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System Optimization from Field Channel Measurement and Performance Evaluation on FuTURE B3G TDD System

Jianhua ZHANG, Guangyi LIU, Weidong Wang
Beijing University of Posts&Telecoms, Research Institute of China Mobile
Email：jhzhang@bupt.edu.cn, lgy@buptnet.edu.cn

***Abstract*-FuTURE B3G TDD is designed to provide 100Mbps peak data rate in both uplink and downlink. In this paper, the MIMO channel measurement campaign carried out in BUPT campus is briefly itroduced. Based on the results from the field channel measurement, the radio transmission prameters of physical layer is optimizaed, and the downlink performance of FuTURE B3G TDD is evaluated in system level with soft frequency reuse and spatial-temperoral-frequency scheduling for multiuser zero forcing beamforming, which is designed to explore the multiuser diversity gain at both spatial and frequency domain. As the channel reciprocity can be obtained in TDD system, the Channel State Information (CSI) can be exploited at the transmitter to obtain the spatial-frequency multiuser diversity by joint spatial-frequency subcarrier and antenna assignment of MIMO OFDMA for the independent fading of different user in spatial and frequency domain. With the optimised radio transmission parameters, the peak data rate and system throughput can be improved 12.7%. The downlink system throughput in multi-cell scenario can achieve about 30Mbps with 4×2 MIMO in 10MHz bandwidth.**

I. INTRODUCTION

As fast increasing of data rate required by the mobile services, 2Mbps is not enough any more for 3G systems in several years. Comparing with WLAN and WiMax, which can provide 54Mbps and 75Mbps peak data rate in 20MHz bandwidth, the peak data rate of 3G is not attractive. To be competitive, 3G systems must be enhanced and evolved. Besides the HSDPA, HSUPA, B3G is also researched worldwidely. Different research programs, such as Future Technologies for Universal Radio Environment (FuTURE) [1], MIRAI [2] and Mobile Virtual Centre Excellence program (VCE) have their own visions on B3G features and implementations. The main characteristics of B3G is higher data rate and frequency efficiency, an extremely flexible air-interface framework which can fully take advantages of the possible radio resource, lower system latency and service delay, higher quality for service, etc.

In China, FuTURE is being supported by national 863 high-tech program since 2002 [1], which includes TDD and FDD mode, both of which are investigating and demonstrating advanced techniques for systems B3G to meet the application requirements around 2010. The basic radio access network architecture is as Fig 1. A possible system structure for B3G TDD, including AP and Mobile Terminals (MT), is plotted in Fig.1. Obviously as the increase of carrier frequency, the cell size will decrease. Considering this tendency, the radio signal of one subscriber is transmitted and received by several antenna arrays, which are connected to one AP in B3G TDD system. By this way the Multiple Input and Multiple Output (MIMO) are formed easily and the radio transmission design is given in section II. In Fig.1, the distributed antenna arrays are connected to their corresponding AP by means of coaxial line or optical fiber. There is two possible ways for Access Point (AP) connected to IP network. One is that APs are directly linked to network and by this way, control and bearer are separated. So the user data will not pass control domain (CD) and there is only high layer signalling transferred between AP and CD. Another is classical layered structure and AP access network by CD (dotted line in Fig.1). In B3G TDD the former type is more preferred.

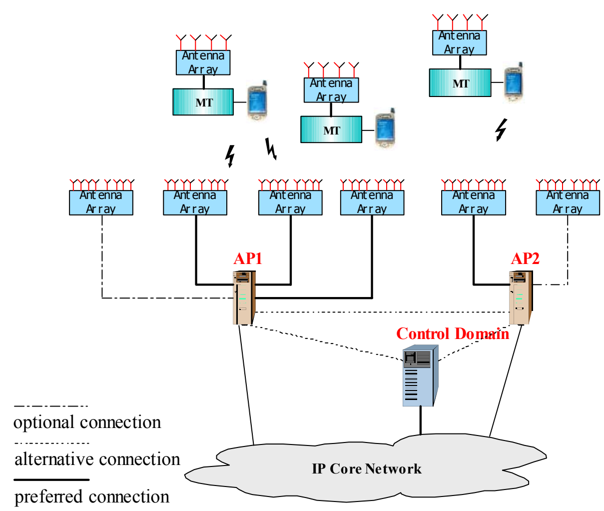

Fig.1 System structure of B3G TDD

In this paper, based on the field channel measurement results from Beijing in china, the system parameters of FuTURE B3G TDD are optimized to improve the system performance and spectrum efficiency. The organization of this paper is as following. The system is overviewed in section II, the channel measurement results related is presented in section III, and the parameters of the radio transmission is optimized in section IV, and the system performance is evaluated in section V, and the conclusion is drawn in section VI.

