

# A Handover Scheme Towards Downlink Traffic Load Balance in Heterogeneous Cellular Networks

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**Abstract**—Traffic load balance is among the most crucial issues in heterogeneous cellular networks (HCNs), which can lead to much higher throughput, better user fairness and larger coverage for HCNs. In this paper, we consider the user association problem in HCNs and design a handover scheme for traffic load balancing among macro and femto cells. Three types of handover factors are delicately designed with different objectives focusing on throughput or fairness or trying to balance the both. Correspondingly, three typical resource schedulers are adopted to improve the desired performance. The performance of the proposed scheme is evaluated by simulations and reveals considerable improvement in comparison with the maximum biased-received-power association scheme, especially the data rates of the low-rate users. The impact of different base station and user distributions on the balancing results is also analyzed.

**Index Terms**— Heterogeneous cellular networks, traffic load balance, user association, user fairness.

## I. INTRODUCTION

Data rates of wireless communications have increased dramatically during the last decade and are expected to rise exponentially in the next one. To meet the capacity requirement with minimum cost of deployment of base stations, wireless cellular networks have been trending towards increasing heterogeneity, which comprise conventional cellular networks overlaid with various lower-power access points, such as femtocells and picocells [1]–[3]. Heterogeneous cellular networks (HCNs) provide a more flexible, specific and economical deployment of access points, making the expansion of indoor and cell-edge coverage much simpler [4]. User association is a significant issue for HCNs, which can influence the throughput and fairness of the network [5].

The most conventional user association approach is that each user accesses the base station (BS) which provides the highest received power or signal-to-interference-plus-noise ratio (SINR). This method helps improving the channel condition of every user, but may lead to unbalanced traffic among BSs and tiers. In the literature, there are some works focusing on the user association problem towards traffic balancing in HCNs, which can be broadly classified into two groups, offline strategies and online strategies. The offline strategies attempt to solve the user association problem within a whole network using optimization methods. However, the optimal solution is inaccessible when the number of nodes is large. Therefore, some suboptimal methods are proposed to improve the data rate or cell coverage [6]–[8].

This paper mainly focuses on the online strategy, which adjusts user access choices based on a connected network according to a given objective. The online strategies are more practical in real networks since only a small amount of users may change their access points. In contrast, offline strategies require all users updating their associated BSs whenever a new user comes about or the user locations change. The online approaches for traffic load balancing in HCNs are still seldom investigated. The user satisfaction and movement are taken into account in [9], where the author designs a weighting function for handover with the aim of traffic balancing in femtocells.

The optimization of cell range is another main type of traffic balancing methods besides the user-oriented association discussed above. The biased association and cell breathing are feasible ways to balance the traffic load in different tiers by controlling the BS coverage. In cell breathing techniques, the transmit power is adjusted to dynamically change the cell size depending on the traffic load [10]–[12]. The biased association is a simple and effective cell range expansion method to balance the load among high and low power BSs [2], [3]. Bias factors control different BSs associating with the appropriate amount of users and traffic load [13]. However, the nonuniform distributions of BSs and users in HCNs can diminish the effect of this approach. Considering its simplicity and feasibility, we employ the maximum biased-received-power (BRP) scheme as a reference to compare it with our proposed load balancing scheme.

In this paper, we propose a handover scheme with the aim of better traffic load balance in HCNs. Throughput, user fairness or balancing the both are three objectives of concern. Three different resource schedulers are adopted when designing our handover scheme, namely, max-min fairness (Max-Min), max carrier-to-interference power ratio (Max C/I), and proportional fairness (PF), which have diverse objectives. The Max-Min scheduler aims at guaranteeing fairness among users while Max C/I maximizes the overall throughput of a cell. PF is a compromise scheduler balancing efficiency and fairness. Three types of handover factors are formulated and used for controlling user handover in order to improve the user data rate and fairness.

The performance of the proposed load balancing scheme is evaluated by simulations, in which different distributions of the BS and user locations are adopted. We consider the pure random point distribution, as well as more realistic ones, such

as cluster distributions of users around hotspots and hexagonal deployment of macrocells. We compare the throughput and fairness performance of our proposed load balancing scheme with the maximum BRP scheme. Simulation results indicate the considerable gains from our proposed scheme and reveal the impact of various user and BS distributions. The data rates of the low-rate users can also be greatly enhanced in comparison with the maximum BRP scheme.

