

Novel Techniques Improving Downlink Capacity for Cellular Systems of B3G

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Abstract—In future public mobile access with high data rate, one of main challenges we are facing is its spectral efficiency. In this paper, we will focus on the following new spectral efficient downlink multiple access techniques which may be essential parts of China's beyond 3G (B3G) system development: adaptive multi-input and multi-output (MIMO) technique in distributed wireless communication system and interleaver pattern division multi-access.

Index Terms—distributed wireless communication system, MIMO, DWCS

I. INTRODUCTION

One of the most important features of future public mobile communications is to support much larger system capacity and much higher service data rate in large area coverage and high mobility environments. That is to say, we should consider not only the increase of user capacity, but also the increase of peak data rate per user and the total system throughput. Since the radio spectrum is very limited, spectral efficiency becomes one of the most important issues in future mobile communications.

In recent years, many techniques have been proposed to increase spectral efficiency. The most popular ones are:

Multiple carrier techniques and orthogonal frequency division multiplexing (OFDM) techniques, which are used to solve the problem of severe self-interference due to multi-path channel;

Multi-input-multi-output (MIMO) techniques, which are used to provide space multiplexing and improve point-to-point link capacity.

Therefore, the peak data rate and spectral efficiency for single user link can be improved greatly by the combination of OFDM and MIMO.

However, the problem of interference among multiple cells in cellular environments is still unsolved. In order to apply the advanced techniques of OFDM and MIMO in cellular systems, new techniques mitigating these interferences should be found.

An OFDM based transmission system may provide very high peak data rate for single user. If multiple cells are considered, the OFDM system could be interfered by similar OFDM signals

from other cells, which may degrade performance greatly. Therefore, a big frequency reuse factor is normally selected to ensure high peak data rate per user. The system capacity may be very limited.

The basic idea to solve this problem, this paper proposed an approach to avoid mutual interference, or to reduce the intensity of interference. In order to reduce the intensity of mutual interference, adaptive MIMO in distributed wireless communication system (DWCS [1]) is proposed in this paper to achieve dynamic resource allocation and management, making full use of the capability of joint signal processing provided by DWCS architecture. Besides, grouped DWCS (G-DWCS) is also proposed to construct effective MIMO channel in large coverage area, ensuring high peak data rate per user.

II. DWCS AND ADAPTIVE MIMO

As mentioned in the introduction of this paper, in order to achieve high capacity (both on throughput and user number) in multi-user and multi-cell environment, we should first try our best to avoid interference between cells. However, the interference from other cells in traditional cellular structure can not be easily controlled, especially when the cell size gets smaller and smaller.

The newly introduced concept of distributed wireless communication system (DWCS) [1] provides the capability of joint control of the signals at multiple cells. Table 1 gives a summary on the main difference of DWCS from traditional cellular systems.

In DWCS, there are only RF modules and antennas at each access point (AP). The function of base band signal processing is moved from access point to processing units (PU). All the processing units construct a distributed processing network to process the signal to and from all access points jointly. Therefore it is possible for DWCS to monitor the interference and control it carefully to minimize mutual interference among users and cells.

A. Scattered DWCS and Grouped DWCS

There are two basic models of DWCS, which are called scattered DWCS (S-DWCS) and grouped DWCS (G-DWCS), respectively. For S-DWCS, we assume there will be only one antenna at each access point, in which case all the access antennas are scattered as evenly as possible. S-DWCS can achieve very large user capacity and total throughput [2].

However, when there are multiple antennas mounted on the mobile terminal, the peak data rate may suffer from the reduction of effective number of antennas at access points, which can be described as following.

In DWCS, the distance from a certain mobile terminal (MT) to its adjacent access points can be quite different, i.e., it may often be very near to an access point, and far away from others. This is also a kind of near-far effect (different from the well known uplink near-far effect in CDMA systems, the difference can be illustrated in Fig.1. In this case, only the dominant access point may be used, therefore the peak throughput for this user in S-DWCS will be limited to a single antenna system, even though the mobile terminal (MT) may have multiple antennas.

In order to provide much higher peak data rate, effective MIMO environment should be constructed. This results in the second DWCS model, in which multiple antennas are grouped at each access point, so that we may get MIMO channel and provide high peak data rate per user everywhere. We call this model with multiple antennas at each access point as grouped DWCS (G-DWCS).

