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後三代行動通訊處理器設計(3/3)

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行政院國家科學委員會補助專題研究計畫 ☑ 成 果 報 告
□期中進度報告

後三代行動通訊處理器設計

計畫類別：☑ 個別型計畫　　□ 整合型計畫
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成果報告類型(依經費核定清單規定繳交)：□精簡報告　☑完整報告

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中　華　民　國　　94 年　　10 月　　24 日

目　錄

一. 中文摘要

在後三代（Beyond 3G）行動通訊系統當中，我們期望這個系統能夠讓許多分散的使用者在相當不確定的無線通道中傳輸較高速的資料。因此在設計無線傳輸介面時，很重要的一件事是讓系統具有高容量的多用戶存取設計來滿足突發型的多媒體資料封包並符合不同的服務品質（QoS）。

多載波分碼多工（MC-CDMA）是滿足後三代行動系統需求中相當有希望的技術。它結合了多載波傳輸技術的優點（例如：對於頻率選擇衰減效應的穩健性）以及分碼多工系統（CDMA）的多用戶存取能力。而且多載波分碼多工相當適合多速率的多媒體資料傳輸。

在這個三年期的計畫當中，我們研究並提出了一個新的在頻域做直接序列分碼多工系統（DS-CDMA）的多用戶偵測。而正交分頻多工（OFDM）的相位同步化也是我們研究的問題之一。然後我們提出了在多載波分碼多工系統中（特別是多調分碼多工（MT-CDMA））的多用戶偵測設計並且估量了它的效能。為了要使得在多載波分碼多工系統中的射頻資源分配（RRA）更有效率，我們還提出了綜合傳輸速率、子載波（sub-carrier）、以及傳輸功率分配的演算法，此演算法還同時具有線性最小均方差（LMMSE）的多用戶偵測技術。除了考量後三代通訊系統設計的物理層，我們也考量了無線隨意式網路（wireless ad hoc network）的群組問題，這種網路結構將會在下一代無線通訊系統中相當普遍。

關鍵字：後三代，同步化，多用戶，分碼多工，正交分頻多工，相位雜訊，多速率，多載波，資源分配，無線隨意網路，群組，服務品質。

二. 英文摘要

In the “Beyond 3G” mobile communication systems, it is expected to be capable of delivering higher data rate service for distributed users in extremely unpredictable wireless channel. Thus it would be very important to design air interface that has high capacity multiple-access schemes to transmit burst-type multimedia data packet with different quality-of-service (QoS).

Multi-carrier code-division multiple-access (MC-CDMA) has been a promising technique to meet the demand of “Beyond 3G” systems. It combines advantages of multi-carrier transmission such as robustness to frequency-selective fading and multiple-access capabilities of CDMA. In addition, MC-CDMA is suitable for multi-rate multimedia data transmission.

In this three-year project, we investigated a novel frequency domain approach for multi-user detection in DS-CDMA systems. Phase synchronization for well-known multi-carrier technique, orthogonal frequency-division multiplexing (OFDM), was studied. Multi-user detection scheme of multi-rate MC-CDMA where we focused on multi-tone CDMA (MT-CDMA) was proposed and the corresponding performance evaluation was given. To make the radio resource allocation (RRA) in MC-CDMA more efficient, we further propose a joint rate, sub-carrier and power allocation algorithm with LMMSE multi-user detection. In addition to the physical layer consideration in “Beyond 3G” receiver design, we also consider wireless ad hoc network clustering issues which may be a widespread network topology in the future generation wireless communication systems.

Keywords: Beyond 3G, synchronization, multi-user, CDMA, OFDM, phase noise, multi-rate, multi-carrier, resource allocation, ad hoc networks, clusters, QoS.

三. 前言

Recently the communication industry has been seeking for a new technology which can offer higher data rate than 2G/3G with high mobility wireless communication services. This future generation communication technology is taking shape and generally called “Beyond 3G” system. Some key parameters comparison between 3G and “Beyond 3G” is shown in Table 1. It targets to provide wireless broadband applications such as wireless multimedia service, wireless internet access, wireless voice over IP (VoIP) and so on. Therefore,

In order to accommodate the wireless broadband applications stated above, “Beyond 3G” system must be spectrum efficient, power efficient and adaptable to channel conditions. In addition, “Beyond 3G” system would be expected to integrate existing systems in a common platform so that connection of different services (or appliances) could be possible.

To meet the features of “Beyond 3G” system, there are quite a few technological challenges. For example, to coexist with other communication technologies, a simple, generic multiple access scheme is very desirable. Without a well-designed multiple access scheme, the system capacity would be highly limited by multiple access interference (MAI). Furthermore, “Beyond 3G” system should also support different quality of services (QoS) in varied channel and applications so that an adaptive resource allocation is also required. The list of technology issues of “Beyond 3G” system can be very long and needs worldwide researchers’ long-time efforts to make the “Beyond 3G” technology mature and full standardized.

Table 1. Key parameters of 3G and Beyond 3G systems [1]

Communication Tech.	3G	Beyond 3G
Frequency band	1.8 - 2.5 GHz	2 - 8 GHz
Bandwidth	5 - 20 MHz	5 - 20 MHz
Data rate	Up to 2 Mbps (384 kbps deployed)	Up to 20 Mbps
Access	W-CDMA	MC-CDMA or OFDM (TDMA)
Forward error correction	Convolutional rate 1/2, 1/3	Concatenated coding scheme
Switching	Circuit/packet	Packet
Mobile top speeds	200 km/h	200 km/h

In this 3-year project, we focus on the following major issues when designing “Beyond

3G" transceiver. It includes:

1) Designing Two frequency domain multi-user communication methods: One is frequency-domain orthogonal multi-user communications with inverse transformation (FDOMC-IT) which can avoid inter-symbol interference (ISI) and multiple access interference (MAI). The other is frequency-domain orthogonal multi-user communication with direct spreading (FDOMC-DS) that can use diversity gain in frequency selective fading channel to improve system capacity.
2) Optimal symbol synchronization based on MAP criterion over frequency-selective slowly fading channel.
3) Study of two multi-rate schemes (Multi-code (MC), Variable-spreading length (VSL)) in multi-tone CDMA (MT-CDMA) systems. The effects of MAI in these two multi-rate schemes are investigated.
4) The performance sensitivity of phase noise in the OFDM system and correction method.
5) Radio resource (rate, sub-carrier and power) allocation for multi-user multi-carrier CDMA system.
6) Novel clustering (grouping) method (Boundary-First Cluster-Minimized (BFCM)) for wireless ad hoc networks with boundary nodes.

These researches aim to solve the MAI issues in multi-user environments, propose synchronization methods in CDMA and OFDM systems (which may be combined to apply in multi-carrier CDMA system), allocate resource that can minimize the total transmission power for given QoS requirements in multi-user environments and propose a clustering method which minimizes the total number of organized clusters in distributed wireless ad hoc networks.

四. 研究目的

Because different issues in designing “Beyond 3G” system are taken into account, we categorize these research results into four parts.

Part I.

In mobile communications systems, multiple access to the common channel resources is vital. In a system based on the conventional direct sequence code division multiple access (DS-CDMA) technique, code division provides simultaneous access for multiple users. Ideally, by selecting mutually orthogonal spreading codes in time-domain for all users, interference-free single-user performance can be achieved. It is, however, impossible to maintain orthogonal spreading codes at the receiver in a mobile environment, and thus multiple-access interference (MAI) is inevitable in the DS-CDMA systems. The multiple access interference severely degrades the performance of conventional DS-CDMA detection techniques and is the major limiting factor to system capacity.