The rest of this paper is organized as follows. We first outline the downlink HCN model in Section II. The traditional user association scheme is introduced in Section III. In Section IV, a traffic load balancing handover scheme is proposed. Section V presents the simulation results of the proposed scheme. Finally, conclusions are drawn in Section VI.

## II. DOWNLINK HCN MODEL

We consider a downlink HCN based on orthogonal frequency division multiple access (OFDMA). The HCN includes  $N$  tiers of overlapping networks which have multiple cells with different densities and transmit power levels. Denote the set of the BSs in the  $n$ -th tier as

$$\mathbf{B}_n = \left\{ b_n \mid b_n = b_n^{(1)}, \dots, b_n^{(M_n)} \right\}, 1 \leq n \leq N, \quad (1)$$

where  $M_n$  is the number of BSs in the  $n$ -th tier. Define the set of all the BSs in the HCN as

$$\mathbf{B} = \bigcup_{1 \leq n \leq N} \mathbf{B}_n. \quad (2)$$

Let  $\mathbf{U} = \{u \mid u = 1, \dots, U\}$  be the index set of the user terminals. In this paper, open access is assumed, which means that a user can access any one tier of the HCN.

The cells on all the tiers share the same frequency band, which is divided into  $K$  resource blocks (RBs), denoted as  $k \in \{1, \dots, K\}$ . In each frame, BSs distribute RBs to their connected users for downlink transmission by a given resource scheduler, i.e., Max-Min, Max C/I or PF.

The user association is based on the received power of each user. The power of the received signal of user  $u$  on RB  $k$  from BS  $b_n$  is given as

$$P_{u,b_n,k} = \left( \frac{P_n}{K} \right) \left( \frac{D_{u,b_n}}{d_n} \right)^{-\alpha_n} L_n \|h_{u,b_n,k}\|^2, b_n \in \mathbf{B}_n, \quad (3)$$

where  $(P_n/K)$  is the transmit power per RB of BSs in the  $n$ -th tier,  $L_n$  is the path loss at a reference distance  $d_n$  (typically about  $(4\pi/\nu)^{-2}$  for  $d_n = 1$  m, where  $\nu$  denotes the carrier wavelength),  $D_{u,b_n}$  is the distance between user  $u$  and BS  $b_n$ ,  $\alpha_n$  is the path loss exponent of the tier  $n$  users.  $h_{u,b_n,k}$  is the independent Rayleigh fading channel gain of UE  $u$  on RB  $k$  from BS  $b_n$ , modeled as  $h_{u,b_n,k} \sim \mathcal{CN}(0, 1)$ <sup>1</sup> with  $\mathbb{E} \left[ \|h_{u,b_n,k}\|^2 \right] = 1$ . Therefore, the power gain of the Rayleigh fading channel, i.e.,  $\|h_{u,b_n,k}\|^2$ , is exponentially distributed with a unit mean value. Thus,  $P_{u,b_n,k}$  can be modeled as a

<sup>1</sup>A circularly symmetric complex Gaussian random value  $x$  with mean  $\pi$  and covariance  $r$  is denoted by  $x \sim \mathcal{CN}(\pi, r)$ .

random variable with exponential distribution. The mean value of  $P_{u,b_n,k}$  is

$$\mathbb{E} [P_{u,b_n,k}] = \left( \frac{P_n}{K} \right) \left( \frac{D_{u,b_n}}{d_n} \right)^{-\alpha_n} L_n \triangleq 1/\lambda_{u,b_n,k}, \quad (4)$$

where  $\lambda_{u,b_n,k}$  represents the parameter of the exponential distribution of the received power.

