New Technology Report

Special Article on Dual-band 800MHz/1.5GHz System

System Overview

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In November 2001, NTT DoCoMo launched the dual-band 800MHz/1.5GHz system which shares the 800MHz and 1.5GHz bands in the PDC, with the aim to disperse traffic in urban districts and other certain areas suffering from frequency saturation.
This article describes the overview of the system.

1. Introduction

Personal Digital Cellular telecommunication system (PDC) [1] specifies two frequency bands for usage, the 800MHz band and the 1.5GHz band. NTT DoCoMo has been providing services using these frequency bands since 1993 and 1994, respectively [2]. In line with the dramatic expansion of the mobile communications service market, subscribers to these services have rapidly grew in number, particularly the saturation of the 800MHz band has become a serious problem. In order to solve this issue, NTT DoCoMo has developed a system of accommodating more subscribers with the limited frequency resources in PDC by dynamically assigning some 800MHz band subscribing mobile stations to the 1.5GHz band, which has more capacity ("dual-band 800MHz/1.5GHz system").

This article describes the system in brief, and reviews radio link control, restriction control, and the Modulation and Demodulation Equipment (MDE).

2. Overview

2.1 Background

NTT DoCoMo offers PDC services using the 800MHz band system equipped with a packet communication function [3] and a high-quality voice communication function based on Conjugate Structure-Algebraic Code Excited Linear Prediction (CS-ACELP) [1] under the service name "HyperTalk," as well as those using the 1.5GHz band system without such functions,

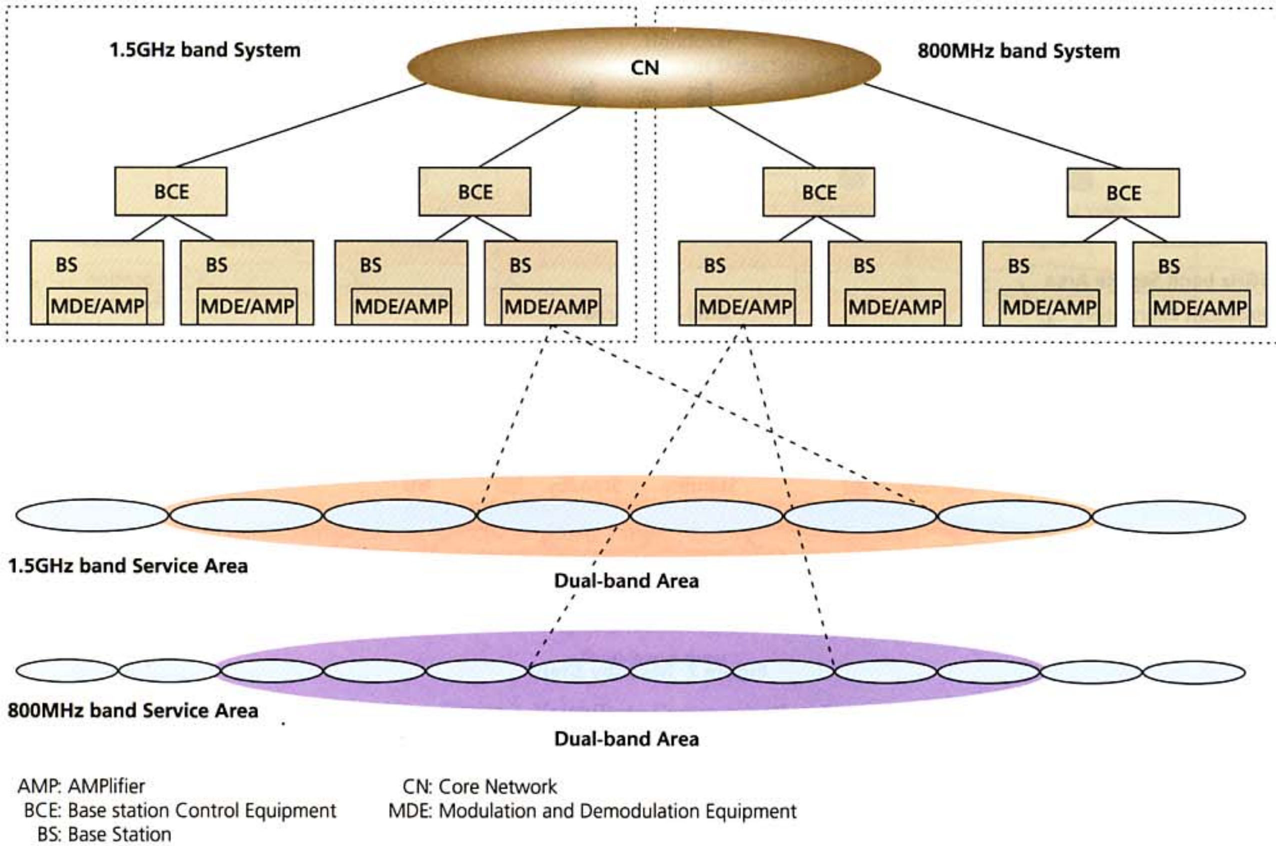

Figure 1 Example of Configuration of Dual-band 800MHz/1.5GHz system

each based on separate contracts. Of these two systems, the 800MHz band system is suffering from serious problems in some densely-populated regions such as the Tokyo metropolitan area, namely, the saturation of traffic channels and the saturation of control channels due to mass alerts and frequent location registration. Under such circumstances, NTT DoCoMo devised, developed and launched the dual-band 800MHz/1.5GHz system in order to accommodate more subscribers with limited frequency resources.

