



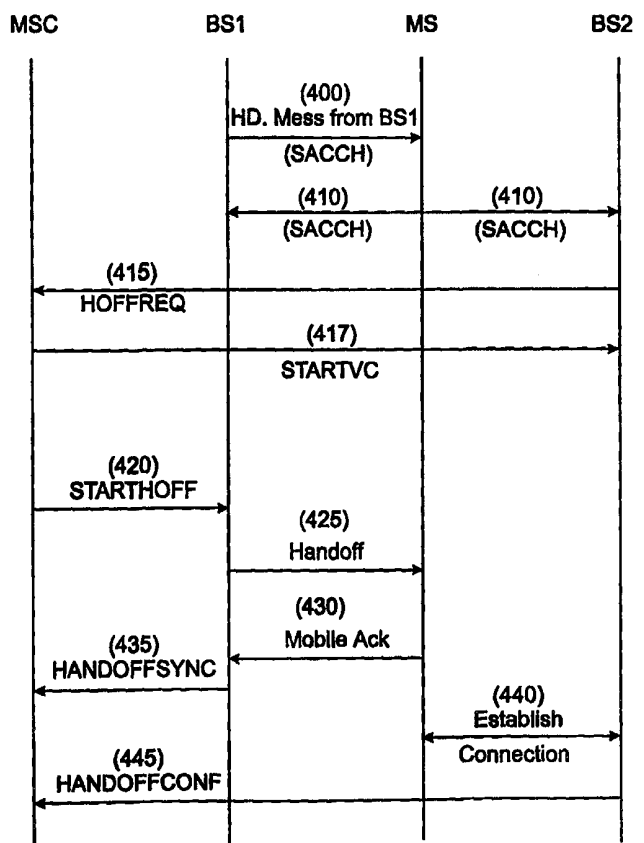
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification <sup>6</sup> : <b>H04Q 7/38</b></p>	<p><b>A1</b></p>	<p>(11) International Publication Number: <b>WO 99/44386</b> (43) International Publication Date: 2 September 1999 (02.09.99)</p>
<p>(21) International Application Number: PCT/SE99/00184 (22) International Filing Date: 12 February 1999 (12.02.99) (30) Priority Data: 09/030,931 26 February 1998 (26.02.98) US (71) Applicant: TELEFONAKTIEBOLAGET LM ERICSSON (publ) [SE/SE]; S-126 25 Stockholm (SE). (72) Inventors: LUNDBORG, Tomas; Fridhemsgatan 29A III, S-112 40 Stockholm (SE). CARLSSON, Göran; Klevbergsvägen 109, S-179 60 Stenhamra (SE). (74) Agent: ERICSSON RADIO SYSTEMS AB; Common Patent Dept., S-164 80 Stockholm (SE).</p>		<p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p><b>Published</b> <i>With international search report.</i></p>

(54) Title: CONTINUOUS VERIFICATION OF MOBILE STATIONS FOR HANDOFF OPERATIONS

(57) Abstract

A method and apparatus for providing continuous verification of a mobile station for handoff operations in a cellular telecommunication system is described. In an embodiment of the present invention, a mobile station (MS) has an established wireless connection with a first base station (BS1). A second base station (BS2) receives the uplink transmissions sent to BS1 from the MS as soon as it comes into receiving range. BS2 immediately initiates a verification procedure on the MS to determine whether a satisfactory connection can be made. The verification step is initiated by the second base station before a handoff procedure is initiated thereby reducing the amount of signaling between the MSC and associated base stations. Since the verification is initiated earlier, it occurs over a relatively longer period of time resulting in improved handoff reliability.



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## Continuous Verification of Mobile Stations For Handoff Operations

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### FIELD OF THE INVENTION

The present invention relates generally to cellular radio telecommunication systems. More specifically, the invention relates to an improved technique for performing verification of mobile stations for handoff operations.

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### BACKGROUND OF THE INVENTION

In a basic cellular telecommunication system, a mobile switching center (MSC) is linked to a plurality of base stations by a series of digital transmission links. The base stations are geographically dispersed to form an area of coverage for the system. Each base station (BS) is designated to cover a specified area, known as a cell, in which two way radio communication can take place between a mobile station (MS) and the BS in the associated cell. As the MS moves from one cell to the next, a handoff procedure is initiated to transfer the communication link from the present BS to the next BS in order to continue the connection. Since the handoff involves oversight from the MSC, valuable system resources are consumed for each of the many MSs requiring handoffs.

Consider the situation illustrated in Fig. 1. A simplified cellular radio telecommunication system is depicted comprising an MSC and base stations BS1 and BS2 serving their respective cells. The border between the respective cells served by BS1 and BS2 is represented by line 110. In an example of a typical handoff procedure, BS1 has an initial established connection with the MS within its cell. As the MS

moves toward the cell served by BS2 to position MS', the signal strength of the connection, which is constantly being monitored, starts to decrease. A handoff to BS2 is therefore initiated when the relative signal strength associated with BS2 indicates that BS2 is deemed more suitable for continuing the connection i.e. signal strength associated with BS2 is typically stronger than that of the current connection. This condition typically occurs in the proximity of cell border 110. The MSC then sends the appropriate commands over transmission links 115 to the BSs in order to execute the handoff.

