

METHOD OF HANDING OVER CALLS BETWEEN TWO CELLS OF A
DIGITAL CELLULAR MOBILE RADIO NETWORK.

The field of the invention is that of digital communications in cellular mobile radio systems. The invention applies in particular to digital transmission systems (voice, data, signalling, ...) employing the time division multiple access (TDMA) technique, for example GSM (Global System for Mobile Communications) networks.

To be more precise, the invention concerns handing over calls between two adjoining cells of a digital cellular mobile radio network.

A cellular mobile radio network, for example a GSM or DCS network, comprises a plurality of cells each of which is controlled by a base station. Conventionally, when a mobile station passes from one cell to another, a handover mechanism assures that the mobile station changes from one base station handling the call to another.

Handover is relatively complex. From the point of view of the mobile station, it is as if a new call were initiated in the new cell with re-allocated call parameters (frequencies used, frequency hopping laws, time slots,...). The network (the base stations and the devices upstream of the base stations) manages the continuity of the call with the remote terminal.

That prior art solution has the major drawback of causing a temporary loss of information (generally a few frames) when a call is handed over from a first cell to a second cell, which generates a disagreeable noise audible to users.

What is more, it imposes many processing operations for each transfer, both in the network and in the mobile stations concerned (which must adopt the new call parameters).

What is more, that standard solution necessitates rigorous planning for allocating frequencies to each cell

of the network. To prevent interference two adjoining cells must not use the same frequencies.

Consideration is currently being given to using microcells, especially in an urban environment. Locating
5 base stations (or their antennas) below roof level allows frequencies to be re-used in a tighter pattern (the "range" of the base station remains localized and so co-channel interference is slight). The microcell solution is therefore more efficient in terms of spectrum and the
10 fact that the cells are smaller means that the capacity (expressed in Erlang/km²/MHz) can be increased relative to a conventional macrocell solution for a given spectrum.

That technique therefore solves the problem of traffic handling capacity. However, it imposes incessant
15 handovers, with all the problems listed above.

Further, so-called "umbrella" cells are needed. Unfortunately, these umbrella cells constitute an additional layer that adds to the complexity of the system. Planning and implementation of a system of the
20 above kind are very difficult.

An object of the invention is to alleviate the various drawbacks of the prior art.

To be more precise, one object of the present invention is to provide a method of handing over calls
25 between two cells of a digital cellular mobile radio network managing handover in a manner that is transparent or quasi-transparent to the user of the mobile station and to the mobile station itself in terms of the processing to be carried out.

30 A complementary object of the invention is to provide a method of the above kind assuring that a call is not interrupted when the associated mobile station changes cell.

One particular object of the invention is to provide
35 a method of the above kind improving frequency re-use.

Another object of the invention is to provide a method of the above kind which simplifies allocating

frequencies to the cells when the network is being configured.

Another object of the invention is to provide a method of the above kind that ensures a particular call
5 quality level (represented for example by the received power level or the signal to noise ratio and/or weighted by the carrier to interference ratio), and a particular grade of service (corresponding both to the level of blocking (all physical resources are used and/or unused
10 resources are unavailable, thus making new calls impossible) and to the call loss rate (directly related to handover problems)).

A further object of the invention is to provide a method of the above kind limiting the transmitted radio
15 power and consequently to provide a method of the above kind limiting the level of interference in the radio spectrum (radio frequencies) allocated to the network.

Another object of the invention is to provide a method of the above kind which improves call quality
20 during handover. This object embodies the following subsidiary objects:

- improving the reactivity of the system;
- combating the "ping-pong" effect (incessant handover when the mobile station is near the cell boundary).

25 The above objects, and others that become apparent below, are achieved in accordance with the invention by means of a method of handing over calls between two cells and of a digital cellular mobile radio network, the method being characterized in that each of said cells
30 comprises a set of at least two transmit-receive relay stations geographically distributed within said cell, each of said relay stations being able to transmit signals to mobile stations present in an area of said cell and to receive signals transmitted by said mobile
35 stations in said area, a set of at least one of said relay stations being selectively allocated to each call with a mobile station so that exchanges of signals with

said mobile station apply to only a part of the cell, and in that, when said mobile station passes from a first cell to a second cell, at least one parameter characterizing the call unambiguously is transmitted from
5 the base station controlling said first cell to the base station controlling said second cell to enable continuity of use of said at least one parameter when said mobile station passes from the first cell to the second cell.

