Optimal Deployment Density for Maximum Coverage of Drone Small Cells

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***Abstract*—In this paper, we intend to study the optimal deployment density of drone small cells (DSCs) to achieve maximum coverage considering the inter-cell interference. Due to the high altitude, the air-to-ground channel of DSCs consist of probabilistic line-of-sight (LoS) and non-line-of-sight (NLoS) links, causing computational difficulties in performance analysis. To accurately analyze coverage performance, we calculate the cumulative inter-cell interference considering both LoS and NLoS links. And we derive an approximate and closed-form expression for it to facilitate the computation of the optimal deployment density in a tractable way. Given the altitude, the optimal deployment density is obtained by determining the optimal coverage radius of a DSC. And numerical results show that, increasing the altitude of DSCs does not necessarily improve coverage performance.**

***Index Terms*—drone small cells, optimal deployment density, maximum coverage ratio.**

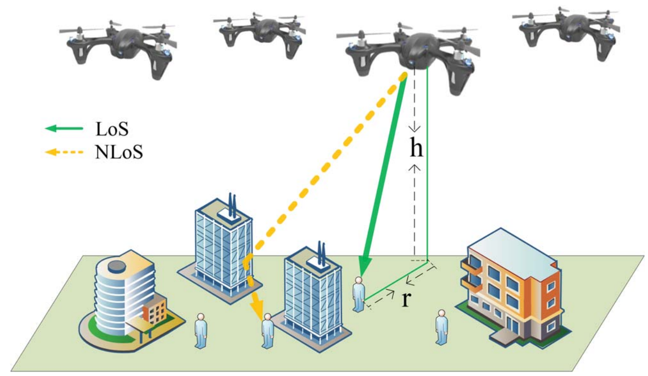

Fig. 1. DSCs serving ground users

I. Introduction

Drones will provide services in every aspect of our life in the near future due to the rapid development of aerial vehicles and the increasing demand for using such vehicles, such as acting as aerial base stations to provide service to ground users [1]. These drone small cells (DSCs) with the advantage of fast and flexible deployment and low deployment cost, can be deployed to enhance the wireless capacity at temporary events and to support rescue and relief when conventional terrestrial networks are damaged. Despite the several advantages for using DSCs, one of the biggest challenges is to determine the deployment of the DSCs for optimal coverage [2].

The coverage performance of DSCs is influenced by many factors, such as altitude, deployment density, etc, and some literatures investigated these issues [3]–[6]. In [4], the authors used two DSCs to provide a maximum coverage in the presence of inter-cell interference, showing the great impact of inter-cell interference on coverage performance. Nevertheless, these works only considered a small number of DSCs. In daily life, there are some tasks that require a great deal of DSCs [7]. When using multiple DSCs, the inter-cell interference become more serious especially under high deployment density, leading to a poor coverage performance. Decreasing the coverage density can reduce inter-cell interference. But coverage performance is poor either when the deployment density is too low. Therefore, we intend to investigate the deployment density of DSCs to achieve maximum coverage.

Inter-cell interference is an important factor affecting coverage performance. Due to the scarcity of resources and the high demand for wireless communication, the wireless resources are reused over the spatial domain, resulting in cumulative inter-cell interference. The cumulative inter-cell interference in DSCs network is similar to the one in terrestrial base stations. However, as Fig.1 shows, due to the high altitude, DSCs have a great probability of using line-of-sight (LoS) links to communicate with ground users, which is different from terrestrial base stations. The air-to-ground channel between DSCs and users can be divided into two main propagation groups: LoS links and non-line-of-sight (NLoS) links [3], [8]. They have different probabilities of occurrence separately, which are determined by the environment and the location of DSCs and users, resulting in difficulties in calculating the cumulative inter-cell interference. [9] and [10] analyzed the cumulative interference when investigating network performance. But both of them focused on a single propagation group, LoS links or NLoS links, when modeling the air-to-ground channel. To accurately analyze the coverage performance, we intend to consider both probabilistic LoS and NLoS links in calculating the cumulative interference and overcome the computational difficulties caused by them.