Over the years researchers have sought ways to improve system performance and to extend user capacity by seeking for more advanced detection strategies. In [6], Verdu developed the optimal (0,1)-constrained maximum likelihood (ML) detector for multi-user DS-CDMA systems. Since then, multi-user detection (MUD) has become the most attractive technique to improve the system performance. Nevertheless, the majority of multi-user detectors have very high complexity and consequently sub-optimal structures have been presented in practical implementations.

In [5], a frequency-domain code division multiple access scheme over additive white Gaussian noise (AWGN) channel was proposed as an alternative to mitigate the multiple access interference due to asynchronous transmissions in the DS-CDMA systems. This scheme considers a novel but equivalent spreading approach and employs mutually orthogonal sequences in the frequency-domain as spreading codes. Due to the fact that shift of a signal in time-domain simply corresponds to multiplication by a scalar factor in frequency domain, orthogonality over frequency-domain can be retained among all users, which eliminates the requirement of perfectly synchronous receptions at the receiver [7,8]. Therefore, the optimal demodulator can be realized with significantly reduced complexity.

By extending this frequency-domain approach to frequency-selective slowly fading channels, this frequency-domain approach is interfered by inter-symbol interference (ISI) introduced by frequency-selective channels, although the signature sequences remain

orthogonal to have zero MAI.

In this part of project, we first introduce the frequency-domain orthogonal multiuser communications systems that are not interfered by ISI over frequency-selective slowly fading channels. In addition, we propose the optimal timing estimation over frequency-selective slowly fading channels to provide the received timing required to the receiver.

Part II.

Wireless multimedia communications require efficient multi-rate physical-layer transmissions. Lots of research extensively studied the multi-rate transmissions over DS-CDMA systems [10] for multimedia communications, where multi-code (MC) and variable-spreading- length (VSL) are the two most widely applied multi-rate concepts. MC scheme assigns multiple spreading codes for data multiplexing and VSL scheme adjusts the spreading factor respectively to achieve multi-rate transmission. Comparatively, VSL was shown advantageous due to its better interference pattern and lower implementation complexity in DS-CDMA [11]. However, with the increasing demand of wideband high-speed communications, research attentions have been changed to multi-carrier systems in recent years, which provide efficient transmissions over broadband wireless channels [12]. Hence, it is natural to apply MC concept to MT-CDMA.

In [16], it is shown that the OFDM is in orders of magnitude more sensitive to carrier frequency offset and phase noise than single carrier systems. And it is also proved that the Wiener phase noise is a much more complex phenomenon than carrier frequency offset. The effects of phase noise are the well-known common phase error (CPE) and inter-carrier interference (ICI). The primary source of phase noise in a receiver is the local oscillator in the mixer. Components with ultra-low phase noise specifications are readily available, but are often large and expensive. Therefore, meeting the phase noise requirements for an OFDM system may add cost to the mixer especially for systems with a large number of subcarriers. Hence, the significance of phase noise suppression algorithms is to transfer the effort from analog to digital part to simultaneously lower the cost and preserve the required performance.

Part III.

Wireless multimedia communications requires not only effective transmission technique but also resource allocation to provide different quality-of-services (QoS) for

users of various demands. Multi-Carrier CDMA (MC-CDMA) that combines Orthogonal-Frequency-Division-Multiplexing (OFDM) and CDMA was shown its advantages in transmitting broadband signals over frequency-selective fading channels and providing high capacity [17-18]. MC-CDMA data stream is spread by a given spreading code and each code chip modulates a different sub-carrier, which is so-called the frequency-domain spread spectrum [12] and all sub-carriers are mutually orthogonal. Power, sub-carrier, and spreading codes are available radio resources in MC-CDMA transmission.

Conventional MC-CDMA uniformly distributes power to all sub-carriers without optimization and obviously it is inefficient. Providing channel state information (CSI) in the transmitters, a method ever proposed to turn off deep-faded sub-carriers and uniformly distribute power to the remaining sub-carriers to improve the performance of maximum-ratio-combining (MRC) receiver [19]. However, it is not proven an optimal method in any sense. RRA in MC-CDMA is critical to multimedia traffic but it still lacks of systematic methodology to jointly utilize these radio resources. Most previous researches about resource allocation in CDMA systems only considered the conventional matched-filter-based single-user-detection (SUD) receivers, but it is well-known that MUD can significantly improve the performance and capacity of CDMA systems [20] and MUD is especially recommended in uplink MC-CDMA due to the serious distortion of code orthogonality in frequency-selective fading channels [21]. Hence, RRA with MUD in uplink channels is essential to practical MC-CDMA applications.

Part IV.

Wireless ad hoc network is a self-organizing network architecture that can be rapidly deployed and can also be dynamically adapted to the propagation and the traffic conditions and the mobility patterns of the wireless nodes. Possible examples of the wireless ad hoc networks are tactical military applications, disaster recovery operation and exhibitions or conferences. The most distinguishing characteristic of the wireless ad hoc networks is the lack of the fixed infrastructure. Thus, designing an efficient and stable operational architecture turns out to be an important issue. One of the general approaches is to partition the entire network into groups of *clusters*. Within each cluster, a node is elected as a *clusterhead* to control communications among the cluster. Some advantages to organize the entire network into clusters are listed as follows.

Frequency spatial reuse: With clustering, the channel assignment strategy can be employed to optimally and spatially reuse the radio frequency among clusters.

Power consumption: In order to achieve mobility, power of the mobile device is mainly supplied by batteries. To prolong the communication duration of the device, the transmission power must be efficiently utilized in order to conserve the limited battery power.

Interference: Without clustering, higher transmission power is needed in order to achieve the global network connectivity. As a result, interference to and from neighboring nodes will be very severe. Through partitioning the entire network into clusters, the interference is reduced since only local connectivity is required.

Robustness: In a fully distributed wireless ad hoc network, it is very difficult for each wireless node to have the correct knowledge about the entire network topology due to the random mobility of the wireless nodes. By clustering, however, each wireless node only needs to know the local network topology information.

Increase system capacity: With clustering, the capacity can be improved both because the frequency reuse and the reduction in transmitting network topology maintenance messages and routing information.

五. 研究方法

Part I.

We consider the asynchronous multiuser communications systems with K users over frequency-selective slowly fading channels such that the channel impulse response of all users are time-invariant within a couple of frames. In order to avoid the ISI introduced from frequency-selective slowly fading channels, sharing the similar rationale behind OFDM systems, we insert the guard intervals of proper length which is the cyclic prefix of the signal as shown in Figure 1. In addition, we employ the frequency-domain orthogonal spreading and the frequency-domain orthogonal signature sequence as shown in Figure 2(a) to mitigate the MAI. As can be seen in Figure 2(b), the receiver only need two discrete Fourier transformation blocks to optimally demodulate the received signals. The transceiver block for FDOMC-DS is plotted in Figure 3.

In the second part, applying the composite hypothesis testing rule, we introduce the optimal timing estimation based on the *maximal a posteriori* probability with unknown channel impulse response over frequency-selective slowly fading channels. The block diagram of the proposed estimation is in Figure 4.

Part II.