When launching the system, NTT DoCoMo developed a mobile terminal, MS, that can switch from the 800MHz band to the 1.5GHz band and vice versa in standby state and communication state ("dual-band MS"), in addition to the existing 800MHz band dedicated MS and 1.5GHz band dedicated MS [4].

2.2 Configuration

Figure 1 shows an example of the configuration of the dual-band 800MHz/1.5GHz system. The system is applied to parts of service areas formed by the 800MHz band system and those formed by the 1.5GHz band system where they geographically overlay with each other ("dual-band areas"). As information for identifying whether a dual-band MS is in a dual-band area or not is notified to the MS in the form of broadcast information by zone units, the dual-band area can be limited to a high traffic area in the 800MHz band. Generally, the zone configuration of the 800MHz band system does not match its counterpart of the 1.5GHz band system due to differences in the antenna location and the wave propagation properties; service areas with such zone configuration can be set as dual-band areas as well.

2.3 Special Characteristics

In a dual-band area, both bands are nominated upon selecting and assigning the traffic channels with respect to dual-band MSs that originate and terminate calls and switch channels in both bands. Also, some dual-band MSs standing by in the 800MHz band are assigned to the 1.5GHz band. These process make it possible to assign the communication traffic and the control traffic to each band. Outside the dual-band area, the dual-band MSs are in standby state and communication state only in the 800MHz band.

Based on this system, the services provided to dual-band MSs assigned to the 1.5GHz band in the dual-band area are

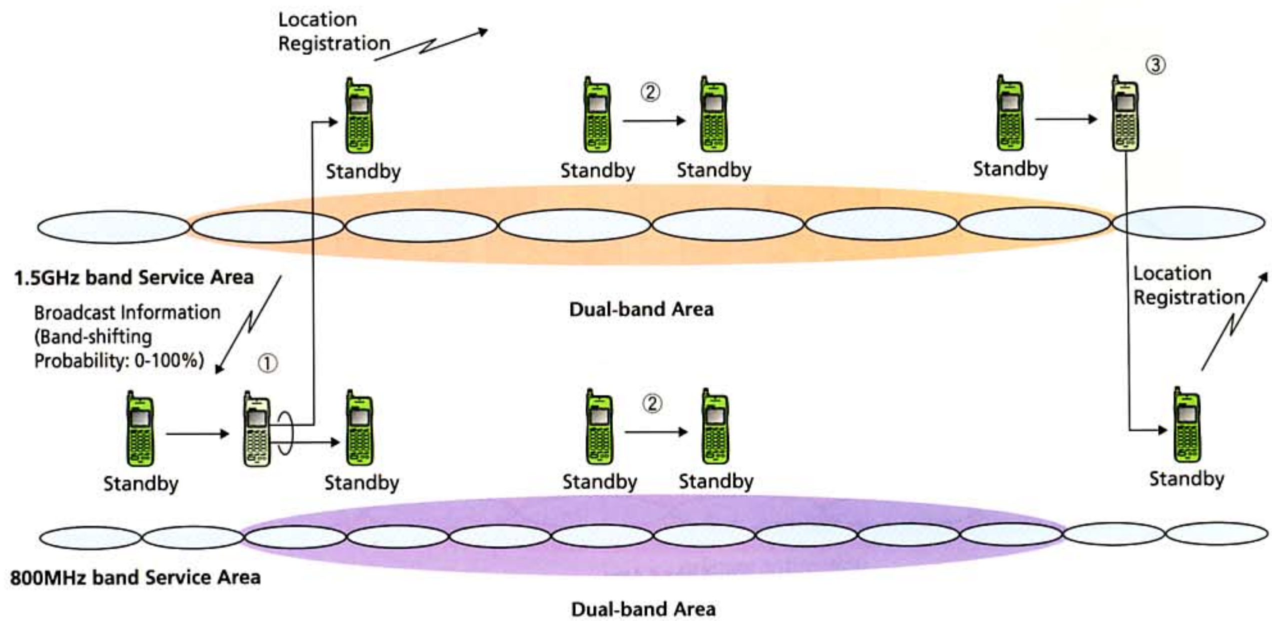

Figure 2 Standby State

equivalent to those provided to the 800MHz band dedicated MSs, which is achieved as follows. Packet communication services are provided in the 800MHz band to dual-band MSs standing by in the 1.5GHz band, because only the 800MHz band system is equipped with the packet communication function. Upon the launching of the dual-band 800MHz/1.5GHz system, NTT DoCoMo adapted the 1.5GHz band MDE for "HyperTalk" to offer the same voice communication quality in the 1.5GHz band as the 800MHz band —previously, only the 800MHz band system had been equipped with the voice communication function based on "HyperTalk". Functional enhancements to MDE for the system will be described later in detail.

3. Radio Link Control

3.1 Standby State

Figure 2 shows a dual-band MS in standby state according to the dual-band 800MHz/1.5GHz system.

① When a dual-band MS standing by in the 800MHz band shifts from a non dual-band area to a dual-band area, it is assigned to either band according to the band-shifting probability notified by the network in the form of broadcast information (Figure 2①). According to the dual-band 800MHz/1.5GHz system, the location of MS is always registered when it shifts to an alternative band. This arrangement is aimed at controlling the increase in mass alert traffic by limiting the mass alert upon call termination to one band.

② In a dual-band area, a dual-band MS moves from zone to zone in the band in which it is standing by, and normally does not shift to another band (Figure 2②). This arrangement is aimed at controlling the increase in the processing load of the MS and the location registration traffic caused by the burden of moving from zone to zone across bands.