In this paper, we intend to investigate the optimal deployment density of DSCs for maximum coverage performance. We model the air-to-ground channel by considering both LoS and NLoS links along with their occurrence probabilities separately, and analyze the coverage performance in the presence of inter-cell interference. The main contributions are listed as follows:

1) The cumulative inter-cell interference consisted of probabilistic LoS and NLoS links are calculated. To facilitate the computation of the optimal deployment density in a tractable way, we derive an approximate and closed-form expression for the cumulative inter-cell interference.
2) On the basis of analysis, we argue that there exist an optimal deployment density and determine the optimal deployment density of DSCs to achieve maximum coverage ratio.
3) In our numerical results, we show that increasing the altitude of DSCs does not necessarily improve coverage performance.

The rest of this paper is organized as follows. In Section II, we review the related work on DSCs deployment. In Section III, we introduce the system model and present the problem formulation. Then, we calculate the cumulative interference and solve the optimal deployment problem in Section IV. In Section V, we present the numerical results. Finally, we conclude the paper in Section VI.

II. Related Work

A. Maximum Coverage

The coverage performance of DSCs is influenced by many factors, and deployment density is one of them. A case in which two DSCs interfere with each other was discussed in [6]. The authors investigated the impact of interference between two DSCs on the coverage performance, showing that the inter-cell interference will significantly reduce coverage performance when the separation distance is small. And then, the authors found an optimal separation distance to achieve a maximum coverage. But the authors only considered two DSCs and did not expand to more DSCs. The authors in [4] investigated maximum coverage performance of DSCs in the presence of inter-cell interference. But only the interference from the nearest DSC was considered, which is not realistic. In this paper, we intend to investigate maximum coverage of multiple DSCs in consideration of the cumulative inter-cell interference from all other DSCs sharing the same underlay spectrum.

B. Inter-cell Interference

Inter-cell interference is a fundamental element of traditional cellular wireless systems [11], and there are many mathematical tools to model the interference and analyze network performance [12], such as Poisson Point Process (PPP). Based on PPP model, the authors in [10] modeled DSCs network as 3D-Poisson Point Process, and carried out the calculation of the interference imposed by all surrounding DSCs with the aid of the Laplace transform and the probability generating function [13]. However, the work did not consider the probabilistic LoS and NLoS links. And it is difficult to utilize such approach to calculate the interference when considering the probabilistic LoS and NLoS links.

The equivalent uniform density plane-entity (EUDPE) is another method for calculating the inter-cell interference in traditional cellular wireless systems [14]. In this paper, we utilize EUDPE to calculate the interference. But the expression derived by this method is not a closed form. To facilitate the computation of the optimal deployment density in a tractable way, we derive an approximate and closed-form expression for the cumulative inter-cell interference.

III. System Model And Problem Formulation

In this section, we introduce the system model first, including the overall model and air-to-ground channel model. After that, the problem formulation for maximizing the network coverage ratio is presented.

A. System Model

1) Overall Model

Consider a set $\mathcal{K}$ of K DSCs that are deployed to provide service for ground users, which are marked as DSC_0 to DSC_{K-1} respectively, and K is a large value. All DSCs are assumed to follow a Poisson distribution with density λ, which is a popular geographic base station distribution in conventional terrestrial networks [12], [13]. And all DSCs locate at an altitude of h meters as shown in Fig.1. Each user is served by the nearest DSC. r_i $(i \in \mathcal{K})$ is the horizontal distance between a typical user and DSC_i, and $d_i = \sqrt{{r_i}^2 + h^2}$ is the corresponding direct distance.