In the interference-limited deployment, the effect of noise is neglected [14]. Thus the wireless transmission performance is mainly influenced by signal-to-interference-ratio (SIR). When user  $u$  is distributed RB  $k$  by a BS  $b$ , the SIR is calculated as

$$\Phi_{u,b,k} = \frac{P_{u,b,k}}{P_{u,k}^{(\mathbf{I}_u)}} = \frac{P_{u,b,k}}{\sum_{i \in \mathbf{I}_u} P_{u,i,k}}, \quad (5)$$

where  $\mathbf{I}_u$  is the interfering BS set of user  $u$ , including the interference sources from multiple tiers, and  $P_{u,k}^{(\mathbf{I}_u)}$  is the sum of the interference signal power from  $\mathbf{I}_u$ . Then, we can calculate the probability distribution function (PDF) of  $\Phi_{u,b,k}$  as

$$\begin{aligned} f_{\Phi_{u,b,k}}(\phi) &= \left[ \sum_{i \in \mathbf{I}_u} \frac{(\lambda_{u,b,k}\phi + \lambda_{u,i,k})^{-2}}{\prod_{j \in \mathbf{I}_u, j \neq i} (\lambda_{u,j,k} - \lambda_{u,i,k})} \right] \lambda_{u,b,k} \prod_{i \in \mathbf{I}_u} \lambda_{u,i,k}. \end{aligned} \quad (6)$$

The cumulative distribution function (CDF) of  $\Phi_{u,b,k}$  is further derived as

$$\begin{aligned} F_{\Phi_{u,b,k}}(\phi) &= \text{P} \{ \Phi_{u,b,k} < \phi \} \\ &= \left[ \sum_{i \in \mathbf{I}_u} \frac{\lambda_{u,i,k}^{-1} - (\lambda_{u,b,k}\phi + \lambda_{u,i,k})^{-1}}{\prod_{j \in \mathbf{I}_u, j \neq i} (\lambda_{u,j,k} - \lambda_{u,i,k})} \right] \prod_{i \in \mathbf{I}_u} \lambda_{u,i,k}. \end{aligned} \quad (7)$$

The derivation processes are not given due to space limitation.

The achievable bitrate of each orthogonal frequency division multiplexing (OFDM) symbol is calculated according to the Shannon capacity, denoted as  $r_s(\phi) = \log_2(1 + \phi)$ , which is a function of SIR. Assuming relatively flat fading within each RB, the achievable data rate of one RB is

$$\hat{r}(\phi) = \frac{N_{sc} S_{eff}}{T_s} r_s(\phi), \quad (8)$$

where  $N_{sc}$  is the number of subcarriers in each RB,  $S_{eff}$  is the number of effective OFDM symbols of one frame in the time domain, and  $T_s$  is the frame time duration [15]. Thus, the average achievable data rate of RB  $k$  distributed to user  $u$  by BS  $b$  can be calculated as

$$\hat{R}_{u,b,k} = \int_0^\infty \hat{r}(\phi) f_{\Phi_{u,b,k}}(\phi) d\phi. \quad (9)$$

## III. THE MAXIMUM BRP ASSOCIATION SCHEME

The channel quality information (CQI) of each user is necessary for the determination of user association. Due to the fast fading property of the radio channel, the detected CQI is transient. We estimate the average received power by the statistical result of CQI, which are used for the user

association control. In order to obtain a higher SIR, a user can access the strongest BS in terms of its averaged biased-received-power [13], which is defined as

$$P_{u,b_n} = \beta_n \sum_{k=1}^K \mathbb{E}[P_{u,b_n,k}], \quad (10)$$

where  $P_{u,b_n,k}$  is the actual received power on RB  $k$  of user  $u$  from BS  $b_n$ , and  $\beta_n$  is the bias factor of tier  $n$ , which controls the trend of accessing the cells in tier  $n$ . The maximum BRP association scheme is a simple way to control the traffic load in each tier and can be employed as a benchmark for the proposed handover scheme [13].

#### IV. THE TRAFFIC LOAD BALANCING HANDOVER SCHEME

The maximum BRP association scheme helps users obtaining the highest SIR expectation based on the detected CQI. However, the unbalanced traffic load caused by the inhomogeneity of BS and user distributions is not considered. It is possible that some users in a crowded cell suffer from shortage of radio resources and low data rates though their SIRs are high.