B. Downlink in DWCS

The environment of uplink and downlink in DWCS is quite different. Comparatively speaking, the downlink in DWCS may be more challenging. Improper use of the antennas in downlink may result in waste of transmission power, increase of interference, loss of peak throughput and system capacity, or even system breakdown. So we will focus our discussion on interference avoiding in the downlink of DWCS.

In order to achieve adaptive MIMO properly, we'd better first find the difference between MIMO in DWCS and normal point-to-point MIMO, which are listed below.

- The downlink of G-DWCS is often a MIMO system with more transmitter antennas than receiving antennas (there are very few antennas at mobile terminal). Therefore we have to select some of the access point antennas carefully to achieve best transmission.
- The antennas of normal MIMO systems are located at same site, which may introduce channel correlation causing severe capacity loss, especially when LOS propagation exists. This loss can be mitigated in DWCS, since we can select antennas from different access points for given user's transmission.
- The distances from all transmission antennas to the mobile are the same in normal MIMO, but might be quite different in DWCS, since the transmission antennas may belong to several access points.
- Unlike normal MIMO system, DWCS is actually a multi-point-to-multi-point system. When multiple MTs have their virtual cell's overlapping, i.e., an access point may serve more than one users, the set of transmitting antennas for each MT should be carefully selected to minimize mutual interference.

All the above mentioned differences convince us that adaptive MIMO will play a much more important role in

DWCS than in normal MIMO systems. In order to achieve the optimized adaptation, the processors in DWCS should have full or part of the following knowledge:

- Number of antennas in each MT and access point
- The set of access points in each MT's virtual cell
- The channel correlation of antennas in each access point and MT
- The location of MT in its virtual cell (relative path loss and shadowing loss)
- The location of other MTs in the overlapping virtual cells
- Transmission data rate requirement for each MT.
- Instantaneous channel condition from each access point antenna to each MT(optional)

Fig. 2 illustrates part of above effects more clearly.

According to the knowledge of above mentioned parameters, the processing units may make the decision of the way of joint transmission including the following operation:

- Transmission antenna set selection for each MT
- Current transmission data rate selection
- Power allocation among the antennas
- Coding rate and modulation scheme for each stream (antenna)
- Beam forming parameter calculating (if possible)

III. SIMPLE EXAMPLE

Here a simple example is given to illustrate the benefit of adaptation in G-DWCS. In this example, we consider a very simple model with only one MT and two access points (1km apart), each has 4 antennas. We try to show how the downlink transmission antenna selection is adapted to the environment when the MT moves from one access point to the other. A simple selection criterion is put forward based on upper bound evaluation of average capacity [3].

Fig.3 shows the mean capacity of the downlink at different locations (labeled as the distance to one access point), with the correlation between transmission antennas at each access point as a parameter. The dashed lines show the results of fixed antenna selection scheme using nearest 4 antennas for transmission, which represents the condition of traditional cellular system with multiple antennas at base station. It is very clear that, when the antennas at each access point are strongly correlated, the degradation of adaptive transmission antenna selection is much less than that of fixed antenna selection, especially when the MT is in the middle of 2 access points. We can find how the number of antennas selected from each access point changes with different MT location in Fig.4.

Of course, for a practical system, one may consider more about the above mentioned optimization, there are still many remaining problems to be solved. So this is an open area for further research.

IV. UNITS

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V. CONCLUSIONS

Spectral efficiency is one of the most important issues in B3G techniques. The currently proposed techniques such as OFDM and MIMO are spectral efficient in single user case. However, there is a gap from these techniques to the need of high spectral efficiency in multi-user and multi-cell environment.

In this paper, some concepts and techniques are proposed to fill in this gap.

First, we introduce dynamic coding division multiplexing technique to approach maximum throughput within each cell, especially for downlink.

Then, the system optimization concerning multiple cells is studied. Adaptive MIMO in G-DWCS is proposed at first to avoid severe interference from adjacent cells while remaining high throughput and peak data rate per user. And, the technique of interleaving pattern division multiple access is proposed to minimize the influence of inter-cell interference. Actually, IDMA has made full use of interference and provided maximum multi-user capacity in multi-cell.

