Outage-based fuzzy call admission controller with multiuser detection for WCDMA systems

Y.-H. Chen, C.-J. Chang and S. Shen

Abstract: An outage-based fuzzy call admission controller with multiuser detection (OFCAC–MUD) is proposed for wideband code division multiple access (WCDMA) systems. The OFCAC–MUD determines the new call admission based on the uplink signal-to-interference ratios from home and adjacent cells and system outage probabilities. The OFCAC–MUD possesses both the effective reasoning capability of a fuzzy logic system and the aggressive processing ability of MUD. Simulation results reveal that OFCAC–MUD without power control (PC) improves the system capacity by 70.5% as compared to an SIR-based CAC–RAKE with perfect PC. It also enhances the system capacity by 53.9% as compared to an OFCAC–RAKE with perfect PC, by 6.7% as compared to an SIR-based CAC–MUD without PC and by 12.9% as compared to an OFCAC–MUD with perfect PC, given the same outage probability requirements. Moreover, OFCAC–MUD can prevent the violation of outage probability requirements in the hotspot environment, which is hardly achieved by SIR-based CAC.

1 Introduction

Wideband code division multiple access (WCDMA) systems adopt spread spectrum technology to achieve higher spectrum efficiency for wireless communications [1]. However, there exists multiple access interference (MAI) affecting the system capacity. If receivers in WCDMA systems can reduce MAI when detecting the signal of interest, the capacity will be markedly increased. Accordingly, methods of multiuser detection (MUD) for receivers in WCDMA systems are proposed.

Verdú [2] proposed an optimal MUD solution, which used a maximum likelihood sequence (MLS) detector. Unfortunately, this method is too complex to be practical. Many simplified or suboptimal detectors have been developed and improved [3, 4]. Usually, the suboptimal detectors are classified into two categories; linear detection and interference cancellation [4]. Interference cancellation in uplinks represents an important direction in MUD development because it is highly feasible in the base station (BS). There are two basic constructions of cancellations; successive interference cancellation (SIC) and parallel interference cancellation (PIC). The strategy of SIC is to discriminate the messages (bits) of other users in series, regenerate the transmitting waveforms and subtract them from the originally received waveform. PIC is similar to SIC, except in that the regenerated messages are subtracted simultaneously. The advantage of PIC is its fast process speed, but its complexity makes its implementation difficult. The performance of SIC and PIC was analysed in [3–10]. According to the results in [4–6] and [10], SIC performs better than PIC in the fading channel without power control (PC). Also the hardware requirement of SIC is less than that of PIC. Therefore, this paper considers SIC MUD for WCDMA systems.

Generally speaking, the MAI of users at the home cell plays a major role in determining the communication quality and the system capacity for WCDMA systems. When the WCDMA system adopts SIC MUD for receivers, the SIC MUD will help to mitigate the negative influence of the home cell interference when detecting the signal of interest. As a result, the admission of a new call request will cause the influence of interference more on existing calls in adjacent cells than on existing calls at the home cell. Thus, the design of call admission control in WCDMA systems using MUD would be different from traditional ones and should lay emphasis more on adjacent cell interference than on home cell interference.

However, intelligent techniques, such as fuzzy logic techniques, have been proven to be capable of dealing with nonlinear and time-varying systems, which are difficult to analyse [11]. Results also show that such intelligent computations produce better performance than parametric models of dynamic and complicated systems. As noted, wireless channels could vary due to several factors, such as channel fading, interference, noise, etc. The traffic controller for wireless communications should adopt intelligent techniques to adapt to changes of channels so as to improve system utilisation.

Therefore, in the paper, an outage-based fuzzy call admission controller with multiuser detector (OFCAC–MUD) is proposed for WCDMA systems. The OFCAC–MUD makes call admission decisions by considering the uplink worst signal-to-interference ratios (SIRs) from not only the home cell but also adjacent cells and system outage probabilities at outputs of SIC MUDs. It can improve system utilisation under the constraint of quality of service (QoS) requirements by constructing an appropriate fuzzy rule base based on the expert domain knowledge. Simulation results indicate that OFCAC–MUD achieves the system capacity more than the SIR-based CAC under the same QoS requirements. It is found that PC may not be

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essential for SIC MUD. Also, when the locations of users are uniformly distributed over cells, the capacity of OFCAC–MUD without PC, in satisfying the outage probability criteria, is improved by 70.5% over that of SIR-based CAC–RAKE with perfect PC. When the system is operated in an extremely unbalanced hotspot environment, OFCAC–MUD can still fulfil the QoS requirements of the outage probability, while SIR-based CAC–RAKE violates.

