System Level Simulation of CDMA Network with Adaptive Array

Yeong-Jee Chung*, Jae-Woo Lee*

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Abstract

In this study, the system level network simulation is considered with adaptive array antenna in CDMA mobile communication system. A network simulation framework is implemented based on IS-95A/B system to consider dynamic handoff, system level network behavior, and deploying strategy into the overall CDMA mobile communication network under adaptive array algorithm. Its simulation model, such as vector channel model, adaptive beam forming antenna model, handoff model, and power control model, are described in detail with simulation block. In order to maximize SINR of received signal at antenna, maximin algorithm is particularly considered, and it is computed at each simulation snap shot with SINR based power control and handoff algorithm. Graphic user interface in this system level network simulator is also implemented to define the simulation environments and to represent simulation results on real mapping system. This paper also shows some features of simulation framework and simulation results.

I. Introduction

The system level network simulation of a mobile communication system is theoretically able to investigate the performance in terms of capacity, handoff and power control.[1]~[3] The optimization of cell parameters are considered by simulating the network behavior. It is also considering the design optimization of cell location by simulating the wireless network with cells on real world map. System level network simulation is necessary for investigating the behavior of network when applying adaptive array beam forming antenna. Particularly, the simulating the network behavior by modeling CDMA(code division multiple access) mobile communication cellular network can do evaluating the network performance under circumstances of multi-base stations, multi-mobile stations with mobility, and under fading channel environments. Even theoretical system level

* School of Computer, Information and Communication Engineering, Wonkwang Univ.
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simulations on this performance evaluation appear to be more successful because large network system and test environments are required to evaluate practically.[4]

For system level network simulation framework, it also has system level receiver model of base stations and mobile stations with mobility, that will allow the adaptive beam forming algorithm to be investigated with handoff and power control considerations. In this study, system level network simulation framework is developed by its receiver model to simulate the CDMA cellular network with graphic user interface. It is considering primarily IS-95A/B with various signal parameters.[5] Some features and simulation results are shown the next sections.

Ⅱ. Simulation Skeleton

A. Simulation Framework

Simulation framework is primarily implemented based on IS-95A/B system to consider network capacity, handoff and power control. In this simulation framework, multi-base stations and mobile stations are considered, which are placed by letting user locate them on real map with MapX interface.The simulation framework for system level network simulation has graphic user interface on GIS(Global Information System) for users to locate base stations and mobile stations to consider exact behavior of network. It is also considering each mobile station in up and down links on each location with adaptive beam forming algorithm.

This system level network simulation framework is built to consider cellular network behavior when applying adaptive beam forming antenna in CDMA cellular network. First of all, tele-traffic model, mobility model is to be defined for call generation in order to investigate system level network behavior. Radio link between base station and mobile station is also defined by multi-path vector channel containing propagation model and interference model in multi-user environment[6]. At cellular base station in CDMA mobile communication system, adaptive array beam forming antenna is applied to increase its capacity, which is modeled by adaptive algorithm referenced by prior research[7][8]. CDMA cellular network generally has deployed power control and handoff, which is operated by instantaneous SINR (signal to interference plus noise ratio), measured at receiver. For calculating SINR and radio link level, a snap shot calculation is to be made at every power control group with mobility. At the stage of representing simulated results, graphic user interface is provided for monitoring and representing up and down link.

Object oriented modular structure of simulation models is more effective for easy change of system architecture along the progress of standard activities. Therefore, it is programmed by object oriented components as figure 1.

