



**TITLE OF THE INVENTION**

A CELL FORMATION CONTROL METHOD, A MOBILE COMMUNICATIONS SYSTEM, AND A BASE STATION AND A MOBILE STATION USED THEREIN

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**BACKGROUND OF THE INVENTION**

1. Field of the Invention

The present invention generally relates to a control method of cell formation and a mobile communications system therewith, and specifically relates to the cell formation method and the mobile communications system therewith, wherein one or more mobile stations are served by a base station that is capable of changing and securing a service area of the mobile stations by changing the cell formation while communications are going on.

The present invention further relates to the base station and mobile station that can communicate according to the cell formation control method.

2. Description of the Related Art

An area where a base station can provide a communication service, i.e., a cell, depends on the quality of a control signal received by a mobile station, the control signal being for connecting the mobile station with the base station. When the base station serves a cell, a conventional method has been that transmission electric power of the control signal is predetermined, and the predetermined value is used. In recent years, an autonomous cell formation control method has been proposed, wherein a base station checks cell formation of adjacent cells, and adjusts its cell formation such that areas not covered by the adjacent cells are efficiently covered. The autonomous cell formation control method mediates traffic congestion by controlling the cell formation according to a

congestion state of the adjacent cells, and can raise frequency use efficiency. If the technology of such autonomous cell formation control is applied to a mobile communications system, a base station will  
5 be capable of changing cell formation, i.e., increasing and decreasing the radius of the cell, while communications are continuing.

When the cell radius is expanded, an increased number of base stations will become  
10 available to a mobile station that is in communication with a first base station. The communication connection to the first base station can be switched to a second base station, if the second base station is carrying a lower amount of  
15 traffic, such that a higher through put may be obtained.

On the other hand, when the cell radius of the first base station with which the mobile station is connected is reduced, it is necessary for the  
20 mobile station to switch the ongoing communication connection to another base station before the service of the first base station to the mobile station becomes unavailable.

However, according to the autonomous cell  
25 formation control of a conventional base station, a relief is not provided to the mobile station that would be made outside the service area of the base station before the base station actually reduces its service area.

30 For example, as shown in Fig.16, when a base station 3 reduces its service area from an area indicated by a dotted line to an area indicated by a solid line, although a mobile station 3 served by the base station 3 is thereby put outside the  
35 reduced service area of the base station 3, the mobile station 3 can be switched to the base station 2 by hand-over, such that the communication can

continue. However, when a base station 1 reduces its service area from an area indicated by a dotted line to an area indicated by a solid line, there is no adjacent base station to perform hand-over for a mobile station 1 that is being served by the base station 1. Consequently, when the base station 1 reduces its service area, the mobile station 1 will be put outside the reduced service area, and the communication will be disconnected.

Thus, the conventional problem is that a normal communication of a mobile station with the first base station cannot be continued due to a disconnection, a packet loss and the like, when the first base station reduces its cell radius, i.e., service area.

Even if there is the second base station available for the service to be continued in an adjacent area, hand-over has to be performed from the first base station to the second base station. Further, there is a possibility that the second base station may later reduce its service area. In this case, further hand-over is required from the second base station to a third base station, or back to the first base station, as the case may be.

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#### **SUMMARY OF THE INVENTION**

It is a general object of the present invention to provide a method, a system using the method, and a base station and a mobile station that operate in the system, which substantially obviate one or more of the problems caused by the limitations and disadvantages of the related art.

Features and advantages of the present invention will be set forth in the description that follows, and in part will become apparent from the description and the accompanying drawings, or may be learned by practice of the invention according to

the teachings provided in the description. Objects as well as other features and advantages of the present invention will be realized and attained by the method, the system using the method, and the  
5 base station and the mobile station that operate in the system, which are particularly pointed out in the specification in such full, clear, concise, and exact terms as to enable a person having ordinary skill in the art to practice the invention.

10 To achieve these and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, the invention provides the method, the system, the base station and the mobile station that enable the system to  
15 function as summarized below.

The base station, serving a cell, is equipped with a facility to change formation of the cell, typically, the radius of the cell within which the service of the base station is available, and a  
20 facility to provide information about a contemplated cell radius change to one or more mobile stations in the cell. Each mobile station is capable of transmitting a request not to change the cell radius, and also capable of searching for another base  
25 station to which a hand-over is to take place, if the mobile station determines that the mobile station will be placed outside the cell if the cell radius change is actually performed by the base station. Then, the base station, upon receiving the  
30 request, is capable of suspending the contemplated cell radius change.

An extension to the above is that the mobile station is capable of calculating the distance between the base station and the mobile  
35 station, using signal strength of a signal from the base station, and other information, and the mobile station transmits information about the distance to

the base station, such that the base station can adjust the cell radius enough to cover the mobile station concerned.

As an extension to the above, the base station is equipped with a facility to change the formation of the cell, i.e., the cell radius, gradually in stages until the contemplated cell radius change is finally reached, and a facility to inform the mobile stations about a next stage cell radius one by one at a predetermined interval. The mobile station is capable of transmitting the request not to change the cell radius when a cell radius change of any of the stages that is contemplated will place the mobile station outside the cell. This contributes to reducing processing load of the cell, because the number of control signals from the mobile stations to the base station in a given period of time is reduced, with transmission of the control signals being distributed over the stages.

