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[Continued on next page]

(54) Title: ALLOCATING BASE STATIONS TO LOCATION AREAS IN CELLULAR TELECOMMUNICATIONS NETWORKS

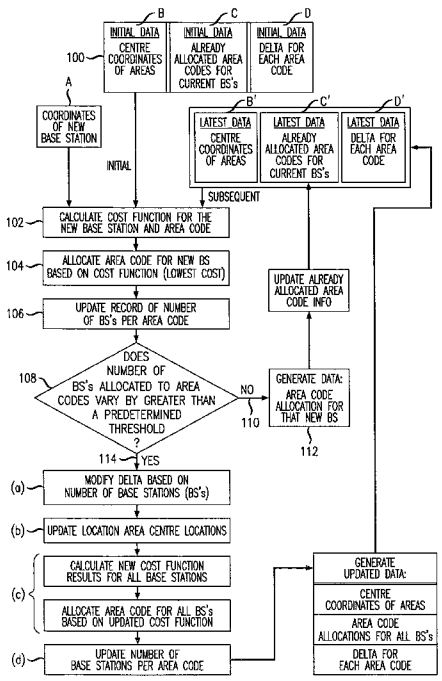


FIG. 3

(57) Abstract: A method is provided of allocating a location area identifier to a cellular base station for wireless communications. The method comprises the following steps. Information is received of geographic location of a base station. For each of a plurality of location areas, each having a location area centre, distance of the base station from the respective location area centre is calculated and a function dependent upon said distance is calculated. The location area giving the lowest function value is selected as the location area for the base station.

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ALLOCATING BASE STATIONS TO LOCATION AREAS IN CELLULAR TELECOMMUNICATIONS NETWORKS

Field of the Invention

The present invention relates to telecommunications, in particular to wireless telecommunications.

Description of the Related Art

Wireless telecommunications systems are well-known. Many such systems are cellular, in that radio coverage is provided by a bundle of radio coverage areas known as cells. A base station that provides radio coverage is located in each cell. Traditional base stations provide coverage in relatively large geographic areas and the corresponding cells are often referred to as macrocells.

It is possible to establish smaller sized cells within a macrocell. Cells that are smaller than macrocells are sometimes referred to as microcells, picocells, or femtocells, but we use the term picocells generically for cells that are smaller than macrocells. One way to establish a picocell is to provide a picocell base station that operates within a relatively limited range within the coverage area of a macrocell. One example of use of a picocell base station is to provide wireless communication coverage within a building.

The picocell base station is of a relatively low transmit power and hence each picocell is small compared to a macrocell.

Picocell base stations can use broadband Internet Protocol connections as "backhaul", in other words they are connected via picocell base station gateways to, for example, a Universal Mobile Telecommunications System (UMTS) core network, for example each gateway may be connected to a UMTS Mobile Switching Centre (MSC) and hence a Signalling Gateway Support Node (SGSN). Picocell base stations are intended primarily for users belonging to a particular home or office. Picocell base stations may be private access or public access. In private access picocell base stations, access is restricted only to registered users, for example family members or particular groups of employees. In public access picocell base stations, other users may also use

the picocell base station, subject to certain restrictions to protect the Quality of Service received by registered users.

There can be a large number of picocells within an area roughly equivalent to the size of a macrocell. Accordingly, there can be a large number of picocells in an operator's coverage area, such that conventional cell planning, as done to optimise location of base stations in macrocell networks, becomes impractical. This is particularly so as picocells are usually deployed by end-users or unskilled individuals installing picocell base stations where they choose in their offices and homes, for example in what is sometimes called a "plug-and-play" manner.

Another area of background is the use of area codes.

During configuration of a cellular network (e.g. Universal Mobile Telecommunications System (UMTS), CDMA2000, Long Term Evolution (LTE)), various types of area codes are assigned to each cell so as to be used in handover procedures and in the provision of location based services. These codes are, of course, identifiers of the relevant areas. Examples include location area codes, routing area codes, and service area codes.

The overall area of coverage consists of location areas. Base stations within any one location area use the same location area code. Location area codes are used to identify in which location area a user terminal currently resides so that a paging signal can be sent from the base stations in that location area only.

