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Effective Subcarrier Allocation for an Uplink-OFDMA to Reduce the Effects of ICI and MUI under Time-Varying Channels

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***Abstract*—Orthogonal Frequency Division Multiple Access (OFDMA) system, Inter-carrier Interference (ICI) and Multiuser Interference (MUI) occurs due to destruction of orthogonality among subcarriers. To reduce these effects, effective subcarrier allocation method is proposed. The key idea is to allocate high speed users near a low speed user's subcarrier. Then, a wide Doppler spread of a high-speed user can be spilled towards a low-speed user's band with inconsiderable influence, and signal-to-interference-plus-noise (SINR) ratio at each high-speed user's can be maximized and also this can provide a significant performance improvement of multiuser detection in an uplink OFDMA.**

***Index Terms*—Inter-carrier interference, multiuser interference, OFDM.**

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) has become the de facto standard for fourth generation wireless network. OFDM is a time-frequency hybrid system where the frequency band is divided into a large number of small bands call subcarriers. Destruction of orthogonality among subcarriers leads to interferences like inter-carrier interference (ICI) and multiuser interference (MUI) [1]. In the literature, cancellation of multiuser interference due to carrier frequency offset (CEO) in uplink Orthogonal frequency division multiple access, self Inter carrier interference - cancellation methods [7] and frequency-domain filter using a low-complexity linear minimum mean square error (LMMSE) equalizer accompanying a Successive interference cancelation (SIC) with a hard-decision feedback [3] or with a soft-value decision feedback [4], [5] was proposed.

On the other side, a time-domain receiver-filter for a Multiple-Input Multiple-Output (MIMO) OFDM was introduced in [6]. All these methods are inefficient when it comes to rapidly time varying channels. So, effective subcarrier allocation is proposed and it is compared with two different interleaved subcarrier allocation methods. The main objective of this paper is to find an efficient subcarrier allocation algorithm that can improve the performance of an uplink-OFDMA under a non homogeneous user environment.

II. SYSTEM MODEL

All users are categorized into two groups to achieve the objective, vehicular users' group of relatively fast moving users and a pedestrian user's group of relatively slow moving users. Only vehicular users are assumed to generate ICI and MUI due to higher Doppler spreads. Then, successive interference with one-tap equalizer becomes significant. Assume that N total number of subcarriers are allocated to U number of uplink users N = UC, where C is the no. of subcarriers per user. In U users, Assuming S number of vehicular users. In other way, vehicular users are considered to generate ICI and MUI. The interference to the subcarriers allocated to the self user referred as ICI, while the interference to the subcarriers allocated to the other users is referred as MUI. In Addition, the maximum Doppler spread of these user, the scheduler of a base station is denoted by $f_d^{(u)}$ for $u \in S_I = \{u|1 \leq u \leq S\}$, are known, where S_I denotes the set of these users.

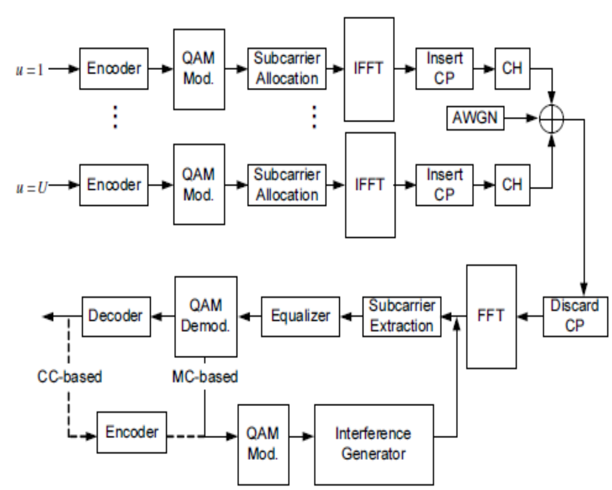

Fig.1 Block diagram of uplink-OFDMA with SIC-aided detector.