Applying MC concept to MT-CDMA is straightforward as transmitting multiple basic-rate MT-CDMA signals. However, simply assigning codes of variable length to users of different symbol rates cannot simultaneously keep constant bandwidth and symbol-level orthogonality in MT-CDMA. It is because the sub-carrier separation in MT-CDMA depends on the symbol rate instead of chip rate, although the bandwidth at each sub-carrier is fixed. Hence, in addition to MC scheme, we propose two varieties of VSL schemes to respectively hold constant bandwidth and symbol-level orthogonality. To evaluate the performance of MT-CDMA receptions in different multi-rate schemes, the suffered interferences, including multiple-access interference (MAI) and ICI, are the most important factors to be considered [6]. Besides comparing basic signal properties, we focus on analyzing the characteristics of the three multi-rate schemes about interference immunity in the receiver based on matched filters and identify their challenging problems. Qusi-synchronous reception is considered for fundamental investigations as a necessary precursor to asynchronous uplink. With BER comparison in simulations, application suggestions are given in the conclusion.

Then we present the phase noise corrupted OFDM signal model and the phase noise model respectively. Based on that, first investigate the statistical characteristics of the sufficient statistics, it then proceed to derive the maximum likelihood estimator for CPE. Afterward, the analysis of the effect ICI is given. Performance evaluations via computer simulation are addressed as shown as follow. Finally, we make some discussions.

Part III.

For multi-rate transmissions, Multi-Code (MC) and Variable-Spreading-Length (VSL) are two widely adopted multi-rate schemes in CDMA systems [11], and their combinations with MC-CDMA were previously studied in [14] with a LMMSE MUD effectively to mitigate the multiple access interference and orthogonality distortion in uplink receptions. In this work, we consider the MC- and VSL- based multi-rate MC-CDMA systems with the receiver applying the LMMSE MUD. All users in the systems have individual QoS demands on physical transmission rate and bit-error-rate (BER).

To save critical power consumption for user terminals, the principle of allocations is to minimize the total uplink power consumption. Novel to conventional methodologies, the optimization is processed over the domain that users are decomposed as unit-rate virtual users such that either of the two multi-rate MC-CDMA systems exhibits structural regularity to make the whole problem easy to handle. We derive the user capacity of both multi-rate MC-CDMA schemes according to all users' QoS constraints and propose a simple and practical user admission criterion. To allocate power of each admitted user, an iterative power allocation algorithm to assign sub-carrier power and adjust signal phase is proposed, in which sub-carrier selection is jointly achieved.

Part IV.

To take the effects of boundary nodes into account, we propose a distributed Boundary-First Cluster-Minimized (BFCM) clustering algorithm to reduce the total number of generated clusters by minimizing the number of organized clusters. We show that with this algorithm, the numbers of the organized clusters are reduced dramatically with compared to the well-known ID-based and Degree-based algorithms. Firstly, a summary of related work is presented. Then we formulates the cluster formation problem as a cluster minimization problem and proposed the BFCM clustering algorithm to achieve the objective. The computer simulation is then driven to verify that our algorithm forms less clusters than conventional methods do.

六. 結果和討論

Part I.

Two frequency-domain orthogonal multiuser communications (FDOMC) schemes, namely FDOMC-IT and FDOMC-DS, have been proposed to mitigate the multiple access interference for the asynchronous communications system over frequency-selective slowly fading channels. In addition, the FDOMC-IT system is further not interfered by ISI introduced by frequency-selective channels and can be optimally demodulated with low complexity. This is the consequence of concentrating the energies of independent information symbols into different sub-bands such that each sub-band experiences frequency-nonselective fading. This approach does not earn the frequency diversity gain inherited from frequency-selective channels without efficiently establishing the correlation between information symbols.

By spreading the energies of independent information symbols into the whole frequency band, the FDOMC-DS system utilizes the frequency diversity to combat channel fading impairment so that it outperforms the FDOMC-IT scheme with similar complexity. Moreover, it was verified by the numerical analysis that the LMMSE estimation is much more efficient than the ML estimation to utilize the frequency diversity by taking the noise enhancement effects into consideration.

We further proposed the optimal symbol synchronization based on MAP criterion over frequency-selective slowly fading channel. In particular, the proposed estimator, designed according to the composite hypothesis testing rule, does not require the information of channel impulse response of the frequency-selective channels. By releasing the assumption in [9], our proposed estimator can be applicable to many wireless communications systems, in addition to the DSSS communications systems with large spreading gain.

This proposed optimal estimator, as justified by the conducted simulations, not only utilizes the frequency-diversity to combat fading channels but also properly mitigates the mutual interference due to multi-path components. In addition, we proposed the sufficient condition for the proposed optimal estimation to be consistent. This introduced sufficient condition can be explained as the consequence of the lack of channel impulse response and therefore is stricter to the case with known channel impulse response. Fortunately, a lot of training symbols can easily satisfy this sufficient condition to have a consistent symbol synchronizer.

Part II.

We studied multi-code (MC) and variable spreading length (VSL) multi-rate transmissions of MT-CDMA, including interference analysis and performance comparison, where the MC scheme is shown more appropriate for applications. Showing constant bandwidth, the major detection challenge of MC scheme is Intra-carrier MAI and can be easily mitigated by orthogonal codes such that users of any rate can achieve the best performance compared to using the other schemes. Variable-Spreading-Length orthogonal (VSL-O) scheme is good for users of higher data rates but it occupies wider bandwidth and the rate-varying bandwidth makes the spectrum utilization a serious concern. Variable-Spreading-Length Fixed-Bandwidth (VSL-FB) scheme shows the best PAPR condition and its constant spectrum profile identical to MC scheme makes their transceiver architectures easier integrated like that in DS-CDMA system [11]. However, the performance of non-basic-rate users in VSL-FB is poor due to severe Self-ICI, even though basic-rate users perform well.

In contrast to MC-CDMA [14] and MC-DS-CDMA [13], where frequency diversity and MAI pattern respectively dominate the transmission performance of a multi-rate scheme, the evaluation of multi-rate schemes in MT-CDMA is dominated by the resistance against ICI and the spectrum utilization. MC scheme is superior in terms of both BER and spectrum efficiency, although adequate PAPR reduction may be necessary due to amplifier restrictions.

Then we propose a common phase error estimator based on maximum likelihood criterion to effectively remove the complex gain caused by phase noise on the frequency domain transmitted symbols. Different from conventional maximum likelihood approach which assumes the inter-carrier interferences observed on different sub-carriers to be independent identically distributed, we combine pilot-aided and decision-directed approaches and investigate their covariance to yield the generalized maximum likelihood estimation scheme. By the autocorrelation function of the ICI weighting function, the effect of ICI is analyzed and verified with numerical results. The effectiveness of the proposed algorithm is manifested by simulations and is shown to outperform the conventional least-squared approach.

Part III.

In this paper, we proposed the resource allocation of MC-CDMA with LMMSE MUD for multi-rate quality-guaranteed uplink transmissions. The user capacity of MC-CDMA

with MC and VSL multi-rate schemes was determined and we derived a useful admission criterion to control the physical-layer signal transmissions under quality constraints. This criterion indicates a simple linear decision rule that relates the admissible rate and BER demands with the number of sub-carriers used in the systems. It in practice can be used to not only determine the supportable transmission rates of the system but also decide the entrance admission of new data streams other than new users. It helps to exploit the system capacity for multimedia traffics. To minimize the total power consumption and meanwhile maintain the QoS demands, the best-quality sub-channels with respect to each user shall be selected and power concentrated. This principle is valid if the best sub-channels are all exclusive. Otherwise, these best sub-channels are shared by codes. The proposed low-complexity iterative algorithm jointly selects the sub-carriers and allocates the power for all users. In terms of resource utilization, MC-CDMA is shown advantageous in contrast to other pure OFDM-based multiple access schemes. For example, each user in OFDMA can only exclusively select its own sub-carriers without the flexibility to share with others, which is generally a sub-optimal solution.

Part IV.

