defined by one cell into that defined by another, the system and the mobile station must break the connection with one base station and establish a connection with another base station whilst minimizing the connection loss between the mobile station and the system. This operation is sometimes known as a cell reselection, a handoff or a handover. For simplicity of description only herein, the term "reselection" will be used as a generic term to describe the operations involved with a mobile station or equivalent moving from operating with one base station to operating with another base station; and the reader should import an alternative term, such as "handover", "handoff" or the like, if the context so dictates. The term "camped on" is commonly used, and will be used hereinafter, to describe the base station with which, and respective cell in which, a mobile station is operating. That is, a cell reselection involves a mobile station moving from being camped on one cell to being camped on another cell.

[0006]   Typically, a cell reselection can be initiated either by the mobile station or by the cellular system. How reselection is initiated can depend on factors such as the kind of cellular system, its mode of operation and on the capabilities of a mobile station. In any event, reselection is typically initiated either as a result of a service degradation, which tends to lead to increased power consumption requirements, or there being an opportunity to improve the service, which would lead to reduced power consumption

requirements. Especially since many mobile stations operate from battery power, an opportunity to reduce power consumption, thereby improving power efficiency, is usually advantageous. Service degradation can result from factors such as increasing distance between a mobile station and a base station or natural or man-made obstructions such as hills or buildings respectively.

[0007]   One known kind of reselection operation requires a mobile station to monitor the signaling level and suitability of cells that neighbor the cell on which the mobile station is camped, which will be referred to hereinafter as the "serving cell", and compare the monitored service levels with the signaling level and suitability of the serving cell. Then, if the signaling level and suitability of a neighboring cell is deemed by the mobile station to be better than that of the serving cell, for at least a predefined period of time (say, five seconds), the mobile station initiates a reselection to the respective neighboring cell, which becomes the new serving cell. Such an operation is described in an ETSI Technical Specification document 145 008 v4.16.0, Digital Cellular telecommunications system (phase 2+); Radio subsystem link control (3GPP TS 45.008, version 4.16.0, release 4, section 6.6.2).

SUMMARY

[0008]   The present inventors have appreciated that, according to the prior art, unnecessary cell reselection operations can occur. Since cell reselection operations can consume a significant amount of power and/or result is a significant break in communications during an established voice call or other connection, the present inventors have appreciated that it would be advantageous to attempt to avoid unnecessary cell reselection operations. Aspects and embodiments of the invention are, therefore, aimed at avoiding unnecessary cell reselection operations.

[0009]   According to a first aspect of the present invention, there is provided a cell reselection method for selecting a target cell in a cellular wireless communications system, the method including monitoring over time signal characteristics of cells, including at least potential target cells, and selecting a target cell by using the monitored characteristics to predict which potential target cell will in future satisfy certain criteria.

[0010]   According to a second aspect of the present invention, there is provided a cellular wireless communications system comprising plural cells, including a serving cell and plural potential target cells, and a mobile station operable according to the

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cellular wireless communications system, the system comprising: a first process to monitor over time signal characteristics of cells, including at least potential target cells; and a second process to select a target cell by using the monitored characteristics to predict which potential target cell will in future satisfy certain criteria.

[0011]   According to a third aspect of the present invention, there is provided a cellular mobile communications apparatus adapted for operation in a cellular wireless communications system, the apparatus comprising: a receiver arranged to receive signals of cells, the signals having certain characteristics; and a processor arranged to operate processes for selecting a target cell, the processes comprising: a first process to monitor over time the signal characteristics of cells, including at least potential target cells; and a second process to select a target cell by using the monitored characteristics to predict which potential target cell will in future satisfy certain criteria.

[0012]   According to a fifth aspect of the present invention, there is provided a communication device in which characteristics of signals of different sources are monitored over respective time periods and a source is selected for communication when the monitored characteristic satisfies certain criteria at a time after its respective time period.

[0013]   According to a sixth aspect of the present invention, there is provided a transceiver in which signals of different communications nodes in a communications network are observed during associated intervals to predict a signal behavior in future, which is used to identify at least one node suitable for subsequent communication with the transceiver.

[0014]   The above and further features, aspects and embodiments of the invention are set forth with particularity in the appended claims and together with advantages thereof will become clearer from consideration of the following detailed description of embodiments of the invention given by way of example only with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]   In the drawings:

[0016]   Figure 1 is a schematic diagram showing a cellular wireless communications system;

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[0017]   Figure 2 is a high-level block diagram showing the main components in a cellular wireless communications system;

[0018]   Figure 3 is a graph showing a comparison of signaling parameter C2 levels for a serving cell and neighbor cells;

[0019]   Figure 4 is shows the same data as in Figure 3 and includes, in addition, straight best-fit lines;

[0020]   Figure 5 is a flow chart illustrating a cell reselection operation according to one exemplary embodiment of the present invention;

[0021]   Figure 6 is a flow chart illustrating a cell reselection operation according to a second exemplary embodiment of the present invention; and

[0022]   Figure 7 is a block diagram showing the main functional components of a typical mobile station that may be configured to operate in accord with embodiments of the present invention.

DETAILED DESCRIPTION

[0023]   Turning now to the schematic diagram in Figure 2 of the accompanying drawings, there is shown a high level block diagram of a typical wireless cellular communications system, for example as shown in Figure 1. For the purposes of illustration, the system includes only four base stations 120, which provide access to the system for mobile stations 130, for example mobile telephone handsets. Each base station 120 is controlled by a controller 210 and each controller 210 is connected to a core network 220 of the system, via an appropriate communications infrastructure. Each controller 210 can control one base station 120 but typically a controller controls more than one base station. The core network 220 in general contains the infrastructure, components and functionality for controlling the controllers 210; routing calls and connections of all kinds from and to mobile stations 130; routing calls and connections from mobile stations 130 to other systems and terminating equipment; and receiving calls and connections, from other systems and terminating equipment, which are intended for mobile stations. Examples of other terminating equipment are traditional telephone equipment 230, which are connected to via a PSTN 234 and PSTN gateway 238 of the core network 220, Internet servers 240, which are connected to via an Internet gateway 244 and the Internet 248, and other telecommunications systems or services (not shown), such as voicemail or corporate networks respectively.

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[0024]   There are various kinds of wireless cellular communications systems, which operate according to various different standards. Such systems and standards include, but are not limited to, GSM, GPRS and third generation standards such as UMTS and WCDMA. The diagram in Figure 2 is intended to be generic, and apply, at least functionally, to all such standards and systems.

[0025]   Particular embodiments of the present invention relate to cell reselection in a GPRS system. According to the GPRS terminology, a base station 120 is commonly referred to as a base transceiver station (BTS) and the controller 210 is commonly referred to as a base station controller (BSC). The combination of BTS and BSC is commonly referred to as the base station subsystem (BSS). Hereafter, while GPRS components will be referred in order to describe particular embodiments of the present invention, it will be appreciated that the principles taught apply equally to other kinds of wireless cellular communications systems, such as GSM and 3G.

[0026]   Turning now to Figure 3, the graph therein shows three curves, which illustrate exemplary signaling relationships between a mobile station, its serving cell (scell), on which the mobile station is camped, and two neighboring cells (ncell1 and –ncell2). The signaling relationships are characterized by a signaling parameter, C2, the value of which provides an indication of the strength of signals received by the mobile station from the respective cells. In general, a higher value of C2 indicates a stronger signal between the mobile station and the cell.