2 SIC MUD and system model

Figure 1 depicts a typical SIC MUD for K users [5, 6, 10]. Each cancellation stage (CS) in the cancellation series consists of RAKE receivers, a maximal power selector, a signal regenerator and a subtractor. In the CS, the input signal is first passed through the RAKE receivers to detect individual signals of all users. Then the signal with the maximal power will be selected, and the signal regenerator reproduces its original signal according to the carrier frequency, the phase, the amplitude and the delay profile. Finally, the subtractor will subtract the reproduced signal from the input signal of the CS. The order of CSs in SIC MUD are sorted according to the received powers of users; the first CS cancels the signal of the user who has the largest received power, and so on.

Let $r(t)$ be the baseband received signal at time t, which can be expressed as

$$r(t) = \sum_{k=1}^{K} [S_k(t)a_k(t)] + I_{OC}(t) + n(t) \tag{1}$$

where $S_k(t)$ represents the signal transmitted by the kth user, $a_k(t)$ is the activity factor of the kth user $a_k(t) \in \{0, 1\}$, and $I_{OC}(t)$ and $n(t)$ represent the aggregated MAI of the other cells and the AWGN channel noise, respectively. The SIC MUD will generate a signal at the output of the ith cancellation series for the ith user, $C_i(t)$, $1 \le i \le K$, given as

$$C_i(t) = r(t) - \sum_{\substack{k=1 \\ k \neq i}}^{K} \hat{S}_k^{(i)}(t)\hat{a}_k^{(i)}(t) \tag{2}$$

where $\hat{S}_k^{(i)}(t)\hat{a}_k^{(i)}(t)$ is the signal regenerated by the kth CS. The $C_i(t)$ will be sent to the OFCAC–MUD for further processing.

Figure 2 presents the system model for OFCAC–MUD, which contains four functional blocks:

(1) system outage probabilities estimator
(2) home cell worst SIR estimator
(3) adjacent cells worst SIR estimator
(4) OFCAC–MUD.

Blocks (1), (2) and (3) generate system performance parameters, which will be used as linguistic variables for block (4).

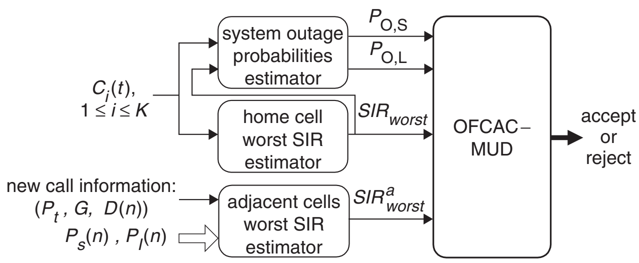

Fig. 2 *System model for the OFCAC–MUD*

2.1 System outage probabilities estimator

The system outage probabilities estimator generates two kinds of home cell system outage probability, long-term and short-term outage probability, denoted by $P_{O,L}$ and $P_{O,S}$, respectively. The outage probability is defined as $Pr\{SIR < SIR^*\}$, where SIR is provided by the home cell worst SIR estimator described in Section 2.2, and SIR^* is the SIR threshold set by the system. Short and long sliding windows are used to collect the SIR values of every user. Generally, the short-term outage probability reflects the instant fluctuations of system traffic, while the long-term outage probability indeed represents the average QoS of the system traffic. Traffic may violate the short-term outage criterion occasionally, but still satisfy the long-term outage criterion.

2.2 Home cell worst SIR estimator

The home cell worst SIR estimator produces the smallest SIR among all users at the home cell, denoted by SIR_{worst}. It first regenerates the ith user's signal, $\hat{S}^{(i)}(t)\hat{a}^{(i)}(t)$, from $C_i(t)$