The user terminal keeps the network informed of which location area the user terminal is currently camped on. Also, the user terminal performs a location update procedure when the user terminal enters a new location area. When there is a call incoming to the user terminal to be set up, only base stations that are within the user terminal's last known location area are instructed to send out paging messages, to page for that user terminal. Location area codes are also used to provide location-based services, and during emergency calls to identify where the user is. Routing areas are similar to location areas but for data calls rather than voice calls. Basically, one or more routing area is contained within a location area.

As regards location area size, on the one hand, large location areas are preferable in order to minimise the number of location area updates that are required. On the other hand, as location area size increases, the amount of paging signalling increases. In consequence, good location area size is a trade-off.

Currently area codes, such as location area codes, are allocated to base stations by a human operator.

Summary of the Invention

The reader is referred to the appended independent claims. Some preferred features are laid out in the dependent claims.

An example of the present invention is a method of allocating a location area identifier to a cellular base station for wireless communications. The method comprises the following steps. Information is received of geographic location of a base station. For each of a plurality of location areas, each having a location area centre, a function is calculated that is dependent upon distance of the base station from the respective location area centre. The location area giving the lowest function value is selected as the location area for the base station.

The inventor realised that the manual allocation of area codes, although feasible for macro-cellular networks, was unsuitable for networks including picocell base stations.

The inventor realised that manual assignment of area codes becomes problematic for networks including picocell base stations as area codes need to be assigned to tens of thousands, hundreds of thousands or more, picocell base stations. Also, the inventor realised that the number of picocell base stations is likely to increase over time as market penetration increases, requiring constant reallocation of area codes to picocell base stations.

The automated approach to area code allocation used in preferred embodiments makes picocell deployments more practical.

In preferred embodiments, each location area is given a centre and picocell base stations are allocated to a location area (identified by a location area code) based on its

distance from location area centres and a range modifier in an iterative process. In each iteration, picocell base station allocations are updated until a converged solution is reached that satisfies the operator's requirements.

In preferred embodiments, each picocell base station is allocated the location area that best minimises a cost function dependent upon distance to the location area centre and a range modifier. Each location area has a range modifier adapted to to achieve a roughly equal number of associated picocell base stations per location area.

Preferred embodiments advantageously provide automatic allocation of area codes, such as location area code. This is useful in view of the plug-and play nature of picocell base station deployment. The approach can provide a quickly converging yet adaptive area code allocation solution despite large numbers of picocell base stations and the unplanned, organic, often changing configuration in which they are deployed. There can be hundreds of thousands of picocell base stations in a network. Preferred embodiments advantageously provide low computational complexity per code assignment.

Some preferred embodiments relate to networks including picocell base stations having public access.

The approach is also usable in networks consisting of, for example, mainly or only macrocells.

Brief Description of the Drawings

An embodiment of the present invention will now be described by way of example and with reference to the drawings, in which:

Figure 1 is a diagram illustrating a wireless communications network according to a first embodiment of the present invention,

Figure 2 is a diagram illustrating the coverage area of the network shown in Figure 1 made up of location areas, and

Figure 3 is a diagram illustrating a method of identifying the location area for each picocell base station in the network shown in Figure 1.

Detailed Description

As shown in Figure 1, in one communication network 20, there are two types of base stations (often denoted BS or BSs) : macrocell base stations and picocell base stations. One macrocell base station 22 for wireless telecommunications is shown for simplicity in Figure 1. The macrocell base station has a radio coverage area 24 that is often referred to as a macrocell. The geographic extent of the macrocell 24 depends on the capabilities of the macrocell base station 22 and the surrounding geography.

Within the macrocell 24, a picocell base station unit (PCBSU) 30 provides wireless communications within a picocell 32. A picocell is a radio coverage area. The radio coverage area of the picocell 30 is much less than that of the macrocell 24. For example, the picocell 32 corresponds in size to a user's home.

Another picocell base station unit (PCBSU) 34 provides wireless coverage within a picocell 36. A further picocell 38 provides wireless coverage within a picocell 40.

It is possible for a mobile terminal 44 within the macrocell 24 to communicate with the macrocell base station 22 in known manner. When the mobile terminal 44 enters into a picocell 32 for which the mobile terminal has access to the picocell base station 30, it is desirable to handover the connection with the mobile terminal from the macrocell to the picocell. In the example shown in Figure 1, the user of mobile terminal 44 is a preferred user to use the picocell 32.