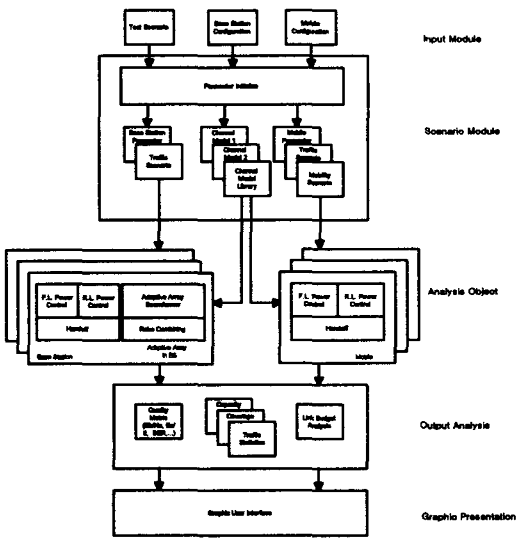


Figure 1. Modular structure of simulation block

B. Simulation environment and parameters

The system level network simulator is built to investigate system level behavior such as handoff, power control with adaptive array beam forming antenna under given simulation environment. The simulation framework is considering SINR based power control and mobile assisted handoff, therefore, individual SINR or link level components are computed at each snapshot of power control group under mobility and traffic load environment. The followings are possible simulation environments of the simulator developed in this study;

- Dimension of base stations and mobile stations
  Number of mobiles : 1500 max
  Number of cells : 30 Omni cells/10-3sector cells max
- Simulation snap shot : simulating time unit for cell-mobile object Currently 1.25msec, 1sec, 10sec
- Propagation channel model : Hata path loss model, Log normal shadowing, Rayleigh fading Vector channel model is being applied in multi-path environment
- Antenna model : Currently fixed beam directional antenna Antenna beam pattern in adaptive array is calculated by Adaptive array algorithm with MAI (Multiple access interference) at each snap shot, and it will be applied after array algorithm is fixed When using vector channel model for multi-path environment, antenna beam pattern of Rake combining adaptive array is considered
- Cell/Mobile position location : MapX interface to adapt real GIS (global information system) map and real world distance After snap shot, all mobiles move forward to next position with mobility model
- Handoff Model : Applying IS-95 Handoff parameters with T_Add, T_Drop, T_Comp Adaptive array algorithm will change handoff scheme into being dynamic
- Power Control : Considering power control error and delay in IS-95

The simulation environment is to be defined interactively on a real mapping system of GIS by a user and The parameters are also defined by a user.

After computing each quality metric component to be used in evaluating the performance of network under adaptive array beam forming antenna, it is represented by pseudo-colored dot on the display of real mapping system of GIS. The followings are simulation parameters to be computed for evaluating the performance of developed algorithm, and for comparing it with other algorithm under a certain simulation environment.

- Quality metric : Eb/No, Ec/It, FER
- Traffic quality statistics : call success rate, call drop rate, call block rate
- Base stations coverage, capacity
  coverage by given Eb/No
  number of users with given Eb/No
- Link budget : power distribution, Rx/Tx power

Ⅲ. Simulation Cockpit Model

In this system level network simulator, we are considering theoretical vector fading channel. Theoretical channel model implemented is shown by figure 2. This simulator is considering Hata-Okumura propagation model, Rayleigh fading channel model and log-normal shadowing model, which are modeled by a vector channel concept referenced by prior papers.[6][9]

The vector channel response generated provides a multi path delay profile with temporal resolution depending upon the probing bandwidth used to estimate the channel, which also provides independent fading envelope on each multi-path for each antenna element.