As the spectrum resources are fast becoming scarce, the inter-cell interference is common and serious, especially in dense networks. Therefore, the users would suffer the interference from other DSCs while communicating with the nearest DSC. Without loss of generality, the air-to-ground channel sharing an underlay spectrum is considered. Certainly, the scenario of frequency reuse is also suitable. To analyze the coverage performance more accurately, it is essential to adopt an appropriate channel model that is suitable for air-to-ground communication of DSCs.

2) Air-to-ground Channel Model

The air-to-ground channel of DSCs is different from the traditional terrestrial channel due to the chance of LoS connectivity. As discussed in [3] and [8], there are two main propagation links including LoS links and NLoS links between the DSCs and the ground users. And each link has a specific probability of occurrence which depends on the environment, the altitude of DSCs h, and the horizontal distance r_i. Considering LoS and NLoS links is one common approach for modeling air-to-ground propagation channel, and is adopted in this paper. Therefore, the received signal power from DSC_i, $P_r(r_i)$, is

$$P_r(r_i) = \begin{cases} P_t d_i^{-\alpha} \eta_l, LoS\ link \\ P_t d_i^{-\alpha} \eta_n, NLoS\ link, \end{cases} \tag{1}$$

where α is the path loss exponent and $\alpha > 2$, η_l and η_n are respectively the additional attenuation factor corresponding to the LoS and NLoS links. Note that η_n is smaller than η_l

due to the shadowing effect and the reflection of signals from obstacles over NLoS links.

The LoS probability is given by [3]

$$P_l(r_i) = \frac{1}{1 + ae^{ab}e^{-b\theta(r_i)}}, \tag{2}$$

where $\theta(r_i) = \frac{180}{\pi} actan \frac{h}{r_i}$. a and b are constant values which depend on the environment (suburban, urban, dense urban, highrise urban and so on). The NLoS probability is $P_n(r_i) = 1 - P_l(r_i)$. Therefore, the average received signal power from DSC_i will be

$$\begin{aligned} \overline{P_r}(r_i) =& P_t d_i^{-\alpha} \left[\eta_l P_l(r_i) + \eta_n P_n(r_i)\right] \\ =& P_t d_i^{-\alpha} \left[(\eta_l - \eta_n) P_l(r_i) + \eta_n\right]. \end{aligned} \tag{3}$$

Let $f(r_i) = (\eta_l - \eta_n) P_l(r_i) + \eta_n$, then the average received signal power can be rewritten as

$$\overline{P_r}(r_i) = P_t d_i^{-\alpha} f(r_i). \tag{4}$$

B. Problem Formulation

In this subsection, we will present the problem formulation. Firstly, the coverage is defined. A point on the ground is covered by DSCs if its signal-to-interference-plus-noise ratio (SINR) is greater than a threshold ε. We assume the threshold ε is not less than $0\ dB$ in this paper. Without loss of generality, we assume that the typical user is under the coverage of DSC_0. Then, the average received signal power of the user is $\overline{P_r}(r_0) = P_t d_0^{-\alpha} f(r_0)$, and the SINR of the user is given as

$$\frac{\overline{P_r}(r_0)}{I + N} \geqslant \varepsilon, \tag{5}$$

where N is the noise, and I is the interference from other DSCs, which is

$$I = \sum_{i \in \mathcal{K}/\{0\}} P_t d_i^{-\alpha} f(r_i). \tag{6}$$

Interference is a fundamental element of wireless systems, especially in dense networks. When DSCs are deployed at high density, users will suffer from serious interferences imposed by other DSCs, which may be much stronger than the useful signal. Most users would not be effectively covered due to strong interference. In such case, decreasing deployment density can reduce the interference and improve coverage performance. But it can't always work. When DSCs are deployed at low density, most of users may be far away from the nearest DSC and can not receive strong enough signal due to the limited transmit power, out of the coverage of DSCs network. Therefore, the deployment density should not be too small, and there is an optimal deployment density of DSCs which results in the best coverage performance. In this paper, we intend to determine the optimal density to maximize coverage ratio, which is the ratio of covered areas to overall area.