The evolution of cellular systems is placing an increasing demand on system resources. For example, increases in subscriber capacity and alternative network configurations such as microcell environments often result in an increase in mobile station handoffs. Furthermore, the addition of new resource taxing services may also increase the loading on the system. Given the aforementioned trend, it is desirable to reduce system loading whenever possible. One way of doing this is to reduce the involvement of the MSC in recurring tasks associated with handoff operations. For example, in prior art digital systems such as those operating in accordance with Digital Advanced Mobile Phone System (D-AMPS), the handoff procedure requires several signals to be sent between the MSC and the participating BSs in order to complete the operation. Some of these signals are related to a verification process which innately requires oversight by the MSC. By way of example, when the MSC receives a handoff request for an MS, the MSC signals the BS targeted for handoff directing it to perform a verification in order to determine if the base station can sufficiently communicate with the MS. The MSC then waits for a confirmation signal back from the BS targeted for handoff indicating that the MS has been verified prior to proceeding with the handoff. The verification is usually performed for a very short period of time and typically requires much signaling activity from the MSC. Consequently, a reduction in the involvement of the MSC during verification can significantly reduce the loading on the system.

Fig. 2 depicts a typical signaling sequence involved in a D-AMPS handoff operation from an originating BS1 to a neighboring BS2. A determination for handoff

is typically based on any of a number of criteria which includes the received signal strength, bit-error rate (BER), interference levels on co-channels from other base stations, and propagation path loss measurements. When conditions in BS1 for handoff are reached, BS1 sends a handoff request DHOFFREQ to the MSC, as shown  
5 in step 200. In step 205, the MSC follows with a command VERIFYMS to BS2 to initiate a verification procedure to determine if the radio link between the MS and BS2 is satisfactory. BS2 performs the verification procedure by tuning a receiver to receive the uplink signals the MS is currently transmitting to BS1, in which the signals are only evaluated for a very short time.

10           When the uplink signals have been received satisfactorily or if a preset time period has elapsed, BS2 sends a response MSVERIFIED to the MSC at step 210 which includes an indication of whether the verification was successful. If successful, the MSC signals BS2 with a STARTVC command (step 215) to set up a digital traffic channel (DTC), which includes setting up a frequency and timeslot for the new  
15 connection. After the DTC has been set up, BS2 signals the MSC with a VCSTARTED acknowledgment message at step 220 to notify the MSC that a traffic channel has been set up. At this point, the MSC issues a handoff order to BS1 with a STARTHOFF command (step 225) which BS1 then forwards to the MS (step 230). The MS responds back with an acknowledgment (step 235) to BS1 which terminates  
20 the connection with the MS and sends a message HANDOFFSYNC (step 240) to the MSC to confirm the release of the MS from the connection with BS1. Next, the MS tunes to the new frequency of the new traffic channel establishing a connection with BS2 in step 245. With the connection established, BS2 signals the MSC in step 250 to confirm that the handoff was completed with a HANDOFFCONF message indicating  
25 that the communication link has been completely transferred to cell 2.

Although the handoff procedure of the prior art works relatively well, modifications may be made to improve efficiency and reliability. For example, the large number of signals being passed, particularly during the verification procedure, causes the handoff operation to be resource intensive. In addition, a known problem  
30 with the prior art handoff procedure is that incorrect handoff decisions may sometimes

occur e.g. due to co-channel interference. This can happen when the verification step, which is performed for a very short time, erroneously verifies an MS operating on the same frequency (co-channel) belonging to another cell. This can result in an inappropriate handoff decision involving the wrong MS. It is therefore an objective of the present invention to provide a verification technique of mobile stations in handoff operations that requires less participation from the MSC thus reducing system loading. A further objective is to provide a more reliable verification technique to reduce the occurrence of incorrect handoff decisions.

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### SUMMARY OF THE INVENTION

Briefly described, and in accordance with an embodiment thereof, the invention discloses a method and apparatus for reducing the loading on a cellular telecommunication system by reducing the involvement of the mobile switching center (MSC) in recurring tasks such as the verification process for mobile station handoffs.

15 In a cellular telecommunication system having an MSC linked to a plurality of base stations, a mobile station (MS) has an established wireless connection with a first base station (BS1). When the MS comes into receiving range of the second base station (BS2) e.g. near the cell border, and while the MS is still in radio communication with BS1, BS2 eavesdrops on the uplink transmissions sent by the MS to BS1. BS2 immediately initiates a verification procedure on the MS, prior to a handoff being initiated, and analyzes the uplink signals to determine if a satisfactory connection can be established with BS2. At the time when a handoff is determined to be necessary by BS1, a handoff message is relayed to BS2 via the MS in the slow associated control channel (SACCH) on the digital traffic channel (DTC). When the verification is completed satisfactorily, the MSC is notified by BS2. The MSC then transmits the command for handoff to BS1 which then orders the MS to establish a connection with BS2. The connection with BS1 is released completing the transfer of the connection to BS2.

