DSmT Based Scheduling Algorithm in Opportunistic Beamforming Systems

Feichi Long, *Student Member, IEEE*, Tiejun Lv, *Member, IEEE*, Hui Gao, Pengfei Chang
Key Lab of Universal Wireless Communications, Ministry of Education,
Beijing University of Posts and Telecommunications, Beijing, China 100876
{longfish, lvtiejun, huigao, cpfe1986}@bupt.edu.cn

***Abstract*—A novel approach based on Dezert-Smarandache Theory (DSmT) is proposed for scheduling in opportunistic beamforming (OBF) systems. By jointly optimizing among system throughput, fairness and time delay of each user, the proposed algorithm can achieve larger system throughput and lower average time delay with approximately the same fairness and acceptable complexity, as compared with the proportional fair scheduler (PFS). Furthermore, unlike the case in PFS, the parameter used for tradeoff between system throughput and fairness is valid for various practical settings, since the weight that each user accounts for in the base station's (BS) choice can be appropriately calculated in DSmT's framework. Simulation results verify that the proposed algorithm outperforms PFS and other conventional scheduling algorithms in terms of the four proposed indexes.**

I. Introduction

One of the mostly concerned characteristics of a wireless channel is its capacity, which can be seriously influenced by the fading of the channel strength due to interference between multi-paths. An effective means to cope with channel fading and increase channel capacity is diversity. Besides time, frequency and space diversity, information-theoretic results in [1] motivate multi-user diversity which can also be gained in these systems with multiple users. And in multi-user systems with fast fading channel and full channel side information (CSI) (both CSI at transmitter and receiver), the total information-theoretic capacity can be achieved by allowing only the user of best channel to transmit at each time, both in uplink [1] and downlink [2]. Thereby diversity can be gained when the number of users whose channels vary independently is large enough, in respect that there is likely to be a user whose channel is near its peak at each time [3].

P. Viswanath and T. David proposed a scheme called opportunistic beamforming (OBF) in [3] to exploit the multi-user diversity. The basic idea is to treat the channel fluctuations as an opportunity that can be exploited rather than averaged out [4]. By using dumb antennas, OBF scheme can introduce large and fast fluctuations into each subchannels between users and base station (BS), therefore the channels appear to be fast fading channels in user's view and the performance deficiency due to deep fading or slow fading can be eliminated. Another advantage of OBF scheme is that only partial CSI or overall signal to interference plus noise ratio (SINR) at receiver is adequate to BS's scheduling.

This work is financially supported by the National Natural Science Foundation of China (NSFC) under Grant No. 60972075.

Selecting the user of best channel to transmit at each time in OBF system is by definition maximum carrier to interference ratio (MAXCI) scheduling algorithm, which maximizes the throughput of multi-user system. However, fairness and quality of service (QoS) can not be guaranteed is the major weak point of MAXCI scheduling [5]. Another scheduling algorithm named round robin (RR) pursues the most fair scheduling but with poor performance in system throughput. To overcome these problems, the proportional fair scheduler (PFS) algorithm, that originally proposed in [6], is introduced to OBF systems [3] [7] [8]. PFS and other algorithms based on PFS [7] [5] [8] capture the tradeoff between throughput and fairness, whereas the time delay of each user is not concerned or the tradeoff parameter in these algorithms should be determined by practical settings.

As a state-of-the-art arithmetic of fusion and uncertainty processing, Dezert-Smarandache Theory (DSmT) is a nice consideration for the issues addressed above. DSmT is proposed by J. Dezert and F. Smarandache at 2003 [9] [10], and is in essence an improved and more general Dempster-Shafer theory (DST) [11]. Via DSmT or DST, many intelligent algorithms have been proposed in many fields, such as artificial intelligence research [12], data fusion [10], MIMO systems [13] [14], with the verification that DSmT or DST can achieve a satisfactory performance. This paper proposes a DSmT based scheduling algorithm to implement a joint optimization among system throughput, fairness and time delay of each user. For each of these three indicators, or *sources* in DSmT's view, DSmT approach assigns a generalized basic belief assignment (GBBA) at each time for each user to characterize the weight it accounts for in the BS's choice. Overall SINR at the user, throughput and time delay of each user are used to calculate the GBBA, thereafter Dezert-Smarandache combination rule (DSmC) with source weight combines these GBBAs to generalized pignistic probabilities for final decision. Contrastively, the proposed algorithm can achieve larger system throughput and lower average time delay with approximately the same fairness and acceptable complexity, as compared with PFS. Furthermore, the tradeoff parameter (source weight) can be set at a fixed value under different practical settings. Simulation

978-1-4577-0024-8/11/$26.00 © 2011 IEEE

results under practical channel model verify that the proposed approach outperforms RR, MAXCI and PFS in terms of four proposed indexes characterizing the system performance.