A further extension to the above is that the base station is capable of transmitting information both about the next stage cell radius and about the cell radius in the final stage. In this case, the mobile station is informed of the final cell radius from the beginning, and is enabled to attempt a hand-over to a second base station if the final cell radius will not cover the mobile station, even if a cell radius of any prior stage may cover the mobile station. This alleviates frequency and traffic of the hand-over. Further, in this case, even if the second base station is in the process of a cell radius change, the mobile station can select a base station that will provide the most favorable communication conditions.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

Fig.1 is a figure showing an example of a structure of a mobile communications system to which a cell formation control method of an embodiment of the present invention is applied;

5           Fig.2 is a figure showing a structure of a base station of the present invention;

Fig.3 is a figure showing a structure of a mobile station of the present invention;

10           Fig.4 is a figure showing an outline of a first embodiment of a cell radius changing process;

Fig.5 is a flowchart showing steps of a process performed by a base station of the first embodiment;

15           Fig.6 is a flowchart showing steps of a process performed by a mobile station of the first embodiment;

Fig.7 is a figure showing an outline of a second embodiment of the cell radius change process;

20           Fig.8 is a flowchart showing steps of a process performed by a base station of the second embodiment;

25           Fig.9 is a flowchart showing a continuation of the steps of the process performed by the base station of the second embodiment (continuation of Fig.8);

Fig.10 is a flowchart showing steps of a process performed by a mobile station of the second embodiment;

30           Fig.11 is a figure showing an outline of a third embodiment of the cell radius change process;

Fig.12 is a flowchart showing steps of a process performed by the base station of the third embodiment;

35           Fig.13 is a flowchart showing a continuation of the steps of the process performed by the base station of the third embodiment (continuation of Fig.12);

Fig.14 is a flowchart showing steps of a process performed by the mobile station of the third embodiment;

Fig.15 is a flowchart showing a  
5 continuation of the steps of the process performed by the mobile station of the third embodiment (continuation of Fig.14); and

Fig.16 is a figure explaining a conventional technology.

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#### **DESCRIPTION OF THE PREFERRED EMBODIMENTS**

Hereafter, embodiments of the present invention are explained based on attached figures.

A mobile communications system to which  
15 the cell formation control methods of the embodiments of the present invention are applied is structured as shown in Fig.1.

In Fig.1, the mobile communications system is, for example, a PDC (Personal Digital Cellular) system, and includes a base station and two or more  
20 mobile stations. In this example, a mobile station A 100 is communicating with a base station A 200, and a mobile station B 110 and a mobile station C 120 are communicating with a base station B 210, and  
25 each base station is capable of changing cell formation. The cell formation is changed according to a cell formation change of an adjacent base station, a congestion situation, and the like. For example, the base station A 200 is capable of  
30 changing the cell formation from A1 to A2. The base station B210 is also capable of changing its cell formation. A change of the cell formation can be realized by changing transmission electric power of a perch channel (a control channel used in order  
35 that a mobile station may synchronize with a base station), thereby a cell radius, i.e., the radius of a service area, is changed. Therefore, a change of

transmission electric power is equivalent to a cell formation change. Further, the base station may use a sector antenna. In that case, a change of the transmission electric power of any of one, more than  
5 one, and all sectors is regarded as a cell formation change.

In the present invention, when the base station A 200, for example, carries out a cell formation change, i.e., a service area (= cell)  
10 change, e.g., from A1 to A2, it is carried out such that the mobile station A 100 does not come outside of the service area. According to the present invention, the base station performs the cell formation change based on a response from the mobile  
15 station that informs the base station whether or not the mobile station will be placed outside of the service area, thereby the base station can adjust the cell formation change such that the mobile station can remain inside the service area.  
20 Consequently, disconnection of communication of the mobile station, due to the cell formation change, can be prevented.

The base station is structured as shown in Fig.2, for example.

25 Fig.2 is a block diagram of the base station of the present invention.

The base station includes a receiving antenna 11, a receiving unit 12, a control signal detection unit 13, a control information processing  
30 unit 14, a cell formation processing unit 15, an information signal processing unit 16, a transmitting unit 17, and a transmitting antenna 18. In Fig.2, an arrow shows a flow of a signal.

The receiving unit 12 receives a signal  
35 transmitted from the mobile station through the receiving antenna 11, and provides the received signal to the control signal detection unit 13 of

the following stage. In the control signal detection unit 13, a change stop signal that is the control signal transmitted by the mobile station is detected from the signal received by the receiving unit 12, and information contained in the signal is provided to the control information processing unit 14 of the following stage. The control information processing unit 14 extracts and temporarily stores the information provided by the control signal detection unit 13. Here, since the change stop signal may be transmitted from two or more mobile stations, the information is stored with a mobile station identifier corresponding to each mobile station. Then, the control information processing unit 14 provides the cell formation processing unit 15 with the information including a value of the cell radius ( $L_{MAX}$ ) that is to be used in the cell formation change. Details about  $L_{MAX}$  will be described later. The cell formation processing unit 15 provides the information signal processing unit 16 with a new cell radius  $R_1$  that the cell formation change is to take. Further, the information signal processing unit 16 provides the new cell radius  $R_1$  (changed cell radius) to the transmitting unit 17. However, at this juncture, in the case that  $L_{MAX}$  is provided by the control information processing unit 14,  $R_1$  is set with the value of  $L_{MAX}$ , and then,  $R_1$  is provided to the transmitting unit 17 through the information signal processing unit 16. The information signal processing unit 16 updates contents of an information signal, and provides it to the transmitting unit 17. The transmitting unit 17 transmits the updated information signal to all the mobile stations in the cell. Further, the transmitting unit 17 is equipped with a function, such as transmission power control, to change the cell radius to  $R_1$ .