③ When a dual-band MS standing by in the 1.5GHz band shifts to a non dual-band area, it shifts to the 800MHz band (Figure 2③). The dual-band 800MHz/1.5GHz system adopts the following technique to achieve this. Firstly, the network sends broadcast information in advance, including information as to whether the periphery zone at the edge of the dual-band area in the 1.5GHz band is within the dual-band area. Secondly, if the dual-band MS determines that the move would involve shifting to a zone outside the dual-band area in the 1.5GHz band, it shifts to the 800MHz band rather than to the zone. Based on this system, the dual-band MS directly shifts to and stands by in the 800MHz band without going through the 1.5GHz band zone outside the dual-band area, which helps shorten the time consumed by shifting from band to band compared to the shifting system to the 800MHz band after standing by once in the 1.5GHz zone outside the dual-band area.

3.2 Voice/Data Communication State

Figure 3 shows a dual-band MS in voice/data communication state according to the dual-band 800MHz/1.5GHz system.

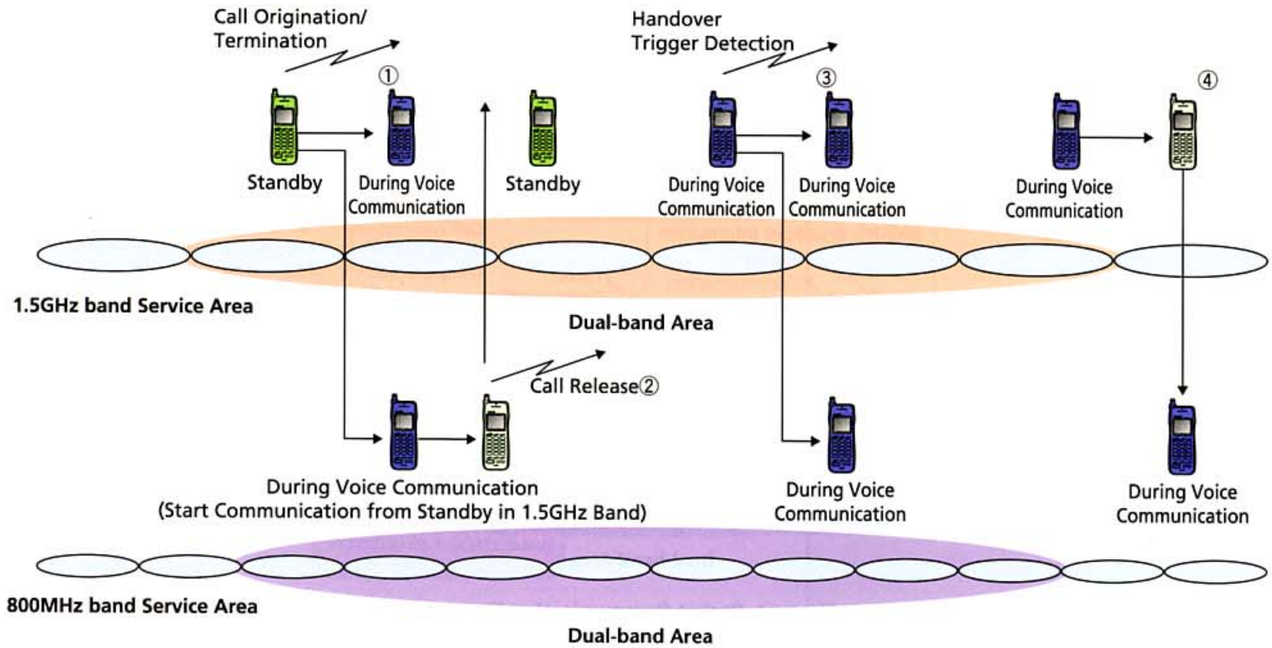

Figure 3 Voice/Data Communication State

① In a dual-band area, when a dual-band MS originates or terminates a call, the network nominates both bands upon selecting and assigning the traffic channel. The MS then starts communication over the assigned traffic channel (Figure 3①). As a way of selecting the traffic channel in an alternative band, the dual-band 800MHz/1.5GHz system resorts to the selection of an adequate traffic channel based on the direct measurement of the radio wave condition in the alternative band by the MS, which makes it unnecessary to strictly administer the zone configuration of the bands and enables the smooth application to commercial systems. Also, the dual-band MS in standby state monitors zones in the alternative band located in the neighborhood as well as the periphery zone in the band in which it is standing by, in order to report the radio wave condition in the alternative band to the network.

② When a traffic channel in an alternative band is assigned to the dual-band MS upon call origination or termination, it preferentially stands by in the band in which it originated or terminated the call at the time of call release (Figure 3②). This arrangement is aimed at controlling the increase in the location registration traffic by raising the frequency at which the location number before and after the communication is the same.

③ Also, handover of a dual-band MS is the same as call origination and call termination in that the network nominates both bands upon selecting and assigning the traffic channel and the dual-band MS switches to the assigned traffic channel accordingly (Figure 3③). In this process, the dual-band MS in communication state monitors zones in the alternative band located in the neighborhood as well as the periphery zone in the band in which it is communicating, in order to report the radio wave condition in the alternative band to the network.

④ The dual-band 800MHz/1.5GHz system also controls a dual-band MS communicating in the 1.5GHz band when it shifts outside a dual-band area to perform handover to the 800MHz band (Figure 3④). When the dual-band MS detects the handover with a strong electric field in the 1.5GHz band zone located closely outside the dual-band area, it is instructed to execute handover to a zone in the 800MHz band with the highest reception power in the network in order to achieve such control.