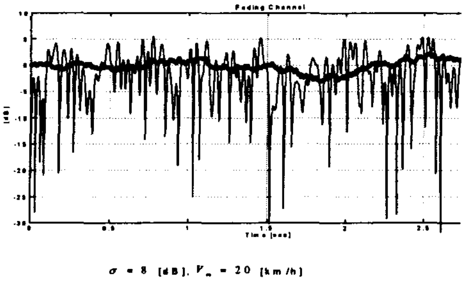


Figure 2. Theoretical channel models

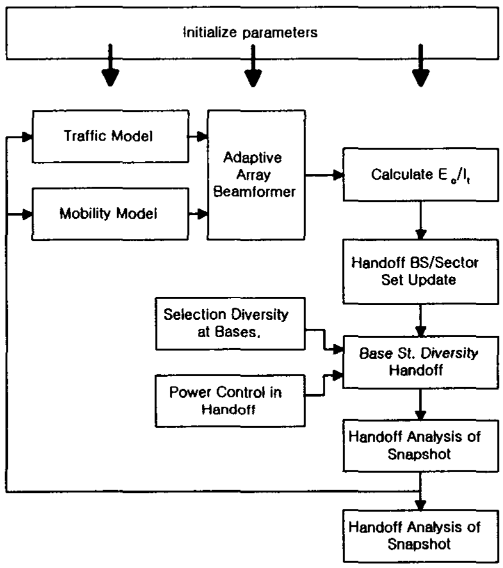


Figure 3. The block diagram for handoff model

The simulator is being built to investigate network performance with handoff, power control under adaptive array beam forming antenna under given simulation environment. The simulator is based upon SINR based adaptive beam forming algorithm to maximize SINR for each link between base and mobile station at simulation snap shot. adaptive beam forming algorithm is implemented for providing antenna radiation patterns to maximize the signal to interference plus noise ratio (SINR). Mobile assisted handoff, affected by SINR based power control and by radiation beam pattern from adaptive beam forming algorithm, is computed and updated at every simulation snap shot.

In IS-95A/B system, selection diversity for up-link, and cell diversity for down-link are considered respectively. Therefore, these two diversity features are implemented in system level network simulator with adaptive array antenna beam forming. During hand off, SINR based power control is different from that of non-handoff state, which is also implemented in this simulator. The block diagram for handoff model is shown in figure 3.

In CDMA system, power control is very effective to solve near-far problem. In system level network simulator, SINR based power control system is also implemented with adaptive beam forming algorithm.

In this network simulator, power control algorithm based on IS-95A/B is primarily implemented by sensing SINR at base station. SINR based power control in handoff state is different from that of non-handoff state, which is also implemented in this simulator. In network simulator, power control is applied to both links, which includes open loop power control, closed loop power control, and outer loop power control. The block diagram for power control model is shown in figure 4.

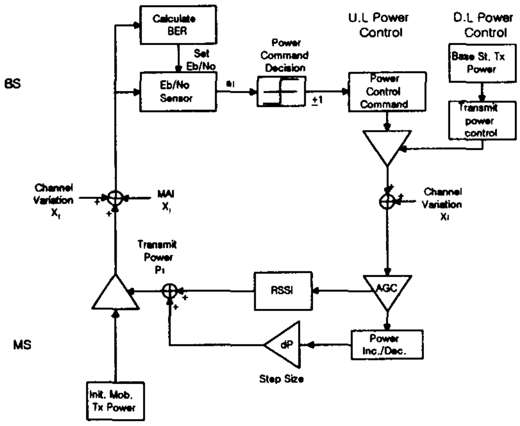


Figure 4. Block diagram of SINR based power control model

Open -loop power control and closed loop power control are defined as follows respec tively;

- Open loop power control model :

$$P_o = k - P_r$$

$$P_{to}(t) = P_o(1 - exp(-t/\tau))$$

- Closed-loop power control model :

$$P_{t+1} = P_i - \Delta P \cdot C(E_{i-k})$$

$$C(E_{i-k}) = \begin{cases} +1 & \text{if } E_{i-k} < 0 \\ -1 & \text{if } E_{i-k} > 0 \end{cases}$$

$$E_{i-k} = P_{i-k} + X_{i-k} - \delta_{i-k}$$

In system level network simulator, adaptive beam forming algorithm is implemented by providing radiation antenna beam patterns to maximize the signal to interference plus noise ratio (SINR). Radiation beam pattern by adaptive beam forming algorithm is computed and updated at every simulation snap shot based on SINR from arrived signal, noise and multiple access interference (MAI).