On the other hand, if no change stop signals from the mobile stations are detected by the control signal detection unit 13, the cell formation processing unit 15 provides R1, with no regard to  
5  $L_{MAX}$ , to the transmitting unit 17, and cell formation change is carried out in the transmitting unit 17.

The mobile station is structured as shown in Fig.3, for example.

Fig.3 is a block diagram of the mobile  
10 station of the present invention.

The mobile station includes a receiving antenna 21, a receiving unit 22, a connectable base station detection unit 23, a distance calculation unit 24, an information signal detection unit 25, a  
15 cell radius comparison unit 26, a hand-over processing unit 27, a control signal processing unit 28, a transmitting unit 29, and a transmitting antenna 30. In Fig.3, an arrow shows a flow of a signal.

20 The receiving unit 22 receives a signal transmitted from the base station through the receiving antenna 21, and an information signal contained in the received signal is provided to the information signal detection unit 25 and the  
25 connectable base station detection unit 23. In the connectable base station detection unit 23, information required to determine a hand-over destination, such as the number of base stations that can communicate with the mobile station, a base  
30 station identifier, a receiving level, and the like, is extracted from the information signal provided by the receiving unit 22, and the information is provided to the hand-over processing unit 27. The  
35 information in the hand-over processing unit 27 contains information about hand-over destination base station candidates when the cell radius comparison unit 26 requires a hand-over control.

In the information signal detection unit 25, the information about the cell radius is extracted from the information signal received from the receiving unit 22. The information here includes, 5 for example, the received electric power  $P_r$  of the signal, the new cell radius  $R_1$  if the cell formation change actually takes place, and the present base station transmission electric power  $P_s$ , and the like. The value of the cell radius after change  $R_1$  is 10 provided to the cell radius comparison unit 26, and other values, such as a value of  $P_s$ , which are needed for calculating a distance (distance between the base station and the mobile station) are provided to the distance calculation unit 24.

15 The cell radius comparison unit 26 checks whether or not the mobile station will remain within the service area of the base station by comparing the new cell radius after change  $R_1$  with the distance between the mobile station and the base 20 station. If it is determined that the mobile station will become outside the service area if the cell radius is actually changed, a hand-over direction is provided to the hand-over processing unit 27 or a change stop direction is provided to the control 25 signal processing unit 28, depending on whether another base station is available for hand-over. The control signal processing unit 28 generates either of the change stop signal or the control signal relative to hand-over, and the generated signal is 30 transmitted from the transmitting unit 29.

Next, an outline of the first embodiment of cell radius change processing of the present invention is described with reference to Fig.4.

35 Section (a) of Fig.4 shows a mobile communications system referenced to explain the outline of the first embodiment. In this figure, mobile stations A and B are present in the service

area ( $R_0$ =initial cell radius) that a base station forms, and each mobile station can communicate with the base station. The base station is to change the cell radius from the initial radius  $R_0$  to a new cell  
5 radius  $R_1$ .

In Fig.4, the distance between the base station and the mobile station A is expressed as  $L_A$ , and the distance between the base station and the mobile station B is expressed as  $L_B$ .

10 Section (b) of Fig.4 shows an outline of the cell radius change processing that the base station performs when only one mobile station A is present in the cell radius  $R_0$  of the base station in the mobile communications system of the section (a)  
15 of Fig.4. Here, the horizontal axis of this graph expresses the time lapse starting when the base station proposes a new cell radius, and the vertical axis expresses the distance (cell radius) from the base station concerned.

20 In the section (b) of Fig.4, at the time of  $t=0$ , the base station starts proposing to change the cell formation and provides information about the change to all the mobile stations in the cell as a part of the information signal. During a period  
25 between  $t=0$  and  $t=T$ , the information signal is transmitted to the mobile stations, and the cell radius is made small at  $t=T$ . The cell radius after change is expressed by  $R_1$ . Here, it is assumed that the position of the mobile station A is not changed  
30 during the period. As the section (a) of Fig.4 shows, the mobile station A is within the service area before and after the cell radius change. In this case, no special processing is necessary as to the mobile station A.

35 Section (c) of Fig.4 shows an outline of the cell radius change processing where only the mobile station B is present in the cell radius  $R_0$

formed by the base station in the mobile communications system as shown by the section (a) of Fig.4.

When the cell radius is made small as shown in the section (b) of Fig.4, the mobile station B becomes outside of the service area after  $t=T$  at which time the cell radius is made small. However, in the present invention, the mobile station B is warned in advance of the cell radius change, that is, the mobile station B becoming outside the service area if the cell radius is actually made small according to the information signal received during the period between  $t=0$  and  $t=T$ . Consequently, the mobile station B can attempt to hand-over the existing communication connection to another base station. The hand-over is performed if another base station is available, avoiding a disconnection. If the other base station is not available, the mobile station B transmits a change stop signal to the base station, such that the base station suspends the cell radius change, or revises the new cell radius such that the mobile station B can continuously be served.

Next, details of the processing procedure of the first embodiment are explained.