The general principle of the invention is therefore
10 based on the geographical distribution of a plurality of relay stations within each cell of the network. At least two relay stations of the same cell can therefore be selected to transmit and receive signals to and from a mobile station on the uplink and downlink channels.

15 During handover, the base station managing the first cell transmits at least one parameter of the call which is held in the first cell to the base station that is to assume responsibility for the remainder of the call. In other words, the remainder of the call uses the same
20 parameter(s). The parameters include those which characterize a call unambiguously (channel, the cell the mobile station is leaving, time slot, set of frequencies, ...).

Thus, by using the invention the mobile station does
25 need to be involved (or significantly involved) in transmitting the parameter(s) and/or even to be kept up to date on the progress of this operation and/or to know that it is being handed over.

In other words, handover is essentially transparent
30 for the mobile station and therefore for its user.

In a preferred embodiment, each of said cells includes a concentration center processing signals received by each of said relay stations and delivering signals to be transmitted to each of said relay stations,
35 the concentration centers and/or the relay stations of a set of cells being synchronized.

The synchronization is advantageously effected at two levels:

- at bit level;
- at frame level.

5 In this preferred embodiment the base station is "distributed" in the sense that it includes the concentration center and the plurality of relay stations.

 In this preferred embodiment, optimal handover efficiency is guaranteed. This avoids loss of data
10 specific to the call to be transferred and retains the same parameter(s) throughout a call. Consequently, optimal call quality is maintained.

 In an advantageous embodiment, each call utilizes a frequency hopping technique.

15 Said cells advantageously utilize the same set of carrier frequencies common to all said cells and during a call initialization phase a single frequency hopping law is allocated to each call.

 In the present case, a slow (for example frame by
20 frame) frequency hopping law is advantageously used.

 Each cell preferably uses at least one (conventionally just one) broadcast control frequency that is specific to it to transmit signalling data.

 The broadcast control frequencies (conventionally
25 one per cell) or signalling frequencies conveying the information enabling mobile stations to log on are different from one cell to another. On the other hand, the channel on which the call information is transmitted remains the same from the start to the end of the call.
30 Clearly, this applies only when the mobile station remains within the coverage area of the network of cells with distributed base stations.

 Calls of two adjacent cells advantageously use the same set of frequencies, and

35 - the frequency hopping laws used by calls initiated within the same cell are mutually orthogonal;

- the frequency hopping laws used by calls initiated by two cells are determined independently of each other.

This prevents interference within the same cell. Also, because the frequency hopping laws used by calls initiated by two cells are independent, the level of interference between adjoining cells is reduced, even though the frequency re-use factor is equal to 1.

Said at least one parameter characterizing the call preferably comprises at least one of the indications selected from the group comprising:

- a time slot number and a frame number;
- an indication of the frequency hopping law;
- an indication of the server relay stations most recently found to be "optimum" stations;
- an indication of the cell which initiated the call.

The above parameters therefore provide the information needed for synchronization (a time slot number and a frame number), for the (call) frequency hopping laws to be used (frequency hopping law), for predicting the relay stations that will be used in the new cell (server relay stations most recently found to be optimum stations), for predicting the concentration center to be alerted and/or for retaining the channel and the identifier of the cell the mobile station is leaving and in which the call was initiated in order to be able to restore the channel to that cell at the end of the call (cell which initiated the call).

In GSM networks, for example, the indication of the frequency hopping law corresponds to an indication of the first frequency to be used in frequency hopping, an indication of the group of frequencies that the frequency hopping law is authorized to use and an indication of the hopping sequence generator.

Clearly, for characterizing the call unambiguously the invention is not limited to the indications in the above list.

Each cell advantageously executes a step of selecting the optimum relay stations in accordance with a predetermined selection criterion for each communicating mobile station. Allocating a set of relay stations to
5 said call in the second cell and the handover from said first cell to said second cell take account of this selection.