[0027]   It will be evident that alternative embodiments of the present invention may rely on deriving and/or monitoring different parameters and characteristics of systems and mobile stations, insofar as the parameters and characteristics relate in some way to the likely signaling performance or capability between the mobile station and a base station or similar.

[0028]   In known GPRS systems, a mobile station monitors the C2 values of all cells that are classed as neighbors of the serving cell. Each cell identifies which other cells are classed neighbors and a list of neighbors is communicated to a mobile station, by a new serving cell, during or soon after a cell reselection operation. The mobile station attempts to monitor the C2 values for the serving cell and all neighbor cells during the time the device is camped on the serving cell. A mobile station generates C2 values in a pre-defined way, for example as described in section 6.4 of the aforementioned ETSI document, by evaluating various characteristics of signals received from the neighbor

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cells; although the most important characteristic is typically signal power. Typically, a mobile station will scan for neighbor cell signals periodically, for example every second, or as otherwise defined by a control program of the mobile station, in order to monitor the C2 levels.

[0029]   Referring to the curves in the graph in Figure 3, it is shown that the C2 value of scell fluctuates between about 30 and 33 for around six seconds and then decreases over the remaining four seconds to about 27.5. This may be as a result of the mobile station moving away from the scell BTS and towards the ncell1 BTS. At around four seconds, the C2 value for ncell1 becomes higher than the C2 value of scell. The C2 value of ncell1 increases steadily up until about nine seconds and then begins to drop. By seven seconds, the C2 value for ncell2 also becomes higher than the C2 value of scell and remains higher for the remaining period shown. However, the C2 value for ncell2 does not exceed the C2 value of ncell1. In principle, it would appear to make sense for the mobile station to select ncell1 as a new serving cell in order to improve power-efficiency. In practice, this is exactly what happens according to prior art reselection operations. Specifically, according to the prior art, as soon as the mobile station detects that the C2 value of ncell1 is higher than the C2 value of scell (which, according to the graph, is when four seconds have lapsed), the mobile station starts a timer running. Then, if, after the timer expires (for example after another five seconds), the situation remains the same, at around nine seconds, a reselection to ncell1 is initiated by the mobile station.

[0030]   A cell reselection operation, by its nature, can cause a significant disruption to communications. This is at least in part because, according to the GPRS standard, as soon as a mobile station reselects to a new cell, the mobile station can spend as long as eight seconds reading broadcast information before camping onto the new cell.

[0031]   The present inventors have appreciated that it can be inefficient to initiate cell reselection to the first neighbor cell that appears to have an improved C2 value. The graph in Figure 4 includes the same C2 curves as in Figure 3 and, in addition, a trend line is shown for each curve. The trend lines have been calculated using the C2 data and have been projected into the future, up until 15 seconds. The trend line for scell clearly shows a steady decline in C2 power. In addition, the trend lines for ncell1 and ncell2 show a steady increase in respective C2 powers. However, significantly, the trend lines provide a clear indication that the C2 power of ncell2 is likely to increase

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above that of ncell1 soon after nine seconds. If this turns out to be what happens in practice then a cell reselection at nine seconds, which would occur according to the prior art, from scell to ncell1, would be followed soon after (probably about 5-7 seconds later) by another cell reselection operation, from ncell1 to ncell2. In other words, the trend lines indicate that a cell reselection operation at nine seconds is unnecessary.

[0032]   Preferred embodiments of the present invention use historic C2 data or the like, as shown in Figure 4, to predict which neighbor cell is likely to be the best one to move to, which may not be the one that would otherwise be selected using known selection criteria.

[0033]   An embodiment of the present invention will now be described in detail, wherein, in a GPRS system, a cell reselection operation uses historic C2 values to predict and then select the most appropriate neighbor cell to move to. It will, however, be appreciated that the principles are equally applicable in GPRS systems and in other kinds of wireless cellular communications systems, wherein the reselection may be initiated by the BSS (or equivalent), the core network or by a mobile station.

[0034]   A cell reselection operation according to an exemplary embodiment of the present invention will now be described in more detail with reference to the flow diagram in Figure 5. In a first step 500, a mobile station becomes camped on a new serving cell (scell) and acquires its necessary upstream signaling information and neighbor cell information from the respective BTS, in a known way. In a next step 510, the mobile station scans for signals from the serving cell and the respective neighboring cells and derives the respective C2 values. In a next step 520, the mobile station stores C2 values associated with successfully scanned signals. In this example, at least the ten most recent values of C2 are stored for each neighbor cell. Then, in step 530, the mobile station uses the stored C2 values to generate a trend of the C2 values, as will be considered in more detail below. In a next step 540, the mobile station determines whether a C2 value of any neighboring cell is better than the C2 value of the serving cell. If the result of the determination is positive for any neighboring cell (that is, the neighboring cell has a higher C2 value than the serving cell), then, in a next step 550, the mobile station starts a timer, which the mobile station associates with the respective neighbor cell. If a respective timer is already running then no additional action occurs and the timer is left running. If, on the other hand, the result of the determination is negative for any particular neighboring cell (that is, the neighboring cell has a lower C2

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value than the serving cell), then, in a step 555, any respective running timer is stopped and reset. If no timer is running, then no action occurs.

[0035]   In other words, according to the present exemplary embodiment, for each scan operation, a timer is started (or permitted to continue) for any neighboring cell which has a better C2 value than the source cell. A timer runs until a pre-determined expiry time, unless, before or on expiry, the C2 value drops below the C2 value of the source cell, in which case the timer is stopped and reset (or otherwise cancelled). Obviously, in the example provided, a timer is not started for a neighboring cell unless its C2 becomes better than the C2 value of the source cell.

[0036]   Next, in a step 560, the mobile station determines whether any timer has expired. In this example, the timers are set to expire after five seconds. In other examples, a different expiry time may be selected. In the step 560, if no timer has expired, then the process returns to the step 510, whereat the mobile station again scans for signals from the source cell and neighbor cells, and the process repeats.

[0037]   If, however, in the step 560, the mobile station establishes that a timer has expired, in a step 570, the mobile station predicts future C2 values for neighbor cells, in this case five seconds in the future, and determines whether the neighbor cell having the expired timer is predicted to have the best C2 value, and hence the best signaling capability, five seconds into the future. If the result of the test is positive, then the mobile station selects that neighboring cell as a target cell and, in a step 590, initiates a reselection operation to that cell. Of course, the future time could be chosen to be more or less than five seconds.

[0038]   If, on the other hand, the mobile station determines that the neighbor cell having the expired timer does not have the best predicted C2 value five seconds into the future, then, in a next step 580, the mobile station compares the predicted C2 values of all valid neighbor cells and selects, as the target cell, the neighbor cell that does have the best predicted C2 value at that future point in time. In this example, a neighbor cell is 'valid' for selection if, at step 580, it has a current C2 value higher than the C2 value of the serving cell. In this example, a neighbor cell that is valid for selection will also by definition have a timer running or also just expired. In other words, according to this criterion, a reselection operation can occur only to select a neighbor cell having a running or just expired timer.

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[0039]   In other examples, a criterion might be that a neighbor cell is valid for selection even if, at step 580, it does not have a C2 value higher than the serving cell C2 value. For instance, according to such examples, a neighbor cell might be selected as the target cell due to its having the fastest rising C2 value and, hence, the highest predicted C2 value at a selected future time, even if, at step 580, it does not have a current C2 value higher than the C2 value of the serving cell, and no respective timer running. Deciding which criterion to apply to which classes of neighbor cell are valid for selection is one of many system design considerations available for consideration.