The present invention provides a method in which handoffs are performed with improved efficiency since the verification step will have been completed or be underway before the time the handoff occurs. The verification of the mobile station is preemptive and carried out in the "background" by neighboring base stations thereby substantially reducing the participation of the MSC by eliminating several communication steps with the associated base stations. Furthermore, the verification procedure has improved reliability since it is performed over a relatively longer period of time. This is because the verification starts well before a handoff procedure is initiated by the currently connected BS i.e. at the time when BS2 is first able to receive uplink signals from the MS. These and other advantages of the present invention will become apparent upon reading the following detailed descriptions and studying the various figures of the drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings in which:

Fig. 1 illustrates a mobile station handoff from one base station to a neighboring base station in a cellular telecommunication system;

Fig. 2 depicts a signaling sequence involved in a typical prior art handoff procedure;

Fig. 3 illustrates the verification process operating in accordance with an embodiment of the present invention.

Fig. 4 depicts a signaling sequence for a handoff procedure operating in accordance with the embodiment; and

Fig. 5 illustrates an exemplary application of the continuous verification function.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

5 A discussion directed toward the signaling associated with prior art handoff operations was provided in the preceding sections. A primary motivation of the present invention is to reduce system loading by reducing the involvement of the MSC in recurring tasks such as overseeing the verification process during handoff operations. In the prior art, the MSC is burdened with directing the verification  
10 procedure after a handoff decision has been made involving the currently connected BS. In contrast and in accordance with the present invention, an improved method of performing verification of mobile stations (MSs) in handoff operations without substantially involving the MSC is described.

In an exemplary embodiment, verification on the MS is performed by all  
15 neighboring base stations (BSs) capable of receiving signals from the MS while it is still in communication with the originating BS. When the MS moves within the receiving range of neighboring BSs, those that can adequately receive signals from the MS will immediately initiate verification of the MS in anticipation of a handoff. Since a neighboring BS will likely be the target for handoff, the verification will be  
20 completed by the time the actual handoff is performed.

Fig. 3 illustrates the verification process utilized in a simplified two-cell radio telecommunication system operating in accordance with the exemplary embodiment. An MS initially located in cell 1 is maintaining a connection with BS1 i.e. transmissions of uplink 315 and downlink 320 signals are made between the MS and  
25 BS1. As the MS moves near cell border 310, it comes into the receiving range of BS2. In BS2, and in addition to the primary transceivers 325, is an array of receivers 330 configured to receive signals from MSs operating in neighboring cells. Receivers in the receiver array 330 are capable of listening to active frequencies of the neighboring

cells e.g. the operating frequencies of BS1. When the MS moves toward cell border 310, and while still maintaining its connection with BS1, uplink signals 315' transmitted by the MS to BS1 are received by a receiver in array 330 in BS2 tuned to the uplink frequency. Upon reception of the uplink signals, BS2 immediately begins a  
5 verification procedure on the MS. As known by those skilled in the art, the verification procedure typically includes signal strength measurements and the evaluation of the signal based on the measurements by, for example, determining the color code and evaluating various statistics such as the number of satisfactory measurement samples.

10 By the time a handoff to BS2 is performed, the verification of the MS by BS2 will be completed satisfactorily without requiring the involvement of the MSC. The verification is effectively performed in the "background" by the neighboring base stations which are constantly monitoring MSs that are within receiving range in anticipation of a handoff. Another advantage of the method is that the verification that  
15 takes place is typically performed over a relatively longer time than that performed in the prior art and thus is more reliable. It should be noted that the application of the invention to a telecommunication system comprising a large number of base stations, having equivalent equipment and capability, is readily attained and that the simplified embodiment was given for purposes of illustration.

20 Fig. 4 illustrates a typical signaling sequence for a handoff procedure operating in accordance with the exemplary embodiment. The embodiment represents a signaling sequence used in a cellular system operating in accordance with the Digital Advanced Mobile Phone System (D-AMPS) standard. In the handoff example, a mobile station (MS) traveling within a cell served by an originating BS1, with which it  
25 has an established connection, towards a neighboring cell served by BS2. BS1 detects that the signal strength of the connection is getting weaker and determines, based on recent signal strength measurements, that a handoff to a more suitable cell served by BS2 should be undertaken. At this point (step 400) BS1 sends a message in a presently existing Slow Associated Control Channel (SACCH) on the digital traffic channel  
30 (DTC) to the MS to indicate that BS1 wishes to initiate a handoff to BS2. The SACCH

is utilized on both the uplink and downlink of the traffic channel for sending system information, thus "piggybacking" the handoff message on the SACCH requires no additional bandwidth. The MS receives this message and retransmits it on the current uplink frequency, as shown in step 410. The message is also received by BS2 since it  
5 is tuned to and listening to MS transmissions for verification.

After receiving the relayed SACCH message from BS1 via the MS, BS2 sends a handoff request HOFFREQ to the MSC in step 415. The handoff request includes the cell identification of BS1 and associated channel information for use by the MSC. In addition, the HOFFREQ indicates to the MSC that the verification has been  
10 completed satisfactorily. In step 417, the MSC issues a command STARTVC to BS2 to start transmitting and receiving on a specified frequency and timeslot. The MSC then issues a handoff order to BS1 by sending a STARTHOFF command in step 420. The STARTHOFF command includes information on the new frequency and timeslot to be used. BS1 then sends a handoff message to direct the MS (step 425) who then  
15 responds back with a mobile acknowledgment in step 430. At this point the connection with BS1 can be released and a message HANDOFFSYNC indicating same is sent to the MSC in step 435. The MS retunes to the specified frequency to establish a connection with BS2 at step 440. And finally, BS2 signals the MSC confirming the handoff is completed by sending a HANDOFFCONF message in step 445. The  
20 communication link has been completely transferred to cell 2 at this point.