The PCBSUs 30,34,38 and macrocell base station 22 are connected via broadband Internet Protocol connections ("backhaul") to an area code controller (ACC) of a UMTS core network.

As shown in Figure 2, in this example the coverage area is divided into, say, nine location areas LA1 to LA9. and the base stations within any one location area use the same location area code. The base stations are typically a mixture of some macrocellular base stations and a greater number picocell base stations.

Location area codes are used to identify in which location area a user terminal currently resides so that a paging signal can be sent from the base station in that location area only.

The user terminal keeps the network informed of which location area the user terminal is currently camped on. Also, the user terminal (for example "mobile" as shown in Figure 2) performs a location update procedure when the user terminal enters a new location area. When there is a call incoming to the user terminal to be set up, only base stations that are within the user terminal's last known location area are instructed to send out paging messages, to page for that user terminal.

Location area codes are also used to provide location based services and during emergency calls. Routing areas are similar to location areas but for data calls rather than voice calls. One or more routing areas need to be contained within a location area.

Location Area Allocation Method

This in an iterative process consists of selecting initial parameter values, then running the calculations to determine a first result for allocation of location area identifying codes to base stations, then repeatedly modifying parameter values and recalculating until an acceptably converged solution results.

Selecting Initial Parameter values

First a decision is taken as to the number of location areas that will be provided in the coverage area, in other words how many different location area codes will be provided.

Next a geographic centre, defined by longitude and latitude coordinates of a map, is selected for each of the location areas. In this example, this is done in a pseudo-random manner within the coverage area of interest as little or no useful information on the distribution of picocell base stations is available. (In an otherwise similar alternative embodiment, not shown, the centres are instead allocated according to the expected base station distribution).

Next a range modifier, that will be explained in more detail below, for each location area is initialised as zero. The range modifier is referred to as delta or delta(c) in this discussion.

The Process

The process is iterative. It is undertaken for each new base station that is deployed.

The steps are explained in more detail below, but basically speaking, each base station is allocated the location area code $c_{allocated}$ with the smallest cost function:

$$c_{allocated} = \arg\min_{c}(\log_{10}(d(c)) + delta(c))$$

where $d(c)$ is the distance between the base station and the centre of the location area having location area code c, and $delta(c)$ is a range modifier for the area code c.

As shown in Figure 3, initial parameter values are selected (step 100)

For each base station, the cost function $cost_c=\log_{10}(d(c))+delta(c)$ is determined (step 102) for various different location area codes identified by their respective code c. Of these, the area code associated with the lowest cost function is allocated (step 104) to the base station.

For each area code, the number of base stations that have been allocated that area code is determined (step 106).

Next a query is made (step 108) as to whether the number of base stations allocated to different area codes differs by greater than a predetermined threshold. This threshold, is, for example, that there is a greater than 20% variation.

If No (step 110), the area code allocation to that base station is accepted and output (step 112) and used to update stored data of the already allocated area codes to the current base stations.

On the other hand, if Yes (step 114) then steps are taken, as explained in more detail below, to:

adjust (step a) the range modifier *delta*(*c*) to achieve an acceptably similar number of base stations allocated to each location area code;

adjust (step b) the centre locations of location areas; then

update (step c) the "best" location area code for each base station (this involves, for each base station, recalculating the modified cost functions and selecting the location area giving the lowest); and

update (step d) the number of base stations per area code.

Adjusting the Range Modifier (Fig 3: step a)

As regards the use of the range modifier, *delta*(*c*), this range modifier is required to change the size of each location area so as to seek to keep the number of base stations within acceptable limits. For example if the base station distribution is non-uniform.

If there are many base stations within one area, then *delta*(*c*) is increased in order to make the associated cost higher, and so less attractive. On the other hand, if there are few base stations within an area, *delta*(*c*) is reduced so as to reduce the cost, making it more likely that base stations are allocated to that location area.

Modifying Area Centres (Fig 3: step b)

This step is done by calculating the point that minimises total distance to all base stations currently allocated to a location area and taking the coordinates of that point as the replacement centre.

Updating Area Allocations (Fig3: step c)

For all base stations, the allocation of location areas is updated by, for each base station, recalculating the cost function using the new location area centres and deltas and selecting the location area giving the lowest cost.