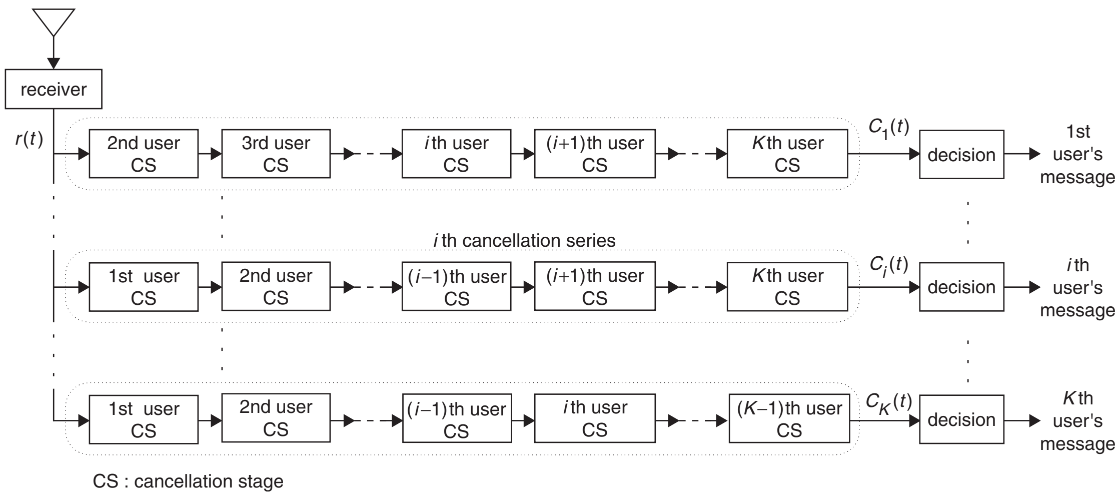

Fig. 1 *Typical SIC MUD for K users*

provided by the ith cancellation series of SIC MUD, $1 \le i \le K$. Then it derives the overall effective MAI of the ith user, $I_{eff}^{(i)}(t)$, by

$$I_{eff}^{(i)}(t) = C_i(t) - \hat{S}^{(i)}(t)\hat{a}^{(i)}(t) \quad (3)$$

The signal-to-interference ratio (SIR) of the ith user, $SIR^{(i)}$, can be yielded as

$$SIR^{(i)} = \frac{\int_T \left(\hat{S}^{(i)}(t)\hat{a}^{(i)}(t)\right)^2 dt}{\int_T \left(I_{eff}^{(i)}(t)\right)^2 dt} \quad (4)$$

where T is a unit time interval. Consequently, the SIR_{worst} at the home cell can be obtained by

$$SIR_{worst} = \min_i \{SIR^{(i)}\} \quad (5)$$

The signal power (numerator) and the interference power (denominator) of SIR_{worst}, denoted by P_s and P_I, respectively, are also provided to adjacent cells worst SIR estimators in adjacent cells.

2.3 Adjacent cells worst SIR estimator

The adjacent cells worst SIR estimator yields an output, SIR_{worst}^a, which denotes the worst SIR among all adjacent cells with the consideration of the new call's interference influence if the new call request is accepted. The adjacent cells worst SIR estimator obtains P_s and P_I of SIR_{worst} from the nth adjacent cell, denoted by $P_s(n)$ and $P_I(n)$. Then SIR_{worst}^a can be calculated by

$$SIR_{worst}^a = \min_n \left[\frac{P_s(n)}{P_I(n) + P_t G D^{-\gamma}(n)\Omega}\right] \quad (6)$$

where P_t is the transmitted power of the new call, G is the miscellaneous gains of transmission [12], $D(n)$ is the location distance between the new call and the BS of the nth adjacent cell, γ is the path-loss exponent decided by the terrain [13], and Ω is the random shadowing component. Note that the $D(n)$ can be obtained by some existing positioning systems such as GPS, and the $P_t G D^{-\gamma}(n)\Omega$ is the amount of the new call's interference effect on the nth adjacent cell. Because of the MUD adopted in the WCDMA system, SIR_{worst}^a is an important parameter in the call admission control. The performance of OFCAC–MUD for the WCDMA system with/without considering SIR_{worst}^a will be shown in Section 4.

3 OFCAC–MUD

The outage-based fuzzy call admission controller (OFCAC–MUD) takes $P_{O,L}$, $P_{O,S}$, SIR_{worst} and SIR_{worst}^a as its input linguistic variables. Term sets of fuzzy logic for these input variables are defined as $T(P_{O,L})$ = {Low (L), Medium (M), High (H)}, $T(P_{O,S})$ = {Low (L), Medium (M), High (H)}, $T(SIR_{worst})$ = {Low (L), Medium (M), High (H)}, and $T(SIR_{worst}^a)$ = {Low (L), Medium (M), High (H)}. Also, membership functions for terms of linguistic variables use the trapezoid function given by,

$$f(x; x_0, x_1, \alpha, \beta) = \begin{cases} \dfrac{x - x_0}{\alpha} + 1, & x_0 - \alpha \le x < x_0, \text{ when } \alpha > 0 \\ 1, & x_0 \le x \le x_1 \\ \dfrac{x_1 - x}{\beta} + 1, & x_1 < x \le x_1 + \beta, \text{ when } \beta > 0 \\ 0, & \text{otherwise} \end{cases} \quad (7)$$