To better balance the traffic load in HCNs, we proposed a user handover scheme with different objectives focusing on throughput or fairness or trying to balance the both. Three handover factors are designed to control user handovers among different tiers and cells so that the traffic load can be balanced according to relative objectives. In order to improve the corresponding performances, we adopt three typical resource schedulers, namely, Max C/I, Max-Min and PF, and analyze their features while designing the handover factors. These resource schedulers can also be used combined with the maximum BRP scheme. However, the characteristics of the resource schedulers are not considered in maximum BRP. Thus, various schedulers can only affect the user transmission per cell but cannot influence the BRP-based user association.

##### A. The Handover Scheme Based on the Max-Min Scheduler

With the aim of fairness among users, Max-Min is often adopted for resource allocation. A RB is allocated to the user with the lowest average data rate in a cell in order to enhance its bitrate to catch up with other users. We propose the handover scheme based on the Max-Min scheduler to reduce the bitrate difference among users as follows.

With the Max-Min scheduler, we estimate the average data rate of all users in a cell with the assumption that their data rates are approximately identical [16], which can be calculated as

$$\bar{R}^{(1)}(\mathbf{U}_b) = \left[ \sum_{u \in \mathbf{U}_b} \left( \sum_{k=1}^K \hat{R}_{u,b,k} \right)^{-1} \right]^{-1}, \quad (11)$$

where  $\hat{R}_{u,b,k}$  is the expected achievable data rate as in (9), and  $\mathbf{U}_b$  is the set of the users associated with cell  $b$ . Denote the user with the minimum actual average bitrate in cell  $b$  as

$$\tilde{u}(b) = \arg \min_{u \in \mathbf{U}_b} \{R_{u,b}\}. \quad (12)$$

Then, we design the handover factor of each user switching from its current cell  $b$  to cell  $i$  with the Max-Min scheduler as in (13), which is the expected enhancement of the joint lower bound of the considered cells.  $R_{\tilde{u}(b),b}$ ,  $R_{\tilde{u}(i),i}$  are the current minimum average user data rate in cell  $b$  and  $i$ , respectively.

Only when  $\eta_{u,i}^{(1)} > 0$ , the handover operation is helpful to improve the lower bound of the user data rate. We choose the neighbor cell with the maximum  $\eta_{u,i}^{(1)}$  as the target cell that user  $u$  intends to switch to, i.e.,

$$\hat{i}_u^{(1)} = \arg \max_{i \in \mathbf{I}_u} \left\{ \eta_{u,i}^{(1)} \right\}, \quad (14)$$

$$\hat{\eta}_u^{(1)} = \max_{i \in \mathbf{I}_u} \left\{ \eta_{u,i}^{(1)} \right\}. \quad (15)$$

Of all the users, we choose the only one with the largest Max-Min handover factor  $\hat{\eta}_u^{(1)} > 0$ ,  $u \in \mathbf{U}$ , and execute its handover operation in each frame. A user cannot continuously change its serving cell and is assumed to be able to transfer to another cell only when enough CQI has been collected for the calculation and judgement. So, only when a user has stayed in a cell for more than the time length of  $T_e$  frames, it is entitled to switch according to the handover policy.

##### B. The Handover Scheme Based on the Max C/I Scheduler

The Max C/I scheduler always distributes a RB to the user with the highest SIR on the RB. This approach helps improving the whole system throughput but lacks fairness among users because the users with poor channel states are starved of RBs. Considering the objective of maximizing the throughput of the whole network, we design the handover factor of each user switching from its current cell  $b$  to cell  $i$  with the Max C/I scheduler as in (16), which is the difference between the sum rate before and after a potential handover.

When  $\eta_{u,i}^{(2)} > 0$ , the handover can help to improve the whole system throughput. Thus, we select the neighbor cell with the maximum  $\eta_{u,i}^{(2)}$  as the potential target cell of user  $u$ . Among all the users, we choose the user with the largest Max C/I handover factor and transfer it to the corresponding cell.

##### C. The Handover Scheme Based on the PF Scheduler

PF aims at maintaining a balance between two competing interests, i.e., maximizing the whole throughput while at the same time keeping relatively fairness according to the channel condition of every user. With the same purpose, we design the handover factor based on the PF scheduler as follows.