These steps of adjusting the range modifier (step a), modifying area centres (step b) and updating area allocations (step c) are most likely to occur in the early stages of a network deployment. Effectively, with even a low number of users the user distribution is quicky adapted to so that area codes are quickly optimised. This may be important in some circumstances because although the allocation to a new base station is relatively simple, the computational complexity of each optimisation that involves adjustments of location area centres and range modifiers depends on the total number of base stations, so can get large. Accordingly, this fast convergence ensures low overall computational complexity.

Adjustments of location area centres and range modifiers in a late stage of deployment, when many base station have already been allocated area codes, could result in many base stations being reallocated codes. The quick convergence of the process means that only a few such reallocation stages are typically required.

Some Variants/Alternatives

This approach is usable in networks which are macrocellular, not just in networks including one or more picocell base station. The approach is usable in various cellular networks, e.g macro-, micro-, pico-, that use the location area concept, e.g. Global System for Mobiles, CDMA2000, Universal Mobile Telecommunications System (UMTS) Long Term Evolution and others).

In some otherwise similar embodiments, the number of area code re-allocations applied to base stations that have already been allocated area codes can be reduced by modifying the updating code allocations (step c) such that an area code is only altered if the cost function for the "new" area for a base station is lower than the cost function for the current area by more than a predetermined amount.

In some otherwise similar embodiments, the computational complexity for optimisation is reduced by only triggering optimising iterations (steps a to d) when both the number of allocated base stations per area code varies by more than a predetermined amount (e.g 10), and the fractional variation in the number of allocated

base stations per area code exceeds a predetermined percentage (say 20%). In some embodiments, the number of iterations that can be performed when new base stations are deployed can be limited. For example a maximum number of iterations can be set to be the higher of ten or the number of new base stations deployed at that stage (this can be expressed mathematically as $I_{max} = \max(10, \text{new base stations})$.

General

The present invention may be embodied in other specific forms without departing from its essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

Claims:

1. A method of allocating a location area identifier to a cellular base station for wireless communications, the method comprising the steps of:

receiving information of geographic location of a base station;

for each of a plurality of location areas, each having a location area centre, calculating distance of the base station from the respective location area centre and calculating a function dependent upon said distance;

selecting the location area giving the lowest function value as the location area for the base station.

2. A method according to claim 1, in which the function is also dependent upon a range modifying parameter, each location area having an associated range modifying parameter value.

3. A method according to claim 2, further comprising for a location area adjusting the associated range modifying parameter so as to adjust the number of base stations to be allocated to the location area.

4. A method according to claim 1, further comprising:

adjusting a location area centre.

5. A method according to claim 4, in which the location area centre is adjusted by determining the point that minimises total distance of all base stations allocated to a location area, and taking that point as the adjusted location area centre.

6. A method according to claim 3, further comprising,

for each of a plurality of base stations:

recalculating the function for each of a plurality of location area centres; and

selecting the location area giving the lowest recalculated function value as the location area for the base station.

7. A method according to claim 1, further comprising the step of recording the number of base stations allocated to a location area, determining whether the distribution of number of base stations allocated to location areas is within predetermined limits, and if not adjusting at least one of a range modifying parameter of a location area and a location area centre, and conducting base station to location area reallocation.

8. A method according to claim 1 in which at least one of the base stations is a picocell base station.

9. A method according to claim 1 which is automatic.

10. A cellular wireless telecommunications network comprising base stations operative to page user terminals within a location area associated with the user terminal, and a location area allocation controller;

the controller being configured to select and allocate base stations to a location area, in which:

the controller is configured to receiving information of geographic location of a base station;

the controller is configured to, for each of a plurality of location areas, each having a location area centre, calculate distance of the base station from the respective location area centre and calculate a function dependent upon said distance;

the controller is configured to select the location area giving the lowest function value as the location area for the base station.

11. A wireless telecommunications network according to claim 10, in which the function is also dependent upon a range modifying parameter, each location area having an associated range modifying parameter value;

and the controller is configured to, for a location area, adjust the associated range modifying parameter so as to adjust the number of base stations to be allocated to the location area.

12. A wireless telecommunications network according to claim 10, in which the controller is further configured to adjust the centre of a location area by determining the point that minimises total distance of all base stations allocated to a location area, and taking that point as the adjusted location area centre.