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II. SYSTEM OVERVIEW OF FUTURE B3G TDD

FuTURE B3G TDD system is a MIMO OFDM based system. OFDM could be easily combined with different multiple access scheme, including Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA) and Spatial Division Multiple Access (SDMA). In order to support multi-rate services and to achieve a frequency reuse factor of one, different combination schemes have been thoroughly researched [4]. In our system, OFDMA/TDMA/SDMA is supported to exploit the multiuser diversity gain in spatial-frequency domain by joint spatial-frequency scheduling.

The frame structure is as Fig 2. The duration of a radio frame is 5ms, and the guard time between uplink and downlink is 106us. There are two types of Time Slot (TS), short and long TS separately. The unequal length of the time slots for downlink and uplink can not only decrease the cost for guard time, but also guarantee the flexibility of resources allocation. TS0 is designed for the downlink dedicated signaling including the system information, paging, etc. The dedicated slots (TS1) is defined for both uplink and downlink synchronization. TS2 to TS7 are designed for data transmission.

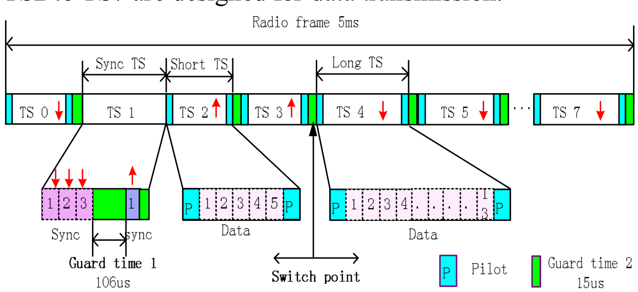


Fig. 2 Frame structure for B3G TDD

Table 1 System parameters

Parameters	Value
Carrier Frequency	3.5GHZ
Bandwidth	20MHz
IFFT/FFT Size	1024
Subcarrier spacing	19.5KHz
Occupied subcarrier	884
CP	216(10.8us)
OFDM symbol length	62
Modulation	QPSK/16QAM/64QAM
Channel coding	Turbo
Antenna Number	2×4/4×8
Multiple Access scheme	OFDMA/TDMA/SDMA

III. CHANNEL MEAUREMENT RESULTS

The measurement system of MIMO channel is presented as Fig 3. The Vector Signal Generator (VSG) is composed of a Band-Pass-Filter (BPF) and a Digital to Analog (D/A). A PN sequence is produced as the source signal and be modulated on the desired carrier frequency. After the VSG, the source signal is amplified by AM (Amplifier) and transmitted on one antenna selected by the high speed antenna switcher. Vector Signal Analyzer (VSA) is composed of a BPF and an Anolog to Digital converter (A/D). At the receiver, the reverse processing is done to the received signal from all antennas. The PN sequence is utilized to abstract the Channel Impulse Response (CIR), and some super resolution algorithms (E.g. SAGE, MUSIC) are used to abstract the angle information, e.g. AOA,DOA, AS.

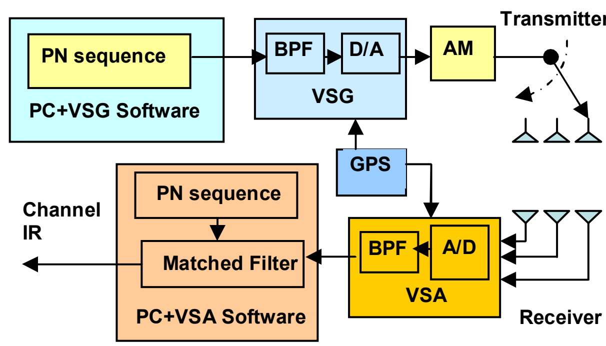
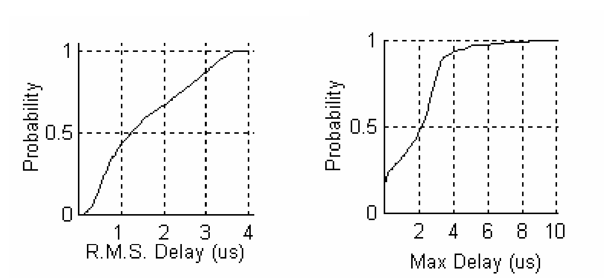
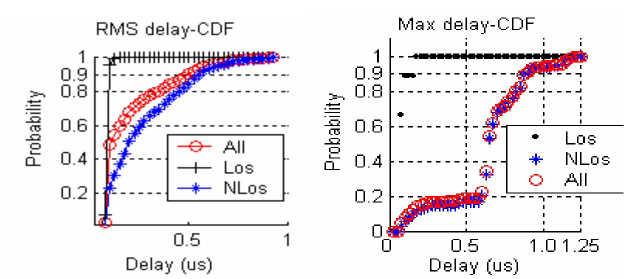


Fig 3. Methodology of MIMO channel measurement



(a) (b)

Fig 4. Delay distribution in outdoor scenario



(a) (b)

Fig 5. Delay distribution in indoor scenario

Based on the channel measurement campaign for 3.5GHz frequency carried out around the campus of Beijing University of posts & Telecoms (BUPT) [5], some results are presented in this section.