Fig.5 is a flowchart that shows the processing procedure of the base station, and Fig.6 is a flowchart that shows the processing procedure of the mobile station.

First, the processing procedure of the base station is explained, referring to Fig.5.

When the base station decides to make a cell radius change, the information signal processing unit 16 generates an information signal that includes information contents such as the new cell radius  $R_1$  and the present transmission electric power  $P_s$ . The information signal is periodically and

repeatedly transmitted (S1) to the mobile stations in the cell, a timer is started, and a response from the mobile station (S2) is waited for. The time length from the transmission start time of the information signal to scheduled time of the cell radius change implementation is set at T as shown in Fig.4. When the predetermined time elapses, i.e., timeout, (YES at S2), the control signal detection unit 13 checks whether a change stop signal has been received from one or more of the mobile stations (S3). If the change stop signal has been received from one or more mobile stations (YES at S3), a value  $L_1$  that indicates the distance between a mobile station and the base station is extracted from the change stop signal, and the value is provided to the control information processing unit 14 (S4).

Otherwise, that is, if it is determined that no change stop signals have been received from the mobile stations (NO at S3), the process ends, and returns to the first processing step.

The control information processing unit 14 determines the largest value  $L_{MAX}$  of the distance values  $L_1$  and the largest value  $L_{MAX}$  is provided to the cell formation processing unit 15 (S5). The cell formation processing unit 15 sets the value  $L_{MAX}$  as the value of the new cell radius  $R_1$  such that the mobile station that gives the largest value can remain within the service area of the base station (S6). Then, the process ends, and returns to the first processing step, and repeats the above-mentioned procedure.

Next, the processing procedure of the mobile station is described with reference to Fig.6.

When the receiving unit 22 of the mobile station receives the information signal from the base station with which it is communicating, the

received signal is provided to the information  
signal detection unit 25. The information signal  
detection unit 25 extracts data such as the received  
electric power  $P_r$ , the new cell radius  $R_1$  after  
5 change, and the present transmission electric power  
 $P_s$  of the base station from the received signal  
(S11), and provides the data to the distance  
calculation unit 24. The distance calculation unit  
24 calculates the distance  $L_1$  between the mobile  
10 station and the base station concerned, applying the  
received electric power  $P_r$  and  $P_s$  received from the  
information signal detection unit 25 to a formula  
(Formula 1) that gives a relationship between the  
signal electric power and the distance (S12).

15 (Formula 1)

$$P_r = A \times P_s \times (1/L_1)^4, \text{ where}$$

A is a coefficient indicative of the  
propagation path situation between the base station  
and the mobile station.

20 Although the present embodiment employs  
Formula 1, for example, for calculating the distance  
between the mobile station and the base station,  
another formula of the relationship between the  
signal electric power and the distance suitable for  
25 the propagation path characteristics of the system  
can be used, and the present invention is not  
limited to using Formula 1.

When the distance calculation unit 24  
calculates  $L_1$ , the calculation result is provided to  
30 the cell radius comparison unit 26. The cell radius  
comparison unit 26 compares  $L_1$  with  $R_1$  (S13). If it  
is determined that  $R_1$  is larger than  $L_1$  (NO at S13),  
the process ends because it means that the mobile  
station will remain within the service area after  
35 the cell radius change. Otherwise, if it is  
determined that  $R_1$  is smaller than  $L_1$  (YES at S13),  
the process moves to the next step (S14) where it is

determined whether a hand-over to another base station is possible (S14). The determination (S14) is performed as follows.

5       The hand-over processing unit 27 receives  
information items sent one by one from the  
connectable base station detection unit 23, and  
determines the availability of a hand-over. The  
result of the determination (availability of base  
stations for hand-over) is periodically provided to  
10   the cell radius comparison unit 26. The cell radius  
comparison unit 26 determines whether a hand-over to  
another base station is possible using the  
information about the availability of connectable  
base stations provided by the hand-over processing  
15   unit 27.

When the cell radius comparison unit 26  
performs determining as mentioned above (S14) and  
determines that a hand-over to another base station  
is possible (NO at S14), it directs the control  
20   signal processing unit 28 to generate a control  
signal that is needed by the mobile station for  
carrying out hand-over. Then, the control signal is  
provided to the mobile station such that the mobile  
station carries out the hand-over to another base  
25   station, and continues communication.

Otherwise, that is, when it is determined  
that the hand-over to another base station is  
impossible (YES at S14), the transmitting unit 29 of  
the mobile station concerned transmits the change  
30   stop signal that contains  $L_1$  to the base station  
(S16). According to this embodiment, a mobile  
station is capable of preventing the base station  
from reducing the cell radius any smaller than  $L_1$  by  
transmitting information that contains the value of  
35    $L_1$  to the base station.

Next, an outline of the second embodiment  
of the cell radius change processing is described

with reference to Fig. 7, wherein a base station changes cell formation based on the cell formation control method of the present invention.