Assume the coverage radius of a single DSC is R, and the average effective coverage area of a DSC is cR^2, where c is an empirically chosen factor and called as area factor in this paper. For example, if the average effective coverage area of a DSC is calculated as a hexagonal one, we have $c = 3\sqrt{3}$. As ε is not less than $0\ dB$ and all DSCs share an underlay spectrum, there is no overlap in the coverage areas. Therefore, the overall effective coverage areas is given as KcR^2. As the deployment density of DSCs is λ, defined as $\lambda = \frac{K}{\text{Network Area}}$ (the number of DSCs per square meter, Num/m^2), the coverage ratio can be given as

$$Ratio = \frac{KcR^2}{\text{Network Area}} = c\lambda R^2. \tag{7}$$

We intend to determine the optimal density to maximize coverage ratio. As R is the coverage radius of a DSC, the user located at the coverage edge can still meet the SINR requirement. Therefore, the optimization problem can be written as

$$\begin{aligned} &\underset{\lambda}{maximize}\ \ c\lambda R^2 \\ &subject\ to\ \frac{\overline{P_r}(R)}{I + N} \geqslant \varepsilon. \end{aligned} \tag{8}$$

IV. Optimal Deployment Density

To accurately analyze the coverage performance and determine the optimal deployment density, it is necessary to evaluate the cumulative inter-cell interference of the user located at the coverage edge of a DSC (hereafter referred to as the cumulative interference). In this section, we would calculate the cumulative interference and derive an approximate and closed-form expression for it. Based the expression, the optimal deployment density which obtain the maximum coverage ratio will be determined.

A. Cumulative Interference

The cumulative interference in DSC networks is similar to the one in terrestrial base stations. However, due to the high altitude, DSCs have a chance to communicate with users through LoS links. And the probability of LoS and NLoS links depends on the location of the DSC and the user, thus increasing the computational complexity of the cumulative interference. This is different from conventional terrestrial networks. In this subsection, we utilize a two-step approach to calculate the cumulative interference.

Firstly, we would model the interference by using EUDPE method [14]. As the coverage radius of each DSC is R, the horizontal distance between the user and the nearest interference source should not be less than R. Therefore, the cumulative interference can be given as

$$\begin{aligned} I =& \sum_{i \in \mathcal{K}/\{0\}} P_t d_i^{-\alpha} f(r_i) \\ \overset{(a)}{=}& \sum_{l=1}^{K-1} \int_0^{2\pi} \int_{R+\varepsilon_{l-1}}^{R+\varepsilon_l} P_t {d_I}^{-\alpha} f(r_I) \lambda r_I dr_I d\theta \\ =& \sum_{l=1}^{K-1} \int_{R+\varepsilon_{l-1}}^{R+\varepsilon_l} 2\pi\lambda P_t {d_I}^{-\alpha} f(r_I) r_I dr_I \\ \overset{(b)}{=}& 2\pi\lambda P_t \int_R^{\infty} {d_I}^{-\alpha} f(r_I) r_I dr_I, \end{aligned} \tag{9}$$

where (a) follows the EUDPE method. As $\alpha > 0$, $\int\limits_{R+\varepsilon_{l-1}}^{R+\varepsilon_l} 2\pi\lambda P_t {d_I}^{-\alpha} f(r_I) r_I dr_I \to 0$ when l is large, meaning that the interference from the DSC which is far away, is very small. Accordingly, step (b) comes from the assumption of a great number of DSCs.

To facilitate the computation of optimal deployment density in a tractable way, we derive an approximate and closed-form expression for the cumulative interference.

Theorem 1 : The approximate and closed-form expression for the cumulative interference is given by

$$I = \frac{2\pi\lambda k P_t}{\alpha - 2} f(R) {d_R}^{2-\alpha}, \tag{10}$$

where k is an approximate parameter.

