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# Methods for Improving Hand-off of Different Generations in CDMA Mobile Communications

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**Abstract**

One of the most important things in mobile phone service is Hand-Off (H/O). Meantime soft H/O and softer H/O have been used between the same generations (2G↔2G) and there is little problem. With user's needs and the development of communication technology, the system with different generation coexists and pilot beacon and time-periodic beacon are used for H/O between generations (2.5G→2G) to start service, but it is not economic and efficient. To improve such problems, ENHHO developed in April 2001 has recently used. Unfortunately, this method also has the defect of momentary cutoff of communication information during the procedure of H/O in case of more than 5 pilot signals. Accordingly, we suggest algorithm to improve the problem of ENHHO and examines its propriety by analyzing the results of field survey using the algorithm.

***Keywords:*** *Beacon, Enhanced hard H/O, Flash, Hand-off, Pilot*

## I. Introduction

One of the most important things in mobile phone service is to maintain call connection and speech quality continuously not to cut off call of MS (Mobile Station) moving between BS (Base Stations) in forming the mobile phone relay system and it is referred as H/O (Hand-Off).

Hard H/O is developed in order to resolve H/O between generations (2.5G→2G) and divided into pilot beacon H/O, flash pilot beacon H/O, and ENHHO (Enhanced Hard H/O)[1-4]. Pilot beacon H/O needs lots of cost of equipment and has the disadvantage that speech quality rapidly gets poor in case the difference in the number of FA (Frequency Allocation) between serving BS and target BS due to a lowering of Ec/Io is more than 3. To supplement this disadvantage, flash pilot beacon H/O was developed, but this method also reduces completion rate of H/O and terminating and originating rate because of abbreviating the period of beacon if the difference in the number of FA between serving BS and target BS is more than 5. To enhance these disadvantages, ENHHO which realizes H/O between generations without equipping the device for generating pilot beacon was developed in April 2001. But it also has the disadvantage of moment cutting off call information in traffic H/O if the pilot signal of target BS needed to search is more than 5[5-7].

Accordingly this study suggests a new algorithm in order to improve the problem of existent EHNNO that call information is cut off moment in traffic H/O. Also

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this study finds the results of field measurement by ENHHO using suggested algorithm and existent ENHHO and verifies the propriety of the suggested algorithm by comparing and analyzing the results.

## II. Method of Hard H/O

### 2.1. Pilot Beacon H/O

Pilot beacon H/O is the transmitting method that generates false pilot beacon as much as the difference in the number of FA between serving BS and target FA.

This method has the advantage of similar linkage to traffic FA in H/O border, but in case of big difference in the number of FA, the quantity of IMD (Inter Modulation Distortion: Io) of power increases as pilot beacon transmit needs many RF power. In particular, if the number of MS using traffic channel is small, pilot beacon noise gets more than that of call. To improve these problems, first, power by pilot beacon needs to be decreased by minimizing the number of pilot beacon or adjusting T_COMP (Threshold Compare : the difference in Ec/Io between serving BS and target BS), the variable of hard H/O. Second, if the superposed distance (the width of the border) between serving BS and target BS is sufficient, power needs to decrease by using only either channel of I channel or Q channel of pilot beacon.

Therefore, pilot beacon H/O shows relatively higher H/O completion rate than flash pilot beacon H/O or ENHHO. But in addition to lots of cost of equipment, Ec/Io may get poor because of the increase in pilot beacon which is an external factor of traffic channel, so speech quality may be lowered if the difference in FA between serving BS and target BS is more than 3.

### 2.2. Flash Pilot Beacon H/O

Flash pilot beacon generates pilot beacon H/O as pilot beacon H/O does but the disadvantage of pilot beacon H/O that Ec/Io is reduce due to the increase in the number of pilot beacon as much as N, the difference in the number between serving FA and target FA is improved. Instead of generating 2000ms period pilot beacon as much as the difference of the number of FA, it generates one pilot beacon by 2000ms/N period and transmits by time division.

Thus, flash pilot beacon H/O needs less cost of equipment than pilot beacon H/O, improves Ec/Io owing to the decrease in power, and expands possible time for H/O. But, since the maximum circulating period is limited to 2000ms, if the number of flash pilot beacon is more than 6, absolute time needed to MS tuning may be not enough and it may bring about lowering the completion rate of H/O and terminating and originating.