In Fig.7, the horizontal axis expresses the time lapse from the time when the base station decides to change the cell radius, and the vertical axis expresses the distance (cell radius) from the base station, like Fig.4. Here, in the base station,  $R_0$  represents the present cell radius, and  $R_1$  represents the new cell radius after the change that the base station proposes to perform. In the second embodiment of the present invention, the cell radius change from  $R_0$  to  $R_1$  is performed in  $N$  steps, without changing all at once. For example, the cell radius change is carried out in three steps ( $N=3$ ) in this embodiment, namely, the cell radius is to be reduced from  $R_0$  to  $R_t=R_0-R_L$ ,  $R_t=R_0-2R_L$ , and then to  $R_t=R_0-3R_L=R_1$ , as shown in this graph. Specifically, the following  $R_t$  values of stage change cell radius are transmitted during each specified period. Namely,

between  $t=0$  and  $t=T$ ,  $R_t=R_0-R_L$ ,  
between  $t=T$  and  $t=2T$ ,  $R_t=R_0-2R_L$ , and,  
between  $t=2T$  and  $t=3T$ ,  $R_t=R_0-3R_L=R_1$  are provided to the mobile station as the new cell radius values to which a cell formation change is proposed. If the mobile station is located at a distance  $L_B$ , the radius changes proposed during  $t=0$  and  $t=2T$  do not affect the mobile station, and no further action is necessary. However, the radius change proposed during  $t=2T$  and  $t=3T$  will make the mobile station become outside the service area. Therefore, the mobile station transmits the change stop signal to the base station such that the cell radius change that makes the mobile station outside the area is stopped.

Next, details of the processing procedure of the second embodiment are explained.

Fig.8 and 9 are flowcharts showing the processing procedure of the base station, and Fig.10 is a flowchart showing the processing procedure of the mobile station.

5 First, the processing procedure of the base station is explained, referring to Fig.8 and Fig.9.

When a cell radius change is decided upon by the base station, a radius decrement interval  $R_L$  is obtained by dividing the difference between the new cell radius after change  $R_1$  and the present cell radius  $R_0$  by the number of times  $N$  of change as indicated by the following formula (Formula 2) (S21).

(Formula 2)

15 
$$R_L = (R_0 - R_1) / N$$

Next, a radius  $R_t$  that the base station changes to in steps is obtained by the following formula (Formula 3) (S22).

(Formula 3)  $R_t = R_0 - R_L$

20 The above processes are performed by the cell formation processing unit 15. The resulting  $R_t$  is provided to the information signal processing unit 16. The information signal processing unit 16 generates an information signal including data of  $R_t$  and the present transmission electric power  $PS$ ,  
25 transmits the information signal to the mobile station in the cell periodically and repeatedly through the transmitting unit 17, operates a timer, and waits for responses from the mobile stations  
30 (S23). The time length from the transmission start time of the information signal to the scheduled implementation time of the cell radius change is set at  $T$  as shown in Fig.7. After waiting for the response for the predetermined time, i.e., after a  
35 time out (YES at S24), the base station determines whether a change stop signal has been received from one or more mobile stations (S25). If a change stop

signal has been received from one or more mobile stations (YES at S25), transmission of the contents of the proposed cell change is stopped, the value of the cell radius setting value set up in the cell formation processing unit 15 is deleted, and the cell radius change processing is stopped such that the mobile station that transmitted the change stop signal can remain in the service area. That is, if the new cell radius  $R_1$  is set equal to  $R_t$  (S26), the cell radius is made the smallest possible while keeping the mobile station within the service area.

On the other hand, if it is determined after the timeout (YES at S24) that no change stop signals have been received from any of the mobile stations (NO at S25), the process reached the final stage and is completed if  $R_t = R_1$  (YES at S27). If  $R_t$  is not equal to  $R_1$  (NO at S27),  $R_t$  is set at  $R_t - R_L$ , and provided to the transmitting unit (S28), and the process returns to the first step.

Next, the processing procedure of the mobile station is described in reference to Fig.10.

The information signal from the base station with which communications are ongoing is received by the receiving unit 22 of the mobile station, and provided to the information signal detection unit 25 that extracts data such as the received electric power  $P_r$ , the cell radius  $R_t$  after change and the present transmission electric power  $P_s$  of the base station included in the information signal (S31), and sends the data out to the distance calculation unit 24. The distance calculation unit 24 calculates the distance  $L_i$  between the mobile station and the base station by applying the received electric power  $P_r$  and  $P_s$  to the above-mentioned Formula 1 (S32).

In addition, although the present embodiment employs Formula 1, for example, for

calculating the distance between the mobile station and the base station, another formula for the relationship between the signal electric power and the distance suitable for the propagation path characteristics of the system can be used, and the present invention is not limited to using Formula 1.

When the distance calculation unit 24 has calculated  $L_i$  as mentioned above, the calculation result is provided to the cell radius comparison unit 26. The cell radius comparison unit 26 compares  $R_t$  with  $L_i$  (S33). If the comparison determines that  $R_t$  is larger than  $L_i$  (NO at S33), which indicates that the mobile station concerned will remain within the service area after the cell radius is changed, the process ends and returns to the first processing step.

Otherwise, if it is determined that  $R_t$  is smaller than  $L_i$  (YES at S33), the process moves to the next step, where it is determined whether a hand-over to another base stations is possible (S34). This determination (S34) is performed as follows.

The hand-over processing unit 27 receives the information items sent one by one from the connectable base station detection unit 23, and determines the availability of a connectable base station for hand-over from the received information. The result of the determination (the information about the availability of a connectable base station that is acquired as a determination result in this case) is periodically provided to the cell radius comparison unit 26. The cell radius comparison unit 26 determines whether the hand-over to another base station is possible using the information about the availability of a connectable base station provided by the hand-over processing unit 27.