Thus, membership functions for $T(P_{O,L})$, $T(P_{O,S})$, $T(SIR_{worst})$, and $T(SIR_{worst}^a)$ are set, respectively, by

$$\mu_L(P_{O,L}) = f(P_{O,L}; 0, a_L P_{O,L}^*, 0, (a_H - a_L)P_{O,L}^*) \quad (8)$$

$$\mu_M(P_{O,L}) = f(P_{O,L}; a_H P_{O,L}^*, a_H P_{O,L}^*, (a_H - a_L)P_{O,L}^*, (1 - a_H)P_{O,L}^*) \quad (9)$$

$$\mu_H(P_{O,L}) = f(P_{O,L}; a_H P_{O,L}^*, 1, (1 - a_H)P_{O,L}^*, 0) \quad (10)$$

$$\mu_L(P_{O,S}) = f(P_{O,S}; 0, b_L P_{O,S}^*, 0, (b_H - b_L)P_{O,S}^*) \quad (11)$$

$$\mu_M(P_{O,S}) = f(P_{O,S}; b_H P_{O,S}^*, b_H P_{O,S}^*, (b_H - b_L)P_{O,S}^*, (1 - b_H)P_{O,S}^*) \quad (12)$$

$$\mu_H(P_{O,S}) = f(P_{O,S}; b_H P_{O,S}^*, 1, (1 - b_H)P_{O,S}^*, 0) \quad (13)$$

$$\mu_L(SIR_{worst}) = f(SIR_{worst}; 0, SIR^*, 0, (c_L - 1)SIR^*) \quad (14)$$

$$\mu_M(SIR_{worst}) = f(SIR_{worst}; c_L SIR^*, c_L SIR^*, (c_L - 1)SIR^*, (c_H - c_L)SIR^*) \quad (15)$$

$$\mu_H(SIR_{worst}) = f(SIR_{worst}; c_H SIR^*, \infty, (c_H - c_L)SIR^*, 0) \quad (16)$$

$$\mu_L(SIR_{worst}^a) = f(SIR_{worst}^a; 0, SIR^*, 0, (d_L - 1)SIR^*) \quad (17)$$

$$\mu_M(SIR_{worst}^a) = f(SIR_{worst}^a; d_L SIR^*, d_L SIR^*, (d_L - 1)SIR^*, (d_H - d_L)SIR^*) \quad (18)$$

$$\mu_H(SIR_{worst}^a) = f(SIR_{worst}^a; d_H SIR^*, \infty, (d_H - d_L)SIR^*, 0) \quad (19)$$

The coefficients a_L, a_H, b_L and b_H are fuzzy set range ratios which are smaller than one. These values affect the ranges of their term sets and should be adjusted to optimise the system utilisation. For example, in order to strictly control the average QoS behaviours in the system, the ranges of Low and Medium in $P_{O,L}$ should be made small because $P_{O,L}$ indicates the genuine traffic load situation. However, $P_{O,S}$ only reflects the instant fluctuation of traffic instead of the average QoS of the system, so the ranges of Low and Medium in $P_{O,S}$ can be set wide. Their thresholds, denoted by $P_{O,L}^*$ and $P_{O,S}^*$, are the system QoS requirements. $P_{O,L}^*$ is usually set to be less than $P_{O,S}^*$ because it is reasonable to leave a larger space for variation tolerance over a short time interval. The other two linguistic variables, SIR_{worst} and SIR_{worst}^a, are the current worst SIRs of existing calls in home and adjacent cells. These two variables should not be lower than the threshold SIR^* given by the system. The coefficients c_L, c_H, d_L and d_H are the fuzzy set range ratios for SIR_{worst} and SIR_{worst}^a. These four coefficients are larger than one and also should be adjusted to achieve the best the system utilisation.

The output linguistic variable Z defined as the acceptability of the new call, has a term set given by $T(Z)$ = {Strongly Accepted (SA), Weakly Accepted (WA), Weakly Rejected (WR), Strongly Rejected (SR)}. Table 1 shows the fuzzy rule base, which is constructed according to expert domain knowledge. The notation X in this Table represents any terms of the linguistic variable. This rule table includes all possibilities of making proper admission decisions. Take rule 10 in Table 1 for example. If $P_{O,L}$ is with term Low, $P_{O,S}$ is with term Medium and SIR_{worst} and SIR_{worst}^a are with term High, it means the system still has room for a new call, and Z would be with term