3.3 Packet Communication State

Figure 4 shows a dual-band MS in packet communication state according to the dual-band 800MHz/1.5GHz system.

As described before, only the 800MHz band system is equipped with the packet-communication function. Therefore, in the dual-band area, packet communication services are provided in the 800MHz band to dual-band MSs standing by in the 1.5GHz band. The procedures are as follows.

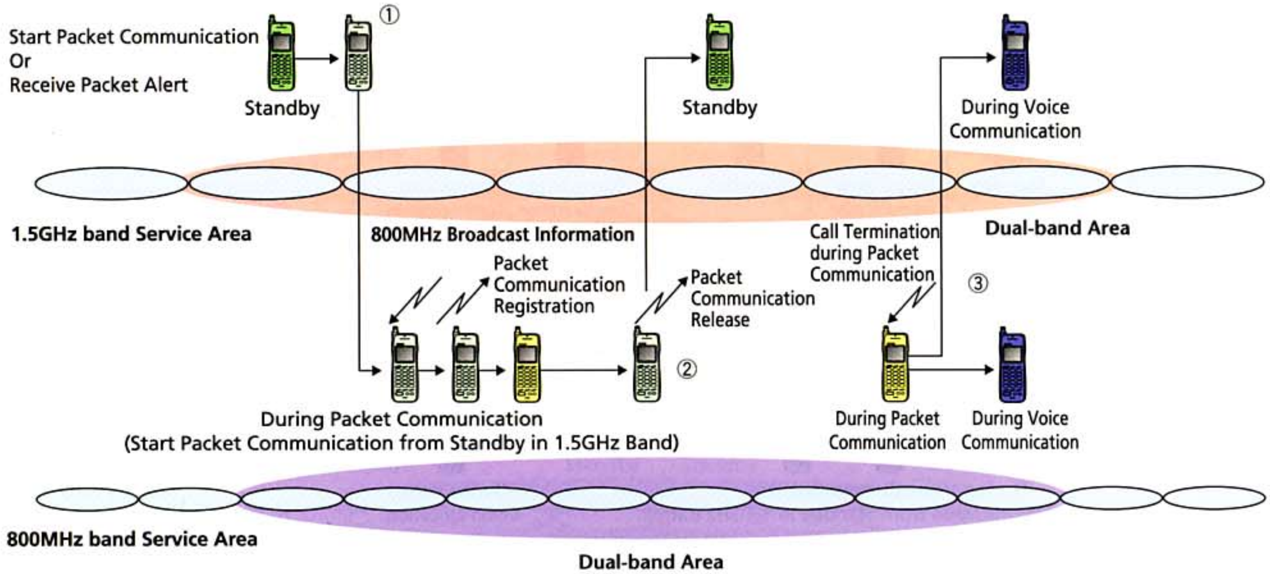

Figure 4 Packet Communication State

① When commencing packet communication, the dual-band MS standing by in the 1.5GHz band shifts to the control channel in the 800MHz band once and acquires information of the User Packet CHannel (UPCH) [5] from the broadcast information. Subsequently, it commences packet communication in the 800MHz band based on the acquired UPCH information (Figure 4①).

② If a traffic channel in an alternative band has been assigned to the dual-band MS upon the commencement of packet communication, it preferentially stands by in the band in which it started packet communication at the time of releasing packet communication (Figure 4②). This arrangement is aimed at controlling the increase in the location registration traffic by raising the frequency at which the location number before and after the commencement of communication is the same.

③ In the 800MHz band system, the MS in packet communication state has the function to start communication in response to the termination of a voice call [6]. Again, the network nominates both bands upon selecting and assigning the voice/data traffic channel with respect to the dual-band MS. The MS then starts communication over the assigned voice/data traffic channel (Figure 4③).

4. Restriction Control

4.1 Band-shifting Control

According to the dual-band 800MHz/1.5GHz system, as mentioned in Chapter 3, the dual-band MS is assigned to either the 1.5GHz band or the 800MHz band for standby. In the event of any congestion or network failure in either band, the network must make the dual-band MS shift to an alternative band for standing by. For this purpose, NTT DoCoMo introduces band-shifting control as a way of arbitrarily changing the band in which the MS stands by from the network.

Figure 5 shows an example of the sequence of band control shifting from the 1.5GHz band to the 800MHz band.

① The 1.5GHz band system gives band-assignment information in the form of a band-shifting message to the dual-band MS standing by in the 1.5GHz band. Band-assignment information sets forth the execution/non-execution of the assignment and the band-shifting probability with respect to each standby shifting group. A standby shifting group refers to a group calculated with reference to the body number unique to each MS.

② When a dual-band MS receives a band-shifting message, it determines the execution or non-execution of the assignment corresponding to the MS's standby shifting group set forth in the band-shifting message.

③ In the event of the execution of the assignment, it compares the band-shifting probability with the random number generated autonomously by the dual-band MS.

④ If the random number is smaller than the band-shifting probability, it scans for a perch channel in the 800MHz band. When it manages to capture a perch channel, it executes location registration in the 800MHz band.