### 2.3. Enhanced Hard H/O

It was developed in April 2001 in order to improve the disadvantage of flash pilot beacon H/O such as the cost of equipment, limitation of the number of FA to searching, and lowering the completion rate of H/O and terminating and originating.

It is divided into idle H/O and traffic H/O. It needs no cost of hardware equipment because it realizes H/O between generations without equipping the device for generating separate pilot beacon unlike pilot beacon H/O and flash pilot beacon H/O.

#### a. Idle H/O

MS entering the service area of 2G (IS-95A) BS from that of 2.5G (IS-95C) BS as idle already receives such information as NGBR_CONFIG 2(Neighbor Configuration 2: the information that FA of neighbor BS is different), NGBR_BAND (Neighbor band: the designation of frequency band of mobile communication, SK Telecom: 800㎒, PCS: 1.8㎓), and NGBR_FREQ (Neighbor Frequency: the selection information of FA including Ec/Io of target BS) via paging channel of 2.5G BS. MS itself compares the difference between Ec/Io of 2.5G serving pilot beacon and that of 2G target BS and becomes idle H/O if H/O condition in Table 2 is satisfied. Figure 1 shows the flow chart of idle H/O. There is no problem found in idle H/O between generations.

#### b. Traffic H/O

Like idle H/O, in traffic H/O, once MS enters the service area of 2.5G BS, it receives such information as

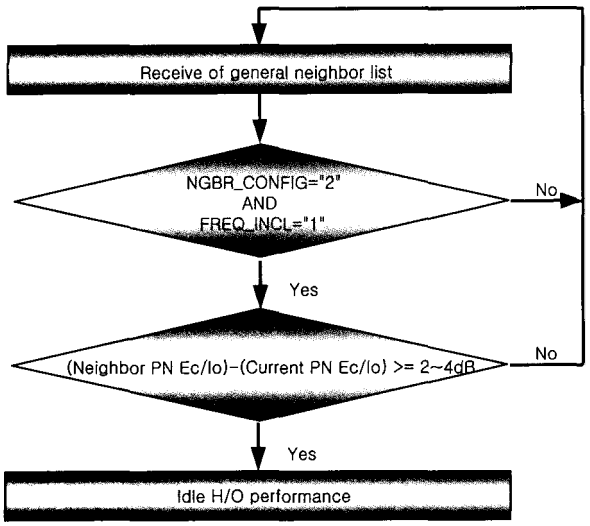


Figure 1. The flow chart of idle H/O in existent ENHHO.

NGBR_CONFIG 2, NGBR_BAND, and NGBR_FREG of 2.5G BS through paging channel of 2.5G BS to use for H/O. But while MS accomplishes H/O by automatically tuning to FA information of target 2G BS in idle H/O, MS in traffic H/O measures Ec/Io of pilot beacon target candidate 2G BS FA and have it reported to 2.5G BS and selected one of candidate FA based on the reported information to execute H/O. Figure 2 shows the flow chart of traffic H/O.

Thus, unlike pilot beacon H/O and flash pilot beacon H/O, ENHHO has the advantage of cutting expenses because it does not need to equip the device for generating pilot beacon for H/O. But the results of actual field application show that the information in traffic H/O is cut off moment and completion rate is relatively low.

# III. Suggestion of Algorithm and Field Measurement for Improving the Efficiency of ENHHO

## 3.1. Suggestion of Algorithm

To prevent information from moment cutting off in traffic H/O between generations of ENHHO, the following three searching conditions are required to be added.