Assuming ergodicity of the radio channel, the average data rate of user  $u$  can be calculated as in (17) according to the equation (14) in [17]. The PF scheduler is proved that can achieve the maximum sum of logarithm of user data rates in a single cell [16]. Based on this characteristic, we design the handover factor of user  $u$  transferring from its current cell  $b$  to cell  $i$  as follows,

$$\begin{aligned} \eta_{u,i}^{(3)} = & \sum_{v \in \mathbf{U}_b/u} \log \bar{R}_{v,b}^{(3)}(\mathbf{U}_b/u) + \sum_{v \in \mathbf{U}_i \cup u} \log \bar{R}_{v,i}^{(3)}(\mathbf{U}_i \cup u) \\ & - \sum_{v \in \mathbf{U}_b} \log R_{v,b} - \sum_{v \in \mathbf{U}_i} \log R_{v,i}, \quad i \in \mathbf{I}_u. \end{aligned} \quad (18)$$

$$\eta_{u,i}^{(1)} = \min \left\{ \bar{R}^{(1)}(\mathbf{U}_b/u), \bar{R}^{(1)}(\mathbf{U}_i \cup u) \right\} - \min \{ R_{\bar{u}(b),b}, R_{\bar{u}(i),i} \}, \quad i \in \mathbf{I}_u \quad (13)$$

$$\begin{aligned} \eta_{u,i}^{(2)} = & \sum_{v \in \mathbf{U}_b/u} \sum_{k=1}^K \int_0^\infty f_{\Phi_{v,b,k}}(\phi) \hat{r}(\phi) \prod_{w \in \mathbf{U}_b/\{u,v\}} F_{\Phi_{w,b,k}}(\phi) d\phi \\ & + \sum_{v \in \mathbf{U}_i \cup u} \sum_{k=1}^K \int_0^\infty f_{\Phi_{v,i,k}}(\phi) \hat{r}(\phi) \prod_{w \in \mathbf{U}_i \cup u/v} F_{\Phi_{w,i,k}}(\phi) d\phi - \sum_{v \in \mathbf{U}_b} R_{v,b} - \sum_{v \in \mathbf{U}_i} R_{v,i}, \quad i \in \mathbf{I}_u \end{aligned} \quad (16)$$

$$\bar{R}_{u,b}^{(3)}(\mathbf{U}_b) = \sum_{k=1}^K \int_0^\infty \hat{r}(\phi) f_{\Phi_{u,b,k}}(\phi) \prod_{v \in \mathbf{U}_b/u} F_{\Phi_{v,b,k}} \left( \hat{r}^{-1} \left[ \hat{r}(\phi) \bar{R}_{v,b}^{(3)} / \bar{R}_{u,b}^{(3)} \right] \right) d\phi \quad (17)$$

TABLE I  
SIMULATION PARAMETERS

Parameter	Value
Number of tiers ( $N$ )	2
BS Transmit power ( $P_1, P_2$ )	(43, 23) dBm
Path loss exponent ( $\alpha_1, \alpha_2$ )	(3.5, 4)
Carrier frequency	2.0 GHz
Bandwidth	5 MHz
Number of RBs ( $K$ )	25
Number of subcarriers in each RB ( $N_{SC}$ )	12
Number of effective OFDM symbols per frame ( $S_{eff}$ )	10
Frame duration ( $T_s$ )	1 ms
Minimum interval of a user's handover ( $T_e$ )	1000 ms

Similar to the handover policy with the Max-Min and Max C/I schedulers, let  $\eta_{u,i}^{(3)} > 0$  be the basic prerequisite. We choose the neighbor cell with the maximum  $\eta_{u,i}^{(3)}$  as the target cell that user  $u$  intends to access. Then, we execute the handover operation of the user with the largest factor.