To reduce communication overheads in transmitting routing information and network maintenance message, incorporating with a generalized weighting function, we present a distributed BFCM algorithm to minimize the total number of generated clusters in an ad hoc network. We first transform this cluster minimization problem into selection of the nodes with the most number of neighbors as clusterheads to maximize the members in a cluster; and, then, based on the characteristic that boundary nodes is the main reason to generate orphan cluster, we further minimized the generation of orphan clusters. Through complexity analyses and simulations, we conclude that with remaining the same message and time complexities, $O(N)$, to the compared ID-based and Degree-based algorithms, the proposed BFCM algorithm combining with a generalized weighting function is effective in minimizing the orphan clusters generated by the boundary nodes and reducing the total number of generated clusters not only in the averaged sense but also in the strict sense.

七. 成果與自評

Allocations of physical transmission rate, sub-carrier, and power in MC-CDMA systems are proposed to minimize total uplink power consumptions for users of different data rate and bit-error-rate (BER) requirements with the receiver using linear minimum-mean-square-error (LMMSE) multi-user detection (MUD). Based on Multi-Code (MC) and Variable-Spreading-Length (VSL) strategies for multi-rate transmissions, we derive propose an admission control criterion, which is simple in implementation, for users of individual quality-of-service (QoS) demands. It can be used to not only determine the supportable transmission rates of the system but also decide the entrance admission of new data streams other than new users. It helps to exploit the system capacity for multimedia traffics. An iterative power allocation algorithm is proposed based on supportable transmission rates to allocate the sub-carrier power of each user and jointly allocate sub-carrier for each user.

八. 附圖與模擬結果

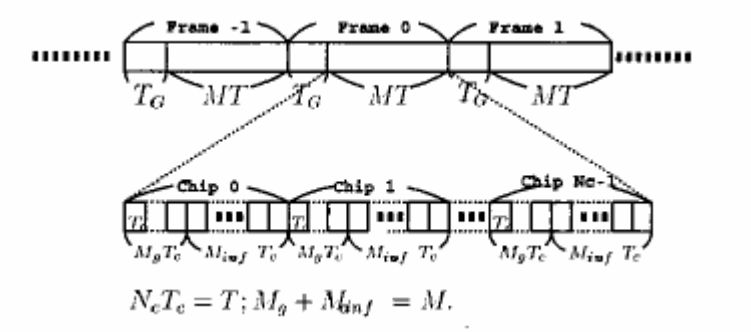


Fig. 1. Frame structure of frequency-domain orthogonal multiuser communication systems.

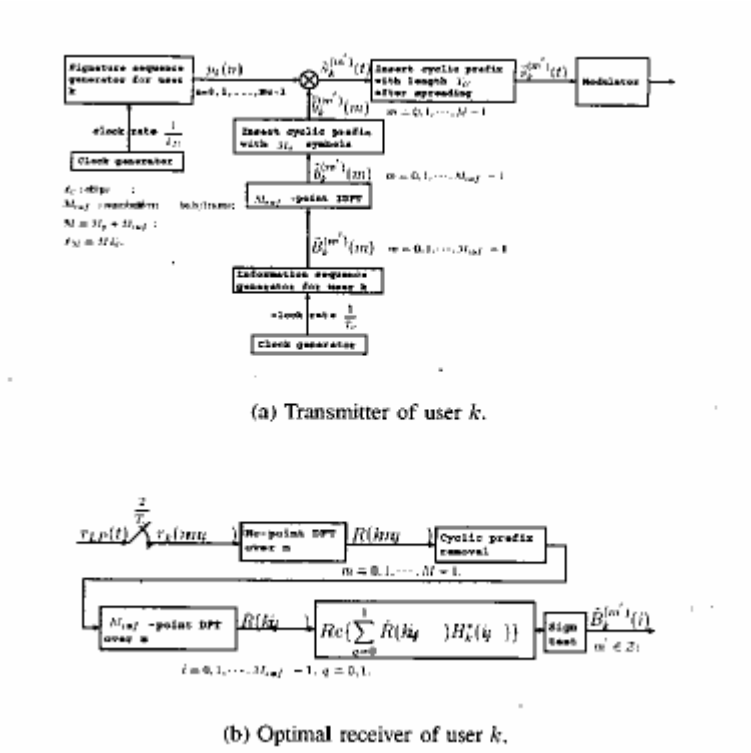
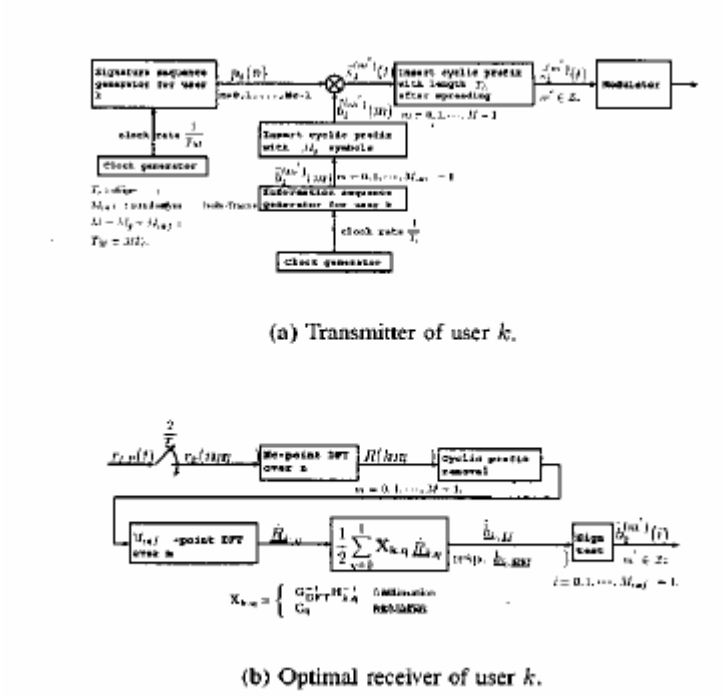


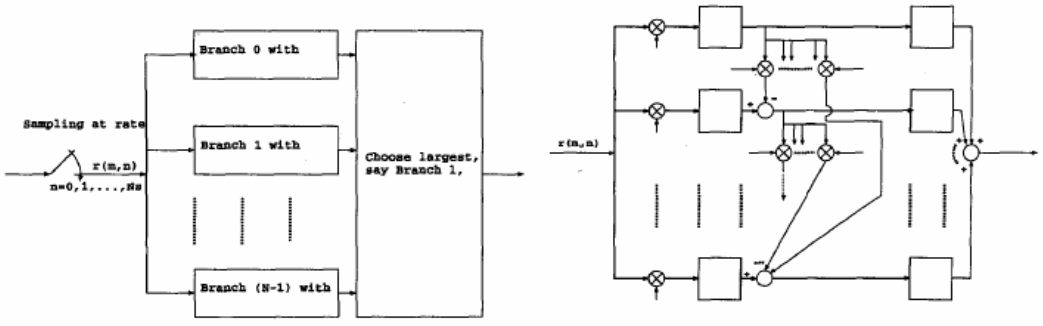
Fig. 2 Transceiver of frequency-domain orthogonal multiuser communication systems with inverse transformation for user k



(a) Transmitter of user k.

(b) Optimal receiver of user k.