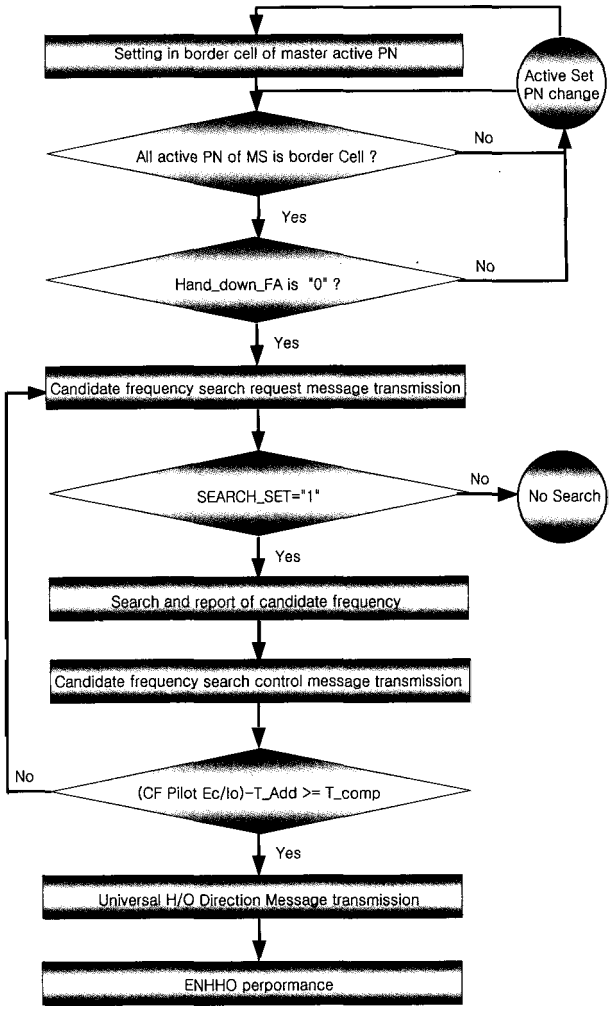


Figure 2. The flow chart of traffic H/O in existent ENHHO.

- While traffic H/O of existent ENHHO does not limit the number of pilot signal of neighbor 2G BS FA needed to searching by serving BS to transmit to MS, it decreases time for searching signal and data information quantity and reduces the time for H/O by limiting the signal within 5 to transmit to MS.
- In existent ENHHO traffic H/O, pilot signal searching starts as soon as MS receives CFSRM (Candidate Frequency Search Request Message) from serving BS regardless of the difference in Ec/Io between serving BS and target BS. But even when Ec/Io of serving BS is big, pilot signal is executed and it brings about an omission of call information. Thus, the condition that MS can achieve H/O by searching pilot signal immediately before H/O without searching pilot signal should be created in the area with good Ec/Io of serving BS.

The conditions include Ec/Io of only serving BS introduced to Rx of MS (SF_ TOTAL _Ec_ Io_ THRESH: Serving Frequency Total Ec/Io Threshold) and searching start at minimum value of receiving field strength (SF_TOTAL _ Ec_THRESH: Serving Frequency Total Ec Threshold) in order to reduce searching time for H/O.

- In existent ENHHO traffic H/O, searching time is cut down by reducing 3dB of the difference in Ec/Io between serving BS and target BS to 2dB.

Although actual searching time can be reduced by delaying starting time for searching for H/O, the results of field measurement show that call information is cut off moment like existent ENHHO traffic H/O.

To prevent the situation of omitting and moment cutting off information when traffic MS served by 2.5G BS enters the border for H/O by 2G BS, algorithm which adds the above three searching conditions to existent ENHHO traffic H/O flow chart is shown in Figure 3.