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Table 1:

	Traditional cellular	DWCS
Basic access components	Base station	Access points(AP), processing units
RF and antenna location	Base station	Access points
Base band signal processing location	Base station	Processing units
Data flow between basic components	Service and signaling data only	Base band signal, service and signal data
Up link	User signal from mobile terminals (MTs) in a cell is processed alone in its corresponding Base station	To retrieve user data from signals received by all antennas within the MT's reach
Down link	The radio signal to all the users in a cell is prepared and transmitted by its corresponding Base station	All the AP antennas within the reach of given MT can serve it for transmission, the resource allocation is done by the processing units
Action on adjacent cell radio signal	Regarded as interference	Can be jointly processed
Co-processing among antennas at different location	None	Yes
Co-processing among signal processors	None	Yes

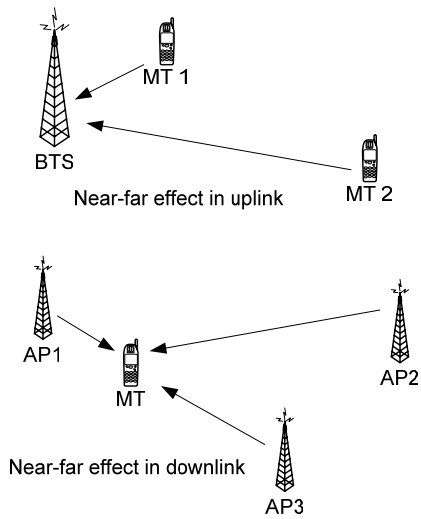


Fig.1. Difference between uplink and downlink near far effect

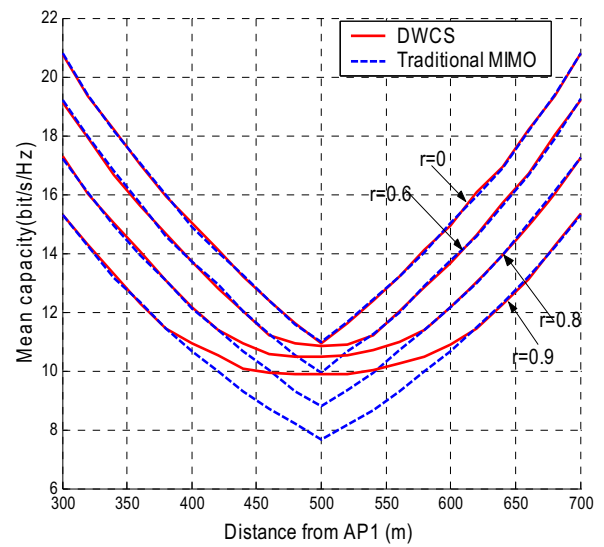


Fig.3 Mean capacity at different locations

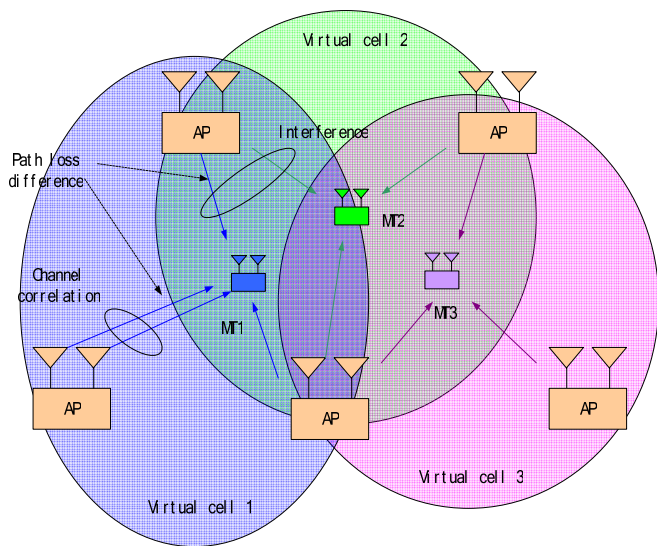


Fig.2. Considerations of adaptive MIMO in DWCS

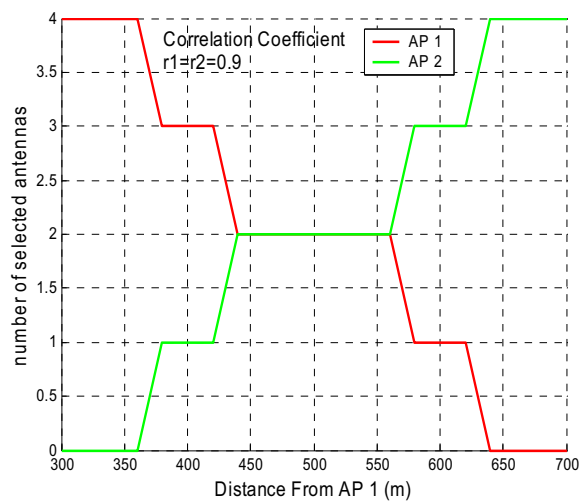


Fig.4 Number of used antennas