Accordingly, handover is not at cell level, in terms of geographical coverage, but only at the level of
10 regions of the cells corresponding to the activated relay stations.

This technique of selecting the optimum relay stations reduces the power used, enables re-use of the same frequencies from one cell to another and improves
15 call quality generally.

In an advantageous embodiment said selection criterion is based on analyzing at least one of the following items of information:

- the power received by said relay station for said
20 call;
- the signal to noise ratio for said call;
- the carrier to interference ratio for said call;
- a raw error rate or an error rate after decoding for said call;
- 25 - a frame loss rate for said call;
- a geographical position indication.

Note that the signal to noise ratio and the carrier to interference ratio are particularly beneficial selection criteria.

30 Clearly combining a plurality of the above indications yields an optimum selection of the optimum relay stations enabling the device (concentration center(s) and relay stations) to be constantly reactive (adapting to call circumstances).

35 For example, during an active call phase in which the call is set up the average received power level of each relay station can be weighted by the carrier to

interference ratio and/or the signal to noise ratio of the same relay station. Such weighting consists in using a weighting coefficient equal to 0 or 1 according to whether the carrier to interference ratio is below or
5 above a predetermined threshold for the call in question, for example. In particular, this means that the selection can be temporarily switched to a relay station other than those selected if an obstacle and/or a source of interference comes between the communicating mobile
10 station and one of the selected relay stations.

A geographical position indication from another system, for example the GPS system, can equally be taken into account, if appropriate.

In a preferred embodiment said analysis of at least
15 one of said items of information is effected on the basis of :

- an average of the values of at least one of said items of information measured over a predetermined time period during an active call phase;
- 20 - a single value of at least one of said items of information measured during a call initialization phase.

In the active call phase the predetermined averaging period corresponds to a fixed number of frames, for example.

25 Accordingly, in the active call phase the fact that the analysis is based on an average value means that the device (concentration center(s) and relay stations) need not react instantaneously. In other words, the measured data (for example the calculated average) is incorporated
30 in order to avoid unnecessary and untimely changes of relay station due to a localized fault, for example.

On the other hand, in the call initialization phase the device (concentration center(s) and relay stations) reacts very quickly (for example within one frame) and
35 therefore allows instantaneous preselection of the optimum relay stations.

In an advantageous embodiment said set of relay stations comprises a predetermined number n of the optimum relay stations according to said selection criterion.

5 The set of relay stations allocated is preferably updated periodically and/or if at least one parameter representative of call quality is below a predetermined threshold.

10 Note that the period for updating the information on the optimum relay stations must be kept relatively short (for example one or two seconds) so that an "emergency relocation" is triggered only occasionally. An emergency relocation corresponds to a new selection of the optimum relay stations when a problem with call quality is
15 detected between two consecutive periods.

During the call initialization phase each call is preferably allocated a single frequency hopping law that is specific to it and that it retains when it is handed over from said first cell to said second cell and said
20 frequency hopping law specific to said call is restored to the cell in which the call was initiated when said call has terminated and/or when said mobile station has left the coverage area of said network.

Accordingly, at the end of each call that has been
25 handed over and/or when the mobile station has left the coverage area of the network of cells with distributed base stations the frequency hopping law allocated during a call initialization phase is restored in the cell in which the call was initiated so that it can be allocated
30 to another call. In other words, as long as a given call handed over to another cell has not terminated, the cell in which the call was initiated cannot allocate the frequency hopping law specific to that call to another call. This reduces some interference problems.

35 In a preferred embodiment of the invention, during a call initialization phase said selection step covers all

the relay stations of said cell to preselect the optimum relay stations to continue said call.

Accordingly, upon sending a call request or an acknowledgment message, for example in a burst on the GSM
5 random access channel (RACH), all the relay stations of the cell concerned are involved in the selection process.

During an active call phase said selection step advantageously effected in order to update the selection of the optimum relay stations covers only the relay
10 station(s) already allocated and at least one available relay station.

Accordingly, when a call has already been set up the selection is limited to the relay stations already allocated to the call in progress and at least some of
15 those that are available (for example those nearest those already allocated). Clearly a relay station can be unavailable for various reasons, including a fault or saturation in terms of the number of calls already supported.

