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

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***Abstract*-FuTURE B3G TDD is designed to provide 100Mbps peak data rate in both uplink and downlink. In this paper, 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. To provide a multi-cell coverage, a soft frequency reuse is adopt. Further, a joint spatial and freqency scheduling is proposed to explore the multiuser diversity gain at both spatial and frequency domain. As the channel reciprocity can be obtained in TDD system, the Channel Status 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.**

Key Words: B3G, MIMO, OFDMA, SFPF, SFR

I. INTRODUCTION

In China, Future Technologies for Universal Radio Environment (FuTURE) [1] 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.

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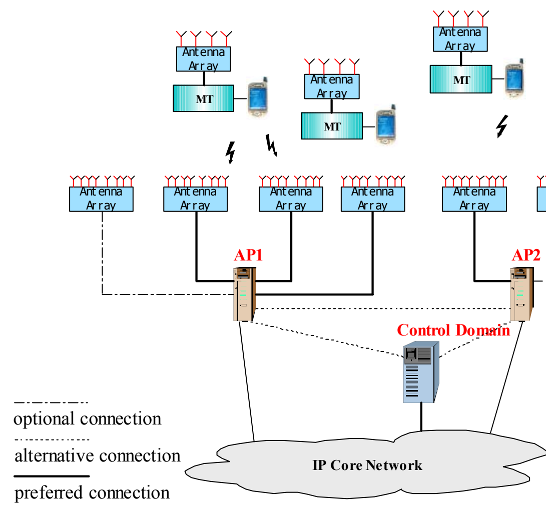


Fig.1 System structure of B3G TDD

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.

II. SYSTEM OVERVIEW OF FUTURE B3G TDD

FuTURE B3G TDD system is a MIMO OFDM based system., and OFDMA/TDMA/SDMA is supported to exploit the multiuser diversity gain in spatial-frequency domain by joint spatial-frequency scheduling. The frame structure of FuTURE B3G TDD is as Fig 2 [2].

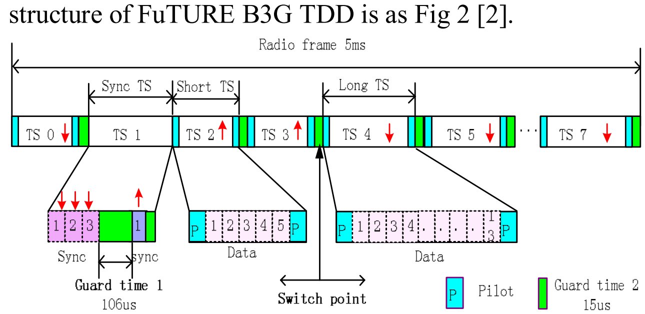


Fig. 2 Frame structure for B3G TDD

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
Channel coding	Turbo
Antenna Number	2×4/4×8
Multiple Access scheme	OFDMA/TDMA/SDMA

III. CHANNEL MEAUREMENT RESULTS

Based on the channel measurement campaign for 3.5GHz frequency carried out around the campus of Beijing University of posts & Telecoms (BUPT) [4], some results are presented as following.

In the measurement result, the r.m.s delay and maximum delay [5] are selected to describe the characteristics of time spread of the channel. For outdoor scenario, as Figure 3, (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 figure 4, 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.

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

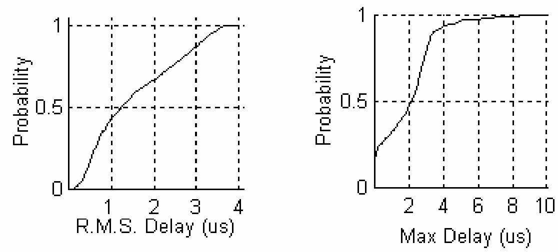
IV. SYSTEM PARAMETER OPTIMIZATION

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.

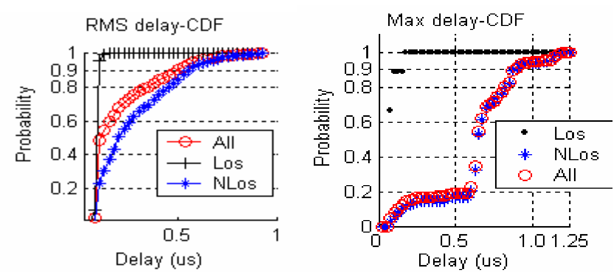
$$r = d_{stream} \times d_{OFDM} \times d_{subcarrier} \times M / T_{subframe} \quad (1)$$

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.