Table 1: Rule base of the fuzzy call admission controller

Rule	$P_{O,L}$	$P_{O,S}$	SIR_{worst}	SIR^{a}_{worst}	Z	Rule	$P_{O,L}$	$P_{O,S}$	SIR_{worst}	SIR^{a}_{worst}	Z
1	L	L	H	H	SA	23	L	H	M	M	WR
2	L	L	H	M	WA	24	L	H	M	L	SR
3	L	L	H	L	WR	25	L	H	L	X	SR
4	L	L	M	H	WA	26	M	L	M	H	WA
5	L	L	M	M	WR	27	M	L	M	M	WR
6	L	L	M	L	SR	28	M	L	M	L	SR
7	L	L	L	H	WR	29	M	L	L	H	WR
8	L	L	L	M	WR	30	M	L	L	M	WR
9	L	M	L	L	SR	31	M	L	L	L	SR
10	L	M	H	H	SA	32	M	M	M	H	WA
11	L	M	H	M	WA	33	M	M	M	M	WR
12	L	M	H	L	WR	34	M	M	M	L	SR
13	L	M	M	H	WA	35	M	M	L	H	WR
14	L	M	M	M	WR	36	M	M	L	M	WR
15	L	M	M	L	SR	37	M	M	L	L	SR
16	L	M	L	H	WR	38	M	H	M	H	WR
17	L	M	L	M	WR	39	M	H	M	M	WR
18	L	M	L	L	SR	40	M	H	M	L	SR
19	L	H	H	H	WA	41	M	H	L	X	SR
20	L	H	H	M	WR	42	H	M	M	X	WR
21	L	H	H	L	WR	43	H	M	L	X	SR
22	L	H	M	H	WA	44	H	H	L	X	SR

Strongly Accepted. Also take rule 37 for example. If SIR_{worst} and SIR^{a}_{worst} are with term Low, which means the system should tend to reject the new call, thus Z would be with term Strongly Rejected.

Finally, the fuzzy inference algorithm for the OFCAC–MUD adopts the max–min inference method [14], and the defuzzification scheme used here is the centre of the area defuzzification method [11].

4 Simulation results

In the simulations, the channel of the WCDMA system suffers intercell MAI, intracell MAI, AWGN noise, log-normal shadowing [15] and multipath fading; the multipath fading adopts the model of case 2 in [16]. The path-loss exponent γ is 4.35 [13]. The spreading factor of the WCDMA in uplink is 64. The incoming call could be new or handover. The arrival of new calls is modelled as a Poisson with a mean arrival rate λ. Two types of traffic are considered; voice and data. The distribution of voice-call holding time is exponential with a mean of 50 s. The data packet length is also modelled as an exponential distribution with a mean of 110 bytes. Data call holding time is also exponentially distributed since the transmission rate and spreading factor of each channel are fixed in the simulations. The traffic intensity is defined as λ/μ, where $1/\mu$ is the mean call holding time of a voice or a data call. The simulations also consider the soft-handover. A soft-handover user chooses at most 3 BSs in its active set selection. The system adopts selection diversity [12] for the soft-handover. The number of outgoing handover calls in a call duration is also assumed to be 10% proportional to the number of users in a cell. Users are also assumed to be uniformly distributed in cells, and the probabilities of handover to all adjacent cells are equal. Furthermore, the 40% activity factor for a voice call is used [1]. The sampling interval for the outage probability is 5 μs, and the sliding window size for long-term (short-term) outage probability is 100 K (10 K). Three QoS requirements are set to be $P^{*}_{O,L} = 10^{-3}$, $P^{*}_{O,S} = 10^{-2}$ and $SIR^{*} = -17$ dB.

We consider a seven-cell region as a 'cluster' and SIR-based CAC for comparisons. Here the SIR-based CAC is implemented to make an admission decision for a new call according to the currently estimated SIR of the system. If the system SIR is higher than SIR^{*}, then the call will be admitted; otherwise, the call will be rejected. In the implementation, parameters of SIR-based CAC, such as the margin of residual capacity [17] and the margin for handover [18] to tolerate the misjudged admissions, are finely tuned to maximise the system utilisation and QoS-guarantee regions. Both perfect power control and no power control situations are investigated. Also, two cases of traffic load distribution; homogeneous and hotspot cases, are investigated. The homogeneous case has all cells given with the same traffic intensity, while the hotspot case has the traffic load in the central cell set to be five times heavier than that in other cells. The following scenarios are observed. In the homogeneous environment there are:

(i) OFCAC–MUD without PC

(ii) OFCAC–MUD with perfect PC

(iii) OFCAC using RAKE receiver (OFCAC–RAKE) with perfect PC

(iv) SIR-based CAC using MUD (SIR-based CAC–MUD) without PC

(v) SIR-based CAC–MUD with perfect PC

(vi) SIR-based CAC–RAKE with perfect PC

In the hotspot environment, there are:

(vii) OFCAC–MUD without PC

(viii) SIR-based CAC–MUD without PC.