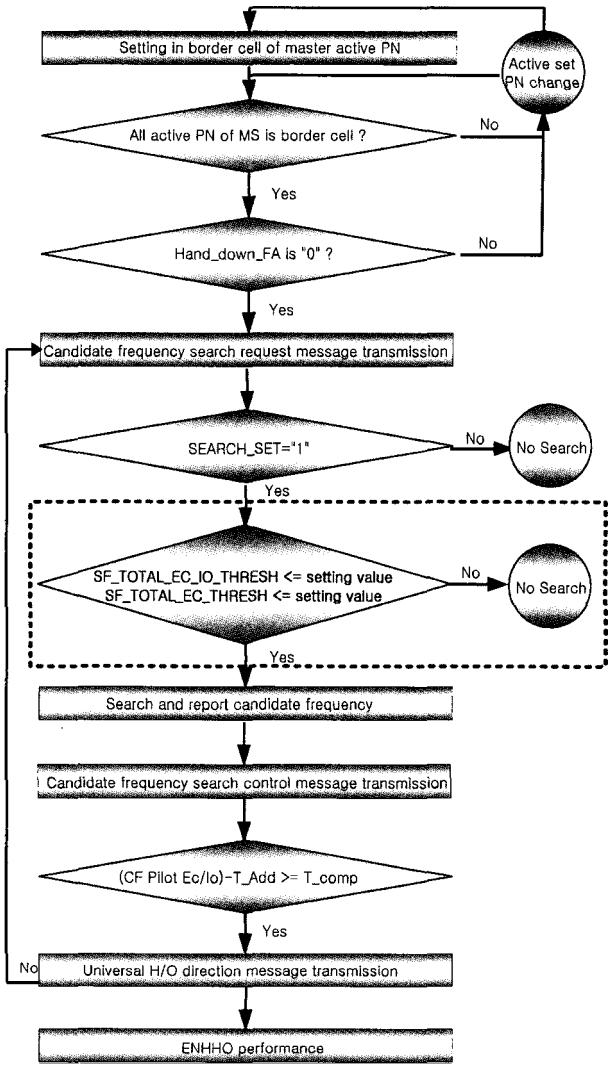


Figure 3. The flow chart traffic H/O in suggest ENHHO.

## 3.2. Field Measurement of ENHHO Traffic H/O

### a. Suggested algorithm

In ENHHO traffic H/O using suggested algorithm, call data mean bit fault error rate (FER), mean data transmitting speed, mean pilot Ec/Io of serving BS, and required time for transmission 1 Mbyte file by searching pilot signal

Table 1. Specification of field measurement.

| | | |
|---|---|---|
| Date measured | existent | June 15. 2001 |
| | suggested | July 2. 2001 |
| By | | SK Telecom engineering team |
| H/O method | | Traffic H/O of suggested ENHHO |
| H/O generation | | Between generation (2.5G → 2G) |
| Subject area | | Honam Expressway and Local Road No. 716 |
| Used measuring machine | | Samsung SCH-x120, DM2K |
| Subject | | FER, Mean data transmission rate,<br>Mean pilot Ec/Io of serving BS, Required time for transmission 1Mbyte |
| MS speed | | 90 ~ 100 km |
| Number of searching pilot signal | | 0 ~ 20 |
| T_COMP | existent | 3dB |
| | suggested | 2dB |
| Searching condition of serving BS | existent | - |
| | suggested | SF_TOTAL_EC_IO_THRESH<-8dB<br>SF_TOTAL_EC_THRESH<-8dB and -80dBm |

Table 2. The results of measurement.

| Number of searching pilot signal | FER (%) | Mean data transmission rate(Kbps) | Mean pilot Ec/Io of serving BS (dB) | Required time for transmission 1Mbyte (sec) |
|---|---|---|---|---|
| N = 0 | 0.66 | 99.8 | - 2.4 | 80 |
| N = 1 | 2.05 | 97.31 | - 3.3 | 87 |
| N = 2 | 3.10 | 79.48 | - 4.9 | 102 |
| N = 3 | 3.42 | 70.43 | - 4.5 | 107 |
| N = 4 | 3.8 | 73.84 | - 5.4 | 108 |
| N = 5 | 3.51 | 67.02 | - 5.3 | 129 |
| N = 6 | 4.90 | 73.66 | - 5.6 | 132 |
| N = 7 | 5.50 | 69.90 | - 5.7 | 133 |
| N = 8 | 6.12 | 66.71 | - 6.2 | 138 |
| N = 9 | 6.88 | 58.3 | - 6.5 | 140 |
| N = 10 | 7.3 | 54.8 | - 6.7 | 148 |
| N = 15 | 10.5 | 38.0 | - 9.8 | 211 |
| N = 20 | 12.6 | 33.7 | - 12.0 | 237 |

Table 3. The results of measurement.

| Number of searching pilot signal | FER (%) | Mean data transmission rate(Kbps) | Mean pilot Ec/Io of serving BS (dB) | Required time for transmission 1Mbyte (sec) |
|---|---|---|---|---|
| N = 0 | 0.68 | 99.6 | - 2.6 | 81 |
| N = 1 | 2.35 | 88.48 | - 3.2 | 94 |
| N = 2 | 3.23 | 72.72 | - 3.7 | 113 |
| N = 3 | 3.8 | 63.84 | - 4.1 | 138 |
| N = 4 | 3.73 | 64.84 | - 4.4 | 135 |
| N = 5 | 3.8 | 60.32 | - 5.6 | 148 |
| N = 6 | 5.11 | 58.44 | - 5.7 | 150 |
| N = 7 | 6.06 | 56.30 | - 5.9 | 155 |
| N = 8 | 7.75 | 55.01 | - 6.3 | 159 |
| N = 9 | 8.20 | 54.44 | - 6.5 | 163 |
| N = 10 | 9.0 | 50.72 | - 6.6 | 168 |
| N = 15 | 13.5 | - | - | - |
| N = 20 | 14.8 | - | - | - |

were measured as the specification in Table 1 and their results are shown in Table 2.