In the measurement result, the r.m.s delay and maximum delay [6] are selected to describe the characteristics of time spread of the channel. For outdoor scenario, as Fig 4, (a) is the distribution of the r.m.s delay, 99.9% of r.m.s is less than 3.6us, and 90% of r.m.s less than 3.2us; (b) is the distribution of the maximum delay for outdoor scenario. 95% of maximum delay is less than 5us.

For indoor scenario as Fig 5, LOS and NLOS cases are considered respectively. (a) is the distribution of the r.m.s, where 90% of average r.m.s is less than 0.575us; it is less than 0.075us for LOS channel, and less than 0.625us for NLOS. (b) is the distribution of the maximum delay for indoor scenario. 90% of average maximum delay is less than 1.05us; but the maximum delay for LOS channel is less than 0.175us, and less than 1.075us for NLOS channel. Since most of the measured channel is NLOS, the comprehensive results approach the NLOS scenario.

IV. SYSTEM PARAMETER OPTIMIZATION

According to the original frame structure, there are 7 OFDM symbols in every short timeslot, and 13 OFDM symbols in every long timeslot, and 4 OFDM symbols in the special synchronization timeslot without considering the guard period. There is total 77 OFDM symbols in a 5ms sub-frame. Since the pilot of the system is designed as TDM, every short timeslot has two OFDM symbols used as pilot, and every long timeslot has 3 OFDM symbols used as pilot, there is 55 OFDM symbols available for data and control information transmission, and 22 OFDM symbols are used for synchronization or pilot.

Based on the parameters above, the rough peak data rate of the system without considering the overhead of the control channel can be calculated as Table 2.

$$r = d_{stream} \times d_{OFDM} \times d_{subcarrier} \times M / T_{subframe} \quad (1)$$

Where $d_{stream} = 4$ is the number of the spatial data streams, $d_{OFDM} = 55$ is the number of the data OFDM symbols in a subframe, $d_{subcarrier} = 884$ is the subcarriers occupied for data transmission, M is the data bit carried on every modulation symbol, and $T_{subframe} = 5ms$ is the length of a sub-frame.

Table 2 Peak data rate of FuTURE B3G TDD system

Data rate	38.9Mbps	116.7Mbps	175Mbps
Modulation	QPSK,	16QAM	64QAM
Channel coding	Turbo	Turbo	Turbo
Coding rate	1/2	3/4	3/4
Antennas at AP	8	8	8
Antennas at MT	4	4	4

According to the r.m.s results from the measurement campaign, and compared to the CP length of the original design of FuTURE B3G TDD system, there has some potential to enhance the system design by reduce the overhead of the CP. Since the Maximum delay is less than 5us in 95 percentage, the CP can be reduced to about 5us. To guarantee the receiver performance of the large coverage, the CP of every OFDM symbol is re-designed as 108 samples. Without change the frame structure, and only adjust the length of every OFDM symbols, 7 extra OFDM symbols can be obtained by the CP adjustment. So every data time slot can have 1 OFDM symbol extra. Then the transmission efficiency of the system can be improved by $7/55 = 12.7\%$ .Peak data rate can be updated as Table 3.

Table 3 Peak data rate of the optimized FuTURE B3G TDD system

Data rate	43.89Mbps	131.5Mbps	197.3Mbps
Modulation	QPSK,	16QAM	64QAM
Channel coding	Turbo	Turbo	Turbo
Coding rate	1/2	3/4	3/4
Antennas at AP	8	8	8
Antennas at MT	4	4	4

V. PERFORMANCE EVALUATION OF THE OPTIMISED FUTURE B3G TDD

In this section, the system performance is evaluated in a multi-cell scenario with multiuser scheduling, and then the system performance is presented.

Based on multiuser zero forcing beamforming and joint spatial-temporal-frequency scheduling [8], a Soft Frequency Reuse (SFR) scheme [7] is adopted in the system evaluation.

1. Simulation parameters

The MIMO channel model is cited as the 3GPP SCM [10], but it is modified to suit for the much wider bandwidth 10MHz. Meanwhile, the Power Delay Profile (PDP) information is changed to be fixed. For the mobility of the user, only the angle information for the SCM channel is updated as need. The PDP model of Typical Urban (TU) is adopted in this paper.

Full buffer service is assumed in the simulation. The other system simulation parameters are as Table 4.