## V. SIMULATION RESULTS AND ANALYSIS

We consider a two-tier OFDM-based HCN for the simulations with the configuration parameters listed in Table I. Femtocells in tier 2, which have relatively lower transmit power and smaller coverage, are randomly located overlapping with macrocells in tier 1. Three different cases of BS and user distributions are assumed as shown in Table II. In case 1 and 2, macro BSs are randomly located according to the Poisson point process (PPP) with the density  $\rho_1$  in a circle area. In case 3, there are 7 macrocells arranged in the hexagonal grid pattern, i.e., one in the center and six around it. The femtocell BSs are all PPP-distributed with a density of  $4\rho_1$  in the three cases. Users are also PPP-distributed in case 1 and 3, while half of the users are cluster-distributed around femtocells in order to simulate hotspots in case 2. We adopt Matern-cluster process for modeling the user cluster distribution.

Fig. 1 presents the average user data rate in the case 1 scenario with the maximum BRP association scheme. The bias factor of macrocell is 0 dB and  $\beta_2$  varies as in the figure, which controls the user preference for accessing the femtocell BSs. With the increase in  $\beta_2$ , more users are associated with femtocells, leading to heavier traffic load and decline of their

TABLE II  
BS AND USER DISTRIBUTIONS

Distribution	Case 1	Case 2	Case 3
Macro BS	PPP	PPP $\rho_1 = 1 / (250^2 \pi) \text{ m}^{-2}$ in a circle (radius = 750 m)	Hexagonal grid 7 cells ISD = 500 m
Femto BS	PPP	PPP $\rho_2 = 4\rho_1$	PPP
User	PPP	50% PPP in macrocells + 50% Matern-cluster in femtocells (radius = 20 m)	PPP
		$\rho_U = 20\rho_1$	

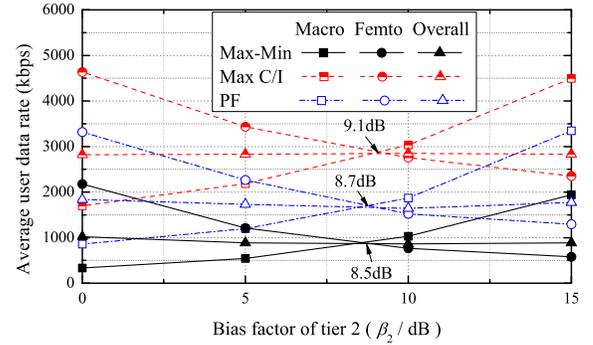
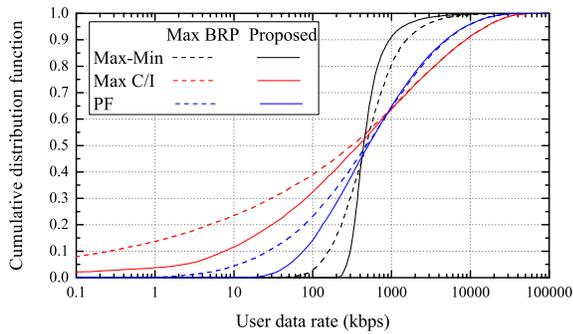


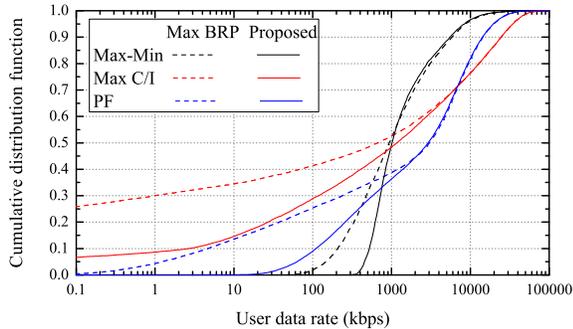
Fig. 1. Average user data rate with the maximum BRP scheme in case 1.

data rates. Meanwhile, the fewer users in macrocells obtain more RBs per user. Therefore, the user data rate in macrocell increases as using higher  $\beta_2$ . As shown in Fig. 1, the variation of the average data rate of the overall users is very slight as the bias factor changes. However, an appropriate bias factor can help obtaining balanced traffic load in each tier, i.e., the same level of average user data rate. With different resource schedulers, the optimal bias factors for traffic balance are diverse as noted in the figure. The Max C/I scheduler obtains the highest data rate while Max-Min results in the lowest one. This is ascribed only to their resource scheduling mechanisms since the association scheme is the identical BRP-based one.