13. A wireless telecommunications network according to claim 11 or claim 12, in which the controller is configured, for each of the plurality of base stations, to recalculate the function for each of the plurality of location area centres and select the location area giving the lowest recalculated function value as the location area for the base station.

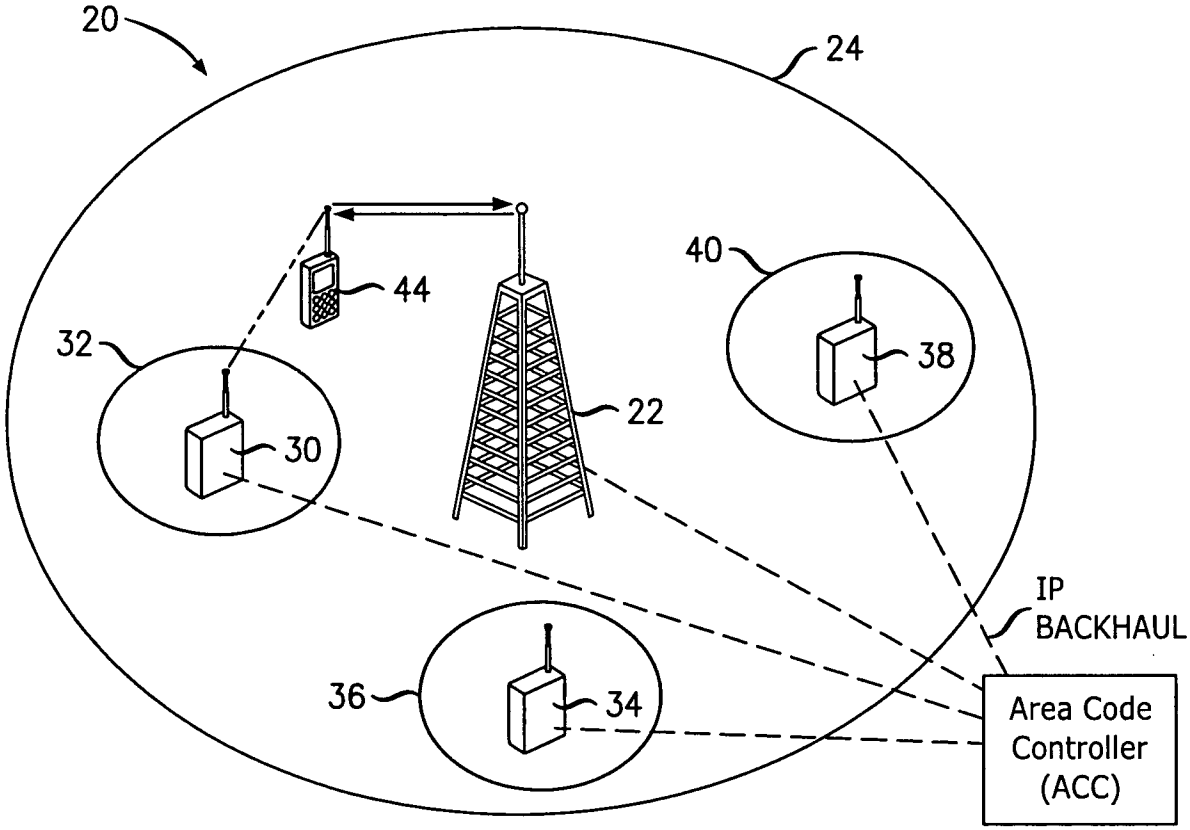

20
24
44
40
32
38
30
22
IP
BACKHAUL
36
34
Area Code
Controller
(ACC)