Proof :

$$\begin{aligned}
&\int\limits_R^\infty {d_I}^{-\alpha} f(r_I) r_I dr_I \\
=&\frac{1}{2-\alpha} \int\limits_R^\infty f(r_I) d({d_I}^{2-\alpha}) \\
\overset{(a)}{=}&\frac{1}{\alpha-2}[f(R){d_R}^{2-\alpha} + \int\limits_R^\infty {d_I}^{2-\alpha} f'(r_I) dr_I] \\
=&\frac{1}{\alpha-2}[f(R){d_R}^{2-\alpha} + \int\limits_R^\infty {d_I}^{2-\alpha} f(r_I)\frac{f'(r_I)}{f(r_I)} dr_I] \\
=&\frac{1}{\alpha-2}[f(R){d_R}^{2-\alpha} - \int\limits_R^\infty {d_I}^{-\alpha} f(r_I) g_a(r_I)\frac{h}{r_I} r_I dr_I] \\
\overset{(b)}{>}&\frac{1}{\alpha-2}[f(R){d_R}^{2-\alpha} - \int\limits_R^\infty {d_I}^{-\alpha} f(r_I) g_b(r_I)\frac{h}{r_I} r_I dr_I] \\
\overset{(c)}{>}&\frac{1}{\alpha-2}[f(R){d_R}^{2-\alpha} - g_b(R)\frac{h}{R}\int\limits_R^\infty {d_I}^{-\alpha} f(r_I) r_I dr_I],
\end{aligned} \tag{11}$$

where

$$\begin{aligned}
f'(r_I) &= -\frac{180bh(\eta_l - \eta_n)P_l(r_I)P_n(r_I)}{\pi {d_I}^2(\eta_l P_l(r_I) + \eta_n P_n(r_I))} \\
g_a(r_I) &= \frac{180b(\eta_l - \eta_n)P_l(r_I)P_n(r_I)}{\pi(\eta_l P_l(r_I) + \eta_n P_n(r_I))} \\
g_b(r_I) &= \frac{180b(\eta_l - \eta_n)}{\pi(\eta_l + \eta_n + \eta_n(\frac{1}{P_l(r_I)} - 1))}.
\end{aligned} \tag{12}$$

Step (a) follows the utilization of integration by parts. Step (b) and (c) come from partial minification.

From above derivation, we can know $\int\limits_R^\infty {d_I}^{-\alpha} f(r_I) r_I dr_I$ is larger than $f(R){d_R}^{2-\alpha} \Big/ (1 + g_b(R)\frac{h}{R(\alpha-2)^2})$ while smaller than $f(R){d_R}^{2-\alpha}$. Thus, the expression of the cumulative interference can be approximated as $\frac{2\pi\lambda k P_t}{\alpha-2} f(R){d_R}^{2-\alpha}$, where k is a parameter and $k \in (1\Big/(1 + g_b(R)\frac{h}{R(\alpha-2)}), 1)$. At this point, we obtain the approximate and closed form expressions of the cumulative interference.

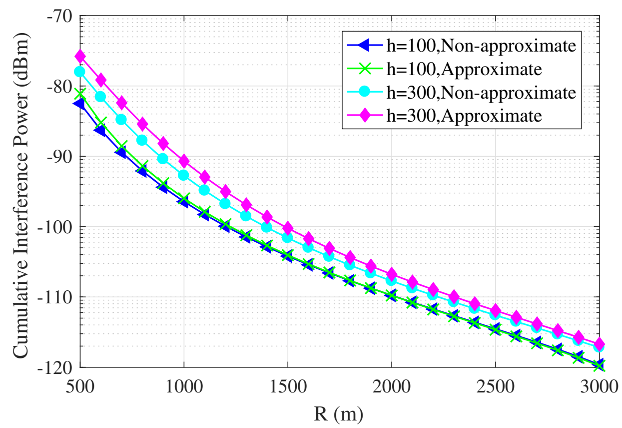

Fig. 2. The cumulative interference power vs. R when $k = 0.9$

In this paper, we make k be 0.9. In Fig.2, we compare the cumulative interference calculated by the approximate expression with the non-approximate one (the simulation parameters are listed in Section V). As Fig.2 shows, the results obtained by the approximate expression coincide with the non-approximate ones, verifying the accuracy and validity of the derived closed-form expression. Now, we can investigate the optimal deployment density based this expression.