Figure 1 shows a simplified block diagram of the transmitter and receiver for an uplink-OFDMA system. Each user transmits; a branch of data bits is given to an encoder and then modulated by a quadrature amplitude modulation (QAM). The modulated symbols are assigned to the subcarriers. A group of subcarriers allocated to user u is defined and an N×1 transmitted vector of dimension u as X_u and K_u. The entry of x_u, denoted by $x_u(i)$, is a transmitted QAM-symbol if $i \in K_u$, and 0 otherwise. After taking an inverse fast Fourier transform (IFFT) using x_u, a cyclic prefix (CP) is appended to each OFDM symbol to avoid the ICI and inter-symbol interference (ISI) due to the multiple path dispersion. At the side of receiver in the base station (bs), the Cyclic Prefix is removed and fast Fourier transform (FFT) is performed. Then, the received signal for the k-th subcarrier can be written as

$$y(k) = \sum_{u=1}^{U} \sum_{i \in k_u} H_u(k,i)\, x_u(i) + w(i), \qquad (1)$$

Where k =0, 1,…N-1, where w(k) is a zero-mean additive white Gaussian noise (AWGN) with variance of σ^2. If the k-th subcarrier is assigned to the u-th user, i.e., $k \in K_u$, y(k) in (1) can be rewritten as

$$y(k) = H_u(k,k)\, x_u(k) + \sum_{i \in k_{u,} i \neq k} H_u(k,i)\, x_u + \sum_{v=1, v \neq u}^{u} \sum_{i \in k_v} H_v(k,i)\, x_v(i) + w(k) \qquad (2)$$

Where the 1st term is a required signal, and the second and third terms are the sum of the ICI and MUI, respectively.

III. SUBCARRIER ALLOCATION ALGORITHM

Subcarrier allocation is a two stage sub-optimal algorithm: In first stage, a particular user sequence O is find out for the successive interference cancelation detector, and in second stage, the distance sequence D of d_q is computed for a given user sequence O. Because the Successive interference cancelation detector can detect and cancel the interference generated by the faster-moving users prior to the slower-moving users, it is desire to design a sequence such that the faster-moving users have less interference, Keeping this fundamental assignment criteria in mind over the entire search of sequence, the number of remaining subcarriers are count that are not assigned in the sequence, and choose a faster (or slower) moving user of the maximum number of remaining subcarriers to be allocated [9].

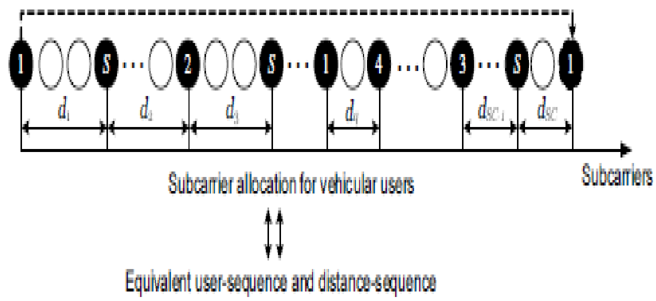

Fig. 2.Subcarrier allocation for vehicular users, and corresponding distance sequence and user sequence.

O= (1, S, 2, S… 1, 4… 3, S)
D= (d_1, d_2….d_q…..d_{sc})

This objective can be achieved using the proper subcarrier assignment, as shown in Table 1. In every step of the first stage, determined all users whose number of remaining subcarriers to be allocated is maximum, the number of remaining subcarriers for user *u* is denoted by *r*(*u*). In the *q*-th step, the set of these users is denoted by S_M^q. The first step of the algorithm, for any user r(u) is equal to C. Among the users in S_M^q, the fastest-moving (slowest-moving) user is assigned to the *q*-th position of the sequence O in an odd (even) step. This assignment will be repeated until the length of O becomes *SC*.