FIG. 1

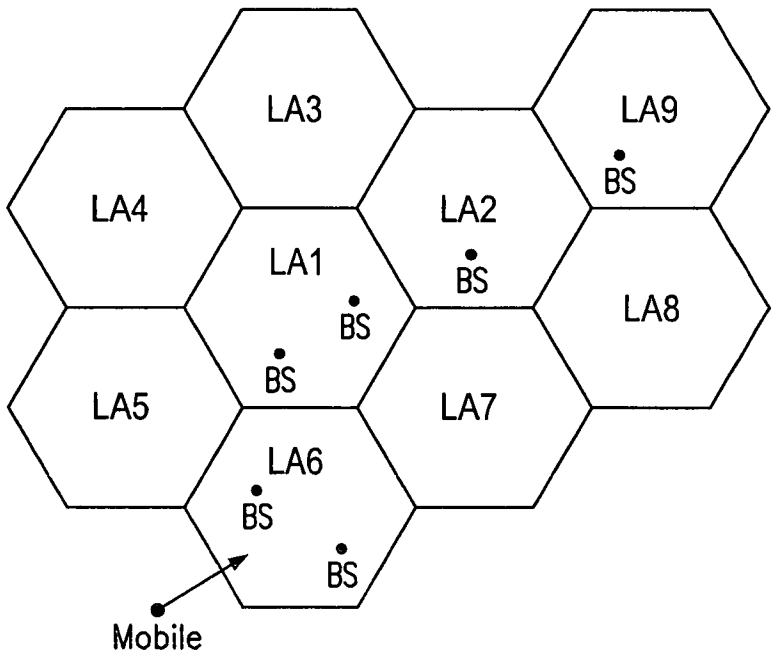
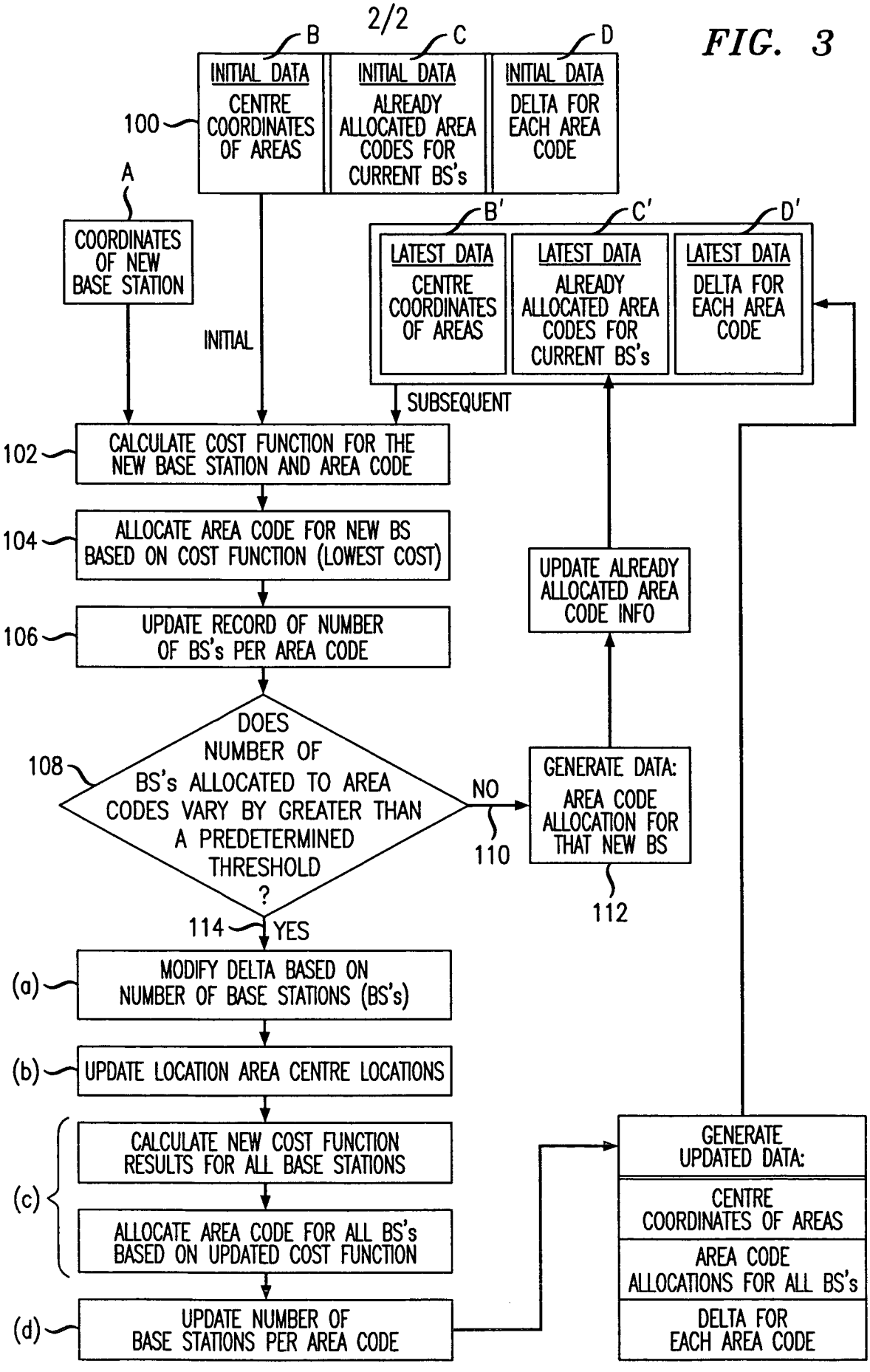