We have implemented adaptive array beam pattern module, which is applicable to fixed radiation beam profile based on IS-95A/B. We are working on implementing adaptive array algorithm on radiation beam pattern module by replacing fixed beam module with adaptive array beam forming. Antenna beam pattern module is being built to consider adaptive array beam forming by Maximin algorithm to maximize SINR first, which is also adaptable to SINR based power control and handoff.

The Maximin algorithm is a novel approach to blind adaptive beam forming that is applicable to CDMA mobile communication system.[10] The algorithm was originally developed for maximizing the signal to interference plus noise ratio (SINR) for frequency-hopping signals and originally worked only for time-gated signals. This algorithm has been extended to handle CDMA.[10] The Maximin algorithm is a blind algorithm that does not require the knowledge of the array manifold, or precise array calibration. Its convergence is faster compared to that of the commonly used blind algorithms such as constant modulus algorithm (CMA) or decision-directed algorithms (DDAs), and it is comparable to that of non-blind algorithms. [11] Also, the Maximin algorithm is guaranteed to converge to the desired solution unlike the other blind algorithms. The Maximin algorithm is also suitable for the adaptive beam forming with CDMA signals and can be used for burst acquisition and code timing synchronization.

Detailed Maximin algorithm referenced by prior paper[7] shows that a code-gated Maximin algorithm can also be designed for the CDMA signals in addition to time and frequency-gated implementations of the Maximin algorithm. At the CDMA receiver, after the received wide band CDMA signal is multiplied with the desired users spreading code, the result is a narrow band signal of the desired user in the wide band multiple access interference. The conventional CDMA receiver filters the desired narrow band signal for further processing. In the code-gated Maximin algorithm, the MAI is also processed for estimating the correlation properties of the interference and the noise. Figure 5 represents expected antenna beam profile from adaptive array beam forming antenna after implementing adaptive array algorithm in adaptive array beam pattern module.

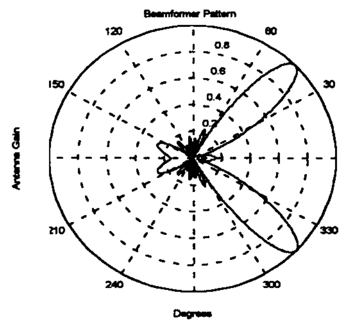


Figure 5. Expected antenna beam profile when implementing adaptive beam forming algorithm

Ⅳ. System Level Network Simulator

A. Control flow of simulator

A simulator is being created to consider the interaction of adaptive arrays with handoff algorithms for CDMA mobile communication system. The simulation is primarily based on IS-95A/B handoff and power control algorithms with dynamic link coverage, computed by Ec/Io when the adaptive array is applied. This simulator will include vector channel model between base station and mobile station to simulate more accurate channel.

In this handoff simulation framework, user can specify the orientation of array and mobility of mobile. Then the impulse response of the channel is estimated for each location of the mobile station (MS) at spatial domain by vector channel model. Once the impulse response of channel is estimated for a given position, Eb/No received at this MS location with adaptive array, are estimated and compared with the handoff threshold. As the MS is traveling along a direction by mobility, this procedure is updated at each location.

Step 1. Define base station location by user or systematically define base station location by predefined patterns such as hexagonal distribution and rectangular distribution.
Step 2. Define initial service coverage by an equal-distance border.
Step 3. Generate randomly a MS inside each cellular coverage boundary with an initial location and initial velocity and direction.
Step 4. Calculate Eb/No in base station and mobile station with inter-cell interference and intra-cell interference and calculate exact cellular boundary at that instance. This is one snap shot of simulation.
Step 5. Move each mobile station by mobility model in which velocity change and direction change are considered
Step 6. Repeat Step 4. and Step 5. and simulate handoff/power control performance.