TABLE I
First Stage Algorithm

1.	Initialization $r(u) = C, \forall_{u \in S_I}$
2.	for q= 1,2,….., SC Mq=max{r(u) $S_M^q = \{u \in S_I / r(u) = M_q\}$ If q is odd O(q)=arg $\max_{u \in s_M^q} \{f_d^u\}$ else O(q)= arg $\min_{u \in s_m^q} \{f_d^u\}$ end r(O(q))=r(O(q))-1 end

Let I ($x_u(k)$ → $x_v(k + d)$) denote multiuser interference power from the k-th subcarrier allocated to the u-th user to the (k+d)-th subcarrier separated

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by d subcarriers and allocated to the v-th user. Then, I ($x_u(k) \rightarrow x_u(k + d)$) represents an ICI power from the k-th subcarrier to the (k + d)-th subcarrier. Then, based on a linearly time-varying channel model, both ICI and MUI power can be expressed as

$$I\left(x_u(k) \rightarrow x_v(k+d)\right) = \mathrm{E}\left\{\left|H_u(k,k+d)\, x_u(k)\right|^2\right\}$$
$$= \xi_u \left| f_N(d) \right|^2 \qquad (3)$$

$$\xi_u = \xi_x \frac{2}{(N-1)^2}\left\{1 - \phi_t^u\left(\frac{T_s N}{N+N_g}\right)\right\}, \qquad (4)$$

$$f_N(d) = \frac{1}{N}\sum_{l=0}^{N-1} l \exp\left(-j\frac{2\Pi l d}{N}\right), \qquad (5)$$

$$\phi_t^u(t) = \sum_{l=0}^{L-1} E\left[h_u(n_1,l)\, h_u^*\left(n_1 + t\frac{N+N_g}{T_s}, l\right)\right] \qquad (6)$$

$$\xi_u = \xi_x \frac{2}{(N-1)^2}\left\{1 - J_0\left(2\Pi f_d^u \frac{T_s N}{N+N_g}\right)\right\}. \qquad (7)$$

Where $\phi_t^u(t) = j_0(2\Pi f_d^u t)$,

Let $D_q \overset{\Delta}{=} \sum_{i=1}^{q} d_j$ denote a cumulated distance in *D*. And *Iq* is define by a mutual interference power between $x_{O(q)}(D_{q-1})$ and $x_{O(q+1)}(Dq)$. Then, I_q becomes the sum of ICI or MUI power and can be expressed using (3) as

$$I_q = I(x_{o(q)}(D_{q-1}) \rightarrow x_{o(q+1)}(D_q))$$
$$+ I(x_{o(q+1)}(D_q) \rightarrow x_{o(q)}(D_{q-1}))$$
$$= \left(\xi_{o(q)} + \xi_{o(q+1)}\right)\left|f_N(d_q)\right|^2 \qquad (8)$$

Since the decision-error in SIC is mainly dominated by greater I_q, the allocation is to minimize the maximum I_q. By solving the integer programming among all possible user sequence O it can be obtained as

min max I_q, $1 \le q \le SC$

$$\text{s. t.} \sum_{q=1}^{SC} d_q = N. \qquad (9)$$

The integer programming to solve (9) can be rewritten as

min I_{max}

$$\text{s.t.}\ (\xi_{\tilde{O}(q)} + \xi_{\tilde{O}(q+1)})\left|f_N(d_q)\right|^2 \le I_{max},\ 1 \le q \le SC$$

$$\sum_{q=1}^{SC} d_q^* = N. \qquad (10)$$

I_{max}^* can be found by solving

$$\sum_{q=1}^{SC} \cos^{-1}\left(1 - \frac{\xi_{\tilde{O}(q)} + \xi_{\tilde{O}(q+1)}}{2 I_{max}^*}\right) = 2\Pi \qquad (11)$$

Since the left-hand side is a monotonic decreasing function of I_{max}^*, it can be easily solved using a numerical method such as the bisection method or Newton's method [13]. We use the bisection method to solve the problem in (11) with the following interval:

$$2\overline{\xi_{\tilde{O}}}\left|f_N\left(\frac{U}{S}\right)\right|^2 \le I_{max}^* \le 2\overline{\xi_{\tilde{O}}}\left|f_N\left(\frac{\max \xi_{\tilde{O}(q)}}{\overline{\xi_{\tilde{O}}}}\frac{u}{s}\right)\right|^2 \qquad (12)$$