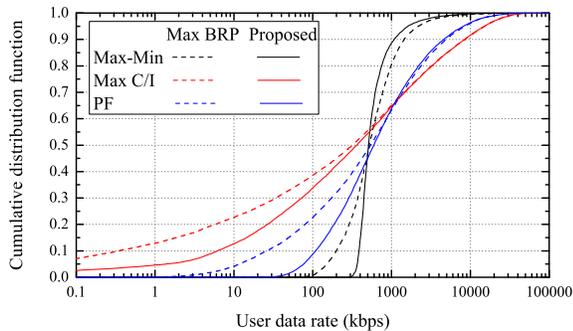
Fig. 2 shows the cumulative distribution functions (CDFs) of the user data rate with the maximum BRP and the proposed scheme. The results of the maximum BRP scheme are obtained by given the optimal bias factors as discussed in Fig. 1.



(a) Case 1



(b) Case 2



(c) Case 3

Fig. 2. Cumulative distribution functions of user data rate.

Although the throughput-oriented scheme with the Max C/I scheduler achieves the highest average bitrate, it obtains larger difference of user data rate and consequently keeps poor user fairness. On the contrary, Max-Min achieves much smaller user difference. The proposed scheme enables the users in the crowded cells to switch to the cells or tiers with lower traffic load. Thus, it effectively decreases the proportion of low-bitrate users and improve the user fairness. For instance, in case 2, the ratio of users with the bitrate lower than 0.1 kbps reduces from 25% to 6% with the proposed scheme based on Max C/I.

The overall average user data rate of different schemes are shown in Fig. 3 with various user densities in case 1. The average data rate is improved with the proposed scheme for Max C/I and PF, which are designed aiming at improving throughput. However, for the Max-Min scheduler, the proposed scheme reduces the average performance. In order to

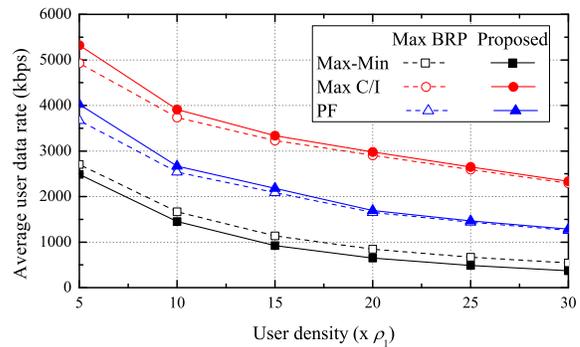


Fig. 3. Average user data rate in case 1 with different user densities.

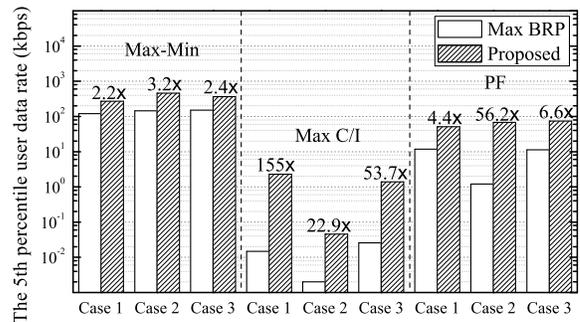


Fig. 4. The 5th percentile user data rate in different cases.

help the low-bitrate users enhancing their data rates by the Max-Min policy, the benefits of the users in uncrowded cells may be reduced by sharing their resources with the switched lower-bound users. With the increase in the user density, the average data rate decreases due to the less RBs per user in each cell. In addition, as there are more users, every cell tends to be full of users. So the data rate improvement brought by the proposed handover scheme also drops since there are fewer cells with light traffic load which a user can transfer to.

We calculate the 5th percentile user data rate and regard the users with a lower bitrate as low-rate users. As shown in Fig. 4, the handover scheme based on Max-Min achieves the highest bitrate of low-rate users. The results in Fig. 4 indicate that more than 2x gain for Max-Min, 20x gain for Max C/I and 4x gain for PF can be obtained by the proposed scheme in terms of the upper-bound bitrate of low-rate users.