Fig. 3. Transceiver of frequency-domain orthogonal multiuser communication systems with direct spreading for user k



(a) Overall block diagram

(b) Branch l with $\tau = lT/N$. ($\kappa_l \equiv \frac{\sigma_l^2}{\sigma_N^2+\sigma_l^2\hat{C}_l^2}$; $\xi_{l,\alpha} \equiv \hat{R}^*(l,\alpha)\kappa_\alpha$)

Fig. 4. Optimal timing estimation with unknown channel information over frequency-selective slowly fading channel

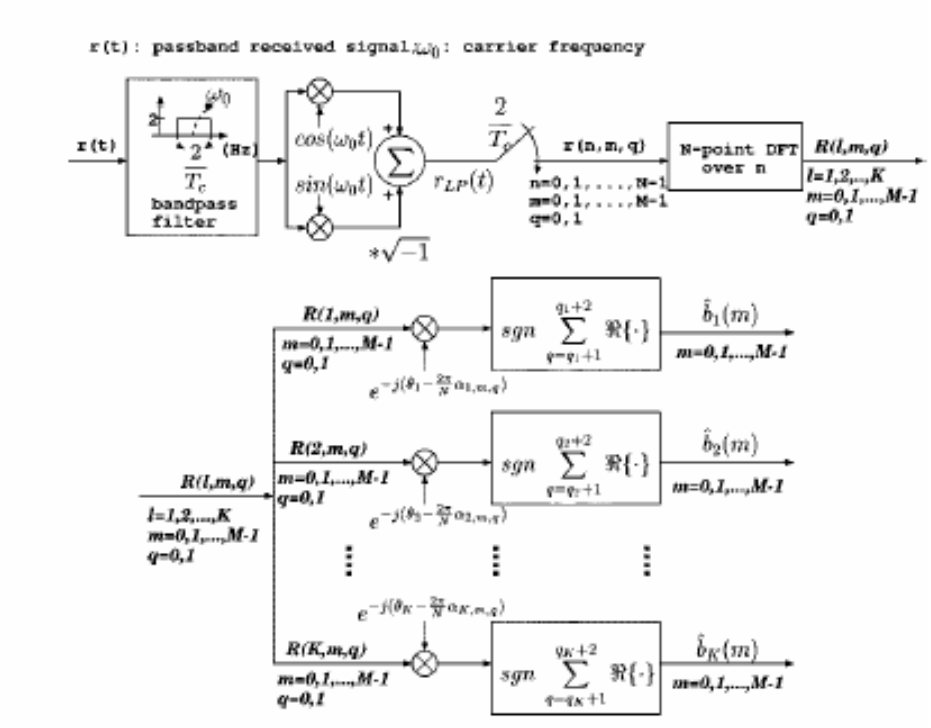


Fig. 5. Block diagram of our proposed linear-complexity multiuser detector