This enables the network to make the dual-band MS shift

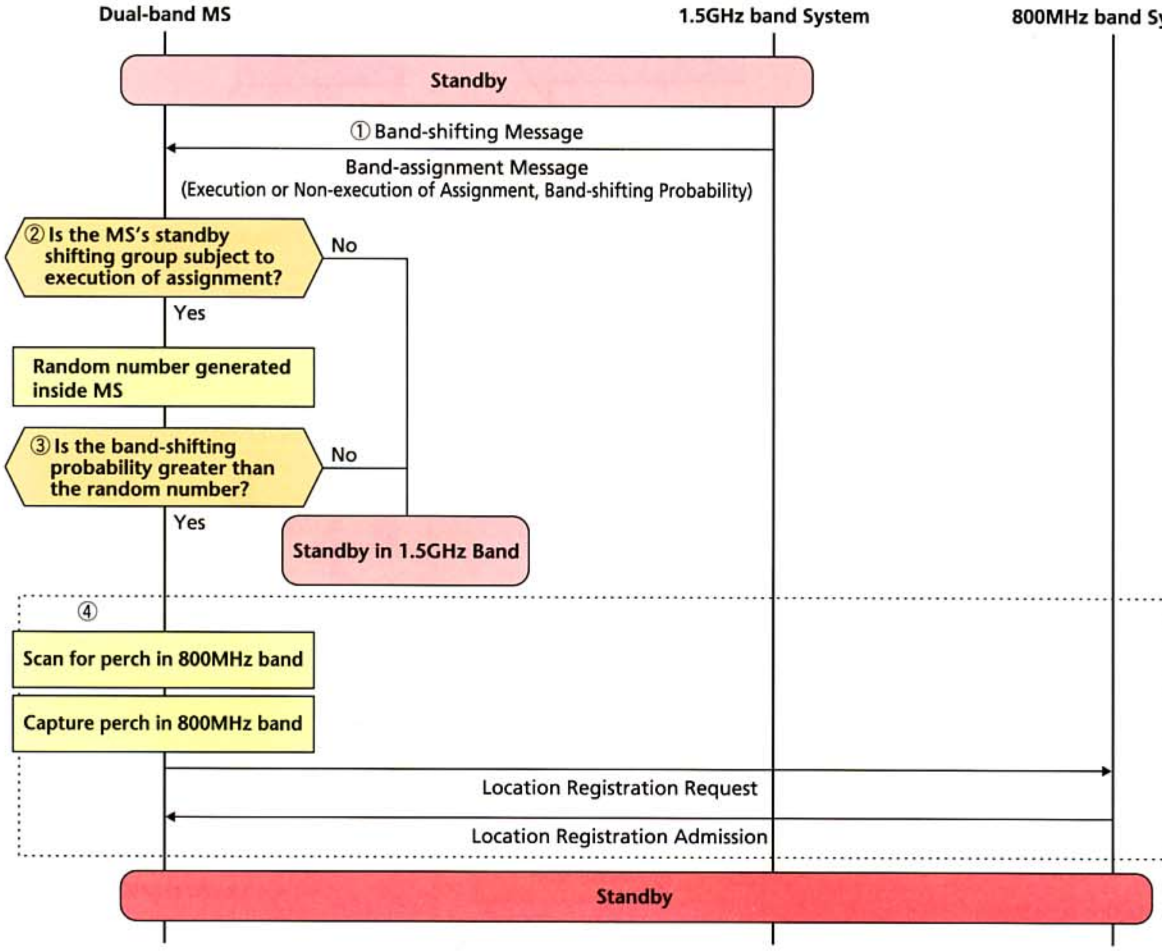

Figure 5 Example of Band-shifting Control Sequence from 1.5GHz Band to 800MHz Band

from band to band in a flexible manner depending on the congestion and network failure status, based on the combination of the standby shifting group and the standby shifting probability.

4.2 Visit Ratio Equalization Control

In a dual-band area, a dual-band MS is exposed to all kinds of radio wave conditions and is therefore forced to shift to and fro between band systems. As a result, it might not be possible to sustain the ratio of the number of visiting MSs assigned to each band at a fixed rate. In order to solve this, NTT DoCoMo has introduced visit ratio equalization control as a way of constantly balancing the visit ratio of each band system at a fixed rate. **Figure 6** shows the concept of visit ratio equalization control.

The first step is to set the time at which visit ratio equalization control is to be executed for each band system ("Time A").

When the 1.5GHz band network receives an hourly traffic preparation request signal which sets forth a time label transmitted on an hourly basis by the Mobile Operating System (MOS), the time label set in the signal is determined as to whether or not it matches Time A. If the times match with each other, the aforementioned band-shifting control is performed to transmit the order to execute the assignment of only one of the standby shifting groups and the band-shifting message as the probability of equalizing the band-shifting probability to the dual-band MS, so as to make the MS shift to the 800MHz band.

Secondly, when the 800MHz band network receives an hourly traffic report request signal which sets forth a time label transmitted after a certain interval subsequent to the transmission of the hourly traffic preparation request signal by MOS, the time label set in the signal is determined as to whether it matches Time A. If the times match with each other, the aforementioned band-shifting control is performed to transmit the order to execute the assignment of only one of the standby shifting groups and the band-shifting message as the probability of equalizing the band-shifting probability to the dual-band MS, so as to make the MS shift to the 1.5GHz band.