In the present invention, the MS is capable of repeating the message received on the SACCH from BS1 to BS2 as illustrated in step 410. The concept of utilizing the MS as a relay mechanism for transmitting information between base stations further reduces the necessity for the information to be sent from BS1 to the MSC to be passed  
25 on to BS2. As a consequence, the handoff procedure of the present invention eliminates several communication steps between the MSC and base stations as compared to the prior art handoff procedure, thereby significantly reducing the loading on the system. Furthermore, the technique of the present invention is especially suitable for applications involving many fast occurring handoffs in a short  
30 amount of time such as fast moving traffic along highways, for example.

Fig. 5 illustrates an application for continuous verification function as described. An array of receivers 520 is placed in BS 515 which continuously listen to MS uplink transmissions of active frequencies of neighboring cells served by BS 505 and BS 510. In an embodiment of the application, a receiver in the array searches the spectrum by scanning for frequencies that are being used by MSs communicating with neighbor base stations such as BS 505 and BS 510. The scanning pattern may follow a succession algorithm such as, for example, round robin or any other suitable model. When an MS transmitting on a new frequency is detected but not yet monitored, a receiver in the array is assigned to continuously listen to that particular MS. In another embodiment, the searching for active frequencies may follow a predetermined list of neighbor frequencies.

The listening procedure of the receivers is relatively straightforward since the direction of oncoming traffic and the operating frequencies of the adjacent cells are known. Thus, an MS traveling in either direction along a highway 500 will initially have an established connection with either BS 505 or BS 510. BS 515, who is the target of the handoff, will perform the verification on the oncoming traffic as described above. The handoff will be more efficiently handled since the verification step will have been completed by the time the handoff is performed to BS 515. Furthermore, there is increased reliability of the verification because it is performed over a relatively longer period of time i.e. the verification starts at the time the MS enters into the receiving range of receivers 520 of BS 515. Additionally, the verification procedure can be further corroborated by detecting whether the MS is moving toward or away from BS 515 by analyzing whether the signal strength is increasing or decreasing.

The embodiment of the present invention not only reduces system signaling for improved efficiency but also produces much more reliable handoffs. The result is a more accurate verification process that is continuous in nature and is better able to confirm the location of the correct MS. Those skilled in the art will appreciate that the prior art verification procedure only measures very brief bursts of data in which the

color code is analyzed in order to determine where the MS is located relative to the BS.

It should be understood that the embodiment shown herein is merely exemplary and that one skilled in the art can make variations and modifications to the signaling steps without departing from the spirit and scope of the invention. Furthermore, the inventive concept of continuous verification of mobile stations for handoff operations may be applied to other telecommunication systems operating in accordance with standards such as Global System for Mobile Communication (GSM), Personal Digital Cellular (PDC), and Advanced Mobile Phone System (AMPS). All such variations and modifications are intended to be included within the scope of the invention as defined by the appended claims.

## WHAT IS CLAIMED IS:

1. In a cellular telecommunication system comprising a mobile switching center linked to a plurality of base stations, and a mobile station having an established wireless connection with a first base station, a method of handing off the mobile station  
5 connection from the first base station to a second base station comprising the steps of:

receiving uplink transmissions of the established connection from the mobile station by the second base station;

performing signal measurements on the received uplink transmissions by the second base station;

- 10 verifying that the uplink transmissions are received satisfactorily by the second base station based on the signal measurements prior to the initiation of a handoff;

determining that the second base station is more suitable than the first base station for continuing the connection with the mobile station;

- 15 transmitting appropriate messages for initiating a handoff procedure from the first base station to the second base station;

releasing the connection between the mobile station and the first base station;  
and

establishing a connection between the mobile station and the second base station.

- 20 2. A method according to claim 1 wherein the uplink transmissions are received by a receiver in a receiver array in the second base station and wherein the receiver array is configured to scan for active mobile stations operating on the frequencies of neighboring base stations.

3. A method according to claim 1 wherein the message for handoff is relayed from  
25 the first base station to the second base station by the mobile station.

4. A method according to claim 1 wherein the verification procedure includes detecting the relative direction of the mobile station with respect to the second base station.
5. A method according to claim 4 wherein the detecting is done by analyzing whether the signal strength is increasing or decreasing.
6. A method according to claim 1 wherein the telecommunication system is operating in accordance with the Digital Advanced Mobile Phone System (D-AMPS) standard.
7. A method according to claim 1 wherein a message for handoff is transmitted on a Slow Associated Control Channel (SACCH) over a digital traffic channel.
8. In a cellular telecommunication system comprising a mobile switching center linked to a plurality of base stations, and a mobile station having an established wireless connection with a first base station, a method of performing verification on the mobile station by a second base station prior to a handoff comprising the steps of:
- 15 receiving uplink signals transmitted from the mobile station by the second base station;
- measuring and analyzing the received uplink signals; and
- 20 verifying the mobile station by determining the suitability for the mobile station to establish a satisfactory connection with the second base station based on the analyzed signals before the handoff is initiated.
9. A method according to claim 8 wherein the uplink signals are received in a receiver array in the second base station.
10. A method according to claim 8 wherein the measuring step includes measuring the signal strength of the uplink signals.