The rest of this paper is organized as follows: Section II describes a system model. Section III presents a brief review of conventional scheduling algorithms. Section IV analyzes the proposed DSmT based scheduling algorithm. Simulations and comparisons are presented in Section V. Finally, conclusions are provided in Section VI.

II. System Model

The model of interest is a single cell with one BS equipped with N_t dumb antennae and K users each with one antenna. The K users that require to be served are randomly distributed in the cell. Channels between BS and users follow independent and identically distributed (i.i.d.) Rayleigh fading with zero mean and unit variance.

In the $m^{th}, m = 1, 2, \cdots M,$ timeslot in downlink, the BS multiplies the signal $s[m]$ through dumb antennae with a random weight vector $\mathbf{q}[m] = [q_1[m], q_2[m], \cdots, q_{N_t}[m]]^T$ and broadcasts the signal to all the users in the cell. The received signal of k^{th} user at m^{th} timeslot is described as

$$y_k[m] = \mathbf{h}_k[\mathrm{m}]\mathbf{q}[\mathrm{m}]s[\mathrm{m}] + w_k[\mathrm{m}],\ \ k = 1, 2, \cdots, K, \tag{1}$$

where $w_k[m]$ is a complex additive white Gaussian noise (AWGN) variable, $\mathbf{h}_k[m] = [h_{k,1}[m], h_{k,2}[m], \cdots, h_{k,N_t}[m]]$ is the complex channel vector of k^{th} user satisfying $h_{k,i}[m] \sim \mathcal{C}N(0, 1), i = 1, 2, \cdots, N_t$.

As OBF system introduces channel fluctuations on its own initiative, the channel coherence time is insignificant for this system model, thereby the assumption of the invariable of $\mathbf{h}_k[m]$ in a large scale time is reasonable.

The weight vector produced by dumb antennae satisfies

$$q_l[m] = \sqrt{a_l[m]} \cdot e^{j\theta_l[m]},\ \ l = 1, 2, \cdots N_t, \tag{2}$$

where $a_l[m]$ varies from 0 to 1 and $\theta_l[m]$ varies from 0 to 2π at each m^{th} timeslot [3]. For preserving the total transmit power, the constraint

$$\sum_{l=1}^{N_t} a_l[m] = 1 \tag{3}$$

must be satisfied.

CSI at BS is not required and only the overall SINR of each user is required. At the beginning of each timeslot, the user calculates its instantaneous SINR by

$$r_k[m] = \sum_{i=1}^{N_t} |h_{k,i}[m] \cdot q_i[m]|^2,\ \ k = 1, 2, \cdots K, \tag{4}$$

and feedback it to the BS, thereafter the BS selects one user to serve via a certain scheduling algorithm. The situation in uplink access is almost the same to the model analysed above.

We propose four indexes to characterize the system performance in this paper, which are defined as follows.

1) total system throughput (primary index, per timeslot):

$$C_{total} = \frac{1}{M} \cdot \sum_{k=1}^{K} \sum_{m=1}^{M} R_k[m], \tag{5}$$

where $R_k[m]$ is an estimate of the maximum data rate the k^{th} user is capable of receiving or transmitting during the m^{th} timeslot [7], calculated by Shannon's capacity formula as

$$R_k[m] = \log_2(1 + r_k[m]), \tag{6}$$

and updated by $R_k[m] = 0$, if $k \neq k^*$, at the end of the m^{th} timeslot, where k^* is the subscript of the user chosen to be served at the m^{th} timeslot.

2) average time delay of each user:

$$\tau_{aver} = \frac{1}{K} \cdot \frac{1}{M} \cdot \sum_{k=1}^{K} \sum_{m=1}^{M} \tau_k[m], \tag{7}$$

where $\tau_k[m]$ is the total waiting time of the k^{th} user at the m^{th} timeslot after the last time it's being in service. $\tau_k[m]$ is updated by BS at each timeslot by

$$\tau_k[m+1] = \begin{cases} \tau_0 & k = k^* \\ \tau_k[m] + \tau_0 & k \neq k^* \end{cases}, \tag{8}$$

where τ_0 represents timeslot's value (e.g. 1.67ms in IS-856).