20 Other features and advantages of the invention become apparent upon reading the following description of a preferred embodiment of the invention given by way of illustrative and non-limiting example and from the accompanying drawings, in which:

- 25 - Figure 1 is a simplified block diagram of one particular embodiment of a system using a method in accordance with the invention;
- Figure 2 is a flowchart of the method of the invention as implemented in a system like that shown in
30 Figure 1.

The invention therefore concerns a method of handing over calls between two cells of a digital cellular mobile radio network.

The invention is based in particular on:

- 35 - selecting relay stations in accordance with a criterion depending on the quality of the call in progress, using relay stations and a concentration center

responsible for collecting the signals transmitted by the relay stations;

- transmitting parameters defining unambiguously a call channel that is retained for the entire duration of a call, or at least some of those parameters, so guaranteeing call continuity.

The parameters are transferred between the respective concentration centers of the first and second cells concerned, which are on the track of the mobile station.

The invention offers increased spectrum capacity by obtaining a call frequency re-use pattern equal to 1.

This is made possible by using various interference limiting techniques:

- frequency hopping. For example, the frequency hopping laws are mutually orthogonal when calls are initiated in the same cell and are independent of each other when calls are initiated in adjacent cells;
- assigning relay station(s) for controlling each call in all the cells so that the mobile station remains at all times in (radio) communication with at least one (or two) relay stations.

The grade of service is guaranteed by:

- good coverage assured by the multiplicity of relay stations constituting each cell;
- optimal limitation of the number of intra- and extra-cell handovers (most calls are lost at the time of handover).

In example shown in Figure 1, a mobile station 11 is in a street in an urban area where there are many buildings 12.

During the call initialization phase, the mobile station 11 is monitored by all the relay stations 13 of the cell 14. Thus if the mobile station 11 sends a request (outgoing call) or an acknowledgment message (incoming call) in a burst on the GSM random access channel all the relay stations 13 receive it. The relays

stations 13 forward the corresponding received signals to the concentration center 15 which decides which relay stations to select to continue the call in progress (preselection). For example, selection is based on
5 analyzing the power level received by each relay station weighted by the carrier to interference ratio (or the signal to noise ratio) (for example, weighting by the value 0 or 1 according to whether the carrier to
10 interference ratio is below or above a predetermined threshold). During this phase, the analysis covers values measured in a single frame.

In the example shown, relay stations 16 and 17 are preselected because they are nearest the mobile station 11 or to be more precise because they offer the best
15 communication.

The relay stations 13 are synchronized at bit level and at frame level.

When the call has been set up (i.e. in the active communication phase), for each new selection of the
20 optimum relay station(s) only relay station(s) already assigned to the call in progress and relay station(s) that are available and near the latter are taken into account. Thus monitoring and therefore selection are effected by a smaller number of relay stations than in
25 the call initialization phase.

In the active call phase, the analysis can be effected over a given time period (for example, a predetermined number of frames) during which an average of the measured values is calculated. The average power
30 level received by each relay station involved in the call is used, for example, possibly weighted by the carrier to interference ratio (or the signal to noise ratio).

The mobile station moves to position 18. Consequently, it passes from cell 14 to the adjoining
35 cell 19.

When the mobile station passes from the first cell 14 to the cell 19, the concentration center 15 of cell 14

sends the concentration center 111 of the cell 19 the following parameters:

- an indication of the designation of the cell 14 that initiated the call,
- 5 - an indication of the designation of the relay stations 16 and 17 that have handled a part of the call,
- the time slot (TN) number in a frame,
- the group of frequencies that the frequency hopping law is authorized to use (mobile radio frequency channel allocation (MA)),
- 10 - the hopping sequence generator (hopping sequence number (HSN)),
- the first frequency to use (mobile allocation index offset (MAIO)).

15 These parameters are therefore retained for all of the call. The call can therefore continue using the same parameters on a single channel. This single channel assures communication on one carrier frequency (when no frequency hopping law is used) or on a group of carrier
20 frequencies (when a frequency hopping law is used) which is the same for all of the call, despite handovers.