11. A method according to claim 10 wherein the analyzing step further includes performing propagation path loss measurements on the uplink signals.
12. A method according to claim 8 wherein the telecommunication system is operating in accordance with the Digital Advanced Mobile Phone System (D-AMPS)  
5 standard.
13. A cellular telecommunication system including a mobile switching center linked to a plurality of base stations, and a mobile station having an established wireless connection with a first base station, the system comprising:
- 10 means for receiving uplink signals transmitted from the mobile station in a second base station;
- means for performing verification of the mobile station by the second base station based on the received uplink signals; and
- 15 means for handing off the mobile station connection from the first base station over to the second base station such that the verification has been performed prior to the handoff being initiated.
14. A method according to claim 13 wherein the telecommunication system operating standard is Digital Advanced Mobile Phone System (D-AMPS).
15. A cellular telecommunication system according to claim 13 wherein the second base station comprises a plurality of receivers forming a receiver array configured to  
20 receive the uplink signals.
16. A cellular telecommunication system according to claim 15 wherein the receivers in the receiver array are configured to receive on the operating frequencies of neighboring cells.
17. A cellular telecommunication system according to claim 13 wherein the mobile  
25 station is capable of relaying system data received from the first base station to the second base station.

18. A cellular telecommunication system according to claim 17 wherein the system data includes handoff information.

**Fig. 1**

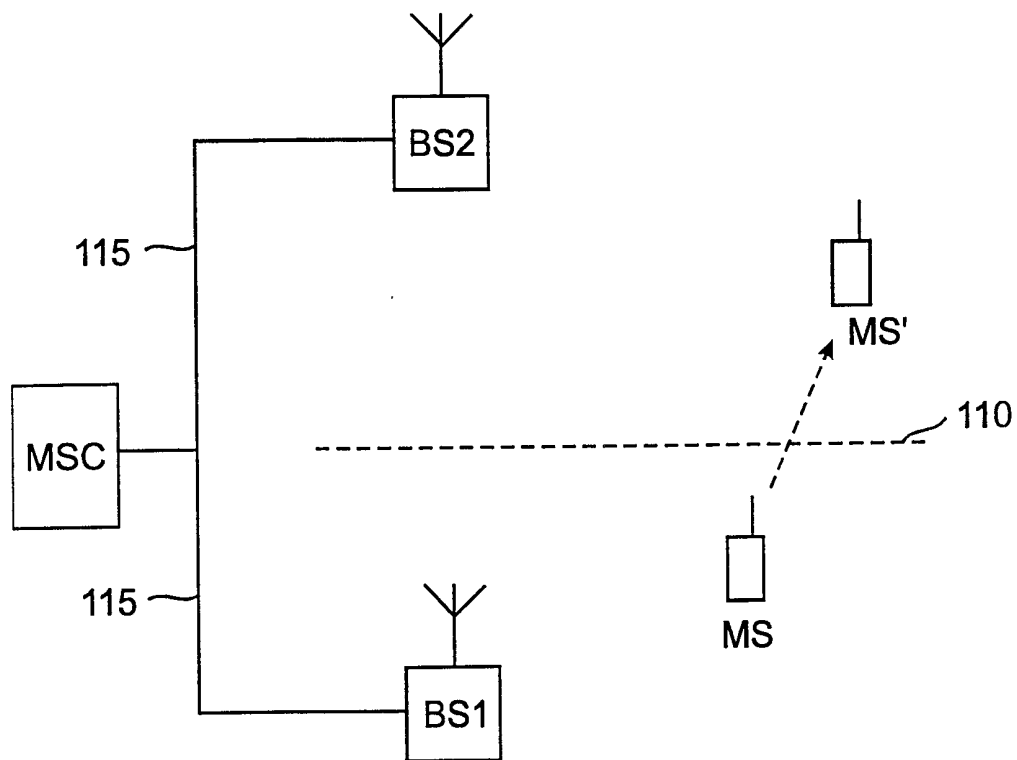


Fig. 2

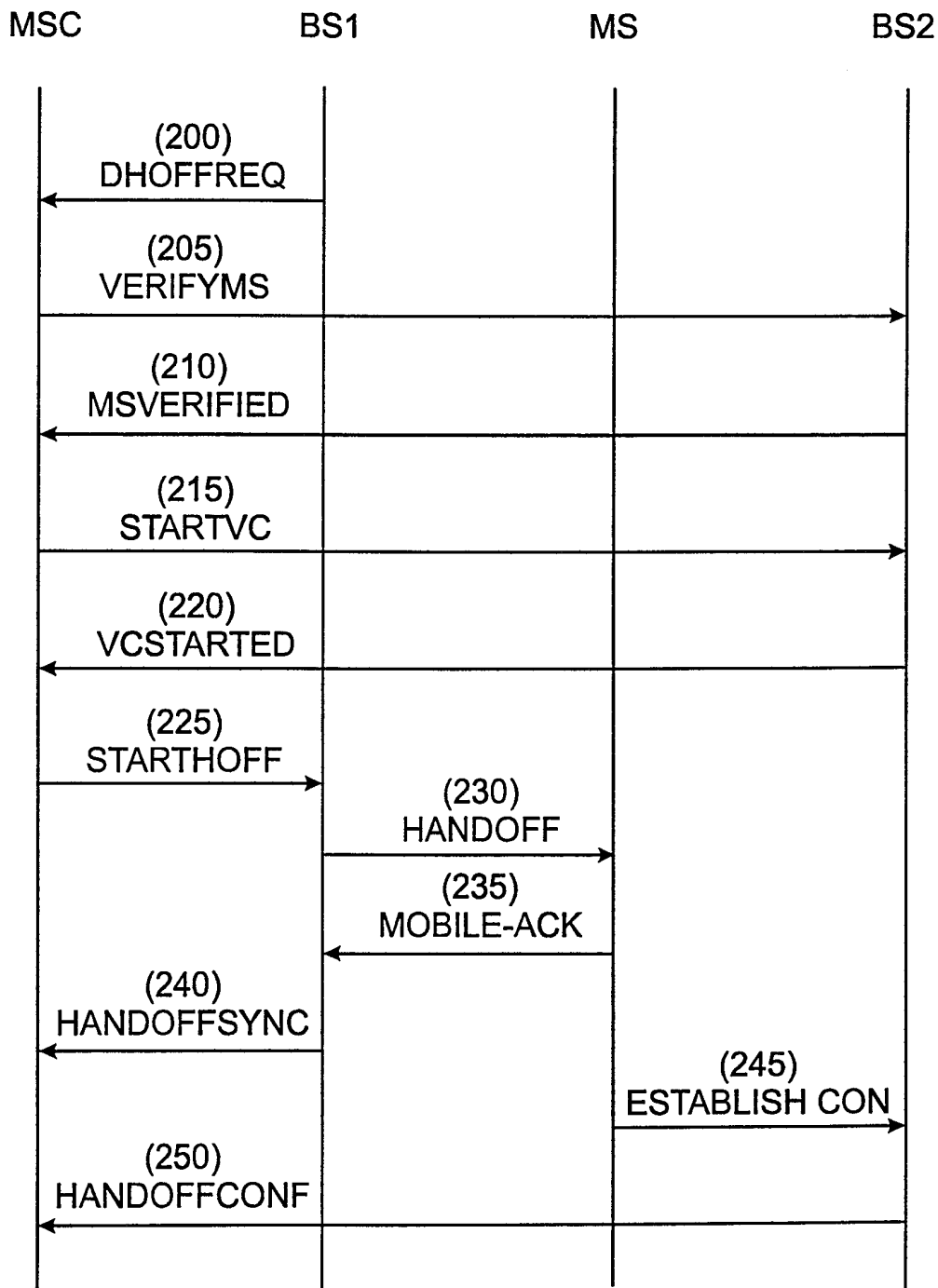
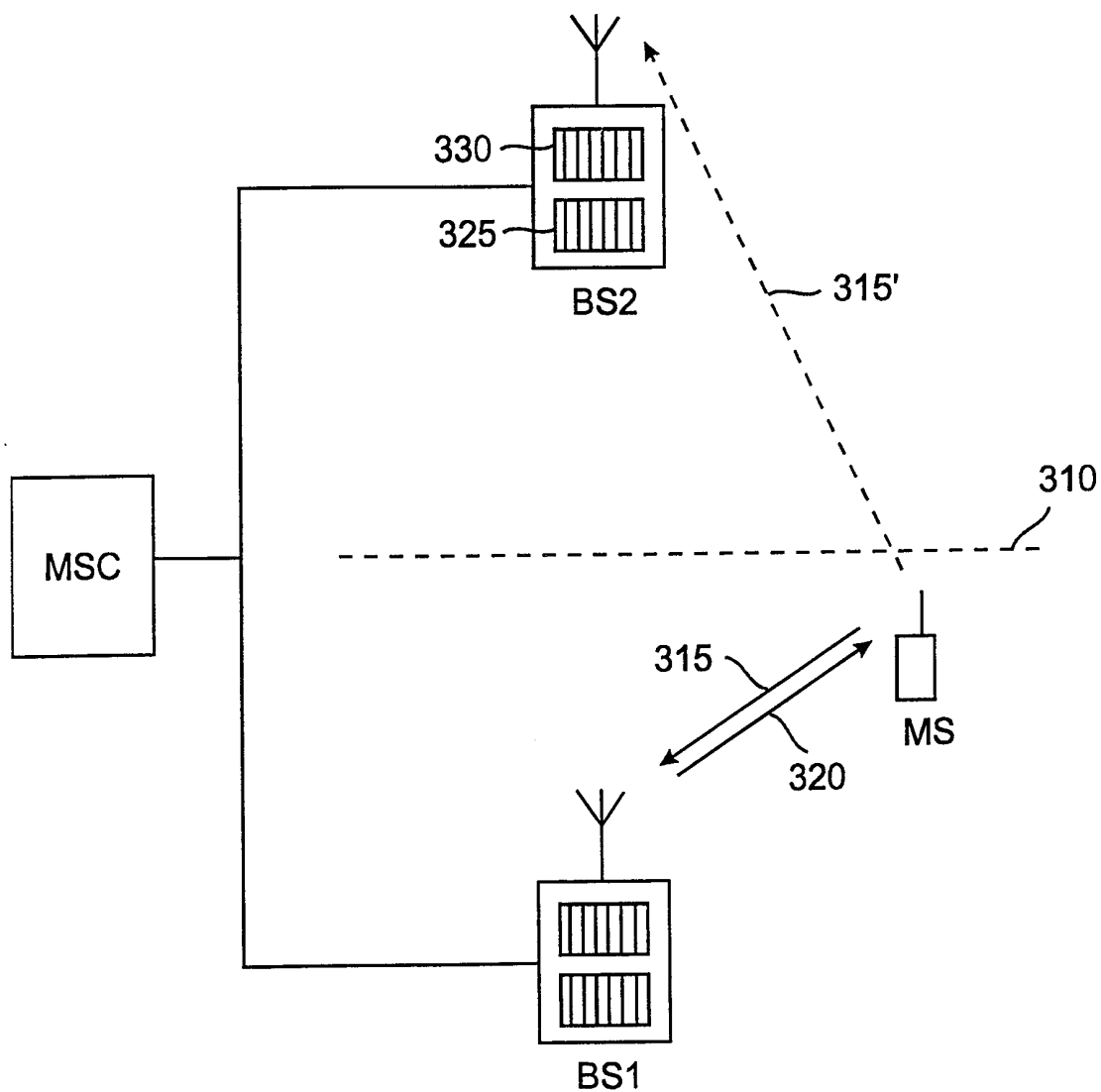