LA3
LA9
BS
LA4
LA2
LA1
BS
BS
LA8
BS
LA5
LA7
LA6
BS
BS
Mobile

FIG. 2

FIG. 3


B
C
D
INITIAL DATA
CENTRE COORDINATES OF AREAS
INITIAL DATA
ALREADY ALLOCATED AREA CODES FOR CURRENT BS's
INITIAL DATA
DELTA FOR EACH AREA CODE
100
A
COORDINATES OF NEW BASE STATION
B'
C'
D'
LATEST DATA
CENTRE COORDINATES OF AREAS
LATEST DATA
ALREADY ALLOCATED AREA CODES FOR CURRENT BS's
LATEST DATA
DELTA FOR EACH AREA CODE
INITIAL
SUBSEQUENT
102
CALCULATE COST FUNCTION FOR THE NEW BASE STATION AND AREA CODE
104
ALLOCATE AREA CODE FOR NEW BS BASED ON COST FUNCTION (LOWEST COST)
106
UPDATE RECORD OF NUMBER OF BS's PER AREA CODE
108
DOES NUMBER OF BS's ALLOCATED TO AREA CODES VARY BY GREATER THAN A PREDETERMINED THRESHOLD ?
NO
110
GENERATE DATA: AREA CODE ALLOCATION FOR THAT NEW BS
112
UPDATE ALREADY ALLOCATED AREA CODE INFO
114
YES
(a)
MODIFY DELTA BASED ON NUMBER OF BASE STATIONS (BS's)
(b)
UPDATE LOCATION AREA CENTRE LOCATIONS
(c)
CALCULATE NEW COST FUNCTION RESULTS FOR ALL BASE STATIONS
ALLOCATE AREA CODE FOR ALL BS's BASED ON UPDATED COST FUNCTION
(d)
UPDATE NUMBER OF BASE STATIONS PER AREA CODE
GENERATE UPDATED DATA:
CENTRE COORDINATES OF AREAS
AREA CODE ALLOCATIONS FOR ALL BS's
DELTA FOR EACH AREA CODE

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/003001

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W16/18

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 H04L H04W

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SAHA ET AL: "Time efficient heuristics for cell-to-switch assignment in quasi-static/dynamic location area planning of mobile cellular networks" COMPUTER COMMUNICATIONS, ELSEVIER SCIENCE PUBLISHERS BV, AMSTERDAM, NL, vol. 30, no. 2, 19 December 2006 (2006-12-19), pages 326-340, XP005808358 ISSN: 0140-3664 page 327, column 1, line 7 - page 329, column 1, line 32 page 329, column 2, line 50 - page 330, column 1, line 19 page 330, column 2, line 15 - page 331, column 2, line 12 ----- -/--	1,2, 4-10,12, 13

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 June 2009	01/07/2009

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Hegeman, Hans

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/003001

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MANDAL S ET AL: "Heuristic search techniques for cell to switch assignment in location area planning for cellular networks" COMMUNICATIONS, 2004 IEEE INTERNATIONAL CONFERENCE ON PARIS, FRANCE 20-24 JUNE 2004, PISCATAWAY, NJ, USA,IEEE, vol. 7, 20 June 2004 (2004-06-20), pages 4307-4311, XP010711942 ISBN: 978-0-7803-8533-7 page 4307, column 1, line 1 - page 4308, column 2, line 22	1,2, 4-10,12, 13
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A	EP 1 351 530 A (ERICSSON TELEFON AB L M [SE]) 8 October 2003 (2003-10-08) paragraphs [0028] - [0032]	1-13
A	US 2005/059404 A1 (BEJERANO YIGAL [US] ET AL) 17 March 2005 (2005-03-17) the whole document	1-13
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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