 The concentration centers 15 and 111 are synchronized with each other and with their respective relay stations 13 and 112 at bit level and at frame
25 level.

 The concentration center 111 selects the relay station 113 on the basis of the information reaching it. The concentration center 15 simultaneously releases the relay station 16. Thus the optimum two relay stations
30 are selected at all times.

 The mobile station continues to move and reaches position 114. The relay station 115 is then selected and the relay station 17 is released because the quality of communication with the relay station 17 has dropped below
35 a predetermined level.

 The procedure for selecting the optimum relay stations is effected periodically to enable progressive

intra-cell or inter-cell handover between relay stations, as required.

The concentration centers 15, 111, 116 communicate (110) with a concentration center controller 117 that is
 5 connected (118) to the remainder of the digital cellular mobile radio network. They assure cell to cell transmission of data and synchronization.

Figure 2 is a flowchart of the method employed in the cells of a system as previously described.

10 During the call initialization phase (21) a request (outgoing call) or acknowledgment message (incoming call) is sent in a burst on the GSM random access channel (RACH) and all the relay stations of the cell monitor (22) the mobile station initiating the call or transmit
 15 to the called mobile station.

If the call has already been set up (i.e. in the subsequent active call phase (23)) only the relay station(s) already allocated and some of the available relay station(s) monitor (24) the communicating mobile
 20 station.

Reception quality (on the uplink channel) of each monitoring relay station of the cell is measured (25) regularly (every one or two seconds for example) for all of the calls monitored by a concentration center.

25 The quality measurements are then analyzed (26) in order to identify the optimum two relay stations, for example.

The quality measurement is analyzed (26):

- in a single frame in the call initialization phase.
- 30 For example, a measured value of the received power level for each relay station of the cell is weighted by the carrier to interference ratio. This weighting consists in multiplying the value of the received power level by 0 or by 1 according to whether the carrier to interference
 35 ratio is below or above a predetermined threshold;
- over a predetermined number of frames corresponding to a fixed period in the active call phase. For example,

measured values of the average power level received by the relay station(s) already allocated to the call in progress and relay station(s) available and near them are weighted using the respective carrier to interference ratio.

Clearly, other types of weighting are feasible (for example in accordance with the signal to noise ratio or using a greater number of coefficients).

The decision (27) to modify the selection of relay stations is based on analyzing (26) the quality measurements.

If the selection of relay stations has to be modified it is necessary to determine whether the mobile station has changed cell (28).

If the mobile station has changed cell the concentration center attached to the cell it has left transmits (29) the parameter(s) of the call to the concentration center associated with the cell it has entered. Thus each call retains the same parameter(s) from the start to the end of the call, in particular the frequency hopping law allocated to it, despite the handover.

Whether the cell the mobile station has left is the cell in which the call was initiated is then determined (210).

If the cell the mobile station has left is that in which the call was initiated the parameter(s) of the call are locked out (211) for the cell where the call was initiated. In other words, their use for another call is temporarily prohibited.

If the cell the mobile station has left is not that in which the call was initiated, once the parameter(s) have been locked out (211) the optimum relay station(s) of the cell it has entered are allocated to the call (212). At the same time the relay station(s) of the cell the mobile station has left are deactivated for the call.

If the selection of relay stations has to be modified (following the decision 27) and if the mobile station has not changed cell (after step 28) new relay station(s) that are better than the previous ones are
5 selected (213). At the same time the previous relay station(s) of the cell are deactivated.

The next step (214) is executed if there is no need to modify the selection of relay station(s) (after the decision (27)) or when the new relay station(s) have been
10 selected (213) or after relay stations of the new cell have been selected (212).

If the call has terminated or if the mobile station has left the coverage area of the network of cells with distributed base stations the frequency hopping law (and
15 possibly one or more other parameters) is restored (215) to the cell in which the call was initiated.

If the call has not terminated a decision (216) whether to instigate a new monitoring procedure is taken.

If the call has not terminated and a new monitoring
20 procedure is instigated steps (21) through (212) are repeated.

Otherwise the process returns to step (214).