[0040]   In a next step 590, the mobile station initiates a reselection operation, to reselect to and camp on the selected target cell. The process then repeats from step 500.

[0041]   The cell reselection operation will now be tested against the C2 level information shown in the graph in Figure 4. In this example, both neighbor cells have a C2 value higher than the C2 value of the serving cell, so would both be valid for selection under either preceding exemplary criterion.

[0042]   As indicated in the graph in Figure 5, the process has two main loops, wherein operation in a particular loop is dictated by the test in step 560. For example, until such time as a timer expires, the process operates in a loop A and, when a timer expires, operation moves to a loop B (for at least one iteration). With reference to the graph in Figure 4, a first timer, which is associated with ncell1, is started, due to the test in step 540, at around four seconds, when the C2 value of ncell1 becomes higher than the C2 level of the serving cell, scell. Then, at seven seconds, the C2 level of ncell2 becomes higher than the C2 level of the serving cell, and a second timer is started. Operation of the process remains in loop A until about nine seconds, when the five-second timer associated with ncell1 expires. At nine seconds, the test in step 560 becomes positive and loop B comes into operation. In step 570, the process predicts future C2 values and finds that the C2 value for ncell1 is not predicted to be the best C2 value at time T1, at around 14 seconds on the graph, which is an additional five seconds after the timer has expired. It is apparent from the graph that, at 14 seconds, the C2 value of ncell2 is just higher than the C2 value of ncell1. This can be confirmed by substituting 14 seconds (as the y value), into the line equations shown on the graph, which gives a predicted C2 value of ncell1 as 40.2 and a predicted C2 value of ncell2 as 40.4. Additionally, it is clear from the graph that, after 14 seconds, the C2 value of ncell2 is predicted to increase at a steeper slope than the C2 value of ncell1. Thus, in step 580, the process

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determines that ncell2 is predicted to have the best C2 value at 14 seconds and selects ncell2 as the target cell. As a result, in step 590, the mobile station initiates reselection to ncell2, at nine seconds, while the second timer is still running.

[0043]   Thus, according to the exemplary process of Figure 5 and the data in the graph in Figure 4, cell reselection occurs at around nine seconds, to reselect from the current serving cell to the neighboring cell ncell2. This avoids an undesirable cell reselection operation, to neighboring cell ncell1, which would otherwise occur.

[0044]   A second, alternative exemplary embodiment of the present invention will now be described with reference to the flow diagram in Figure 6. As shown, steps 500 to 560 of the graph are essentially the same as the same-numbered steps of the graph in Figure 5, and will not be described again. However, after step 560, the process is different. In particular, when the test in step 560 becomes positive, as a result of a timer expiring, a next step 670 predicts C2 values, at a specified future time, for each neighbor cell that is associated with a running timer and for each neighbor cell that is associated with an expired timer (but not for a neighbor cell associated with a stopped or reset timer). Then, step 670 determines if any neighbor cell, for which a timer is still running, has the best predicted C2 value at the specified future time. If the result is positive, the process returns to step 510. In other words, the process holds-off from reselecting to a new serving cell while any neighbor cell, having a running timer, is predicted to have the best C2 value at the specified future time.

[0045]   If, in the alternative case, step 670 determines that a neighbor cell associated with an expired timer has the best predicted C2 value at the selected future time, then, in step 680, reselection is initiated to that neighbor cell. In this example, in essence, reselection is held-off if a neighbor cell, for which a timer is still running after another timer has expired, is projected to have the best C2 value at the future time.

[0046]   As with the first exemplary embodiment, neighbor cells may be valid for selection according to different criteria. For example, a neighbor cell may be valid for selection only if its respective C2 value, at step 670, is higher than the C2 value of the serving cell. Alternatively, a neighbor cell may be deemed valid for selection irrespective of the respective C2 level at step 670. In the latter case, all neighbor cells would be potential candidates for reselection on the basis of projected future C2 level.

[0047]   A cell reselection operation according to the second exemplary embodiment will now be tested against the C2 level information shown in the graph in Figure 4. As

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before, both neighbor cells have a C2 value higher than the C2 value of the serving cell, so would both be valid for selection under either preceding exemplary criterion.

[0048]   As indicated in the graph in Figure 6, the process has three main loops, wherein operation in a particular loop is dictated by the test in step 560 and the test in step 670. For example, until such time as a timer expires, the process operates in a loop A and, when a timer expires, operation moves to a loop B or a loop C. With reference to the graph in Figure 4, a first timer, which is associated with ncell1, is started, due to the test in step 540, at around four seconds, when the C2 value of ncell1 becomes higher than the C2 level of the serving cell, scell. Then, at seven seconds, the C2 level of ncell2 becomes higher than the C2 level of the serving cell, and a second timer is started. Operation of the process remains in loop A until about nine seconds, when the five-second timer associated with ncell1 expires. At nine seconds, the test in step 560 becomes positive. Then, in step 670, the process determines that the best projected future C2 value, at a time T1, belongs to neighbor cell ncell2. As neighbor cell ncell2 still has an associated timer running, the process enters loop C, and iterates therein until 12 seconds have elapsed, at which point the second timer expires. At this point, step 670 determines that no other timers are running and that ncell2 has the best predicted future C2 value at a time T2, which is five seconds later, at 17 seconds. Accordingly, loop B is selected and step 680 initiates a reselection operation to ncell2 at around 12 seconds. In other words, the reselection operation is held-off for a further three seconds after a corresponding reselection operation of the first exemplary embodiment would have occurred.

[0049]   Thus, according to the exemplary process of Figure 6 and the data in the graph in Figure 4, cell reselection occurs at around 12 seconds, to reselect from the current serving cell to the neighboring cell ncell2. This, again, avoids an undesirable cell reselection operation, to neighboring cell ncell1, which would otherwise occur.

[0050]   There are a number of parameters in the foregoing process that can be varied to meet different requirements. For example, the number of historic C2 values that is used to plot trends can be increased or reduced, depending upon how sensitive the prediction needs to be to more recent C2 values. In addition, timers may be set to expire before or after five seconds, where a longer time could increase the accuracy of the prediction but risk delaying reselections for too long. Furthermore, the predicted C2 values might be predicted for before or after an additional five seconds, where a longer time would tend

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to be less accurate but a shorter time might lead to an increased number of unnecessary or undesirable reselection operations. All such parameters can be varied individually or collectively according to experimentation or system modeling.

[0051]   Considering, for example, step 530 in more detail, one way of generating a trend is to take the stored, historic C2 values and construct a straight line of best fit for each neighbor cell, as illustrated in the graph in Figure 4. Then, for each best fit line, the line is projected to a particular point in time in the future and used to predict a C2 value at the particular time. One way of predicting future C2 values will now be described using known linear regression techniques, thereby avoiding having to construct a graph as such.

[0052]   If a set of data is expected to have a linear correlation, which is an assumption applied to the C2 data in the present exemplary embodiment over the period of time selected, then it is not necessary to plot actual data points on a graph in order to determine the constants m (slope) and b (y-intercept) of the straight line equation $y = mx + b$. Instead, a statistical treatment known as linear regression can be applied to a series of data points to determine these constants.