B. Optimal Deployment Density

As R is the coverage radius of each DSC, which is the maximum horizontal distance that satisfies the SINR threshold, we have $\frac{P_r(R)}{I+N} = \varepsilon$. Substituting equations (5) and (10) into this equation, we have

$$P_t d_R^{-\alpha} f(R) = \varepsilon \frac{2\pi\lambda k P_t}{\alpha-2} {d_R}^{2-\alpha} f(R) + \varepsilon N. \tag{13}$$

And the equation can be rewritten as

$$\lambda = \frac{(\alpha-2)}{2\pi k P_t}\frac{1}{d_R^2}[\frac{P_t}{\varepsilon} - \frac{N{d_R}^\alpha}{f(R)}]. \tag{14}$$

It is easy to prove that $\frac{\partial\lambda}{\partial R} < 0$. Then we can know $\frac{\partial R}{\partial\lambda} = 1\Big/\frac{\partial\lambda}{\partial R} < 0$, denoting that R decreases monotonically with λ, and there is a one-to-one relationship between R and λ.

We intend to find the optimal deployment density to maximize coverage ratio, but it is difficult to derive the explicit expressions of $Ratio$ in terms of λ, and we can't obtain the optimal density directly. As the one-to-one relationship between R and λ, we can solve the optimization problem by determining the coverage radius corresponding to the optimal deployment density, and then the optimal density can be obtained.

By substituting equation (14), the objective function can be rewritten as

$$c\lambda R^2 = \frac{c(\alpha-2)}{2\pi k P_t}\frac{R^2}{d_R^2}[\frac{P_t}{\varepsilon} - \frac{N{d_R}^\alpha}{f(R)}]. \tag{15}$$

Now, the objective function is expressed as a function of R. And then, we take the derivative of this objective function, obtaining that

$$
\begin{aligned}
&\frac{\partial Ratio}{\partial R} \\
&= \frac{c(\alpha-2)}{2\pi k P_t}\{\frac{2Rh^2}{d_R^4}[\frac{P_t}{\varepsilon} - \frac{N{d_R}^{\alpha}}{f(R)}] \\
&\qquad + \frac{R^2}{d_R^2}[-N\frac{\alpha R {d_R}^{\alpha - 2} f(R) - {d_R}^{\alpha} f'(R)}{f^2(R)}]\} \\
&= \frac{cN(\alpha-2)Rh^2}{2\pi k P_t d_R^{4-\alpha} f(R)}[\frac{2P_t {d_R}^{-\alpha} f(R)}{N\varepsilon} \\
&\qquad\qquad -(2+\alpha\frac{R^2}{h^2}) - g_a(R)\frac{R}{h}] \\
&= \frac{cN(\alpha-2)Rh^2}{2\pi k P_t d_R^{4-\alpha} f(R)}[\frac{2\overline{P_r}(R)}{N\varepsilon} - (2+\alpha\frac{R^2}{h^2}) - g_a(R)\frac{R}{h}].
\end{aligned} \tag{16}
$$

We make $T(R) = \frac{2\overline{P_r}(R)}{N\varepsilon} - (2+\alpha\frac{R^2}{h^2}) - g_a(R)\frac{R}{h}$. It is easy to prove that $\frac{cN(\alpha-2)Rh^2}{2\pi k P_t d_R^{4-\alpha} f(R)}$ is always greater than 0, thus the extreme point would be determined by $T(R) = 0$. Noting that, $\overline{P_r}(R)$ is the average received signal power, decreasing as R increases. When R at a smaller value, the value of $\frac{2\overline{P_r}(R)}{N\varepsilon}$ is very large while the value of $\frac{R}{h}$ is small, thus $T(R)$ is greater than 0. And when R at a larger value, the opposite is true and $T(R) < 0$. Therefore, there is an extreme point where the maximization coverage ratio can be achieved. The extreme point R_{opt} is the root of $T(R) = 0$. In this paper, we use bisection method to find the root.