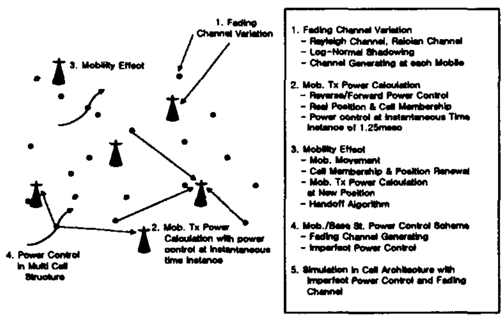


Figure 6. Concept of system level network simulation

The simulator will allow us to investigate the effectiveness of adaptive beam forming antenna algorithm using a CDMA system model that includes handoff, power control, and vector channel models. The simulator will provide insight into developing new adaptive array algorithms and how the adaptive array should be integrated into the overall network. The simulation concept in system level network simulator is shown in figure 6.

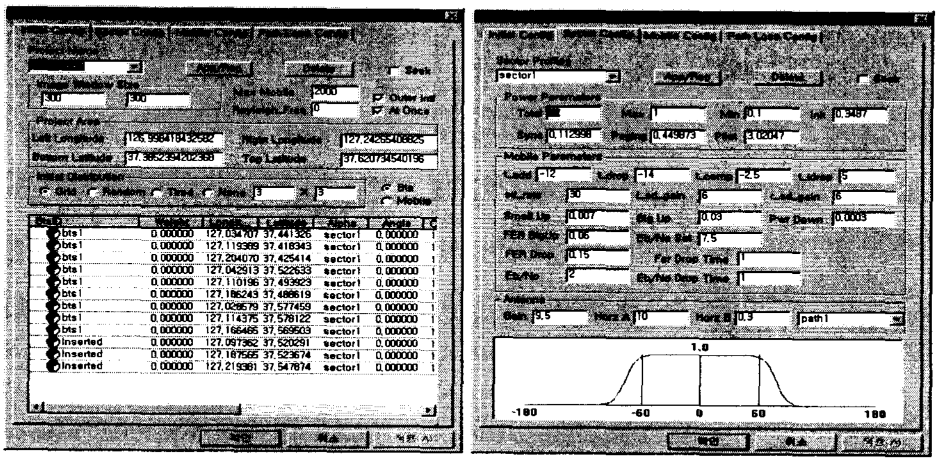
The simulation steps are outlined below.

B. Graphic user interface of system configuration

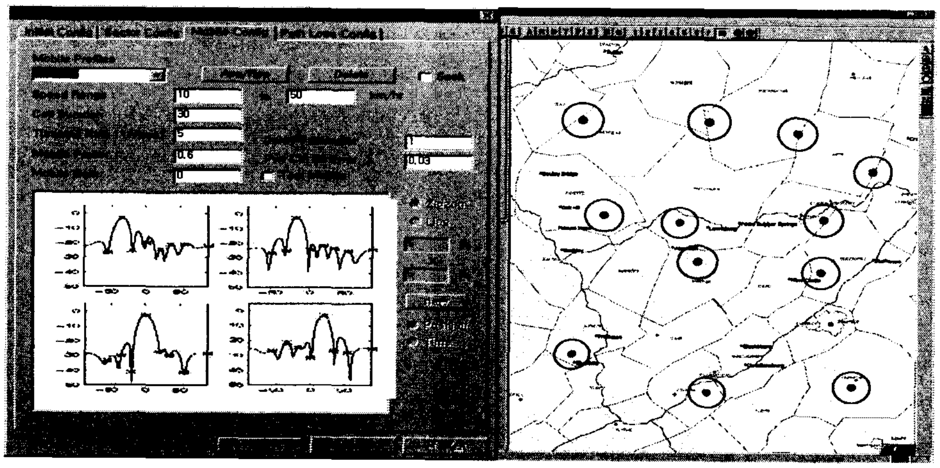
In this section of this paper, graphic user interfaces being built in system level simulator, are shown by following figures. This graphic user interfaces are implemented by Microsoft Visual C++ to define simulation environments.