CLAIMS

1. A method of handing over calls between two cells (14) and (19) of a digital cellular mobile radio network, characterized in that each of said cells comprises a set of at least two transmit-receive relay stations (13) geographically distributed within said cell, each of said relay stations being able to transmit signals to mobile stations present in an area of said cell and to receive signals transmitted by said mobile stations in said area, a set of at least one of said relay stations (16) and (17) being selectively allocated to each call with a mobile station (11) so that exchanges of signals with said mobile station (11) apply to only a part of the cell, and in that, when said mobile station (11) passes from a first cell (14) to a second cell (19), at least one parameter (29) characterizing the call unambiguously is transmitted (110) from the base station controlling said first cell (14) to the base station controlling said second cell (19) to enable continuity of use of said at least one parameter.

2. A method according to claim 1, characterized in that each of said cells includes a concentration center (15) processing the signals received by each of said relay stations (13) and delivering signals to be transmitted to each of said relay stations (13) and in that the concentration centers (15), (111) and (116) and/or the relay stations (13) of a set of cells are synchronized.

3. A method according to claim 2, characterized in that synchronization is effected at two levels:

- at bit level;
- at frame level.

4. A method according to any one of claims 1 to 3, characterized in that each of said calls uses a frequency hopping technique.



5. A method according to any preceding claim,
characterized in that said cells use the same set of
carrier frequencies common to all said cells and in that
5 a single frequency hopping law is allocated to each of
said calls during a call initialization phase.

6. A method according to any preceding claim,
characterized in that each of said cells uses at least
10 one broadcast control frequency specific to it to
transmit signalling data.

7. A method according to any preceding claim,
characterized in that calls of two adjacent cells use the
15 same set of communication frequencies and in that:

- the frequency hopping laws used by calls initiated
within the same cell are mutually orthogonal;
- the frequency hopping laws used by calls initiated
by two cells are determined independently of each other.

20

8. A method according to any preceding claim,
characterized in that said at least one parameter (29)
characterizing the call comprises at least one of the
following items of information:

- 25 - a time slot number and a frame number;
- an indication of the frequency hopping law;
- an indication of the server relay stations most
recently found to be optimum stations;
- an indication of the cell which initiated the call.

30

9. A method according to any preceding claim,
characterized in that each of said cells selects (211)
the optimum relay stations in accordance with a
predetermined selection criterion for each communicating
35 mobile station (11) and in that the set of relay stations
(16) and (17) allocated to said call and handover from



said first cell (14) to said second cell (19) allow for said selection.

10. A method according to claim 9, characterized in that
5 said selection criterion is based on analyzing (26) at least one of the following items of information:

- the power received by said relay station for said calls;
- the signal to noise ratio for said calls;
- 10 - the carrier to interference ratio for said calls;
- a raw error rate and/or an error rate after decoding for said calls;
- a frame loss rate for said calls;
- a geographical position indication.

15

11. A method according to any preceding claim, characterized in that at least one of said items of information is analyzed (26) on the basis of:

- an average of the values of at least one of said
20 items of information measured over a predetermined time period during an active call phase (24);
- a single value of at least one of said items of information measured during a call initialization phase (22).

25

12. A method according to claim 9 or claim 10, characterized in that said set of relay stations (16) and (17) includes a predetermined number n of the optimum relay stations in accordance with said selection
30 criterion.

13. A method according to any preceding claim, characterized in that the set of relay stations allocated is updated periodically and/or if at least one parameter
35 representative of call quality is below a predetermined threshold (27).



14. A method according to any preceding claim,
characterized in that in the call initialization phase
each call is allocated a single frequency hopping law
that is specific to it and that it retains on being
5 handed over from said first cell (14) to said second cell
(19) and in that said frequency hopping law specific to
said call is restored to the cell (14) in which the call
was initiated when said call has terminated and/or when
said mobile station (11) has left the coverage area of
10 said network.

15. A method according to any preceding claim,
characterized in that during a call initialization phase
(22) said selection step covers all the relay stations
15 (112) of said cell (19) in order to preselect the optimum
relay stations (113, 115) to continue said call.

16. A method according to any preceding claim,
characterized in that in an active call phase (24) said
20 selection step covers only relay stations (113, 115)
already allocated and at least some available relay
stations (112) in order to update the selection of
optimum relay stations.