The cell radius comparison unit 26 directs the control signal processing unit 28 to generate

the control signal that is needed for the mobile station to carry out the hand-over, when it is determined that the hand-over to another base station is possible by the above-mentioned check  
5 (S34) (NO at S34). Using the control signal, the mobile station performs the hand-over to another base station, and continues communications.

Otherwise, when it is determined that the hand-over to another base station is impossible by  
10 the above-mentioned check (YES at S34), the mobile station concerned transmits a change stop signal to the base station (S35). Thereby, the mobile station can stop cell radius change processing of the base station, and can avoid disconnection of ongoing  
15 communications.

Next, an outline of the third embodiment of the cell radius change processing is described with reference to Fig. 11, wherein a base station changes cell formation based on the cell formation  
20 control method of the present invention.

As for Fig.11, like Fig.7, the horizontal axis expresses the time lapse from the time when the base station decides to make a cell radius change, and the vertical axis expresses the distance (cell  
25 radius) from the base station concerned. Here, in the base station cell,  $R_0$  represents the present cell radius, and  $R_1$  represents the new cell radius after change. In the third embodiment of the present invention, the cell radius change from  $R_0$  to  $R_1$  is  
30 divided in  $N$  stages. For example, the cell radius change is carried out in three steps ( $N=3$ ) in this embodiment, namely, the cell radius is to be reduced from  $R_0$  to  $R_t=R_0-R_L$ ,  $R_t=R_0-2R_L$ , and then to  $R_t=R_0-3R_L=R_1$ , as shown in this figure. Specifically, the  
35 following  $R_t$  values of stage change cell radius are transmitted during each specified period. Namely,  
between  $t=0$  and  $t=T$ ,  $R_t=R_0-R_L$ ,

between  $t=T$  and  $t=2T$ ,  $R_t=R_0-2R_L$ , and,  
between  $t=2T$  and  $t=3T$ ,  $R_t=R_0-3R_L=R_1$  are  
provided to the mobile station as the new cell  
radius to which the cell formation is proposed to be  
5 changed.

In the third embodiment, information about  
the final cell radius  $R_1$  is added to the information  
signal in each stage, which is in addition to the  
second embodiment.

10 In this example, if the distance between  
the mobile station and the base station is  $L_B$ , the  
cell radius change proposed during  $t=0 - 2T$  is  
acceptable, and no special process is needed.  
However, in the third embodiment, the final cell  
15 radius  $R_1$  that the base station will ultimately  
propose is also provided from the beginning of  $t=0$   
to the mobile station. Therefore, the mobile station  
can start attempting to find another base station, a  
second base station, for hand-over at an earlier  
20 stage. Further, even when the second base station is  
in the process of changing its cell radius, the  
mobile station can determine whether the final cell  
radius  $R_1$  of the second base station will contain  
the mobile station. In this manner, the number of  
25 times of hand-over can be decreased. Further, even  
when there is no candidate base station to which the  
distance from the mobile station is shorter than the  
final cell radius of the base station, it is  
possible to choose a base station for hand-over,  
30 with which communication can be maintained for the  
longest possible time, based on  $R_1$  and the stage  
change cell radius  $R_t$ . Consequently, since the  
number of times of hand-over can be minimized, and  
transmission and reception of control signals, such  
35 as a change stop signal, can be minimized, wireless  
resources can be used efficiently.

Next, the detailed processing procedure of

the third embodiment is explained.

Fig.12 and Fig.13 are flowcharts showing the processing procedure of the base station, and Fig.14 and Fig.15 are flowcharts showing the processing procedure of the mobile station.

First, the processing procedure of the base station is explained, referring to Fig.12 and Fig.13.

When the base station decides to make a cell radius change, a radius decrement interval  $R_L$  of the cell radius is obtained by dividing the difference between the present cell radius  $R_0$  and the final cell radius after change  $R_1$  by the number of times of change  $N$  (refer to Formula 2) (S41).  
Next, the base station obtains  $R_t$  from the difference between  $R_0$  and  $R_L$ , using Formula 3 (S42),  $R_t$  being the stage change cell radius that the base station uses when gradually changing the cell radius. The processes are performed by the cell formation processing unit 15. The information signal processing unit 16 generates information containing data such as  $R_1$ ,  $R_t$ ,  $P_s$ ,  $R_L$ , and  $T$ , and transmits the information to mobile stations in its cell periodically and repeatedly through the transmitting unit 17, operates a timer, and waits for responses from the mobile stations (S43). The time length from the time when transmission of the information signal is started to the scheduled time of cell radius change implementation is set at  $T$  as shown in Fig.11.  
After waiting for the responses for the predetermined time, that is, after a timeout (YES at S44), it is determined whether a change stop signal is received from one or more mobile stations (S45). If it is determined that a change stop signal is received from one or more mobile stations (YES at S45), transmission of the information of the proposed cell change is stopped, the value of the

cell radius set in the cell formation processing unit 15 is deleted, and the cell radius change processing is stopped, such that the mobile station that transmitted the change stop signal can remain  
5 in the service area. By replacing  $R_1$  with  $R_t$  (S46), the cell radius is set at the smallest possible while keeping the mobile station in question within the service area.

Otherwise, if it is determined after the  
10 timeout (YES at S44) that no change stop signals are received from any of the mobile stations (NO at S45), the process reaches the final step and is completed if  $R_t = R_1$  (YES at S47). If  $R_t$  is not equal to  $R_1$  (NO at S47),  $R_t$  is replaced with  $R_t - R_L$ , which is provided  
15 to the transmitting unit 17 (S48), and the process returns to the first step.