When defining the simulation environment of CDMA network, system configuration, cell configuration, and mobile configuration are used to define each parameter to be entered as simulation environment.

Initial configuration shown as a) in figure 7. In cell configuration shown as b) in figure 7, user can define radiation beam pattern of antenna, which is applied at base station. The radiation beam pattern is computed by adaptive array algorithm at each simulation snap shot after implementing adaptive array algorithm in network simulator. Simulation environment for mobile station is defined in mobile configuration shown as c) in figure 7. At each simulation snap shot, adaptive array beam pattern for selected mobile is computed with adaptive array algorithm. In system level network simulator has MapX interface to



a) System configuration b) Base station configuration



c) Mobile station configuration d) Locating base station on GIS

Figure 7. Graphic user interface of system configuration

accommodate base station on real mapping location on GIS shown as d) in figure 7. User easily locate base stations on real world map to simulate network performance with SINR based adaptive array antenna with dynamic handoff and power control algorithm.

V. Simulation results

This section represents simulation results, that is equi-distance boundary based on base station located on GIS, instantaneous link connection between base station and mobile station, Eb/No distribution of forward/reverse link, and analysis of soft/softer handoff region on bit mapped color display.

In order to calculate initial state of simulation network, equal-distance boundary is very useful to define initial ownership of each call among multi-base stations. Equal-distance boundary is physical reference for calculating initial interference and SINR for each mobile station. Then, exact signal power and SINR for each mobile station are computed from power control and handoff algorithm at each snap shot with mobility and traffic loading. After applying power control and handoff algorithm on each links between mobile and base stations, each mobile station is placed under actual call state by power control and soft/softer handoff.

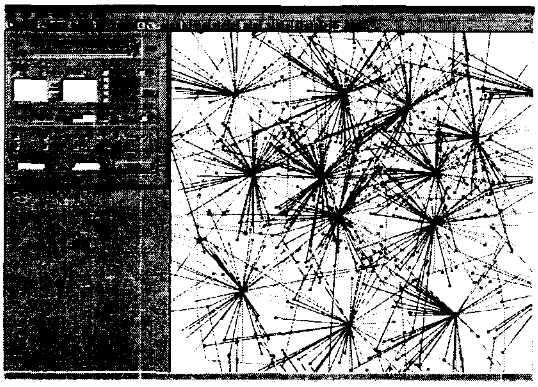
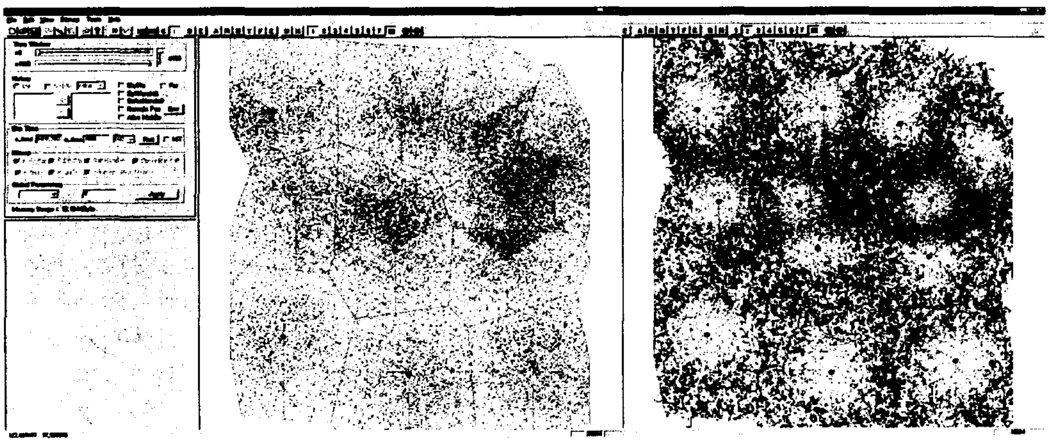


Figure 8. Link connection between base station and mobile station

During system level network simulation, it is necessary to look at each link between base stations and mobile station shown as figure 8. Link connection between BS/sector and MS reflects soft or softer handoff from multiple connections with base stations or with sectors. Three-way handoff is also displayed on this link display window. Its handoff status is stored on each bit mapped mobile location by color code from the number of handoff. Bit mapped color code is displayed on handoff display window to represent handoff region or handoff behavior.