Fig. 3



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**Fig. 4**

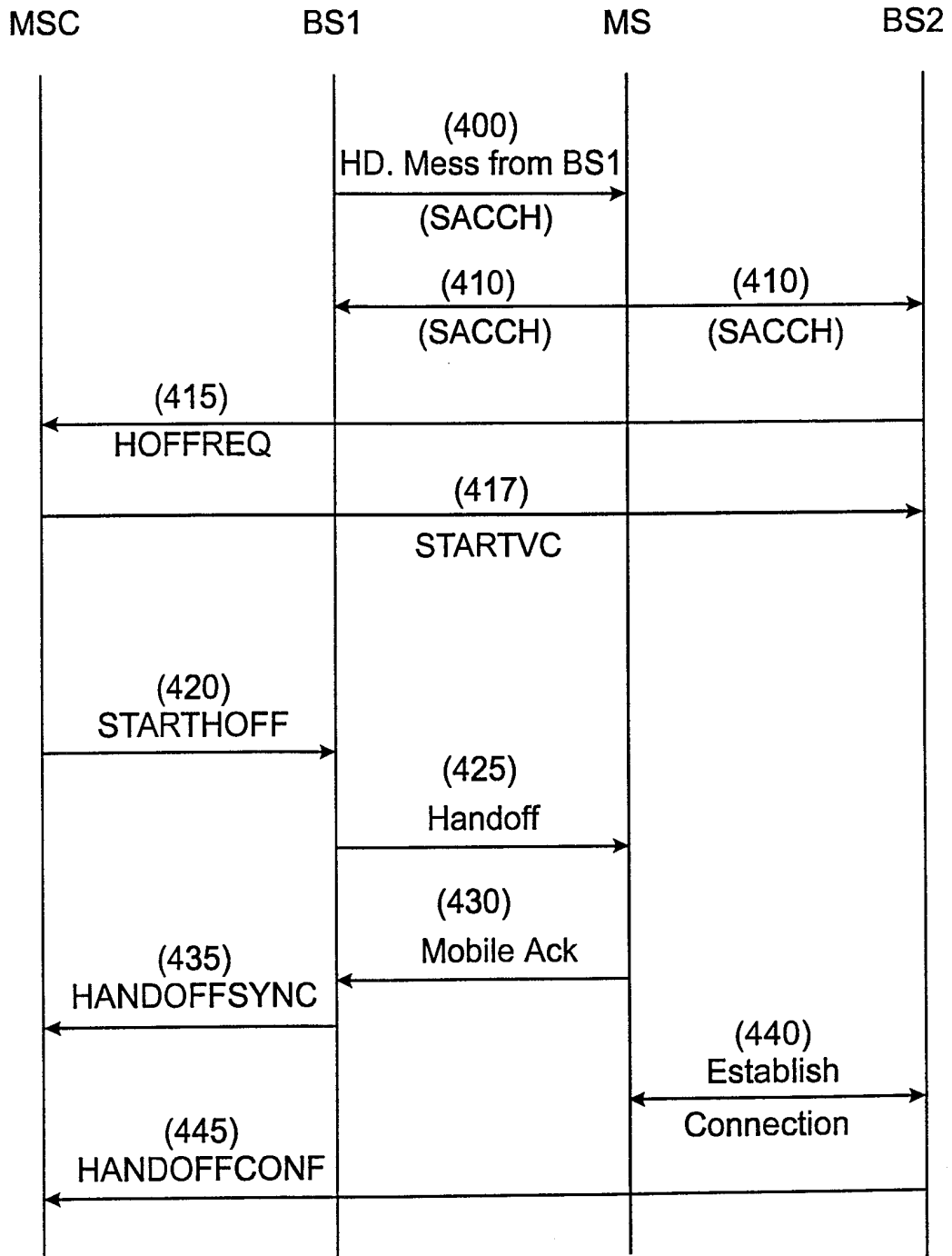
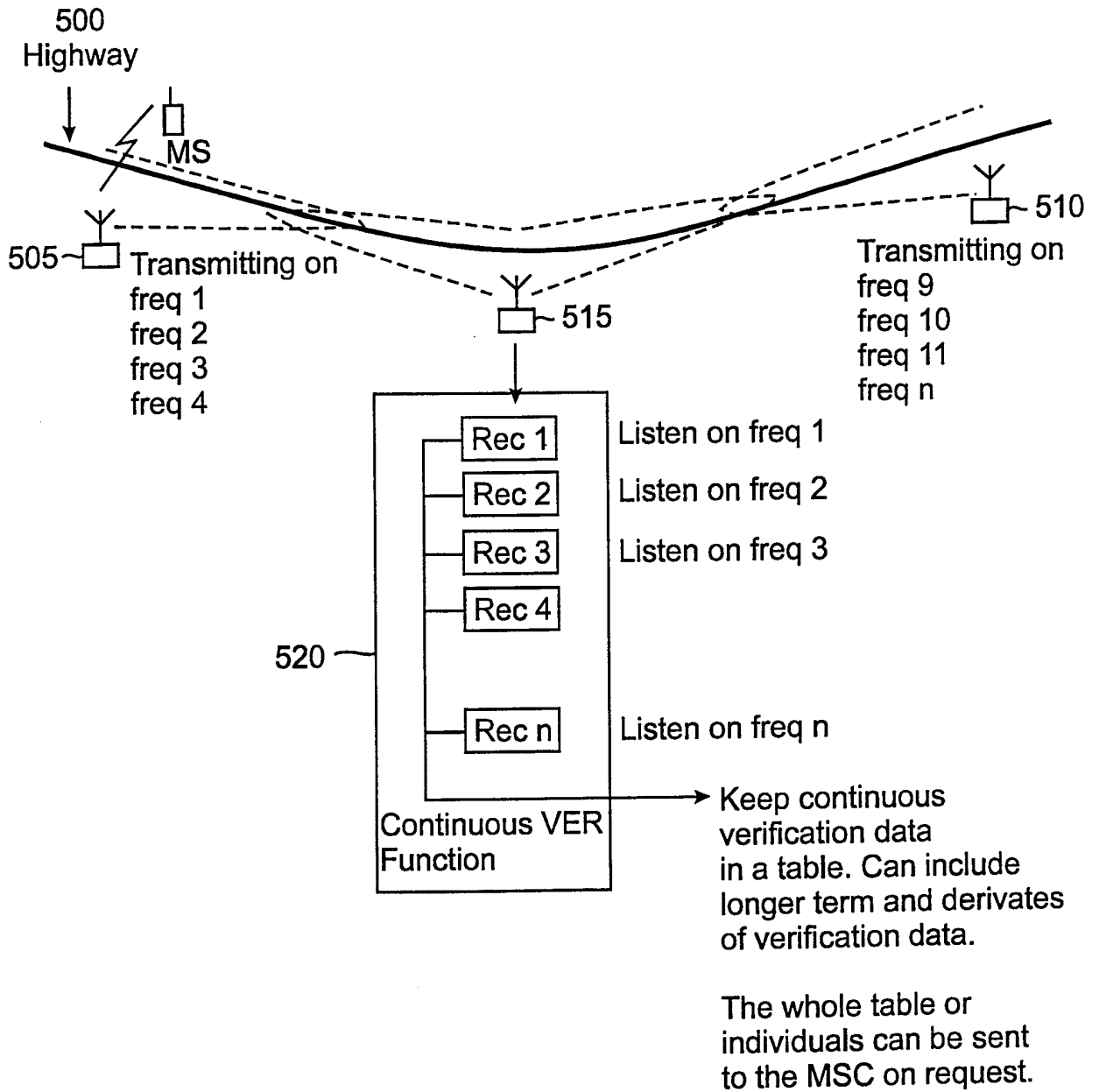


Fig. 5



# INTERNATIONAL SEARCH REPORT

Internationa Application No

PCT/SE 99/00184

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 6 H04Q7/38

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

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H04Q

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

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

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 504 122 A (ERICSSON TELEFON AB L M) 16 September 1992 see column 2, line 48 - column 3, line 10 see column 9, line 18 - line 37 see column 10, line 7 - column 11, line 6 see column 12, line 34 - line 49	8-16
A	see column 13, line 31 - line 42 ---	1,2,6
X	WO 97 31487 A (NOKIA TELECOMMUNICATIONS OY ;SAVOLAINEN JARI (FI)) 28 August 1997 see page 3, line 29 - page 4, line 23 see page 5, line 21 - line 35	8-11,13, 15,16
A	see page 6, line 26 - page 7, line 29 ---	1,2
	-/--	

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Date of the actual completion of the international search

27 April 1999

Date of mailing of the international search report

12/05/1999

Name and mailing address of the ISA

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Internat. Application No.

PCT/SE 99/00184

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