As R decreases monotonically with λ, we can know that the coverage ratio increases as λ increases up to the optimal point λ_{opt}, and after that it decreases. And λ_{opt} can be obtained by

$$\lambda_{opt} = \frac{(\alpha-2)}{2\pi k P_t}\frac{1}{d_{R_{opt}}^2}[\frac{P_t}{\varepsilon} - \frac{N{d_{R_{opt}}}^{\alpha}}{f(R_{opt})}]. \tag{17}$$

When DSCs are deployed at λ_{opt}, we can achieve maximum coverage.

V. Numerical Results

We consider multiple DSCs serving ground users in urban environments. Note that the values of a, b, η_l and η_n, which depend on the environment and are different when DSCs operate in other areas, are calculated based on [3] and [8]. As $\alpha > 2$ in realistic networks, we consider $\alpha = 4$ in our numerical analysis. Other numerical parameters used in the numerical analysis are listed in Table I.

TABLE I
Channel Parameters

Description	Parameters	Value
Path loss exponent	α	4
DSC transmit power	P_t	5 W
Noise power	N	-120 dBm
SINR threshold	ε	0 dBm
Parameters for urban environment	a, b	9.61, 0.16
Area factor	c	$3\sqrt{3}/2$
Excessive attenuation factor for LoS	η_l	1 dB
Excessive attenuation factor for NLoS	η_n	20 dB