3) variance of user's throughput:

$$\sigma_c = Var\left\{ \left[\sum_{m=1}^{M} R_k[m] \right]_{K\times 1} \right\}, \tag{9}$$

where the content in the brace denotes a $K \times 1$ vector, and the content in the outside bracket represents the k^{th} user's throughput. This index is reasonable on the assumption that all the K users require to be served at all the M timeslots.

4) variance of user's probability of being in service:

$$\sigma_p = Var\left\{ \left[\frac{1}{M} \cdot \sum_{m=1}^{M} 1\left(R_k[m]\right) \right]_{K\times 1} \right\}, \tag{10}$$

where $1(x)$ is an indicator function defined as $1(x) = 0,$ if $x = 0,$ and $1(x) = 1,$ if x $\neq 0.$

III. Conventional Scheduling Algorithms

Three conventional scheduling algorithms are briefly reviewed in this section. Improved algorithms are put forward later, whereas most of them are modified PFS algorithm [5] [8] with limited improvements.

A. Round Robin

Via RR algorithm, BS chooses the users in turns which can achieve the best fairness.

B. MAXCI

Via MAXCI algorithm, the subscript of the user chosen to be served at m^{th} timeslot is determined by

$$k^* = \arg \max_{k\in\{1,2,\cdots K\}} \left(r_k[m]\right). \tag{11}$$

C. Proportionally Fair Scheduler

PFS algorithm can capture the tradeoff between throughput and fairness, the subscript of the user chosen to be served at m^{th} timeslot is determined as follows

$$k^* = \arg \max_{k\in\{1,2,\cdots K\}} \left(\frac{R_k[m]}{T_k[m]}\right), \tag{12}$$

where $R_k[m]$ is defined by (6) and $T_k[m]$ is the k^{th} user's average throughput in a time window of T_c at the m^{th} timeslot, updated by

$$T_k[m+1] = \left\{ \begin{array}{ll} (1-{T_c}^{-1})\cdot T_k[m] + {T_c}^{-1}\cdot R_k[m] & k = k^* \\ (1-{T_c}^{-1})\cdot T_k[m] & k \neq k^* \end{array} \right. \tag{13}$$

As a free parameter, T_c offers a flexible selection between total system throughput and fairness [7], but determining its value is not effortless for it varies much according to different practical settings and environments.

IV. The Proposed Scheduling Algorithm

We first present a brief review of DSmT and thereafter further explain how it is introduced into the proposed scheduling algorithm in OBF system. For more details, the original book of Dezert and Smarandache [10] can be referred.

A. A Brief Review of DSm Theory

Let $\Theta = \{\theta_1,\theta_2,\cdots,\theta_n\}$ represents a finite set of elements or hypotheses, called the frame of discernment. Let $\mathbf{S} = \{S_1, S_2, \cdots, S_n\}$ represents experts in a broad sense who give evaluation to the frame of discernment, and this is called source in DSmT. In Shafer's model in DST denoted $\mathcal{M}^0(\Theta)$, elements in Θ must be exclusive and exhaustive. However, in DSmT framework, elements in Θ must be exhaustive only, and this is called free DSm-model denoted $\mathcal{M}^f(\Theta)$. Another important basic definition in DSmT is the power set and hyper-power set, the former denoted 2^Θ is the set of all subsets of Θ and the latter denoted D^Θ is defined as follows

1) : $\emptyset,\theta_1,\theta_2,\cdots,\theta_n \in D^\Theta$;

2) : If $A, B \in D^\Theta$, *then* $A \cap B$ *and* $A \cup B$ *belong to* D^Θ;

3) : *No other elements belong to* D^Θ, *expcept* 1 *and* 2.

A generic notation of G^Θ is introduced by [10] for denoting either 2^Θ or D^Θ.

The free DSm model $\mathcal{M}^f(\Theta)$ corresponding to D^Θ allows to work with vague concepts which exhibit a continuous and relative intrinsic nature [10].