The reason to select Honnam Expressway, the border of serving BS (2.5G) located at Sangrim-dong, Wanju-gun, Jellabuk-do and target BS (2G) located in Iseo is that this area is the border of 2G system and 2.5G system and at the same time crosses Honam Expressway and Local Road No. 716, so many passing cars provide a lot of measurement samples and random traveling speed can be maintained. Besides, the surrounding area is open where there are many superposed pilot signal from neighbor BS.

b. existent algorithm

Like suggested algorithm, call data mean bit fault error rate(FER), mean data transmission rate, mean pilot Ec/Io of serving BS, and required time for transmission 1 Mbyte file by searching pilot signal were measured as the specification in Table 1 and their results are shown in Table 3.

# IV. The Results of Measurement and its Comparison and Analysis

## 4.1. Traffic Data mean bit Fault Error Rate (FER)

Based on MOS (Mean Of Score) by opinion test, for FER to maintain good speech quality in a wireless section, existent ENHHO is within 4% and suggested is within 8%. As a result of field operation, for existent ENHHO call information was cut off momently at the point of 4% of FER and for suggested EHNNO, at the point of 8% of FER. Thus, based on MOS, while the maximum number of pilot signal possible for searching was within 5 in existent ENHHO, suggested ENHHO expanded to within 10.

The reason that MOS evaluation based on FER is different is that in existent ENHHO, if MS should search many numbers of pilot signal of neighbor BS, packet data of serving BS cannot be decoded while Ec/Io of each pilot signal is examined and the call information will be omitted.

## 4.2 Mean Data Transmission Rate

Based on the theory of design, the maximum data transmission rate of 2G system is 9.6Kbps/ch and that of 2.5G system is 144 Kbps/ch. But the results of field operation shows that while there was little effect of wireless environments on 2G system in data transmission rate, 2.5G system had been greatly affected by wireless environment and if wireless environment was good, the transmission rate was 60Kbps/ch~80Kbps/ch.

Based on 62 Kbps of minimum data transmission rate of 2.5G (SK Telecom), in existent ENHHO, the maximum number of pilot possible for searching was within 4

Table 4. The comparison of the results of field measurement.

| Number of searching pilot signal | FER (%) | | | | Improvement rate (suggested/exist) (%) | Mean data transmission rate (Kbps) | | Improvement rate (suggested/exist) (%) |
|---|---|---|---|---|---|---|---|---|
| | suggested | | existent | | | suggested | existent | |
| | FER | MOS valuat-ion | FER | MOS valuat-ion | | | | |
| N=0 | 0.66 | good | 0.68 | good | 3.0 | 99.8 | 99.6 | 0.2 |
| N=1 | 2.05 | good | 2.35 | good | 14.6 | 97.31 | 88.48 | 10.0 |
| N=2 | 3.10 | good | 3.23 | good | 4.2 | 79.48 | 72.72 | 9.3 |
| N=3 | 3.42 | good | 3.8 | good | 11.1 | 70.43 | 63.84 | 10.3 |
| N=4 | 3.8 | good | 3.73 | good | 1.9 | 73.84 | 64.84 | 13.9 |
| N=5 | 3.51 | good | 3.8 | good | 8.3 | 67.02 | 60.32 | 11.1 |
| N=6 | 4.90 | good | 5.11 | insufficiency | 4.3 | 73.66 | 58.44 | 26.0 |
| N=7 | 5.50 | good | 6.06 | bad | 10.2 | 69.90 | 56.30 | 24.2 |
| N=8 | 6.12 | good | 7.75 | bad | 26.6 | 66.71 | 55.01 | 21.3 |
| N=9 | 6.88 | good | 8.20 | bad | 19.2 | 58.3 | 54.44 | 7.1 |
| N=10 | 7.3 | good | 9.0 | bad | 23.3 | 54.8 | 50.72 | 8.0 |
| N=15 | 10.5 | normal | 13.5 | bad | 28.6 | 38.0 | measurement impossibility | comparison impossibility |
| N=20 | 12.6 | insuffi-ciency | 14.8 | bad | 17.5 | 33.7 | measurement impossibility | comparison impossibility |
| Standard value | ≤8% | good | ≤4% | good | | ≥62Kbps | ≥62Kbps | |