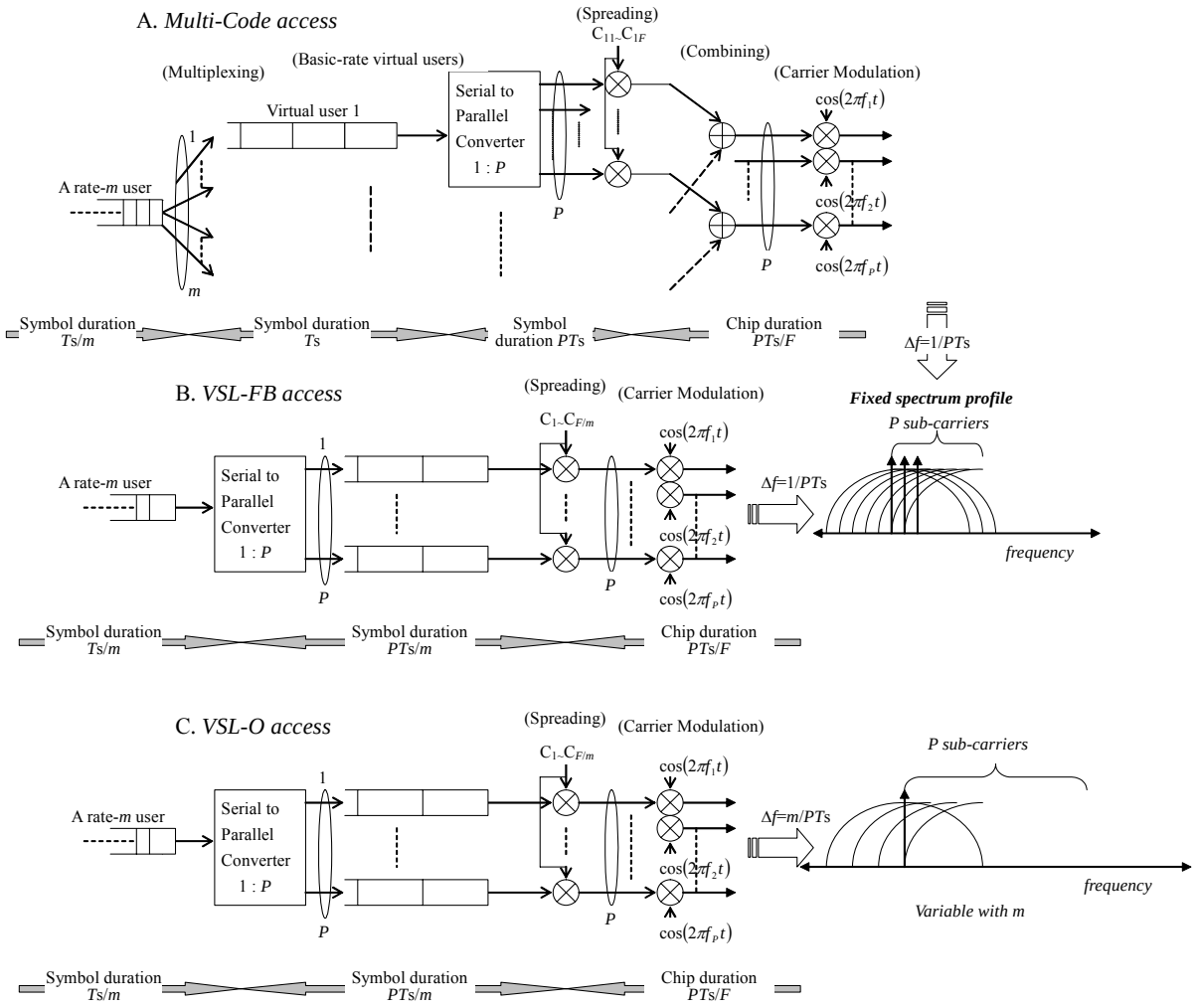


Fig. 6. Three multi-rate MT-CDMA transmission schemes

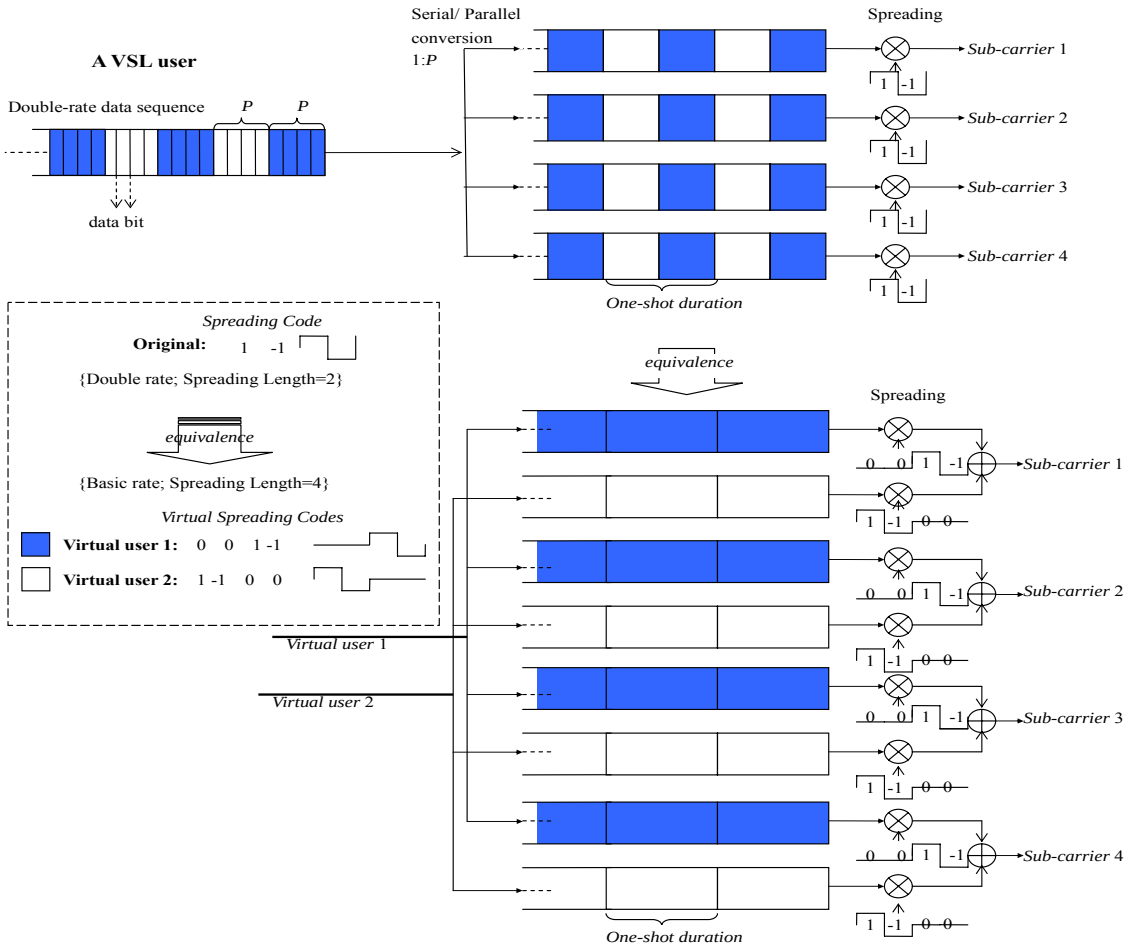
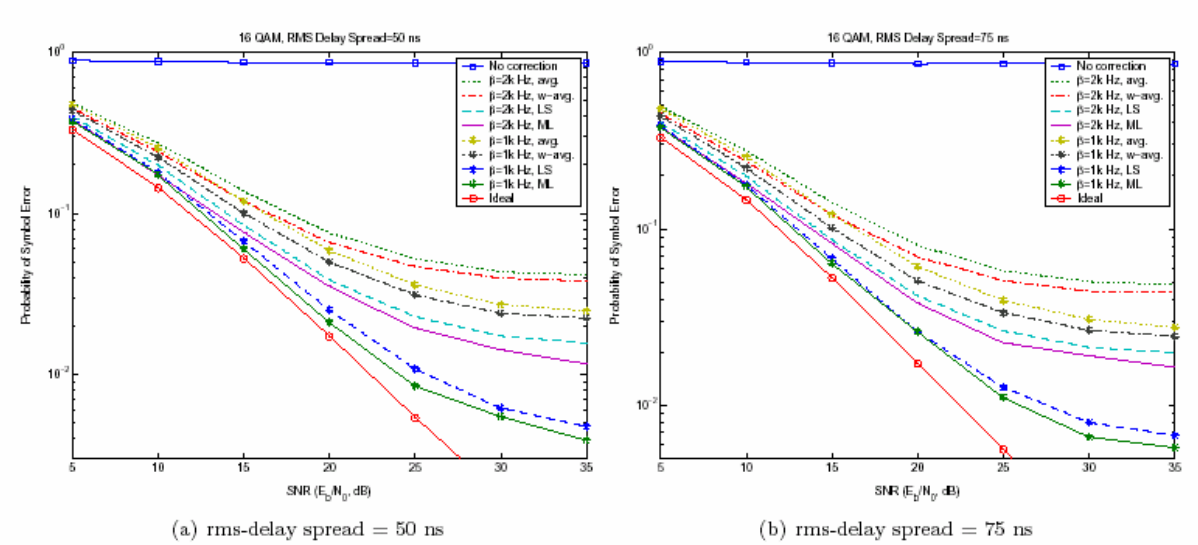
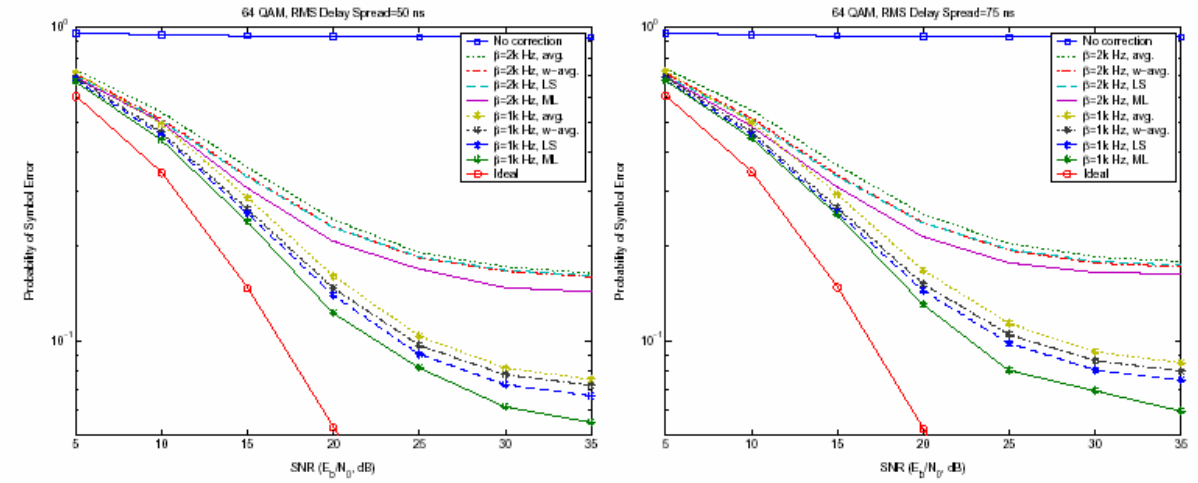


Fig. 7. Virtual users in VSL-FB and VSL-O schemes of MT-CDMA. This is an example of a double-rate user with spreading codes 1 -1; Serial-to-parallel conversion ratio P= 4. The colored bits belong to the virtual user 1 and white bits belong to the virtual user 2.