Next, the processing procedure of the mobile station is explained with reference to Fig.14 and Fig.15.

20 The processing procedure of the mobile station in the third embodiment is similar to the processing procedure of the second embodiment, as shown in this figure. However, the mobile station in the third embodiment is capable of selecting a base  
25 station that can continue connection longer than others as the hand-over destination. That is, the mobile station can receive the information signal from a candidate base station, and calculate remaining time until the cell radius of the  
30 candidate base station reaches  $R_1$ , using  $R_t$ ,  $R_1$ ,  $R_L$ , and  $T$  contained in the information signal. In this manner, the mobile station can attempt to hand-over to the candidate base station before the mobile  
station becomes outside the service area of the  
35 candidate base station.

Further, the mobile station is capable of calculating the distance to the candidate base

station from  $P_s$  and the receiving signal level of the information signal from the candidate base station. By comparing the calculation result with  $R_1$ , the mobile station can determine whether the mobile station will remain within the service area after the cell radius change. Using this information, the mobile station can select a base station to communicate with such that the number of times of hand-over is minimized.

10                Although the embodiments described above are based on the base station autonomously controlling the cell formation, the present invention is applicable to a structure wherein a central station that governs a plurality of base stations controls the cell formation. In such a structure, the cell formation control is based on information acquired from the base stations governed by the central station. The central station may be, for example, a wireless circuit control station.

20                In the embodiments, the cell formation control function of the cell formation processing unit 15 of the base station includes a cell formation change stop means, a cell formation change means, and a cell radius gradual change means, and the information function of the information signal processing unit 16 includes a first cell information providing means and a second cell information providing means.

30                Further, the comparison function of the cell radius comparison unit 26 of the mobile station represents a preparatory outside-the-cell detection means, the signal transmitting function of the transmitting unit 29 represents a detection result providing means and a distance information providing means, the distance calculation function of the distance calculation unit 24 represents a distance calculation means, and the hand-over processing

function of the hand-over processing unit 27 represents a first hand-over means and a second hand-over means.

As mentioned above, the cell formation  
5 control method and the mobile communications system of the present invention can prevent a disconnection of communication that is due to a reduced cell radius excluding a mobile station in communication from occurring by the mobile station being capable  
10 of informing the base station whether a planned cell radius reduction is acceptable, and by the base station reducing the cell radius enough to cover the mobile station based on the information from the mobile station.

15 The present invention further realizes a base station that can change cell formation according to the above cell formation control method.

The present invention further realizes a mobile station that can maintain communication  
20 without being disconnected, according to the above cell formation control method.

Further, the present invention is not limited to these embodiments, but various variations and modifications may be made without departing from  
25 the scope of the present invention.

The present application is based on Japanese priority application No. 2001-274214 filed on 9/10, 2001 with the Japanese Patent Office, the entire contents of which are hereby incorporated by  
30 reference.

WHAT IS CLAIMED IS

5

1. A cell formation control method that controls formation of a cell, which is performed by a base station while the base station communicates with a mobile station in the cell, comprising:

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a step wherein the base station provides the mobile station with information relative to cell formation change,

15

a step wherein the mobile station determines whether the mobile station will be placed outside the cell if the cell formation change is performed, in advance of the base station performing the cell formation change, based on the information relative to the cell formation change,

20

a step wherein a result of the determination by the mobile station is provided to the base station, and

25

a step wherein the base station suspends the cell formation change based on the result of the determination provided by the mobile station.

30

2. A cell formation control method as claimed in claim 1, further comprising:

35

a step wherein the mobile station calculates a distance between the mobile station and the base station, when the mobile station determines that the mobile station will be placed outside the cell if the cell formation change is performed,

a step wherein the mobile station provides the base station with information relative to the

distance, and

a step wherein the base station performs the cell formation change based on the information relative to the distance.

5

3. A cell formation control method as claimed in claim 1, further comprising a step wherein the mobile station attempts a hand-over to another base station, when the mobile station determines that the cell formation change will place the mobile station outside the cell.

15

4. The cell formation control method as claimed in claim 1, further comprising a step wherein the base station provides at a predetermined interval within a predetermined period all the mobile stations in the cell with the information relative to the cell formation change, in advance of the cell formation change being performed.

25

5. A cell formation control method that controls formation of a cell, which is performed by a base station while the base station communicates with a mobile station in the cell, comprising:  
a step wherein the base station provides the mobile station with information relative to cell formation change, where the cell formation change is to be performed in two or more stages, including a

30

35

final stage, at a predetermined interval,

5 a step wherein the mobile station determines whether the mobile station will be placed outside the cell if the cell formation change is performed through the final stage, and

10 a step wherein the mobile station attempts a hand-over to another base station if the mobile station determines that the mobile station will be placed outside the cell if the cell formation change is performed through the final stage, even if the mobile station will remain within the cell in any of prior stages.

15

6. The cell formation control method as claimed in claim 5, further comprising a step wherein the base station provides at a predetermined interval within a predetermined period all the mobile stations in the cell with the information relative to the cell formation change, in advance of the cell formation change being performed.