Where $\overline{\xi_{\tilde{O}}} = \frac{1}{SC}\sum_{q=1}^{SC}\xi_{\tilde{O}(q)}$, and the left-hand and right hand sides in (12) are obtained using Jensen's inequality with the convex property and the concave property respectively. Once the I_{max}^* calculated, the continuous solution d_q^*, by rounding the distance we can obtain the solution. If the solutions don't satisfy the constraint in (9), then a calibration is performed by successively widening the distance with largest or smallest mutual interference power and fig.4 represents that, two stage suboptimal subcarrier algorithm flow is as shown below.

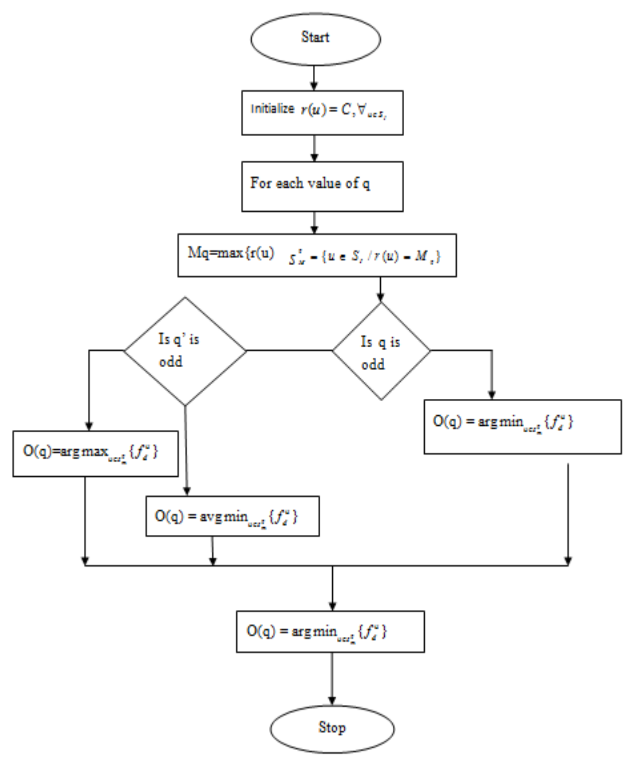

Fig.4 Suboptimal subcarrier algorithm flow

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IV SIC AIDED DETECTION TECHNIQUES

This section briefly introduces an SIC detector to demonstrate the performance of proposed subcarrier allocation algorithm for a coded OFDMA system. An successive interference cancelation detector using a soft-value feedback in [4], [5] shows superior performance to the SIC using a hard-decision feedback in [2], [3], we only consider the latter scheme because the performance of hard-decision feedback with our proposed allocation is already close to the interference free case, which will be shown in section V. Two possible SIC detectors using hard-decision feedback are introduced: a demodulation and cancelation (MC)-based detector, and a decoding and cancelation (CC)-based detector, as shown in the lower portion of Fig. 1. Since $f_d^{(1)} \geq f_d^{(2)} . . . \geq f_d^{(S)}$, a receiver first equalizes all subcarriers allocated to the first user using a one-tap equalizer in parallel as

$$\overline{x_1(k)} = G_1(k) y(k), \forall k \in K_1 , \quad (13)$$

Where an LMMSE equalizer coefficient for the user u, $G_u(k)$, i

$$G_u(k) = \frac{H_u^*(k,k)}{\left|H_u(k,k)\right|^2 + \sigma^2} \quad (14)$$

Using the equalized symbols $\tilde{x}_1(k)$, an MC-based detector finds the closest symbol $\bar{x}_1(k)$ in the set of QAM symbols and eliminates the MUI generated by the first user as follows:

$$y_u(k) = y_{u-1}(k) - \sum_{i \neq k, i \in k_u} H_u(k,i) x_1(i), \forall_{k \in k_1^c} \quad (15)$$

where $y_u(k)$ denotes the k-th subcarrier signal after the cancelation of interference generated by the u-th user. By using proposed allocation scheme the subcarriers allocated to the same user are separated as far as possible, the inter carrier interference is negligible, and the MUI is eliminated in (15). In the case of a CC-based detector, $\bar{x}_1(k)$ can be obtained by decoding of the user's bit streams using several OFDM symbols to form a one-coded block and regenerating the estimated symbols. Until all MUI generated by user in S_I are eliminated These cancelation will be repeated and the k-th received subcarrier signal becomes

$$y_u(k) = y_{u-1}(k) - \sum_{i \neq k, i \in k_u} H_u(k,i) x_u(i),$$

$$\forall_{k \in u_{v \leq u} k_v^c}, 2 \leq u \leq S, \quad (16)$$

where $\bar{x}_u(i)$ is the hard decision or the decoded and regenerated symbol of $\tilde{x}_u(i) = G_u(i) y_{u-1}(i)$. If there is no decision error in $\bar{x}_u(i)$, then $y_S(k)$, the received symbol, there is no ICI and MUI after the cancelation of the MUI from the S-th user. Therefore, the pedestrian users are assigned by the remaining subcarriers in $S_I^C = \{u|S + 1 \leq u \leq U\}$ can be detected using

$$x_u(k) = G_u(k) ys(k), \forall_{k \in k_u}, u \in s_I^C, \quad (17)$$

Note that, in general, the performance of a CC-based detector can be better than that of an MC-based detector, if the error-correction capability is larger than the no. of equalized. If decision errors are more than its error correction capability, then the CC-based detector can produce more serious error propagation. Hence, the careful subcarrier allocation design will be more appreciated in a CC-based detector.

V. NUMERICAL RESULTS

Maximum mutual interference power of the proposed method along with another two subcarrier allocation methods i.e., "interleaved A" and "interleaved B" are simulated with reference to number of total users as shown in fig. 4 below. The proposed subcarrier allocation method yields better performance than "interleaved A" and "interleaved B" methods. In interleaved A method all vehicular users are arranged in a sequence where as in interleaved B, all users are arranged randomly so, performance of interleaved B method is much better than interleaved A method but less than proposed one and also proposed calss-2 is compared which gives better performance than two interleaved methods but less than proposed method. Proposed class-2 is nothing but quantizing doppler information into binary number and it is denoted as 2-class.

Figure 5 shows the average BER performance over all users' data using the MC-based and CC-based SIC detectors. Regard-less of the decoding methods and the number of total users, the proposed allocation method shows the best performance among the three subcarrier allocation schemes. When the MC-based detector is employed and the number of total users is 7, Fig. 5(a) shows that the performance improvement made of the proposed subcarrier allocation method is marginal, because the interference power of the users in S_I is still significant despite applying the proposed method.

Therefore in the successive interference cancelation, multiple no. of decision error are procedure. Using the CC-based detector these decision errors can be corrected, if the error correction capability of the code is greater than their number. In Fig. 5(a) the CC-based detector with the conventional allocation schemes cannot guarantee

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performance improvement over the MC-based detector. Performance is close to the interference-free case when the CC-based detector used in the proposed subcarrier allocation method. The relative number of subcarriers corrupted by ICI or MUI decreases as number of total user's increases, for all vehicular users considered, as shown in Fig. 5(b).