[0053]   In particular, given a set of data (x_i, y_i) with n data points, the slope m, y-intercept b and a correlation coefficient, r, can be determined using the following equations:

$$m = \frac{n \sum (xy) - \sum x \sum y}{n \sum (x^2) - (\sum x)^2}$$

Equation 1

$$b = \frac{\sum y - m \sum x}{n}$$

Equation 2

$$r = \frac{n \sum (xy) - \sum x \sum y}{\sqrt{\left[n \sum (x^2) - (\sum x)^2 \right] \left[n \sum (y^2) - (\sum y)^2 \right]}}$$

Equation 3

[0054]   It should be noted that the limits of the summation, which are i to n, and the summation indices on x and y have been omitted, for reasons of clarity only.

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[0055]   In the present example, the ten stored C2 values for each neighboring cell are treated as y values and the respective scan times are treated as x values, which are used in the foregoing equations to derive values of m and b for each neighboring cell. Then, the predicted C2 value, y_T, for each neighboring cell at a particular future time T1, is generated by substituting T1 as the value of x into the equation $y = mx + b$ - where m and b are now known - and calculating the value of y. Thus, the predicted future value of C2 at time T1 for each neighboring cell can be generated, in order to facilitate a cell reselection to a neighbor cell that has the best predicted C2 value at a pre-determined future point in time.

[0056]   It is anticipated that other techniques could be used to predict future C2 values, for example employing a weighted straight line fitting, where later C2 values are weighted to be more influential in the trend than earlier values, or even a curve fitting (such as logarithmic, exponential, power or polynomial) algorithm. Clearly such techniques would be more processor intensive on a mobile terminal, and it is expected that simple straight-line fitting would be appropriate for most situations.

[0057]   The functional components of an exemplary mobile station 700 are illustrated in the block diagram in Figure 7. The device in this example might be a mobile telephone handset. Embodiments of the present invention can be enacted by such a device. The device generally comprises an embedded processor 705, for controlling the overall operation of the device 700. The processor 705 has associated memory, including ROM 720, RAM 715 and non-volatile memory 720, for example for storing a control program of the device, application programs and/or an address book. Some or all of the memory might be separate from the processor. The device includes an antenna 725, which is connected to transmit/receive circuit 730, which communicates signals to and from the processor 705 via a modem 735. The device is arranged to interact with a base station according to several protocols, for example GSM, GPRS and/or 3G, which are supported by respective application programs, which are typically stored in a protocol module area 740 of non-volatile memory of the device. An interface module 740 facilitates communications with a keypad 745, a subscriber identity module (SIM) 750 and a display screen 755 of the device. An audio module 760 supports a speaker 765 and a microphone 770. A graphics processor 775 is included for processing graphics, for example for display on the display screen 755 and, in this example, the device includes a camera module 790.

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[0058]   A device of the kind shown in Figure 7 is generally known in the prior art and it is typically an application program that needs to be arranged to control the device to operate in accord with embodiments of the present invention.   For example, in embodiments of the present invention that operate in a GPRS cellular wireless communications system, a GPRS application program is arranged to operate generally in accord with one of the flow diagrams of Figure 4 or Figure 5, at least insofar as a cell reselection operation is concerned.   In any event, at least a subset of the main components of the device in Figure 7, as shown within the dotted line 785, may be provided as a single chip device, or as plural chips or components, which can be installed in a mobile station to operate according to embodiments of the present invention.

[0059]   Having thus described the invention by reference to the embodiments shown in the drawings it is to be well understood that the embodiments in question are by way of example only and that modifications and variations such as will occur to those possessed of appropriate knowledge and skills may be made without departure from the spirit and scope of the invention as set forth in the appended claims and equivalents thereof.

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CLAIMS

1.   A cell reselection method for selecting a target cell in a cellular wireless communications system, the method including observing over time signal characteristics of cells, including at least potential target cells, and selecting a target cell by using the observed characteristics to predict which potential target cell will in future satisfy certain criteria.

2.   The method according to claim 1, including observing a first indicator, which is indicative of the signaling level of a serving cell of the system, and observing second indicators, each one being indicative of a signaling level of one of plural potential target cells.

3.   The method according to claim 2, including selecting a target cell, from the potential target cells, by using the observed indicators to predict which potential target cell is most likely to provide the best signaling level at a first time in the future and then selecting that target cell for reselection.

4.   The method according to claim 3, wherein selecting a target cell occurs at a second time, which is before the first time and after a third time.

5.   The method according to claim 4, wherein the third time is when an observed second indicator indicates that the signaling level of a respective potential target cell is better than the signaling level of the serving cell.

6.   The method according to claim 5, including starting a timer at the third time, and associating that timer with the said respective potential target cell.

7.   The method according to claim 6, wherein the timer has a predetermined duration and the expiry of the timer coincides with the second time.

8.   The method according to claim 6, including starting a timer whenever an observed second indicator indicates that the signaling level of a potential target cell is better than

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the signaling level of the serving cell, and associating the timer with the respective potential target cell.

9. The method according to claim 8, wherein each timer has a predetermined duration and expiry of a timer, in combination with certain criteria being satisfied, coincides with the second time.

10. The method according to claim 9, wherein the certain criteria includes there being no other timers running.

11. The method according to claim 9, wherein the certain criteria includes a prediction that the potential target cell most likely to provide the best signaling level, at the first time in the future, is not associated with a running timer.

12. The method according to claim 9, wherein the certain criteria includes a prediction that the potential target cell most likely to provide the best signaling level, at the first time in the future, is associated with an expired timer.

13. The method according to claim 9, wherein the first time is a predetermined period after the second time.

14. The method according to claim 9, wherein the signaling level of the selected target cell is greater than the signaling level of the serving cell at the second time.

15. The method according to claim 9, wherein, the signaling level of the selected target cell can be less than the signaling level of another potential target cell at the second time.

16. The method according to claim 9, wherein, the signaling level of the selected target cell can be less than the signaling level of the current serving cell at the second time.

17. The method according to claim 3, wherein selecting the target cell, selects the target cell on the basis of a predicted future signaling level, even if the signaling level of that

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cell is worse than the signaling level of another potential target cell, and/or a current serving cell, at the time of making the selection.

18. The method according to claim 1, including storing plural historic values of observed characteristics for each potential target cell.

19. The method according to claim 18, including predicting which potential target cell is likely to provide the best signaling level in the future by using at least two stored historic values for each respective potential target cell.

20. The method according to claim 19, wherein the stored values for each potential target cell are used to generate a trend, which is projected into the future, in order to predict which potential target cell is likely to have the best signaling level.

21. The method according to claim 20, wherein the future signaling levels are predicted using the equation $y = mx + c$, where y represents a predicted signaling level at a time in the future, m represents the gradient of the trend line, x represents the point in the future, relative to a selected earlier reference time, and c represents a historic signaling level, which is determined by the trend line to be the signaling level at the selected reference time.

22. The method according to claim 1, wherein the cellular wireless communications network supports packet switched communications.

23. The method according to claim 22, wherein the cellular wireless communications network supports GPRS communications.

24. The method according to claim 2, wherein the signaling indicator is a C2 parameter.

25. The method according to claim 1, wherein the cellular wireless communications network supports circuit switched communications.

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26. The method according to claim 25, wherein the cellular wireless communications network supports GSM communications.

27. The method according to claim 1, wherein a mobile station of the system initiates cell reselection.

28. The method according to claim 1, wherein a cellular wireless communications network of the system initiates cell reselection.