(a) (b)

Fig 3. Delay distribution in outdoor scenario



(a) (b)

Fig4. Delay distribution in indoor scenario

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

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.

V. PERFORMANCE OF OPTIMISED SYSTEM

The MIMO channel model is cited as the 3GPP SCM [9], 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 the channel from the filed trial is adopted in this paper. Full buffer service is assumed in the simulation.

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

Besides the Soft Frequency Reuse (SFR) scheme [6], a multiuser scheduling scheme is proposed. In multiuser MIMO OFDMA system, different users experience independent spatial and frequency selective fading, and thus the multiuser diversity can be exploited by multiuser scheduling [7]. In this paper, the frequency domain multiuser diversity of OFDMA and spatial multiuser diversity of MIMO are jointly considered and a joint spatial-frequency subcarrier and antenna allocation algorithm [8] is proposed to exploit the multiuser diversity in spatial-frequency domain. To guarantee the user fairness, the Spatial Frequency Proportional Fairness scheduling (SFPF) is proposed.

Assume the set of M_R selected receiving antennas from all the MTs is presented as C_n, the selected optimal antenna set can be obtained optimally as following:

$$C_n^{'} = \underset{C_n\in[1,M_T]}{\arg}\ \underset{U_n\in[1,K]}{\arg}\ \max \sum_{U_n} C(C_n, U_n) \quad (2)$$

Where $C(C_n, U_n)$ is the total capacity of the selected users and antennas. To find the optimal solution, all the possible sets are compared. It is too complicated to be implemented. The user and antenna assignment algorithm proposed above can approach the multiuser MIMO capacity without considering the user fairness. In a real system, a proper algorithm is to guarantee the user fairness which achieves the multiuser diversity gain as much as possible.

We propose a joint spatial and frequency proportional fairness scheduling as following:

$$\Pr_n^k(t) = \frac{R_n^k(t)}{T_k(t)} \quad (3)$$

Where R_n^k is the theoretical data rate on subcarrier n of user k , and T_k is the average transmission data rate of user k , and it is updated as equation (8).

$$R_n^k = B\log_2\left(\det\left(\mathbf{I} + \rho\left(\mathbf{H}_n^k\right)^H \mathbf{H}_n^k\right)\right) \quad (4)$$

Where B is the subcarrier spacing Here we assume that only one antenna at most can be assigned to one user on a subcarrier. Then on subcarrier n , group C_n with M_T users is selected as following:

$$\underset{C_n\in[1,K]}{\arg}\ \max \sum_{k\in C_n} \Pr_n^k(t) = \underset{C_n\in[1,K]}{\arg}\ \max \sum_{k\in C_n} \frac{R_n^k(t)}{T_k(t)} \quad (5)$$

M_T users with highest priority are selected to transmit in next timeslot.

For Zero Force Beamforming (ZFB), one antenna of every selected UE is chosen to maximize the total system capacity. Then the virtual MIMO channel matrix on subcarrier n between Node B and the selected antennas of the selected UE can be expressed as:

$$\mathbf{H} = \left[\mathbf{H}_n^{C_n(1)} \quad \ldots \quad \mathbf{H}_n^{C_n(i)} \quad \ldots \quad \mathbf{H}_n^{C_n(M_T)}\right] \quad (6)$$

Where $\mathbf{H}_n^{C_n(i)}$ is the selected channel of UE $C_n(i)$ on subcarrier n and $C_n(i)$ means the element i of C_n . Then equation (3) and (4) can be used to calculate the channel gain and the beamforming vector for Mu-ZFB.

The power allocated to different data streams is expressed as p_n^k , and $P_T = \sum_{n=1}^{N}\sum_{k\in C_n} p_n^k$. If the user k is not scheduled to share the subcarrier n , then $p_n^k = 0$. Based on $\mathbf{H}$, the data rate of the user $C_n(k)$ on subcarrier n can be calculated as:

$$R_n^{C_n(k)} = B\log_2\left(1 + SNR_n^{C_n(k)}\right) \quad (7)$$

Where B is the subcarrier spacing. In fact, in our simulation, the data rate of every data stream is decided by the selected Modulation and Coding Scheme (MCS) adopted in this work according to the Signal to Interference and Noise Ratio (SINR) on the data stream of every subcarrier. By configuring proper SINR threshold for the switching among the different MCS, the highest system throughput can be achieved with adaptive Modulation and coding (AMC).