TABLE 4. SYSTEM PARAMETERS

Parameter		Assumption
Carrier Frequency		3.5GHz
Band width		10MHz
Occupied subcarrier		442
Inter-site distance		2Km
Distance-dependent path loss		L=133.3 + 37.6log10(.R)
Shadowing standard deviation		8 dB
Correlation distance of Shadowing		50 m
Shadowing correlation	Between cells	0.5
	Between sectors	1.0
Penetration Loss		20dB
Channel model		SCM
Total BS TX power (Ptotal)		43dBm
Minimum distance between UE and cell		>= 35 meters

The modulation and coding schemes adopted in the simulation is as Table 5:

TABLE 5 THE MCS AND THE ES/N0 THRESHOLD

MCS	Mod	Code Ratio	data bits	SNR threshold

1	QPSK	1/3	2/3	-2dB,0.5dB
2	QPSK	1/2	1	0.5dB,3.7dB
3	QPSK	3/4	3/2	3.7dB,6.3dB
4	16QAM	1/2	2	6.3dB,10dB
5	16QAM	3/4	3	10dB,15.2dB
6	64QAM	3/4	9/2	15.2dB

2. Simulation results

From Fig 6, the system throughput increases with the user number per cell since the multiuser diversity gain can be achieved by SFPF scheduling. The system throughput and spectrum efficiency converges to 30Mbps and 3bps/Hz with 4×2 MIMO respectively. The user data rate decreases as the user number increases since multiple users compete the same system radio resource.

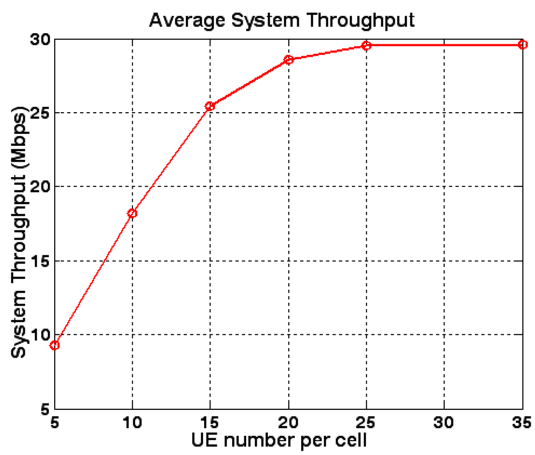


Fig 6 Cell throughput Vs. MT number per cell)

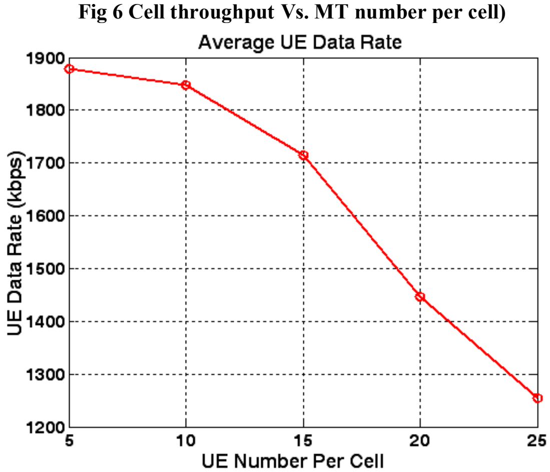


Fig 7 data rate distribution of the users

VI. Conclusion

In this paper, based on the results from the field channel measurement in Beijing, the radio transmission prameters of physical layer of FuTURE B3G TDD is optimizaed, and its downlink performance is evaluated with soft frequency resue in multi-cell scenario. Furthermore, a joint spatial and freqency scheduling is proposed to explore the multiuser diversity gain at both spatial and frequency domain. With the optimised radio transmission parameters, the peak data rate and system throughput can be improved 12.7%. With the proposed scheduler, the system throughput and spectrum efficiency in multi-cell scenario can achieve about 30Mbps and 3bps/Hz respectively with 4×2 MIMO and full buffer service.

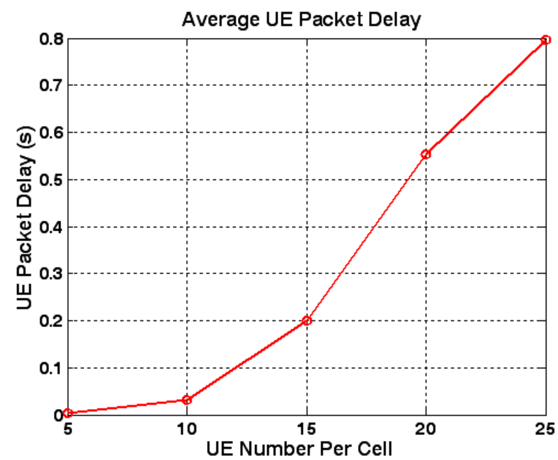


Fig 8 Packet delay Vs. MT number per cell

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