A generalized basic belief assignment (GBBA) is defined as a mapping $m_S(\cdot) : G^\Theta \to [0,1]$ associated to a given body of source S which satisfies

$$m_S(\emptyset) = 0 \quad and \quad \sum_{A\in G^\Theta} m_S(A) = 1 \tag{14}$$

for any element or hypothesis A in G^Θ. GBBA can give the basic elements or hypotheses a probability in a broad sense and is commonly one of the most important issues one should concern about.

DSm classic rule (DSmC) is performed on $G^\Theta = D^\Theta$ in free DSm model $\mathcal{M}^f(\Theta)$ as a pure conjunctive consensus, which can combine different evaluation given by various sources effectively. DSmC with source weight of two independent sources S_1 and S_2 associated with GBBA is thus given as follows

$$m_{DSmC}(C) = \sum_{\substack{A,B\in D^\Theta \\ A\cap B=C}} m_{S_1}(A)^{\partial_1} m_{S_2}(B)^{\partial_2}, \tag{15}$$

where ∂_1 and ∂_2 are coefficients associated with the source weight and satisfy $\partial_1 + \partial_2 = 1$.

Finally, one can make decision via comparing the value of generalized pignistic probabilities (denoted $BetP(\cdot)$) of the elements in G^Θ. $BetP(\cdot)$ represents the confidence level one can rely on and defined by $BetP(\emptyset) = 0$ and for $\forall A \in G^\Theta \backslash \{\emptyset\}$,

$$BetP(A) = \sum_{B\in G^\Theta} \frac{\mathcal{C}_\mathcal{M}(A\cap B)}{\mathcal{C}_\mathcal{M}(B)} \cdot m(B), \tag{16}$$

where $\mathcal{C}_\mathcal{M}(B)$ denotes the cardinal of B.

In the following subsections, how DSmT is introduced into the scheduling problem in OBF system is addressed in details.

B. Frame of Discernment

Let $X_k, k = 1,2,\cdots,K$, represents the k^{th} user in the cell who requires to be served, and $H(X_k)$ represents the hypothesis that X_k is the best user the BS should choose to serve at a certain timeslot. The target of the proposed algorithm is to select out the user with the largest generalized pignistic probability of $H(X_k)$.

C. Free DSm Model

In OBF system, the BS choose one user to serve at each timeslot, the elements in frame of discernment are thus exclusive and exhaustive. Therefore the free DSm model $\mathcal{M}^f(\Theta)$ is performed at $G^\Theta = D^\Theta = 2^\Theta$ in our situation, which can reduce the complexity to some extent.

D. Three Indepent Sources and the GBBA

For scheduling in OBF system with the four indexes defined by Sec.II, three indicators, including channel quality (denoted S_1), throughput of each user (denoted S_2), time delay of each user (denoted S_3), can be introduced as three independent sources in DSmT's sense. This is reasonable if we treat the three indicators as experts who give evaluation about how much weight that each user accounts for in the BS's choice.

The GBBAs of each source at the m^{th} timeslot is calculated as follows

$$m_{S_1}(H(X_k)) = \frac{R_k[m]}{\sum\limits_{i=1}^{K} R_i[m]}, \tag{17}$$

representing the weight that the user accounts for in the BS's choice evaluated by source S_1, where $R_k[m]$ is defined by (6) in Sec.II, and

$$m_{S_2}(H(X_k)) = \frac{\left(\sum_{i=1}^{K}\sum_{j=1}^{m} R_i[j]\right) - \left(\sum_{j=1}^{m} R_k[j]\right)}{(K-1)\left(\sum_{i=1}^{K}\sum_{j=1}^{m} R_i[j]\right)}, \quad (18)$$

as the evaluation given by the source S_2, and

$$m_{S_3}(H(X_k)) = \frac{\tau_k[m]}{\sum_{i=1}^{K}\tau_i[m]}, \quad (19)$$

which represents the weight evaluated by source S_3, where $\tau_k[m]$ is defined by (7) and updated by (8).

Unlike S_1 (channel quality) and S_3 (time delay of each user), the larger the each user's throughput is, the less likely it will be chosen to be served, therefore $m_{S_2}(H(X_k))$ is normalized as the format of (18).