The total data rate of user k in the next scheduling period is:

$$R_k = \sum_{n=1}^{N} R_n^k \quad (8)$$

Where N is the subcarrier number. T_k can be updated with R_k after the scheduling:

$$T_k = \begin{cases} (1-\alpha)T_k + \alpha R_k, \textit{if user k is served}. \\ (1-\alpha)T_k, \qquad\qquad\qquad \textit{else} \end{cases} \quad (9)$$

Where $0 < \alpha < 1$ is the forgetting factor.

Then with the $\mathbf{H}$ selected, the zero forcing beamforming is applied. The beamforming weight for every data stream is:

$$\mathbf{B} = (\mathbf{H})^{\dagger} \left(\mathbf{H}(\mathbf{H})^{\dagger}\right)^{-1} \mathbf{D} \quad (10)$$

Where $\mathbf{D} = diag(d_1,...,d_K)$ is the diagonal matrix which keeps the transmit power unchanged after beamforming, and † means the hermit transpose.

$$d_k = 1 \Big/ \sqrt{\left[\left(\mathbf{HH}^{\dagger}\right)^{-1}\right]_{k,k}} \quad (11)$$

From Fig 5, 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.

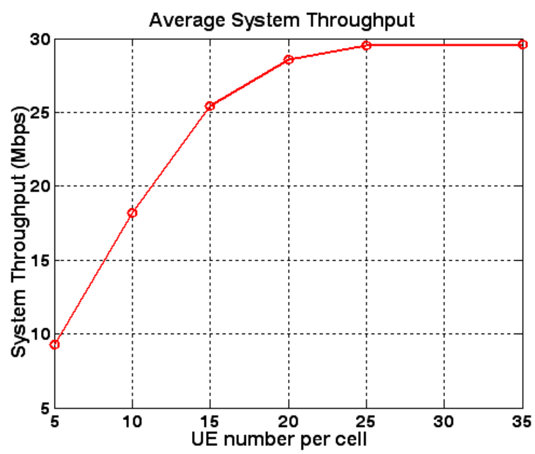


Fig 5 Cell throughput Vs. MT number per cell)

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 scheduling algorithm, joint spatial frequency multiuser diversity gain can be exploited to improve the system performance, and the system throughput and spectrum efficiency can achieve about 30Mbps and 3bps/Hz respectively with 4×2 MIMO for full buffer service.

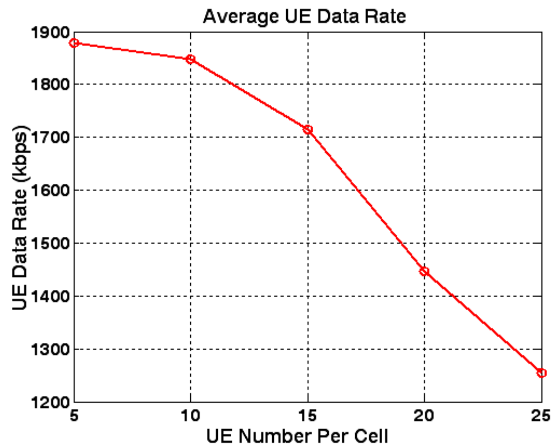


Fig 6 data rate distribution of the users

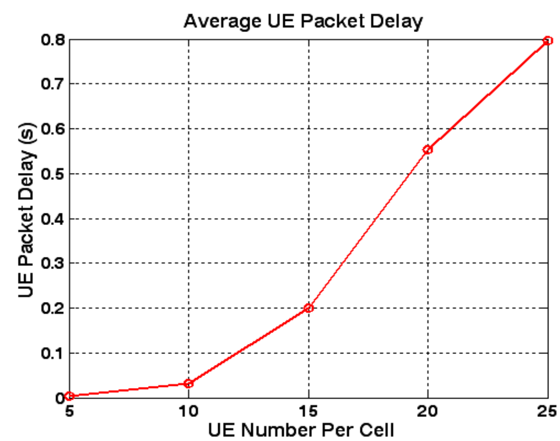


Fig 7 Packet delay Vs. MT number per cell

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