In order to investigate the impact of different BS and user distributions, the simulation results of the three cases with the PF-based scheme are presented and analyzed in the following part. Fig. 5 presents the average data rate in the three cases. In case 2, where some users are cluster-distributed in femtocells, the throughput is much higher than that in case 1 and 3, owing to the better channel conditions of the femtocell users who are closer to their connected BSs than those with the entire PPP distribution. On the other hand, the regular hexagonal grid pattern of macrocells in case 3 helps improving the throughput by planarization of inter-cell interference.

We further present the CDFs of user data rate in macrocells

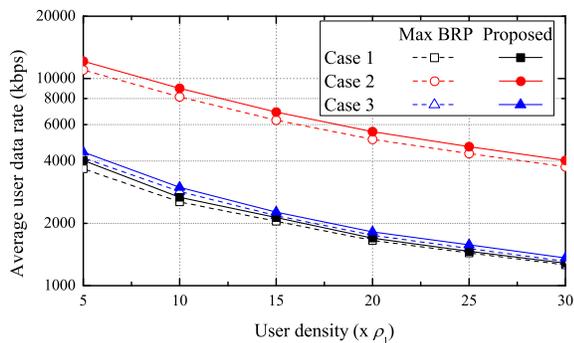


Fig. 5. Average user data rate with different user densities.

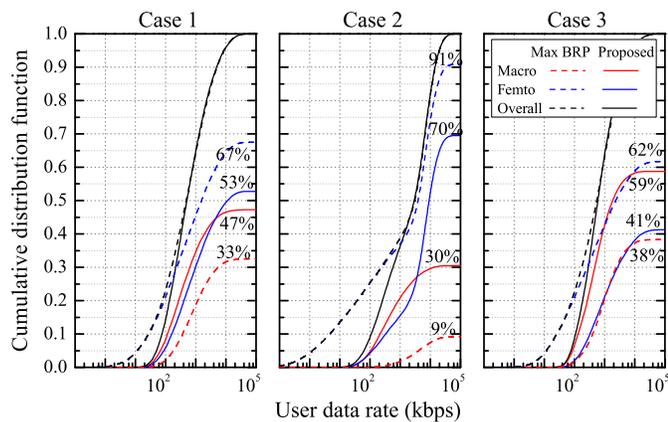


Fig. 6. Cumulative distribution functions of user data rate in different cases with the PF-based scheme.

and femtocells in different cases in Fig. 6. Our proposed scheme is able to balance the traffic load across tiers and cells more effectively than maximum BRP. For instance, in case 1, 33% and 67% users access macrocells and femtocells with the maximum BRP scheme, respectively, while they become 47% and 53% using the proposed scheme. In case 2, half of the users are cluster-distributed around the femto BSs, leading to more users accessing femtocells and much heavier traffic load in femtocells. Consequently, the shortage of radio resources in femtocells results in a larger number of low-rate users. The proposed scheme appropriately transfers the low-rate users in femtocells to macrocells so that the users around the hotspots can obtain more RBs and better service. In case 3, macrocells are located in a hexagonal grid pattern, providing better cell coverage than the random located counterpart. Hence, more users prefer to access macro BSs due to higher SIRs.

## VI. CONCLUSION

In this paper, we propose a handover scheme for traffic load balance in HCNs with three different objectives. In order to improve the desired performance, three handover factors are designed for our proposed scheme based on different resource scheduler, respectively. With the aim of user fairness, the Max-Min scheduler is adopted and lower-bound users are given priorities to transfer to the light-load cells so that the difference

of the bitrates among users can be reduced. With Max C/I and PF, the user handover is depending on its gain of the sum of the data rates or the logarithmic sum. The simulations evaluate our proposed balancing scheme in terms of efficiency and fairness. By using the proposed scheme, the low bitrate users can obtain considerable improvement with any one of the three resource schedulers. Besides the pure random PPP distributions of BSs and users, we further investigate two more realistic cases, where user clusters around hotspots and hexagonal deployment of macrocells are adopted. The results reveal that the proposed scheme achieves better balancing effect than maximum BRP and that the traffic loads in HCNs depend much on the actual BS and user locations.

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