Figures 3*a* and 3*b* present the maximum long-term and short-term outage probabilities against the traffic intensity, respectively. The Figures reveal that when OFCAC is adopted (scenarios (i), (ii), (iii) and (vii)), the QoS requirements can be always guaranteed. The long-term and short-term outage probabilities of OFCAC grow as the traffic intensity increases, and eventually saturate to $P^*_{O,L}$ and $P^*_{O,S}$ requirements, respectively, in both homogeneous and hotspot environments. On the contrary, when SIR-based CAC is adopted (scenarios (iv), (v), (vi) and (viii)), the QoS requirements are violated. It is because fuzzy logic technology provides a robust mathematical method for admission control in realistic environments [19–21], especially when the mathematical model of the process is too complicated to find. By adopting expert systems to set up the bounded admission rules, the fuzzy approach has the capability to adapt to the dynamic and bursty traffic in the multimedia environment to make the best decisions. Another reason is that we use outage probabilities instead of the instant SIR values. When the system is at heavy load, it is possible to encounter the moments when some users are inactive and thus the instant SIR values are low; then the SIR-based CAC may accept some call requests and the violation of QoS requirements occurs. However, the outage-based CAC can prevent the misjudgment because the outage probability is the average of many SIR values.

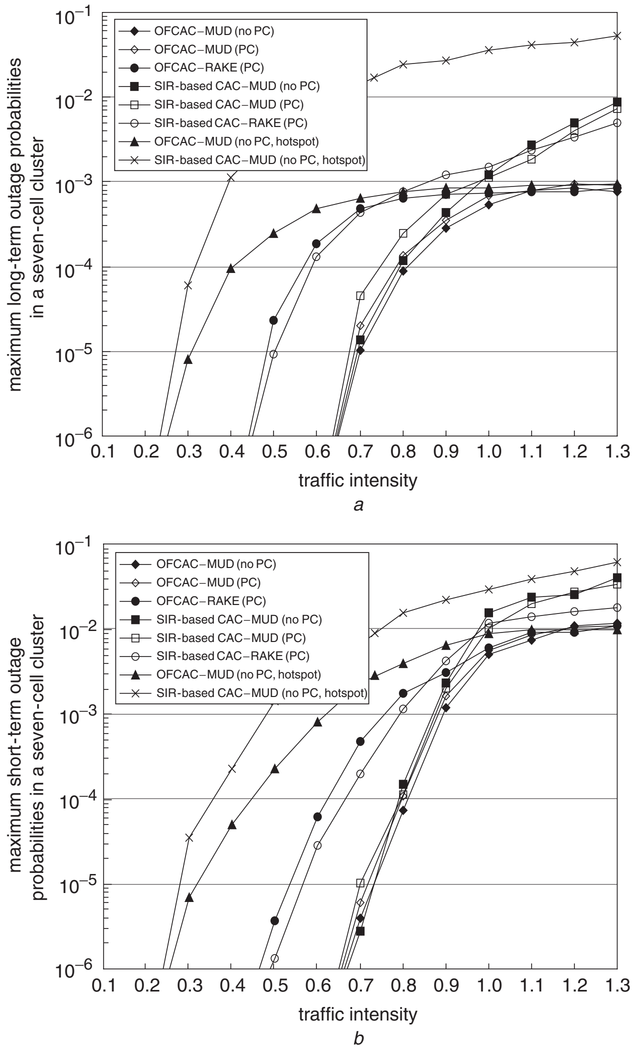

Fig. 3 *Seven-cell cluster*
a Maximum long-term outage probabilities
b Maximum short-term outage probabilities

Figure 4 presents the average number of using channels against the traffic intensity. It shows that, in homogeneous environment, the maximum capacity of OFCAC–MUD with perfect PC is 225 channels in a cluster, which is about 51% higher than the capacity (about 149 channels) of SIR-based CAC–RAKE with perfect PC before QoS violation (traffic intensity $\leq$ 0.83). The improvement is brought about by the contributions from SIC MUD and OFCAC. SIC MUD obtains an improvement in capacity by 36.4% as compared to OFCAC–RAKE with perfect PC. The reason is that SIC MUD cancels the home cell's MAI significantly. With perfect PC, OFCAC obtains an improvement in capacity by 5.6% as compared to SIR-based CAC–MUD with perfect PC. Without PC, OFCAC obtains an improvement in capacity by 6.7% as compared to SIR-based CAC–MUD without PC. This is because fuzzy logic techniques have the reasoning capability for resource monitoring and management and takes more aggressive strategies in CAC.