29. A cellular wireless communications system comprising plural cells, including a serving cell and plural potential target cells, and a mobile station operable according to the cellular wireless communications system, the system comprising:

        a first process to observe over time signal characteristics of cells, including at least potential target cells; and

        a second process to select a target cell by using the observed characteristics to predict which potential target cell will in future satisfy certain criteria.

30. The system according to claim 29, wherein the first process is arranged to observe a first signaling indicator, indicative of a signaling level of the serving cell, and second signaling indicators, each one being indicative of the communications signaling capability of one of the plural potential target cells and the second process is arranged to select a target cell, from the potential target cells, by using the observed indicators to predict which potential target cell is most likely to provide the best signaling level at a first time in the future and then selecting that target cell.

31. A cellular mobile communications apparatus adapted for operation in a cellular wireless communications system, the apparatus comprising:

        a receiver arranged to receive cell signals, the signals having certain characteristics; and

        a processor arranged to operate processes for selecting a target cell, the processes comprising:

                a first process to observe over time the signal characteristics of cells, including at least potential target cells; and

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a second process to select a target cell by using the observed characteristics to predict which potential target cell will in future satisfy certain criteria.

32. The apparatus according to claim 31, wherein the first process is arranged to observe a first signaling indicator, indicative of a signaling level of the serving cell, and second signaling indicators, each one being indicative of the communications signaling capability of one of the plural potential target cells, and the second process is arranged to select a target cell, from the potential target cells, by using the observed indicators to predict which potential target cell is likely to provide the best signaling level at a first time in the future and then selecting that target cell.

33. A programmed processing arrangement arranged to operate in accord with the method of claim 1.

34. A mobile communications apparatus arranged to operate in accord with the method of claim 1.

35. A communication device in which characteristics of signals of different sources are monitored over respective time periods and a source is selected for communication when the monitored characteristic satisfies certain criteria at a time after its respective time period.