Reverse link Eb/No is computed at base station by sensing signal from mobile station with interference environment under power control and rake combining. As shown in an example of simulation, reverse Eb/No is generally uniform on coverage area by power control algorithm of reverse link shown as a) in figure 9. If power control algorithm is not accurate to maintain constant Eb/No at base station, and/or power control step size is not given properly, the network performance is getting worse.

Forward link Eb/No is computed at mobile station by sensing signals from base station with interference environment. Forward link Eb/No display window is useful to investigate the performance of adaptive array for power transmission in spatial domain. As shown in b) of figure 9, forward Eb/No is related on



a) Eb/No distribution at reverse link　　b) Eb/No distribution at forward link

Figure 9. Eb/No distribution at forward and reverse link

propagation loss at each mobile station.

Analysis of soft/softer handoff region is representing handoff region computed from SINR based handoff algorithm with power control under radiation beam pattern by adaptive array antenna. In order to develop the innovative adaptive beam forming algorithm to be applied to array antenna, it is necessary to investigate the network performance under its adaptive algorithm whether its algorithm into network architecture represent innovative or not. It is one reason for building the system level network simulation.

Ⅵ. Conclusion and Future work

This section reviews the system level network simulator to consider adaptive array antenna in CDMA mobile communication system. In system level simulator, network simulation framework is implemented based on IS-95A/B system to consider adaptive array algorithm. Its simulation model, such as vector channel model, adaptive beam forming algorithm, handoff model, and power control model, are described with simulation block diagram. In order to maximize SINR of received signal at antenna, Maximin algorithm is considered, and it is computed at each simulation snap shot with SINR based power control and handoff algorithm. Graphic user interface in this system level network simulator is also implemented to define the simulation environments and to represent simulation results on real mapping system.

The future work will be implementation and enhancement of simulation framework of IMT-2000 mobile communication system. It will provide insight into investigating dynamic handoff under adaptive array antenna, and into simulating system level network behavior of IMT-2000 with adaptive array. It will also provide deploying strategy of adaptive array beam forming antenna into the overall network by vector channel model in multi-path environment.

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정 영 지(Yeong-Jee Chung)

1978년 3월 ~ 1982년 2월 : 연세대학교 전기공학과(학사)

1982년 3월 ~ 1984년 2월 : 연세대학교 전기공학과(석사)

1984년 3월 ~ 1993년 2월 : 연세대학교 전기공학과(박사)

1984년 1월 ~ 1987년 7월 : 금성계전(주) 연구소(주임연구원)

1987년 7월 ~ 1993년 2월 : 삼성종합기술원 소재부품연구소(선임연구원)

1993년 3월 ~ 1995년 2월 : 한국전자통신연구소 이동통신기술연구단 무선제어연구실(선임연구원)

1997년 12월 ~ 1999년 2월 : Visiting Professor at MPRG, Virginia Tech.

1995년 3월 ~ 현재 : 원광대학교 공과대학 컴퓨터및정보통신공학부 조교수

* 주관심 분야 : 탄성표면파 필터 설계, 디지털 신호처리, 이동통신 및 위성통신시스템 등

이 재 우(Jae-Woo Lee)

1994년 3월 ~ 1998년 2월 : 원광대학교 공과대학 컴퓨터공학과 학사

1998년 3월 ~ 현재 : 원광대학교 공과대학 컴퓨터공학과 석사과정

* 주관심 분야 : 디지털 신호처리, 이동통신 시스템 등