It can also be found that OFCAC–MUD without PC in scenario (i) can accommodate 254 channels in a cluster. The capacity is improved by 12.9% as compared to OFCAC–MUD with perfect PC in scenario (ii). It also has the improvements in capacity by 70.5%, 53.9%, and 19.3% as compared to SIR-based CAC–RAKE with PC (scenario (vi)), OFCAC–RAKE with PC (scenario (iii)) and SIR-based CAC–MUD with PC (scenario (v)), respectively. This indicates that PC may not be suitable in the application of SIC MUD. The reason is that the difference among the users' signals of the received signal for SIC MUD without PC would be more significant than that for SIC MUD with PC. Therefore, SIC MUD without PC can regenerate these MAI signals for cancellation more effectively than SIC MUD with PC. Consequently, few errors are generated in the case without PC. Note that SIC MUD cancels the MAI of received signals in order.

For the hotspot environment, the average number of using channels in OFCAC–MUD without PC (scenario (vii)) are much fewer than those of other cases in a homogeneous environment. The OFCAC–MUD without PC accommodates 103 channels, while the SIR-based CAC–MUD without PC accommodates 82 channels before QoS violation (traffic intensity $\leq$ 0.35). We also simulate the following two scenarios; OFCAC–MUD with perfect PC and SIR-based CAC–MUD with perfect PC. Their average

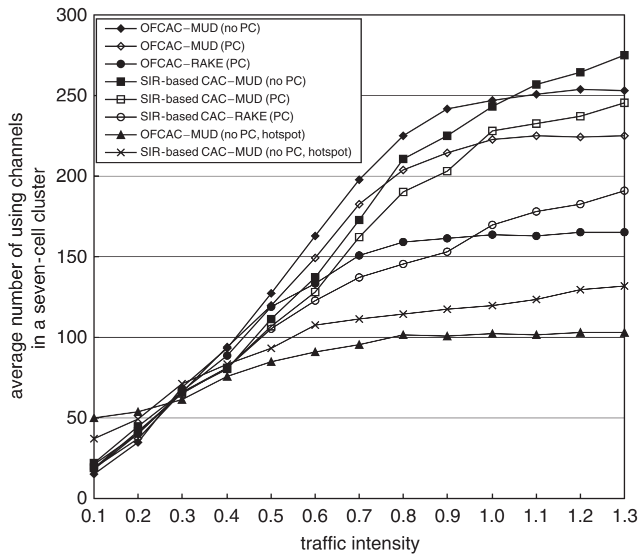

Fig. 4 *Average number of using channels in a seven-cell cluster*

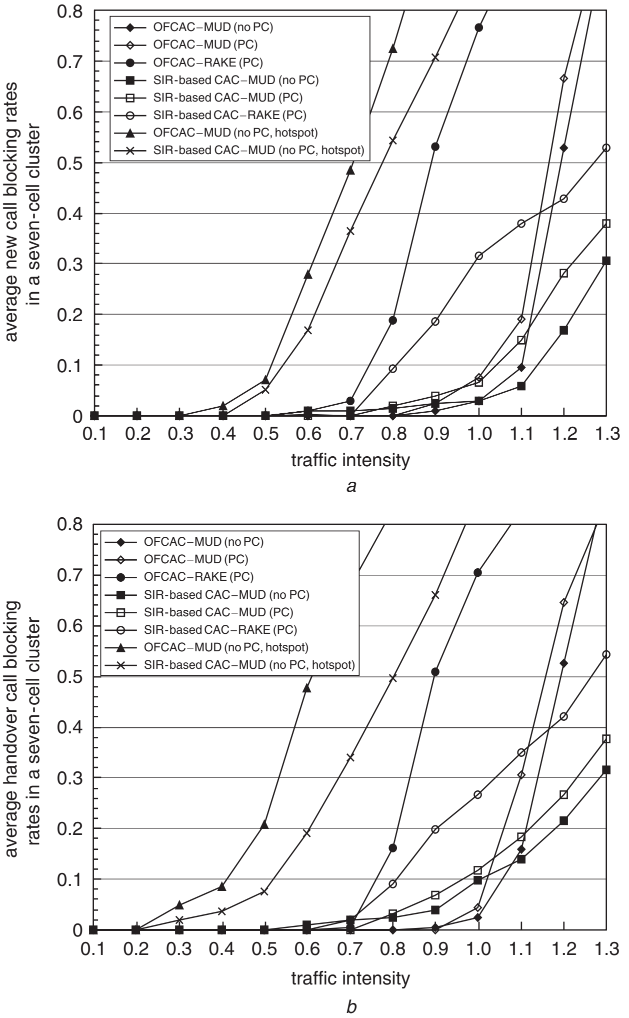

Fig. 5 *Seven-cell cluster*
a Average new call blocking rates
b Average handover call blocking rates