25

7. The cell formation control method as claimed in claim 5, further comprising a step wherein the base station provides all the mobile stations in the cell with the information relative to the cell formation change, in advance of the cell formation change being performed, at a predetermined interval within a predetermined period, where the information relative to the cell formation change contains information about a cell radius of a next stage and a cell radius of the final stage.

35

5                   8. A mobile communications system  
configured by two or more mobile stations and a base  
station that controls formation of a cell,  
comprising:

                  preparatory outside-the-cell detection  
10 means that enables each of the mobile stations to  
determine whether the mobile station will be placed  
outside the cell if a cell formation change is  
performed, in advance of the base station performing  
the cell formation change, based on information  
15 relative to the cell formation change provided to  
the mobile station by the base station,

                  detection result providing means that  
enables the mobile station to provide a result of  
the preparatory outside-the-cell detection to the  
20 base station, and

                  cell formation change stop means that  
enables the base station to suspend the cell  
formation change based on the result of the  
determination provided by the mobile station.

25

                  9. The mobile communications system as  
30 claimed in claim 8, further comprising:

                  distance calculation means that enables  
the mobile station to calculate a distance between  
the mobile station and the base station, when the  
mobile station determines that the mobile station  
35 will be outside the cell,

                  distance information providing means that  
enables the mobile station to provide the

calculation result as distance information to the base station, and

cell formation change means that enables the base station to perform the cell formation  
5 change based on the distance information provided by the mobile station.

10

10. The mobile communications system as claimed in claim 8, further comprising first hand-over means that enables the mobile station to attempt a communication connection change to another  
15 base station when the mobile station determines that the mobile station will be placed outside the cell.

20

11. The mobile communications system as claimed in claim 8, further comprising first cell information providing means that enables the base station to provide all the mobile stations in the  
25 cell with the information relative to the cell formation change at a predetermined interval within a predetermined period, in advance of the cell formation change being performed.

30

12. A mobile communications system configured by two or more mobile stations and a base  
35 station that controls formation of a cell, comprising:

cell radius gradual change means that

enables the base station to perform the cell formation change in two or more stages, including a final stage, at a predetermined interval, and

second hand-over means that enables the  
5 mobile station to attempt a communication connection change to another base station, when the mobile station determines that the mobile station will be placed outside the cell if the cell formation change is performed through the final stage, even if the  
10 mobile station will remain within the cell in any of prior stages.

15

13. The mobile communications system as claimed in claim 12, further comprising first cell information providing means that enables the base  
20 station to provide at a predetermined interval within a predetermined period all the mobile stations in the cell with the information relative to the cell formation change, in advance of the cell formation change being performed.

25

14. The mobile communications system as  
30 claimed in claim 13, further comprising second cell information providing means that enables the base station to provide at a predetermined interval within a predetermined period all the mobile stations in the cell with the information relative  
35 to the cell formation change, in advance of the cell formation change being performed, where the information relative to the cell formation change

contains information about a cell radius of a next stage and a cell radius of the final stage.

5

15. A base station that changes cell formation according to a situation of adjacent cells, while communicating with a mobile station in the cell, comprising cell formation change stop means that suspends the cell formation change based on information provided by the mobile station.

15

16. The base station as claimed in claim 15, further comprising first cell information providing means that enables the base station to provide information about a cell radius to which a change is scheduled, to all the mobile stations in the cell at a predetermined interval in a predetermined period before the change is performed.

25

17. The base station as claimed in claim 16, further comprising cell radius gradual change means that enables the base station to change the cell radius gradually in stages at a predetermined interval until it reaches a final cell radius.

35

18. The base station as claimed in claim

17, further comprising second cell information providing means that enables the base station to provide the mobile station, at a predetermined interval within a period, information about a cell  
5 radius corresponding to a next stage, and the final cell radius, where the cell radius is gradually changed at a predetermined interval.

10

19. A base station that changes cell formation according to a situation of adjacent cells, while communicating with a mobile station in the  
15 cell, comprising cell formation change means that changes the cell formation according to a parameter that can be revised based on information from the mobile station, such that the mobile station can remain within the cell after the cell formation  
20 change.

25 20. A mobile station that communicates with a base station, comprising:  
preparatory outside-the-cell detection means that enables the mobile station to determine whether the mobile station will be placed outside a  
30 cell of the base station if the base station performs a cell formation change prior to the cell formation change being performed, and  
detection result providing means that enables the mobile station to provide the result of  
35 the preparatory outside-the-cell detection to the base station.

21. The mobile station as claimed in claim  
5 20, wherein the preparatory outside-the-cell  
detection means further comprises:

distance calculation means that calculates  
a distance between the mobile station and the base  
station when the mobile station determines that the  
10 mobile station will be placed outside the cell, and

distance information providing means that  
provides the base station with a result of the  
calculation performed by the distance calculation  
means.

15

22. The mobile station as claimed in claim  
20 20, further comprising first hand-over means that  
enables the mobile station to attempt a  
communication connection change to another base  
station, when the mobile station determines that the  
mobile station will be placed outside the cell as  
25 the result of the preparatory outside-the-cell  
detection.

30

23. A mobile station in a cell, which  
communicates with a base station, comprising second  
hand-over means that enables the mobile station to  
attempt a communication connection change to another  
35 base station, when the mobile station determines  
from information relative to a cell formation change  
provided to the mobile station by the base station,

that the mobile station will be placed outside the cell if the base station performs the cell formation change through a final stage, even if the mobile station will remain within the cell in any of prior stages.

5