(a) rms-delay spread = 50 ns (b) rms-delay spread = 75 ns

Fig. 8. SER Performance of the CPE correction schemes with 16 QAM



(a) rms-delay spread = 50 ns (b) rms-delay spread = 75 ns

Fig. 9. SER Performance of the CPE correction schemes with 64 QAM

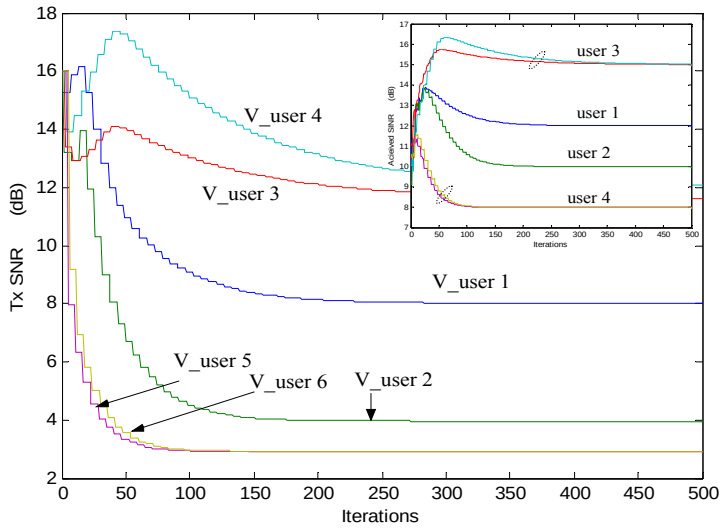


Fig. 10. The power update of user 1 (Virtual user 1), user 2 (Virtual user 2), user 3 (Virtual user 3 & 4), and user 4 (Virtual user 5 & 6) to achieve received SINR targets of 12 dB, 10 dB, 14 dB, and 8 dB respectively in MC-CDMA.

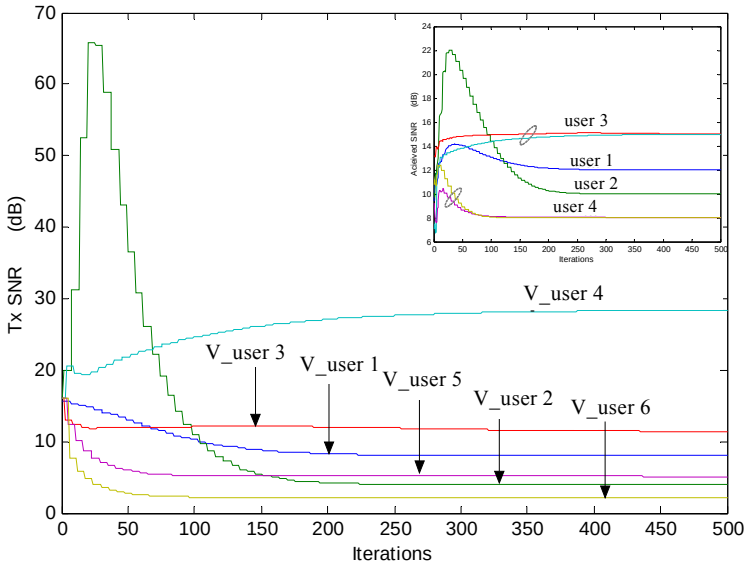


Fig. 11. The power update of user 1 (Virtual user 1), user 2 (Virtual user 2), user 3 (Virtual user 3 & 4), and user 4 (Virtual user 5 & 6) to achieve received SINR targets of 12 dB, 10 dB, 14 dB, and 8 dB respectively in VSL MC-CDMA.

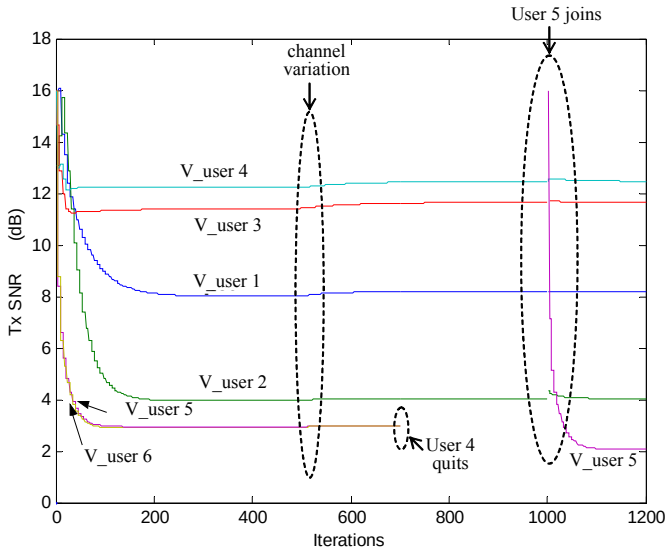


Fig. 12. Transmit power adjustments of MC MC-CDMA. V_user 3 and V_user 4 are the virtual users from user 3; V_user 4 and V_user 5 are the virtual users from user 4. The virtual user from the new user 5 is numbered as '5' after the quit of user 4.

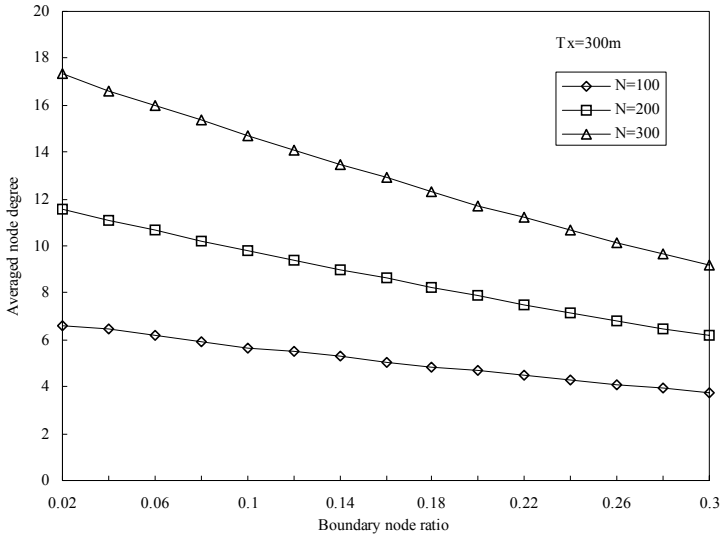


Fig. 13. The averaged node degree of the generated network.

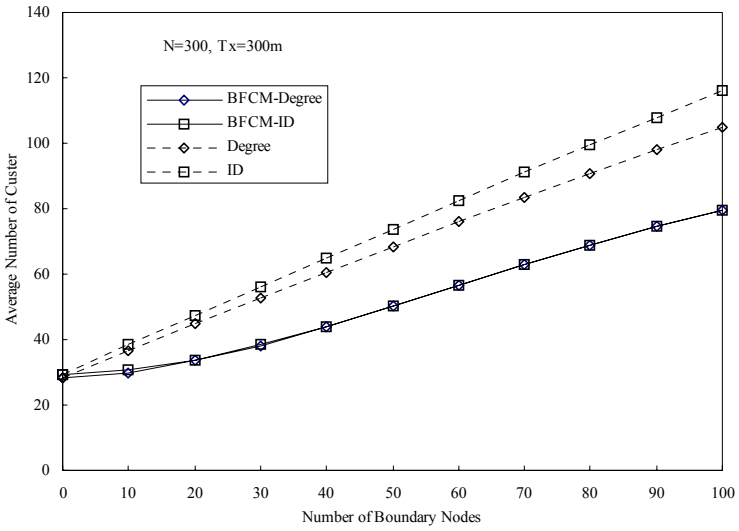


Fig. 14. Comparison average of number of clusters.