| Number of searching pilot signal | Mean pilot Ec/Io of serving BS (dB) | | Improvement rate (suggested/exist) (%) | Required time for transmission 1Mbyte (sec) | | Improvement rate (suggested/exist) (%) |
|---|---|---|---|---|---|---|
| | suggested | existent | | suggested | existent | |
| N=0 | -2.4 | -2.6 | 1.0 | 80 | 81 | 1.3 |
| N=1 | -3.3 | -3.2 | -2.1 | 87 | 94 | 8.0 |
| N=2 | -3.6 | -3.7 | 2.3 | 102 | 113 | 10.8 |
| N=3 | -4.1 | -4.1 | 0 | 107 | 138 | 29 |
| N=4 | -4.2 | -4.4 | 5.6 | 108 | 135 | 25 |
| N=5 | -5.4 | -5.6 | 3.6 | 129 | 148 | 14.7 |
| N=6 | -5.6 | -5.7 | 3.7 | 132 | 150 | 13.6 |
| N=7 | -5.7 | -5.9 | 1.0 | 133 | 155 | 16.5 |
| N=8 | -6.2 | -6.3 | 1.0 | 138 | 159 | 15.2 |
| N=9 | -6.5 | -6.5 | 0 | 140 | 163 | 16.4 |
| N=10 | -6.7 | -6.6 | -4.5 | 148 | 168 | 13.5 |
| N=15 | -9.8 | measurement impossibility | comparison impossibility | 211 | measurement impossibility | comparison impossibility |
| N=20 | -12.0 | measurement impossibility | comparison impossibility | 237 | measurement impossibility | comparison impossibility |
| Standard value | ≥-6.2dB | ≥-4.4dB | | ≤150sec | ≤150sec | |

(Ec/Io=more than -4.4dB), whereas suggested ENHHO expanded it to within 8 (Ec/Io = -6.2dB).

## 4.3. Mean Ec/Io of Serving BS

To maintain minimum data transmission rate as more than 62Kbps/ch, the mean Ec/Io of existent ENHHO was more than -4.4dB, but that of suggested ENHHO was more than -6.2dB, suggesting the improvement of 1.8dB. It was because suggested ENHHO limited the number of pilot signal of neighbor BS needed to searching to within 5 to minimize searching time. Thus, suggested ENHHO could maintain reference data transmission rate in lower Ec/Io than existent ENHHO.

### 4.4. Required Time for Transmission 1 Mbyte File

In sending 1Mbyte of data file, based on 4 and 8 of the number of searching pilot signal of neighbor BS, the required time of existent ENHHO was 135 sec. and 159 sec respectively, whereas that of suggested ENHHO was 108 sec. and 138 sec. respectively, suggesting that it reduced about 27 sec. and 21 sec. respectively. It was because transmission rate was affected by the number of pilot signal neighbor BS to search. In other words, if the number of pilot signal to search is increased, transmission rate will be relatively reduced.

In result, major performance comparison based on the standard value of every data is found in Table 4.

## V. Conclusion

In this paper suggests ENHHO traffic H/O using a new algorithm in order to resolve its problem, compares the results of field measurement using existent ENHHO to that of suggested ENHHO, and identifies the utility of suggested algorithm. Important findings are as follows.

First, based on MOS by opinion test, maximum FER is improved from 4% to 8% and protects momentary cut off of call information in H/O between generations.

Second, based on 62Kbps of minimum data transmission rate of 2.5G system, the number of maximum pilot signal possible for searching is increased from 4 to 8.

Third, Ec/Io to maintain reference data transmission rate to more than 62Kbps is improved from -4.4dB to -6.2dB.

Fourth, mean transmission rate by the number of searching FA in sending 1Mbyte file can be shortened about 15% (20 sec.).

The results of this study may be very important as the development of technology should be prepared for efficient H/O between 3G IMT-2000 mobile phone service which plans to commercialize in 2002 and 2G and 2.5G which are on service.

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## [Profile]


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