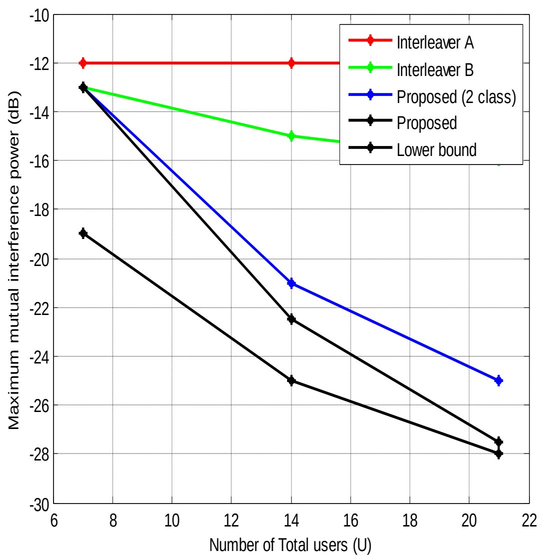
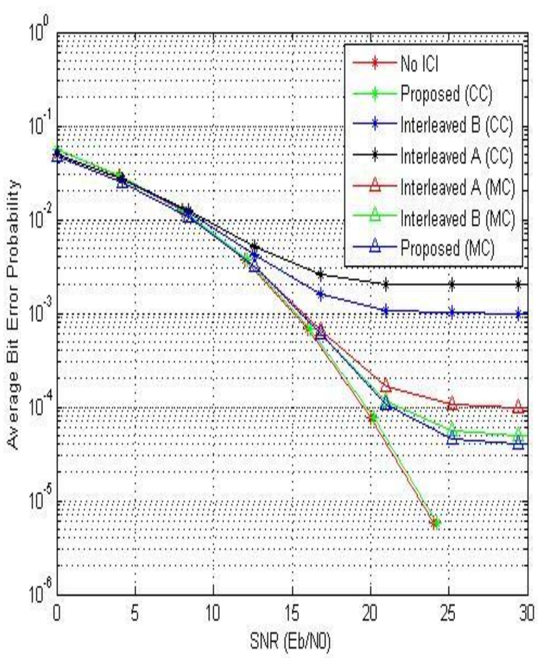
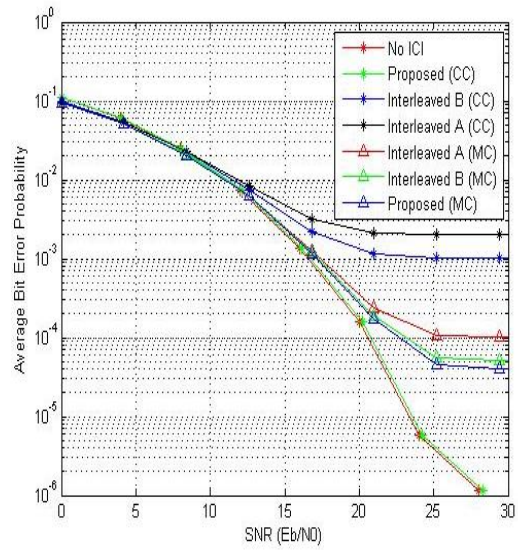


Fig.4 Maximum mutual interference power (db) vs. Number of total users (U).



(a) U=7



(b) U=14

Fig. 5 Average BER vs. SNR in time-varying channels with S=4 and 16-QAM.

The proposed allocation scheme is tested for two digital modulation techniques namely QPSK and QAM using MATLAB toolbox. MIMO-OFDM system with QPSK scheme is suitable for low capacity, short distance application. The comparison of QPSK and QAM indicates that, BER is large in QPSK as compared to QAM and it generally depends on applications. We conclude that QAM modulated MIMO - OFDM system achieves better BER results than QPSK and other modulated MIMO - OFDM systems for the same bandwidth efficiency.