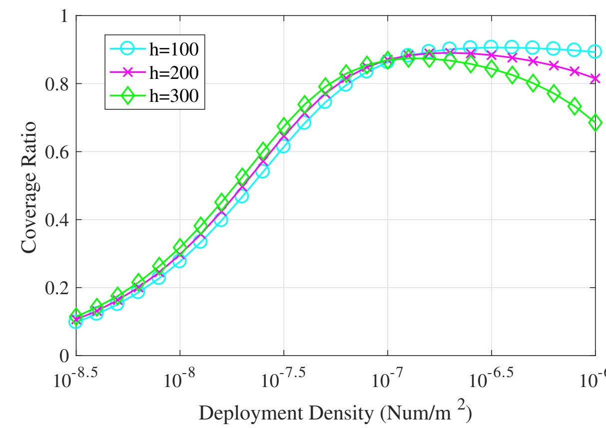

Fig. 3. Coverage ratio vs. deployment density λ

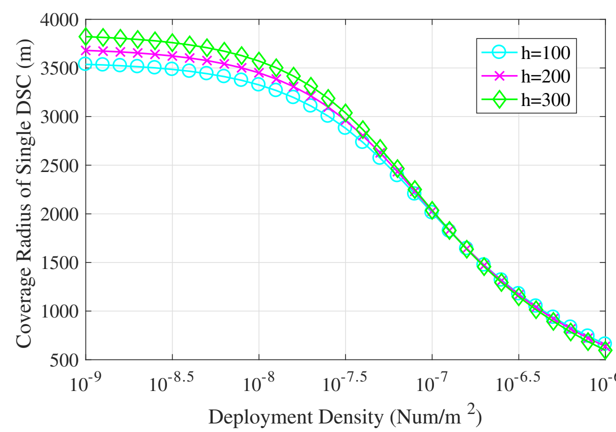

Fig. 4. Coverage radius of a single DSC R vs. deployment density λ

Fig.3 shows the variations of coverage ratio at different altitudes. From this figure, we can know that, when the deployment density is low, the impact of inter-cell interference is small, and increasing the deployment density lead to an increase in coverage ratio. When the deployment density is high, increasing deployment density can not improve the coverage performance, but make the interference more serious and result in a decrease in coverage ratio. Therefore, there is an optimal density for maximum coverage ratio. As Fig.3 shows, the coverage ratio increases as the deployment density λ increases up to the optimal point λ_{opt}, and after that it decreases. Based on our analytical results, we achieve that $\lambda_{opt} = 3.41 \times 10^{-7}$, 1.94×10^{-7}, 1.36×10^{-7} correspond to $h = 100$, 200, 300, equivalent to the deployment of 0.341, 0.194 and 0.136 DSCs per square kilometer.

Besides, from Fig.3, we can observe that the DSCs network can achieve a greater coverage ratio at low altitude when the deployment density is high, and the opposite is true when

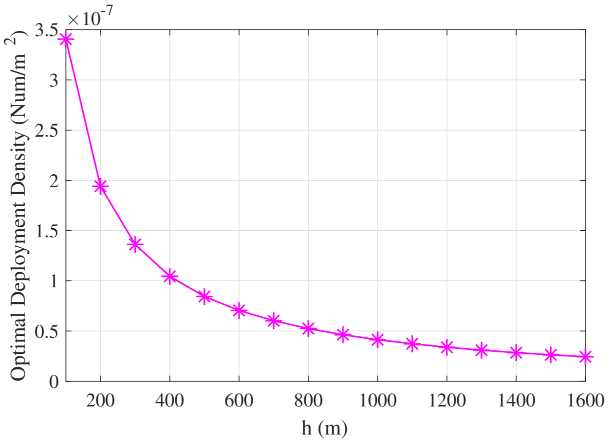

Fig. 5. Optimal deployment density λ_{opt} vs. DSCs altitude h

the deployment density is low. And this is consistent with the case in Fig.4. As Fig.4 shows, each DSC can achieve a greater coverage radius at higher altitude when deployed at low density, but achieve a smaller coverage radius at higher altitude when deployed at high density. When DSCs are deployed at high density, increasing the altitude leads to an increase in the direct distance between the edge users and DSCs, decreasing the received signal power as well as the interference power. But the decrease in interference power is less than that in received signal power because the interference comes from multiple DSCs, resulting in a decrease in coverage performance. While, when deployed at low density, DSCs network will become a noise limited network instead of an interference limited one. Increasing the altitude leads to a slight increase in the direct distance and enhances the LoS probability, resulting in stronger received signal and greater coverage. Besides, we can know that the coverage radius increases as the deployment density decreases from Fig.4. But the coverage radius would not increase indefinitely as the transmit power is fixed.

Fig.5 shows the optimal deployment density of DSCs at different altitudes. According to Fig.5, the optimal deployment density goes down with the altitude of DSCs. As the increase in height leads to increased interference, DSCs need to be deployed sparsely to reduce the impact of interference. As a result, a lower deployment density is obtained when the altitude of DSCs increases. Note that, due to the complexity of $T(R)$, we can't determine the optimal deployment density directly. And we use bisection method to calculate the optimal density in this section, resulting in high computation cost. In the future work, we will improve our method to have a simpler calculation for the optimal density.

VI. Conclusion

In this paper, we investigated the coverage performance of multiple DSCs in consideration of inter-cell interference. Firstly, we calculated the inter-cell interference using EUDPE method and derived an approximate and closed form expression for it. As the coverage ratio is affected by the deployment density, we determined the optimal deployment density to obtain maximum coverage ratio. As numerical results show, the coverage ratio raises with the deployment density up to the optimal point, and after that, it decreases. And we also showed the impact of altitude in numerical results. In the future work, we will improve the method to have a simpler calculation for the optimal density and consider that DSCs are deployed at different altitudes.

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