Shifting the assignment group by one group every day and

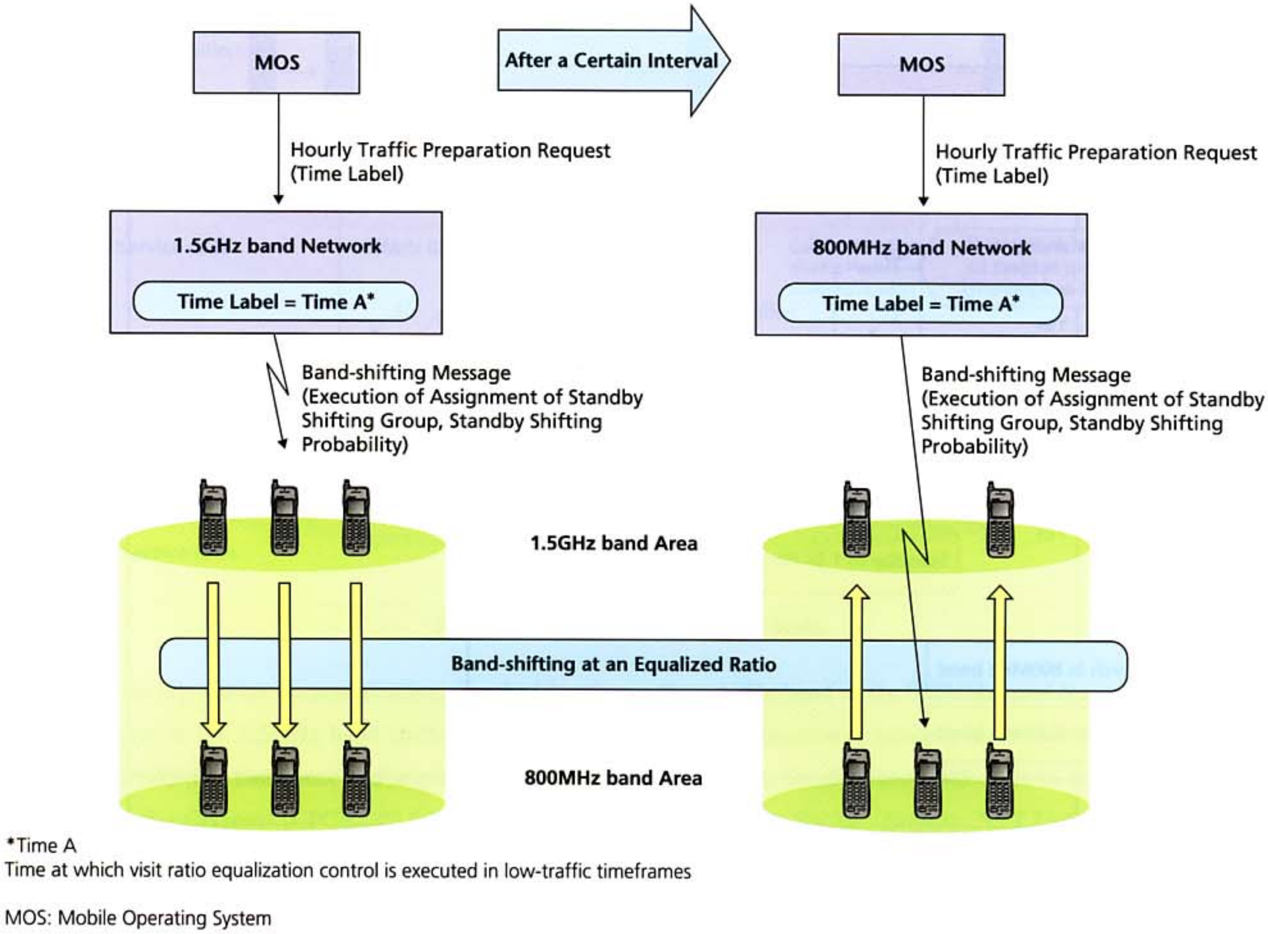

Figure 6 Concept of Visit Ratio Equalization Control

executing this process makes it possible to keep the visit ratio more or less constant.

4.3 Equipment Failure Notification Control

When an MS enters a zone by handover, etc., the MS must re-acquire information necessary for standby because it has no information on the zone in which it is supposed to stand by after call release. Accordingly, the network informs the MS during communication of the information on the control channel required for standing by based on system information and information relating to faults and restrictions. The network thereby controls MS in a manner that simplifies the standby state and prevents it from standing by in a zone suffering from equipment failure.

According to the dual-band 800MHz/1.5GHz system, as stated in Chapter 3, the band system in which the MS communicates might be different from the band system in which it will stand by after call release. In the event of any equipment failure in the zone of the band system in which the MS stands by, the dual-band MS in communication state must be informed of the failure and controlled so that it will not stand by in that zone, as done by the system information mentioned above. As a way of notifying the equipment failure status across band systems, NTT DoCoMo introduced equipment failure notification control.

Figure 7 shows an example of equipment failure notification control.

① In the event of any equipment failure in a zone in the 800MHz band network, equipment-failure detection is performed in the Base station Control Equipment (BCE) of the 800MHz band network, and the BCE in the 1.5GHz band network is informed of the equipment failure via the New Mobile Local Switch (NMLS) or the Mobile Local Switch (MLS) (Figure 7①).

② Then, the BCE in the 1.5GHz band network that has been informed of the equipment failure notifies the MS communicating in the shared 1.5GHz band network zone (Figure 7 ②).

This makes it possible to simplify the standby state of the dual-band MS.