E. Combination with DSmC

DSmC combination rule with source weight defined by (15) can be applied after the GBBAs are calculated. Considering there is three sources, we can assign three coefficients ∂_1, ∂_2 and ∂_3 to the three sources satisfying $\partial_1 + \partial_2 + \partial_3 = 1$. Thereafter the combination can take place as follows

$$m_{DSmC}(D) = \sum_{\substack{A,B,C\in G^{\Theta}\\ A\cap B\cap C=D}} m_{S_1}(A)^{\partial_1} m_{S_2}(B)^{\partial_2} m_{S_3}(C)^{\partial_3} . \quad (20)$$

Since the source S_1 is primary according to the index defined by (5) and $\partial_2 = \partial_3$ can hold on assumption that S_2 and S_3 give the equivalent evaluation about the weight that each user accounts for in the BS's choice, in view of that each user's throughput and time delay are both important for fairness, the coefficients ∂_1, ∂_2 and ∂_3 can thus be substituted by one coefficient ∂ for simplification, then $\partial_1 = \partial$, $\partial_2 = \partial_3 = \frac{1}{2}(1-\partial)$ hold with the constraint $0 < \partial < 1$.

∂ is a free parameter which controls the tradeoff between total system throughput and fairness, when $\partial = 1$ the proposed algorithm equals MAXCI. In practical environment ∂ can be set as a fixed value (e.g. 0.5).

F. Make Decision with Generalized Pignistic Probability

After all the GBBAs of the elements of the free DSm model are calculated out, the generalized pignistic probabilities can thus be calculated by (16). Fortunately, since $G^{\Theta} = D^{\Theta} = 2^{\Theta}$ in our situation, the calculation can be simplified as

$$\begin{aligned} BetP(H(X_k)) &= \sum_{B\in G^{\Theta}} \frac{|H(X_k)\cap B|}{|B|} m_{DSmC}(H(X_k)) \\ &= m_{DSmC}(H(X_k)) \end{aligned} \quad (21)$$

Finally, the BS choose the user with the largest generalized pignistic probability to serve, and this can be formulized as

$$k^* = \arg \max_{k\in\{1,2,\cdots,K\}} BetP(H(X_k)), \quad (22)$$

which is formally similar to (11) and (12).

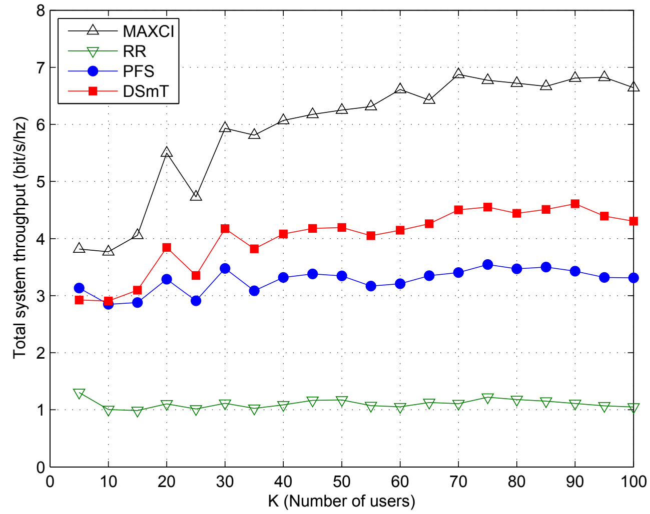

Fig. 1. Comparison of total system throughput of DSmT scheduling, PFS, MAXCI and RR.

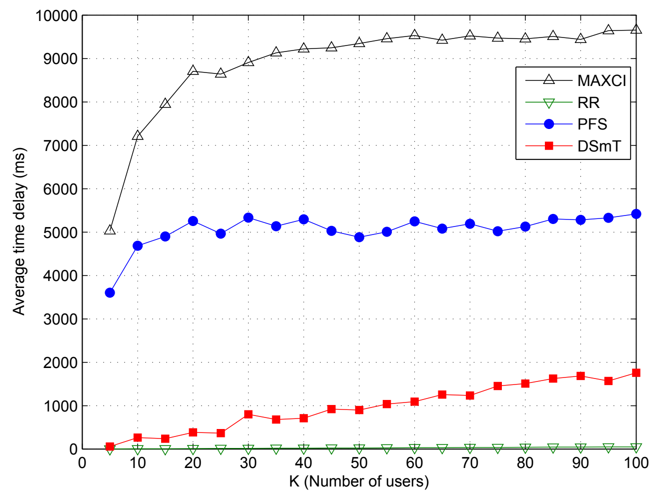

Fig. 2. Comparison of average time delay of DSmT scheduling, PFS, MAXCI and RR.