36. A transceiver in which signals of different communications nodes in a communications network are observed during associated intervals to predict a signal behavior in future, which is used to identify at least one node suitable for subsequent communication with the transceiver.
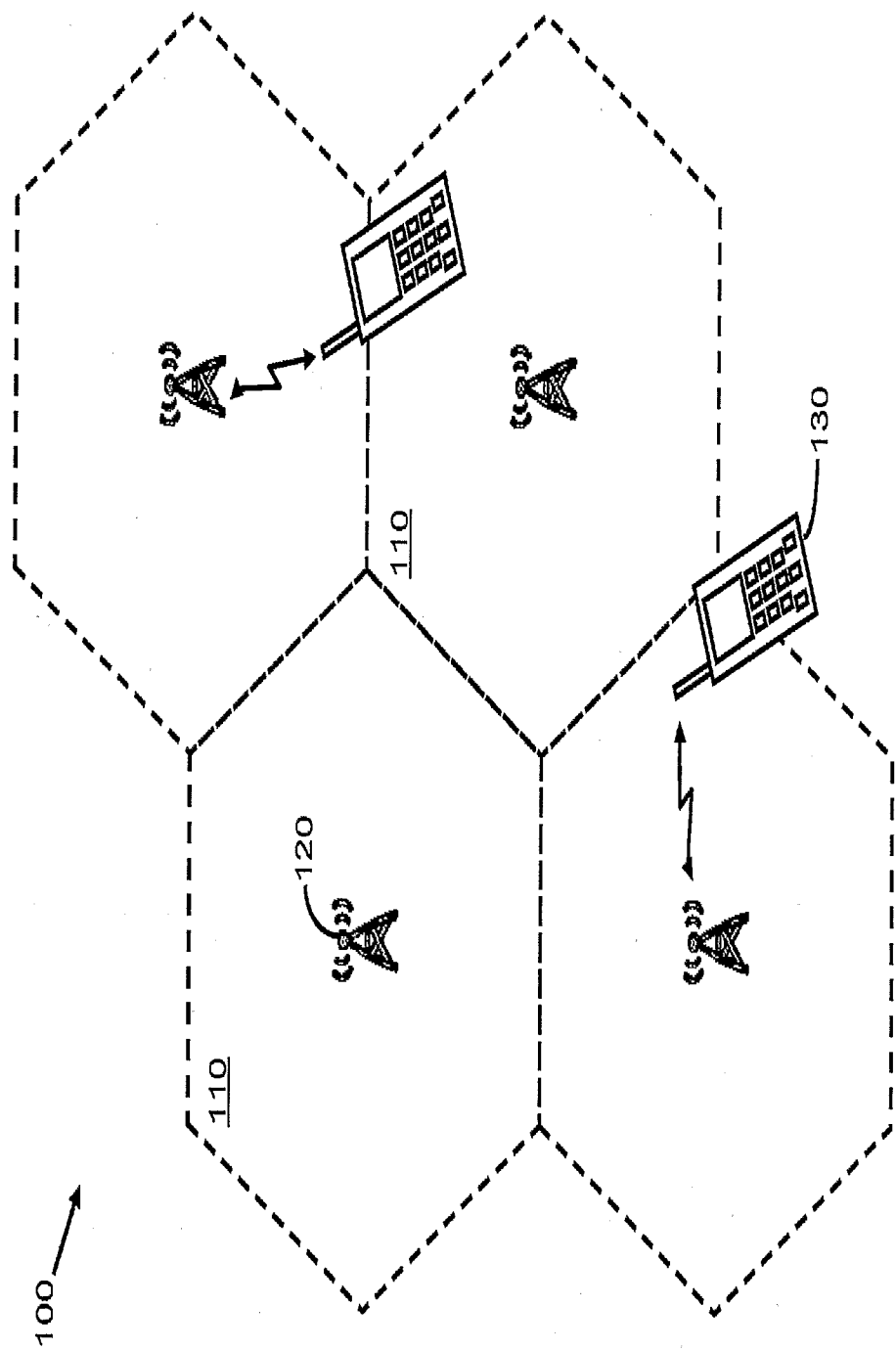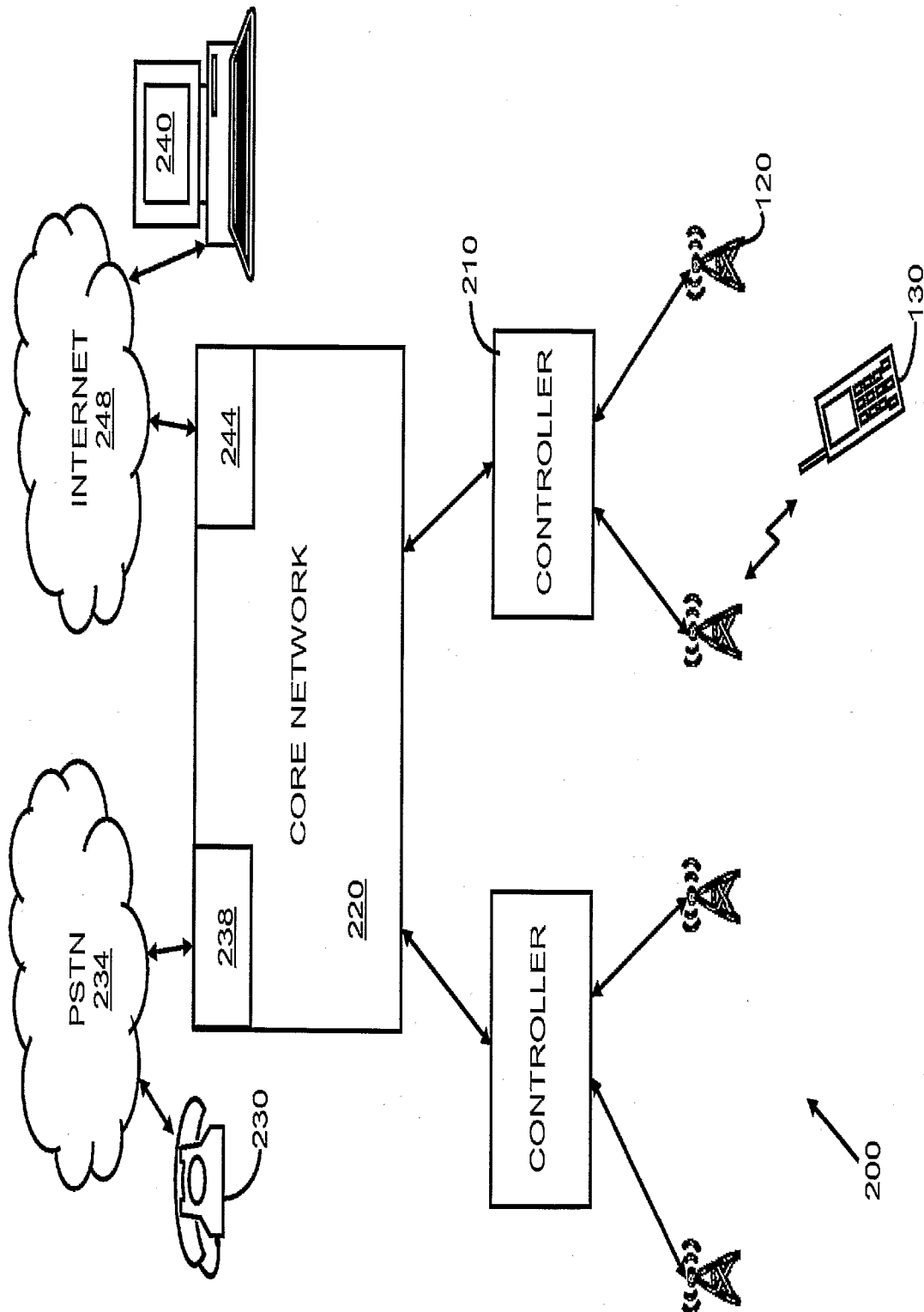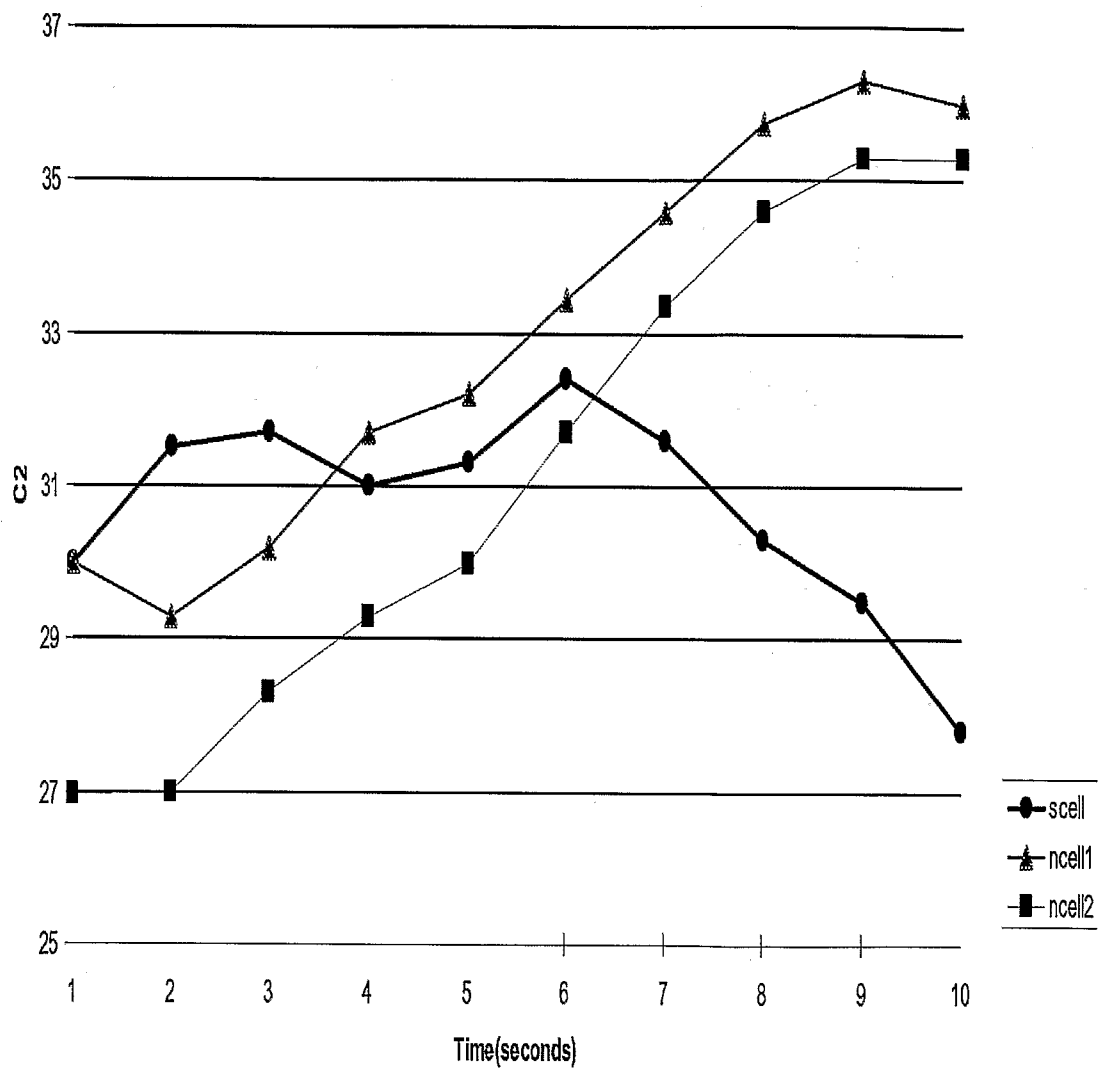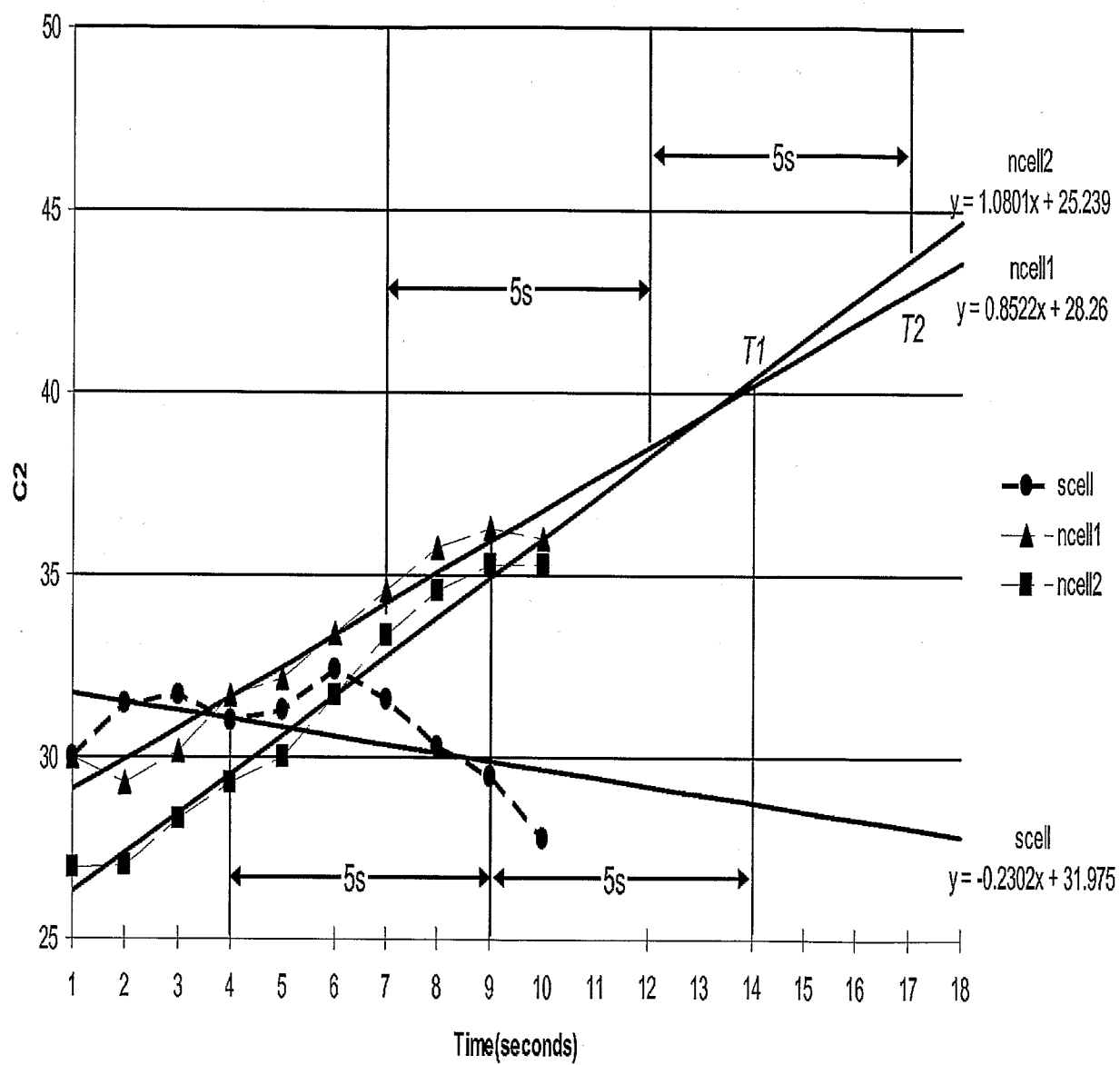
Figure 1