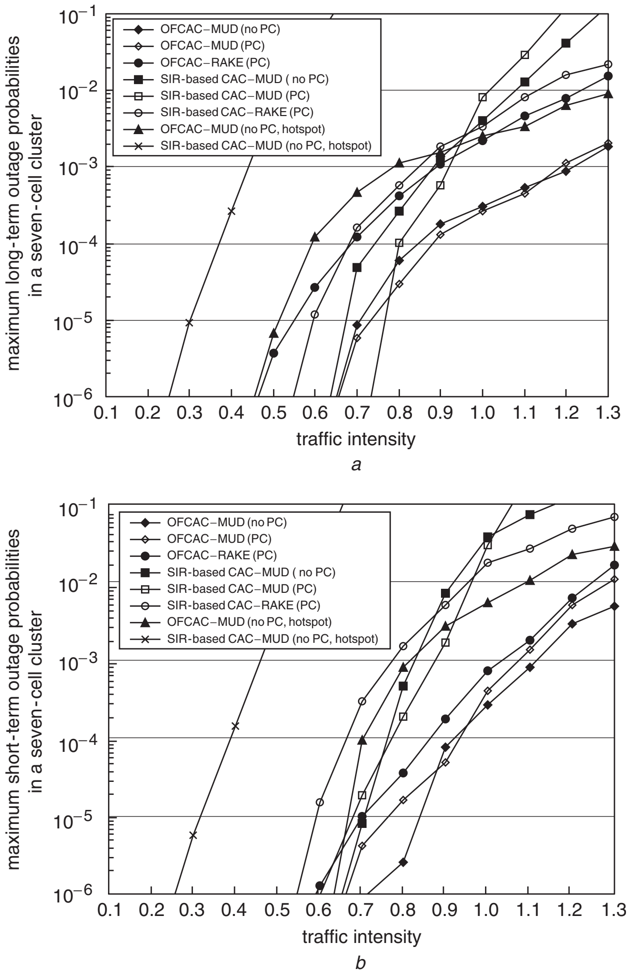

Fig. 6 *Seven-cell cluster without considering SIR^a_{worst}*
a Maximum long-term outage probabilities
b Maximum short-term outage probabilities

numbers of using channels are fewer than those of OFCAC–MUD without PC and SIR-based CAC–MUD without PC, which are quite similar to the phenomena which happened in a homogeneous environment. The results reveal again that OFCAC–MUD still has better utilisation than SIR-based CAC–MUD in the hotspot case. Besides, it means that OFCAC can be applied in dynamic and bursty traffic environment.

Figures 5*a* and 5*b* present the new call and handover call blocking rates, respectively. Both Figures reveal that, when the traffic intensity is smaller than 1.0, OFCAC–MUD without PC has the lowest blocking rates. When the traffic intensity is greater than 1.0, OFCAC–MUD with PC has higher blocking rates than SIR-based CAC–MUD and SIR-based CAC–RAKE because the SIR-based CAC has the risk to violate the QoS requirements and continues to accept call requests.

Figures 6*a* and 6*b* depict the maximum long-term and short-term outage probabilities, respectively, for the WCDMA system with SIC MUD but without considering the adjacent cells worst SIR, SIR^a_{worst}. It is found that the two outage probability requirements are greatly violated for all scenarios under heavy traffic intensity conditions. This verifies the fact, stated previously, that the adjacent cell SIR plays an essential role in call admission control for WCDMA systems with SIC MUD.

5 Concluding remarks

The paper proposes an outage-based fuzzy call admission controller with multiuser detection (OFCAC–MUD) for WCDMA systems. The OFCAC–MUD considers the short-term outage probability, the long-term outage probability, the home-cell worst SIR, and the adjacent cells worst SIR including the interference influence of the new call request as the input linguistic variables. Simulation results show that OFCAC–MUD without PC achieves a significant improvement by 70.5% in system capacity as compared to SIR-based CAC–RAKE with PC. Also, OFCAC–MUD without PC can offer more channels for users, by an amount of 12.9%, than OFCAC–MUD with perfect PC. The reason is that, in the case of perfect PC, the phenomenon of the equal power signals received by SIC MUD will degrade the discrimination of interference of SIC MUD, and then results in the lower cancellation effect. Moreover, OFCAC–MUD can always keep QoS guaranteed, while SIR-based CAC–MUD or SIR-based CAC–RAKE may violate the QoS requirements. Besides, whenever without considering the intercell interference in CAC for WCDMA systems with MUD, the QoS violation would occur at heavy traffic intensity even if OFCAC is adopted. This illustrates that it is essential to take the intercell interference into account when making call admission decisions. The OFCAC–MUD, combining the capabilities of the fuzzy logic system and multiuser detection for call admission control, indeed achieves capacity improvement and QoS guarantee for WCDMA systems.

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