V. SIMULATIONS AND COMPARISONS

This section presents numerical results to demonstrate the performance of the proposed DSmT based scheduling algorithm in OBF system, comparison between PFS and other conventional algorithm is addressed as well. In order to achieve a practical results, the settings of the channel model refers to IS-865 and some of them is set as follows.

The value of timeslot is 1.67ms, $N_t = 2$, Rayleigh fading channel is concerned, and the delay due to multi-path is not considered. All the K users are randomly distributed in the cell and the distance d between BS and users is Uniform-distributed from 50 to 500 meters. Simplified path loss model is considered as $P_t = P_r\left(\frac{d_0}{d}\right)^{r_d}$, where the pass loss exponent r_d is set at 3. Therefore the variable $h_{k,i}[m]$ in (4) can be calculated by $h_{k,i}[m] = h\left(\frac{d_0}{d}\right)^{r_d}$, where h is a complex Rayleigh-distributed variable satisfying $h \sim \mathcal{CN}(0,1)$. Fur-

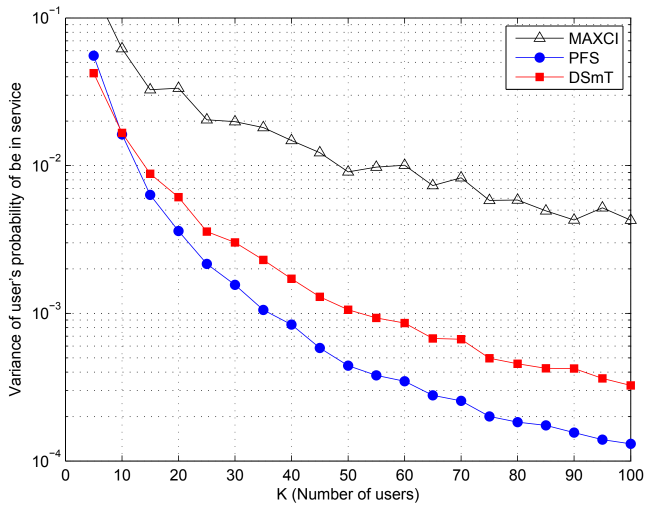

Fig. 3. Comparison of variance of user's probability of being in service of DSmT scheduling, PFS and MAXCI (RR's results are all zero).

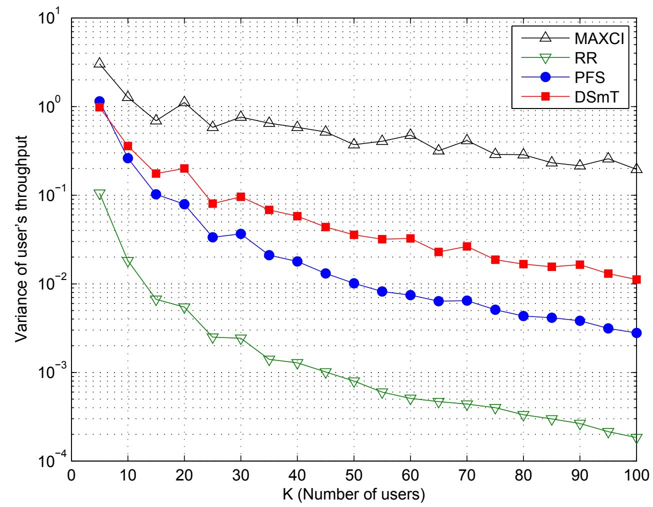

Fig. 4. Comparison of variance of user's throughput of DSmT scheduling, PFS, MAXCI and RR.

thermore, the overall SINR at receiver without channel fading and pass loss is all assumed to be 20db.

Simulation results via averaging 100 times' results, each of 20,000 timeslots and different user numbers, are shown by Fig. 1-4 corresponding to the four indexes defined in II respectively. PFS and DSmT based approach can both achieve the same performance of MAXCI by substituting T_c with ∞ [7] and ∂ with 1, while how large T_c should be set is a issue needs to be investigated in practical environment. Therefore T_c is set at 50000 in our simulation experimentally, and ∂ is set at 0.5 which can be applied as a fixed coefficient.