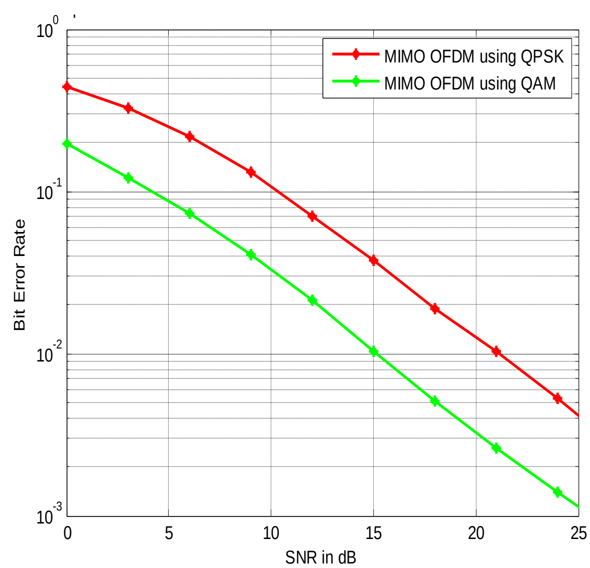


Fig. 6 Comparison of different modulation scheme using proposed allocation method.

VI. CONCLUSION

This paper proposed an effective subcarrier allocation scheme for an uplink-OFDMA system to reduce the effects of ICI and MUI. Allocating the subcarriers of the fast-moving users nearby stationary users, was working effectively. The SINR of every subcarrier allocated to the fast-moving users could be maximized with the proposed method. To implement these method, The mutual interference power between any two unique subcarriers allocated to any two vehicular users are defined, and then formulated an integer program to minimize the maximum of the mutual interference power with respect to all possible allocations. A two-stage algorithm is proposed to find a subcarrier allocation efficiently. Simulation results verified that regardless of the choice of detection schemes and other allocation methods, proposed method yield better performance.

REFERENCES

[1] M. Russell and G. Stuber, "Interchannel interference analysis of OFDM in a mobile environment," in *Proc. 1995 IEEE VTC*, pp. 820–824, 1995.

[2] R. Fantacci, D. Marabissi, and S. Papini, "Multiuser interference cancellation receivers for OFDMA uplink communications with carrier frequency offset," in *Proc. 2004 IEEE Globecom*, pp. 2808–2812.

[3] X. Cai and G. B. Giannakis, "Bounding performance and suppressing intercarrier interference in wireless mobile OFDM," *IEEE Trans. Commun.*,, vol. 51, no. 12, pp. 2047–2056, Dec. 2003.

[4] P. Schniter, "Low-complexity equalization of OFDM in doubly selective channels," *IEEE Trans. Signal Process.*,vol. 52, no. 4, pp. 1002–1011, Apr. 2004.

[5] K. Fang, L. Rugini, and G. Leus, "Low-complexity block turbo equalization for OFDM systems in time-varying channels," *IEEE Trans. SignalProcess.*vol. 56, no. 11, pp. 5555–5566, Nov. 2008.

[6] A. Stamoulis, S. N. Diggavi, and N. Al-Dhahir, "Intercarrier interference in MIMO OFDM," *IEEE Trans. Signal Process.*, vol. 50, no. 10, pp. 2451–2464, Oct. 2002.

[8] Y. Zhao and S. H¨aggman, "Intercarrier interference self-cancellation scheme for OFDM mobile communication systems," *IEEE Trans. Commun.*, vol. 49, no. 7, pp. 1185–1191, July 2001.

[9] IEEE 802.16 TGe Working Document, (Draft Standard) - Amendment for physical and medium access control layers for combined fixed and mobile operation in licensed bands, 802.16e/D4, Aug. 2004.

[10] C. Y. Wong, R. S. Cheng, K. B. Letaief, and R. D. Murch, "Multiuser OFDM with adaptive subcarrier, bit, and power allocation," *IEEE J. Sel.Areas Commun.*, vol. 17, pp. 1747–1758 Oct. 1999.

[11] H. Saeedi-Sourck, Y. Wu, J. W. M. Bergmans, S. Sadri, and B. Farhang-Boroujeny, "Complexity and performance comparison of filter bank multicarrier and OFDM in uplink of multicarrier multiple access networks," *IEEE Trans. Signal Process.*, vol. 59, no. 4, pp. 1907–1912, Apr. 2011.

[12] S. Boyd and L. Vandenberghe, *Convex Optimization.* Cambridge Uni-veristy Press, 2004.

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