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附錄一

可供推廣之研發成果資料表

□ 可申請專利　☑ 可技術移轉　日期：94 年 9 月 21 日

國科會補助計畫	計畫名稱：後三代行動通訊處理器設計 計畫主持人：陳光禎 教授 計畫編號：NSC 93－2213－E－002－018－ 學門領域：無線通信
技術/創作名稱	Rate, Sub-carrier, Power Allocations of MC-CDMA with LMMSE Multiuser Detection 採用線性最小均方差多用戶偵測之多載波分碼多工系統的速率、子載波及功率分配
發明人/創作人	Po-Wei Fu (傅柏偉); Kwang-Cheng Chen(陳光禎)
技術說明	中文：我們針對多載波分碼多工系統提出其實體傳送速率、子載波、以及功率的分配技術，在滿足各傳送用戶的速率及品質的要求下，使得用戶上傳功率的消耗能達到最小化的程度，而此接收器是採用適合上鏈連結接收的 LMMSE 多用戶偵測技術。以多碼(Multi-Code)及長度可變碼(Variable-Spreading-Length)於多載波分碼多工系統上實現多速率傳輸，我們提出一套對於不同品質需求用戶的許可控制法，此一方法可以很簡單的在系統中實現，不僅僅是可以快速的決定系統是否可再容許新的用戶進入，更可以決定各用戶是否容許再同時傳遞新的資料流。此控制法則對於系統容量的有效利用相當有幫助。針對已決定之各用戶傳送速率，我們提出一套疊代式的分配演算法，可以針對各用戶同時完成子載波的選擇以及功率的分配。 英文：Allocations of physical transmission rate, sub-carrier, and power in MC-CDMA systems are proposed to minimize total uplink power consumptions for users of different data rate and bit-error-rate (BER) requirements with the receiver using linear minimum-mean-square-error (LMMSE) MUD. Based on Multi-Code (MC) and Variable-Spreading-Length (VSL) strategies for multi-rate transmissions, we derive propose an admission control criterion, which is simple in implementation, for users of individual quality-of-service (QoS) demands. It can be used to not only determine the supportable transmission rates of the system but also decide the entrance admission of new data streams other than new users. It helps to exploit the system capacity for multimedia traffics. An iterative power allocation algorithm is proposed based on supportable transmission rates to allocate the sub-carrier power of each user and jointly allocate sub-carrier for each user.

可利用之產業 及 可開發之產品	行動通訊產業 手機，基地台，個人無線行動終端接收設備
技術特點	採用多用戶偵測接收技術 支援多速率資料傳輸 支援多媒體差異化品質傳送應用 最小化終端設備功率消耗 低複雜度用戶傳輸許可 低複雜度資料流許可控管 疊代型子載波選擇及功率分配演算法
推廣及運用的價值	無線多媒體通訊將成為未來行動通訊的主流型態，在通訊系統中所傳遞的是各類具有不同品質需求及頻寬要求的資料訊息。而其關鍵在於高效能的多速率傳輸技術以及高效率的系統資源利用，而本技術藉著目前相當被看好，適用於第四代行動通訊系統的Multi-Carrier CDMA 技術，利用多速率傳輸技術以及多用戶偵測法來有效的實現高效能多速率傳輸，適用於需要低耗能的用戶端設備的上鏈傳輸。並針對各媒體特性來對系統的無線資源做最佳化分配，可有效提升資源使用效率及系統用戶容量，尤其是可使得移動式終端設備的功率消耗達到最小化的目標。

※ 1. 每項研發成果請填寫一式二份，一份隨成果報告送繳本會，一份送　貴單位研發成果推廣單位（如技術移轉中心）。

※ **2. 本項研發成果若尚未申請專利，請勿揭露可申請專利之主要內容。**

※ 3. 本表若不敷使用，請自行影印使用。

附錄二

行政院國家科學委員會補助國內專家學者出席國際學術會議報告

94 年 9 月 21 日

報告人姓名	陳光禎	**服務機構**及職稱	國立臺灣大學電機工程系暨電信工程研究所教授
時間 會議地點	94.05.16 – 94.05.19 韓國首爾(Seoul)	本會核定補助文號	NSC 93-2213-E-002-018
會議名稱	(中文)2005 年國際通訊研討會 (英文)IEEE International Conference on Communications 2005 (ICC 2005)		
發表演講題目	(中文) 無線寬頻通訊 (英文) Wireless Broadband Communications		

一、參加會議經過

國際通訊研討會(International Conference on Communications, 簡稱 ICC)從 1965 年起，一般在 5 月或 6 月舉行，以技術和專業活動完整整合熱門話題的所有範圍由聲音、資料、圖像、服務質量(QoS)，家庭網路，信號處理，無線，光學和多媒體通信。

ICC 2005 年探討的範圍有: 通信品質和可靠性(Communications Quality and Reliability)、通信軟體(Communications Software)、通信交換和路由(Communications Switching & Routing)、通信系統整合和模組化(Communications Systems Integration & Modeling)、通信理論(Communication Theory)、電腦通信(Computer Communications)、企業聯網技術(Enterprise Networking)、高速率網路(Gigabit Networking)、資訊基礎設施(Information Infrastructure)、相容於高速數位系統(Interconnections in High-Speed Digital Systems)、網際網路(Internet)、多媒體通信(Multimedia Communications)、網路操作和管理(Network Operations and Management)、光學網路(Optical Networking)、個人通信(Personal Communications)、無線電通訊(Radio Communications)、衛星和太空通訊(Satellite and Space Communications)、信號處理和通信電子(Signal Processing and Communications Electronics)、信號處理之存貯(Signal Processing for Storage)、戰術通信(Tactical Communications)、傳輸、存取和光學系統(Transmission, Access and Optical Systems)。

此次研討會於第一天及最後一天為教學性之演講，本人則為第一天第一場之演講教授。這一次的教學性演講包含三種無線寬頻網路連結的場合：個人無線網路、區域無線網路、都市無線網路。與其分開討論，普遍的 OFDM 與網路連結技術將是研究探討的主題。在不久的將來，電腦、PDA、網路儀器、手機，消費科技物品都必須成為多功能無線通訊系統的架構(或許可視為一種可程式化的彈性系統架構)。不只深入探討這三種技術，我們還會從技術普遍層面集中網路連結的應用，這將是無線通訊和網路技術的基礎，而這也是想要研究的主要方向。

二、與會心得

此次會議是在韓國的首爾，也就是漢城，是 ICC Globecom 會議第一次在亞洲舉行。

漢城是韓國和政治、文化、商業的首都和金融中心，漢城也是一座有歷史意義的城市。有機會能到漢城觀察一下韓國這個亞洲目前發展相當迅速的國家，由衷希望我們台灣可以保持領先並超過他們的程度。

目前電信的主要的兩個趨勢為：‘convergence’和‘seamless provision’。為了反映出這兩個趨勢， ICC 2005 把主題訂為“到無所不在的網路的時代”。在這個主題下，ICC 2005 與從全世界前來的主要技術專家討論可能的趨勢。同時有影響力的商業人士也被吸引到 ICC 2005 與從全世界前來的參加者交換心得。

本次會議中有與實際應用結合的商業應用討論，主題如下:

- “Broadband Access and Metropolitan Networks: The Wired Infrastructure”
- “Broadband Access Networks II: Wireless Access Alternatives”
- “3G and Wi-Fi: Competitors or Cooperators?”
- “Broadband Wireless Services & Applications”
- “Convergence of Broadcasting & Telecommunication”
- “Trends and Challenges in the Mobile Communications Industry”
- “Standards - An Enabler for the Communications Industry”
- “Internet Technologies for Communication”
- “Home Electronics and Networks”
- “New Network Paradigms: Sensor and Ad-Hoc Networks”
- “Current Trends and Reform Activities in Radio Frequency Spectrum Management”

將學術與產業技術結合，是一件很重要的事情。也是一件需要被重視的事情。

我們應該更積極參與會議的籌辦工作，特別是國際級的會議, 如此可以加強與國際學者合作交流的機會，這樣不但能幫助論文的發表，也能發揮我們在世界學術舞台上的影響力。

三、考察參觀活動(無是項活動者省略)

無

四、建議

五、攜回資料名稱及內容

大會會議Proceeding CD

六、其他