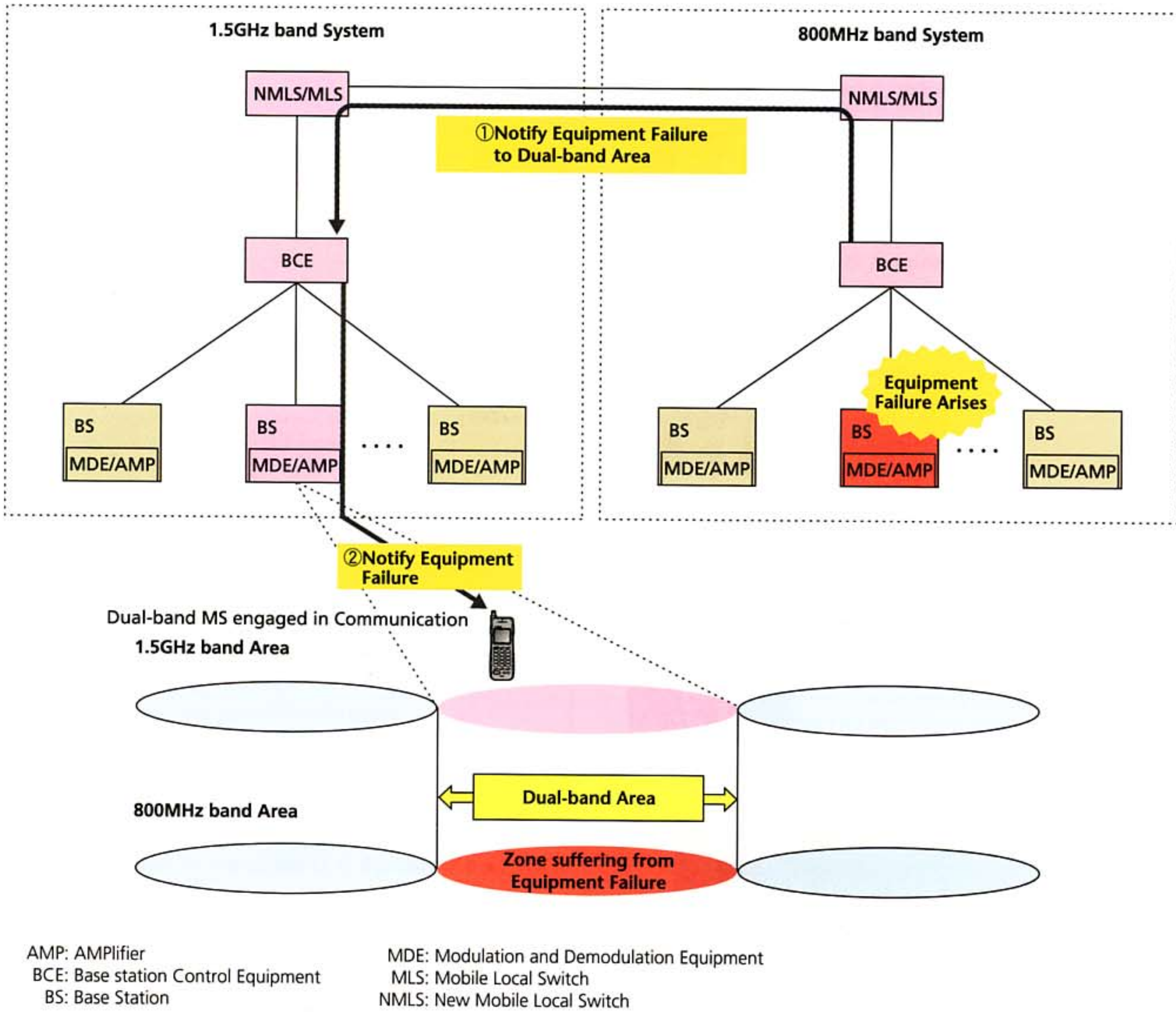

Figure 7 Example of Equipment Failure Notification Control

5. Modulation and Demodulation Equipment (MDE)

5.1 Functional Enhancements to Hardware

In 1999, CS-ACELP service was launched under the name of "HyperTalk" in the 800MHz band system. Previously, however, there had been no functional enhancements made to the 1.5GHz band system. As the dual-band 800MHz/1.5GHz system needs to provide voice quality in the 1.5GHz band system equivalent to the 800MHz system, functional enhancements were made to the hardware so that CS-ACELP can be used in the MDE for the 1.5GHz band as well.

As a result, "HyperTalk" can be assigned to dual-band MS in both the 800MHz band system and the 1.5GHz band system.

According to the dual-band 800MHz/1.5GHz system, the MDE consists of the supervisory and control unit, the interface with BCE and Speech Processing Equipment (SPE), transmitter and receiver, and the Radio Frequency (RF) distribution and combining unit. **Figure 8** shows the configuration of MDE. As a functional enhancement to the 1.5GHz band MDE, NTT DoCoMo newly developed the Transmitter and Receiver (TRX) card, by which the existing equipment can be used as is. **Photo 1** shows the exterior of MDE.

Whereas the existing 1.5GHz band TRX card has functions of Vector-Sum Excited Linear Prediction coding (V-SELP) and Pitch Synchronous Innovation-Code Excited Linear Prediction (PSI-CELP), the newly-developed 1.5GHz band TRX card has functions of PSI-CELP and CS-ACELP.