Figure 2

Figure 3

Figure 4
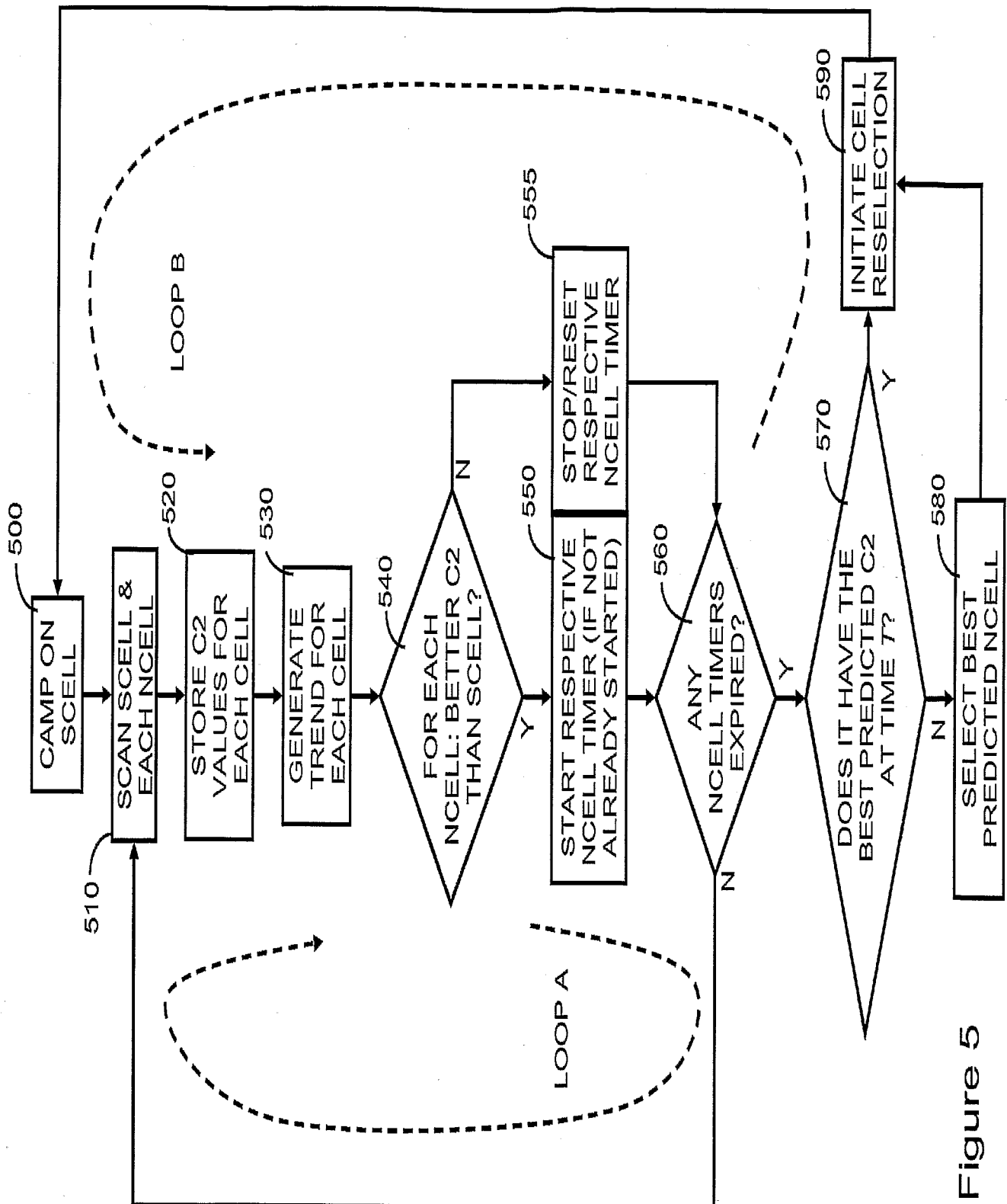
Figure 5
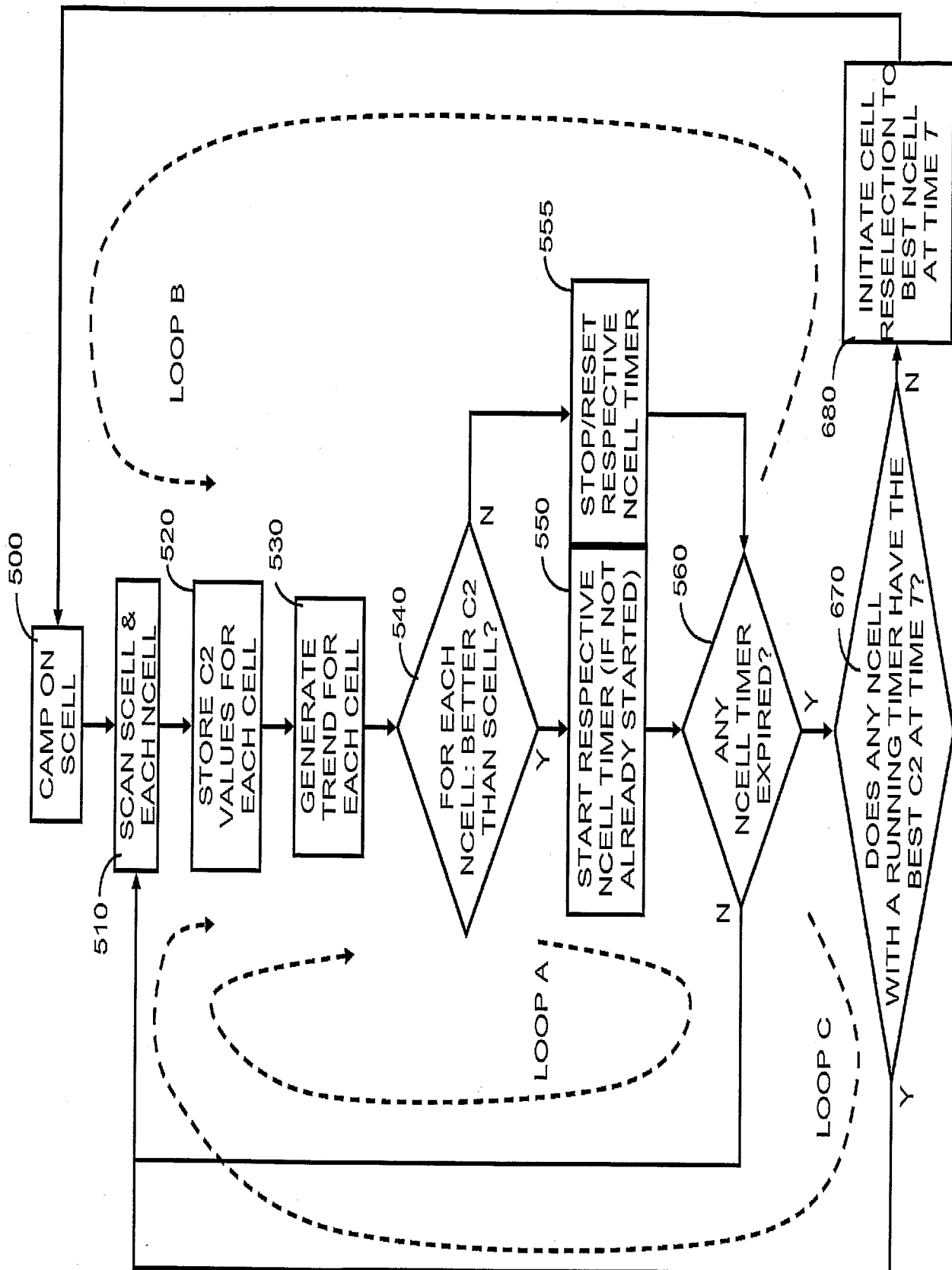
Figure 6
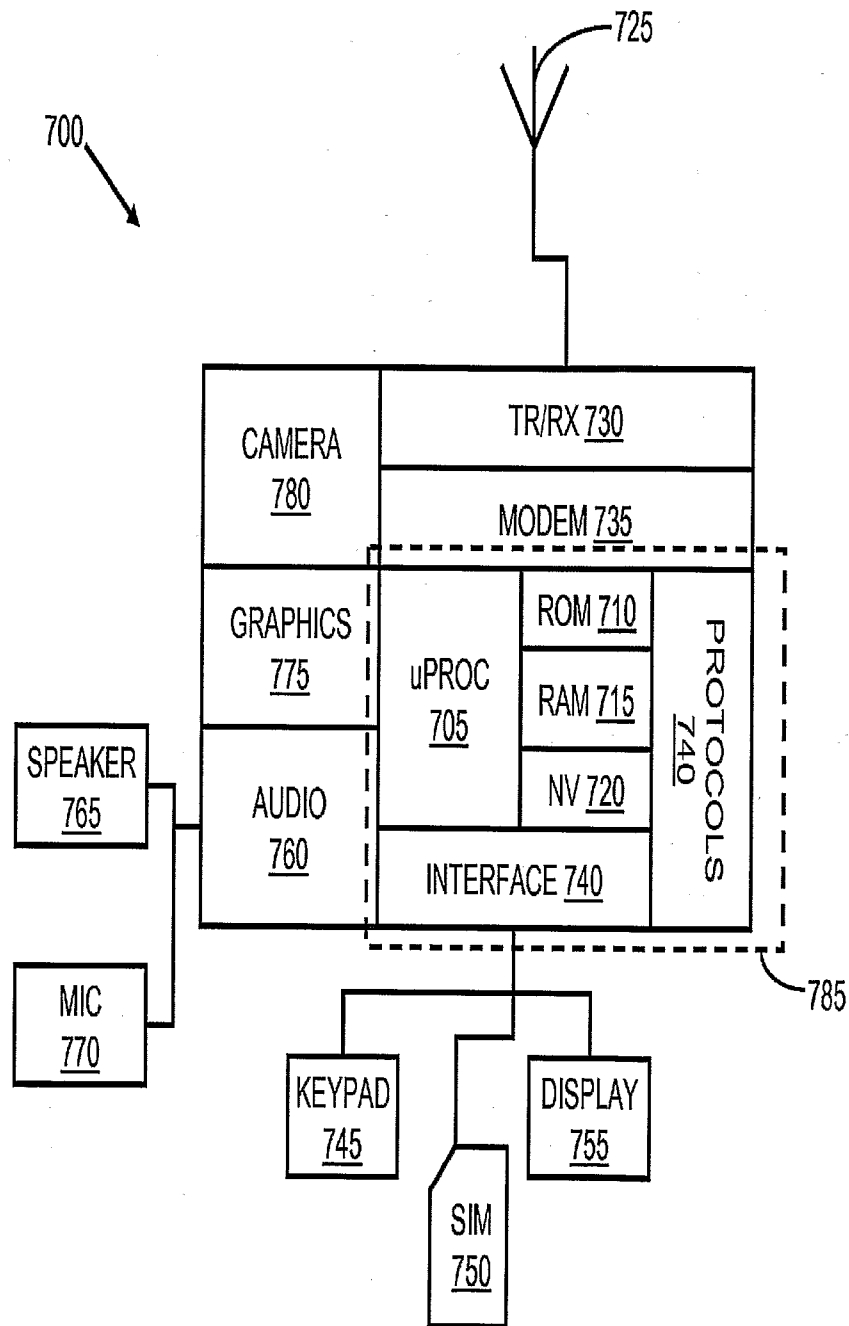
Figure 7

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04Q7/32
ADD. H04Q7/38

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04Q

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 052 598 A (RUDRAPATNA ASHOK N [US] ET AL) 18 April 2000 (2000-04-18) abstract; figures 1-3 column 2, line 31 - line 39 column 3, line 12 - column 5, line 20	1-36
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A	WO 2004/073322 A (MOTOROLA INC [US]; PECEN MARK [US]; ANDERSEN NIELS PETER SKOV [DK]; HO) 26 August 2004 (2004-08-26) the whole document	1-36

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 May 2007	01/06/2007

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No

PCT/US2007/061165

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