Fig.1 illustrates the total system throughput of different scheduling algorithm, which is the primary issue we concern about. One can easily observe that MAXCI achieves the largest system throughput while RR the smallest, and DSmT outperforms PFS at system throughput under our simulation settings.Average time delay is given in Fig.2, and it's clear that MAXCI achieves the largest time delay while RR achieves the smallest, as we expect. However, what is amazing is that the proposed algorithm can obtain much smaller time delay than PFS and achieves similar time-delay performance of RR algorithm when K is small. What is more, the variance of user's throughput and probability of being in service is almost the same according to Fig.3 and Fig.4, considering the magnitude of the numbers on the longitudinal axis. This implies that DSmT based approach achieves approximately the same fairness compared to PFS.

VI. Conclusion

The proposed scheduling algorithm based on DSmT can achieve larger system throughput and lower average time delay with approximately the same fairness, as compared with PFS. Furthermore, the proposed algorithm is universal to different practical settings. Other methods of assignment of GBBA need to be further investigated with consideration of some other characterization in OBF systems.

References

[1] R. Knopp and P. Humblet, "Information capacity and power control in single-cell multiuser communications," in *Communications, 1995. ICC '95 Seattle, 'Gateway to Globalization', 1995 IEEE International Conference on*, 1995, pp. 331–335.

[2] L. Li and A. Goldsmith, "Capacity and optimal resource allocation for fading broadcast channels .I. Ergodic capacity," *Information Theory, IEEE Transactions on*, vol. 47, no. 3, pp. 1083–1102, 2001.

[3] P. Viswanath, D. Tse, and R. Laroia, "Opportunistic Beamforming Using Dumb Antennas," *Information Theory, IEEE Transactions on*, vol. 48, no. 6, pp. 1277–1294, 2002.

[4] T. David and P. Viswanath, *Fundamentals of Wireless Communication*. Cambridge University Press, 2004.

[5] T. rui Pei, Z. Peng, J. lian Cao, and Z. qiang Yao, "A New Scheduling Algorithm and Performance with Opportunistic Beamforming," in *Advanced Communication Technology, 2006. ICACT 2006. The 8th International Conference*, 2006, pp. 6–21.

[6] A. Jalali, R. Padovani, and R. Pankaj, "Data throughput of CDMA-HDR a high efficiency-high data rate personal communication wireless system," in *Vehicular Technology Conference Proceedings, 2000. VTC 2000-Spring Tokyo. 2000 IEEE 51st*, vol. 3, 2000, pp. 1854–1858.

[7] D. Avidor, J. Ling, and C. Papadias, "Jointly Opportunistic Beamforming and Scheduling (JOBS) for Downlink Packet Access," in *Communications, 2004 IEEE International Conference on*, vol. 5, 2004, pp. 2959–2964.

[8] L. Tan, G. Su, G. Zhu, and P. Shang, "Adaptive Proportional Fair Scheduling Based on Opportunistic Beamforming for MIMO Systems," in *Wireless Communications, Networking and Mobile Computing, 2009. WiCom '09. 5th International Conference on*, 2009, pp. 1–4.

[9] J. Dezert and F. Smarandache, "On the generation of hyper-powersets for the DSmT," in *Information Fusion, 2003. Proceedings of the Sixth International Conference of*, 2003, pp. 1118–1125.

[10] F. Smarandache and J. Dezert, *Advances and Applications of DSmT for Information Fusion*. American Research Press, 2009, vol. 3.

[11] R. R. Yager and L. Liu, *Classic Works of the Dempster-Shafer Theory of Belief Functions*. Springer Berlin Heidelberg New York, 2008.

[12] L. Aihua, "A method for condition evaluation based on DSmT," in *Information Management and Engineering (ICIME), 2010 The 2nd IEEE International Conference on*, 2010, pp. 263–266.

[13] J. Xia, T. Lv, Y. Li, and J. Cioffi, "A novel bit-level DS combining scheme for MIMO systems with HARQ," in *Information Theory, 2009. ISIT 2009. IEEE International Symposium on*, 2009, pp. 244–248.

[14] J. Xia and T. Lv, "Uncertainty Processing Applied to Packet Combining in MIMO-HARQ Systems," in *Global Telecommunications Conference, 2009. GLOBECOM 2009. IEEE*, 2009, pp. 1–5.