5.2 Alteration to Software

As an alteration to the software, the control message was added for the restriction between BCE and MDE and between

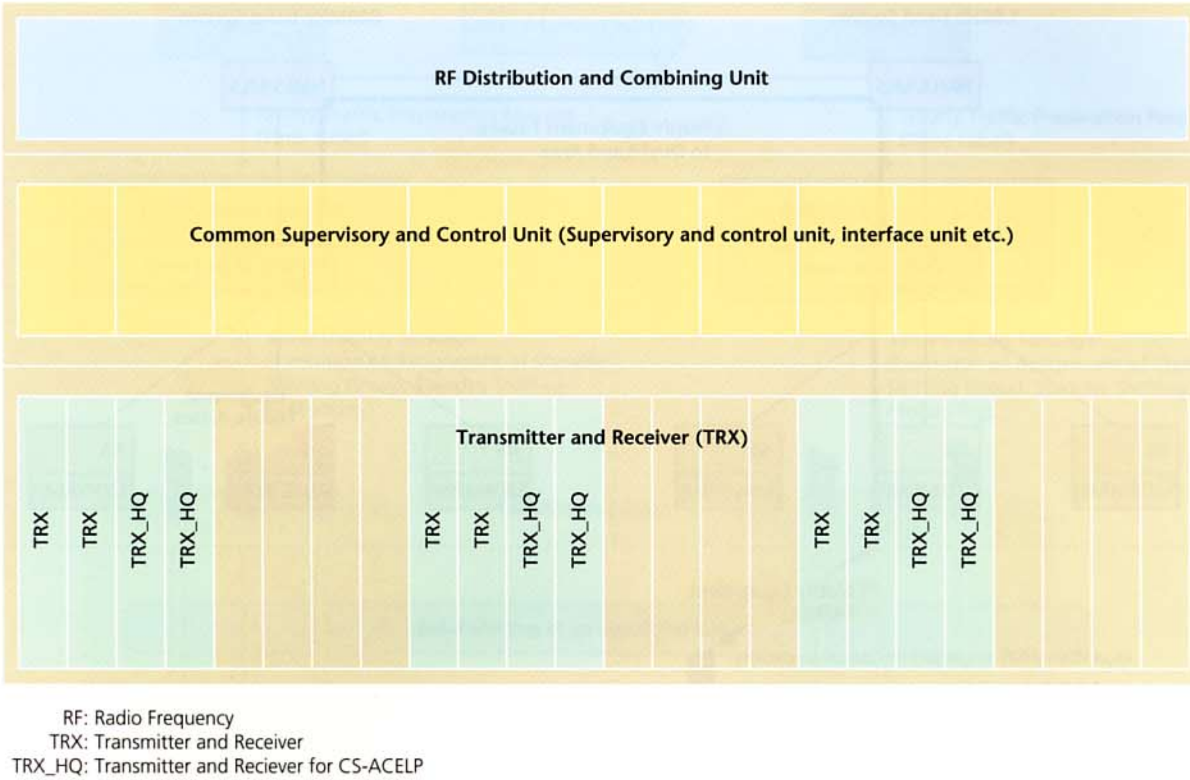

Figure 8 Configuration of MDE

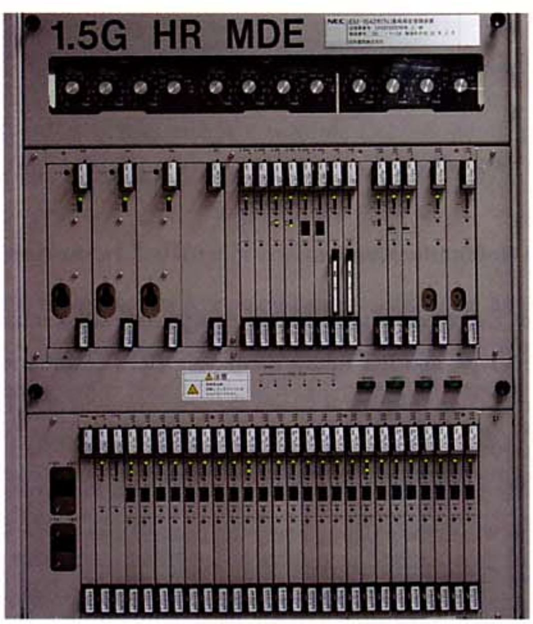

Photo 1 Example of 1.5GHz band MDE

MDE and MS. This enables the restriction control referred to in Chapter 4.

5.3 Application of HyperTalk

Based on the functional enhancements described above, users of the dual-band MS can communicate via "HyperTalk" in both 800MHz and 1.5GHz bands. This is applicable by the replacement of the existing TRX card in the MDE with the new TRX card. Although it is necessary to write an application, firmware and system data compliant to the new TRX card, but it makes it easier, and low-cost running possible.

6. Conclusion

This article briefly described the dual-band 800MHz/1.5GHz system, and reviewed radio link control and MDE. NTT DoCoMo commercially launched the dual-band 800MHz/1.5GHz system in the Tokyo metropolitan area in November 2001. In the future, it will be necessary to optimize the band-shifting probability and other parameters of the system, in line with the increase in the share of dual-band MSs.

References

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GLOSSARY

AMP: AMPlifier
BCE: Base station Control Equipment
BS: Base Station
CN: Core Network
CS-ACELP: Conjugate Structure-Algebraic Code Excited Linear Prediction
MDE: Modulation and Demodulation Equipment
MLS: Mobile Local Switch
MOS: Mobile Operating System
MS: Moblie Station
NMLS: New Mobile Local Switch
PDC: Personal Digital Cellular telecommunication system
PSI-CELP: Pitch Synchronous Innovation-Code Excited Linear Prediction
RF: Radio Frequency
TRX: Transmitter and Receiver
TRX_HQ: Transmitter and Reciever for CS-ACELP
UPCH: User Packet CHannel
V-SELP: Vector-Sum Excited Linear Prediction coding