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Article

Performance Analysis of Heterogeneous Networks in presence of Deliberate Jammers using Reverse Frequency Allocation

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Abstract: The demand of high data rate and ubiquitous coverage in heterogeneous cellular (HetNets) is increasing progressively. In order to meet this demand, sophisticated model having applied interference reduction scheme and cell association technique is needed. The small base station (sBS are deployed inside the broadcasting area of macro base station (mBS), in heterogeneous cellular networks (HetNets). Since mBS has high transmission power therefore a large number of users get connected with mBS. This causes disproportion of load distribution across the HetNets. For load balancing users from high power mBS are migrated to low power sBS to increase network capacity and to decrease the load from mBS. This results in interference in the communication signal because of strong mBS Interference. Hence, we need interference management technique to mitigate interference and user association and to efficiently use sBSs' resources. Inter-cell interference (ICI) limit the HetNets' performance. Additionally, there exist deliberate jamming interference which depends on jammers transmission power and its proximity with the target, which notably degrades the network performance. In this paper, we employ reverse frequency allocation scheme (RFA) to reduce inter cell interference, deliberate jamming interference and to accomplish load balancing. The proposed setup is analyzed inquisitively and with the help of simulations. The result shows reduction in interferences as well as balance of load distribution in the network achieved by employing RFA scheme together with cell association.

Keywords: Heterogeneous Cellular Networks,Deliberate Jamming, Inter-cell Interference, Independent Homogenous Poisson Point Process, Coverage Probability, Reverse Frequency Allocation

1. Introduction

1.1. Motivation

As the number of cellular users are increasing, hence the need of higher bandwidth, higher capacity and ubiquitous coverage is also increasing. Therefore, wireless data networks are slowly

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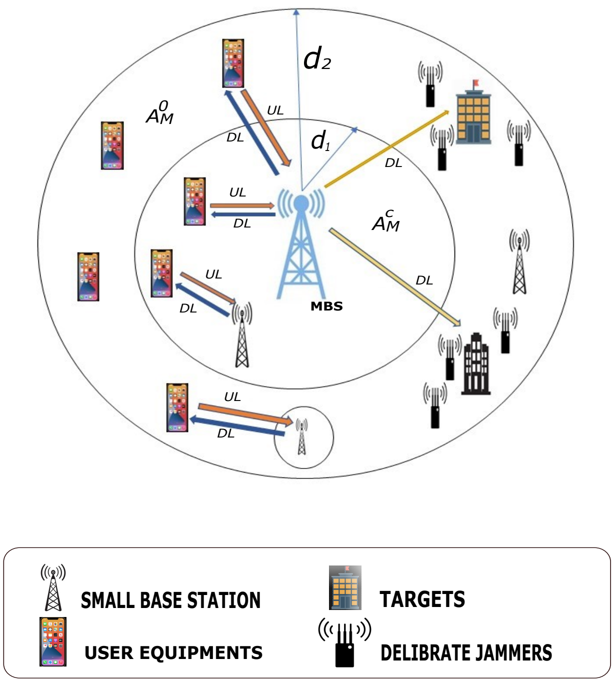

Figure 1. The suggested two tier HetNet System Model with RFA and Deliberate jamming.

evolving to adjoin the requirements [1]. In modern times deliberate jamming (DJ) is also an issue. It can be used for distributed denial of service attack in cellular networks. For such purpose, the assailant must have information about the networks characteristics such as transmission power duration and position. So that with the help of this information legitimate communication of network can be disrupted.

The suggested work investigates the uplink broadcasting recital of HetNets in ubiquity of both deliberate jamming interference and (ICI). To reduce deliberate jamming interference and ICI, reverse frequency allocation is implemented that is a dynamic interference receding strategy.

To facsimile the locations of base stations, Poisson point process (PPP) has been suggested because of its precision and complaisant. The positions of users and macro base stations (mBSs) are marked by using independent homogeneous Poisson Point Process (IHPPP).

Since orthogonal frequency Division multiplexing (OFDM) is used in (HetNets) therefore system experience inconsequential intra cell interference however ICI persists the leading factor restricting the performance [2,3]. In Non Uniform HetNets (NU-HetNets) sBSs positioned by using Poisson Hole process while users and mBSs are positioned using (IHPPP). NUHetNets ameliorate the performance of network coverage by alleviating ICI [4].

Many interference alleviating setups, for instance soft frequency reuse (SFR)[5] and fractinal frequency reuse (FFR)[6], were researched. Since SFR system employs frequency reuse therefore it yields higher spectral efficiency and while FFR system employs partitioning [7] a usable bandwidth therefore it yields reduced interference. Reverse frequency allocation [2,6] which is a dynamic resource management system accessible at avant-garde. RFA make utmost bandwidth in a cell utilizable for mBS as well as sBS. Therefore, RFA has better spectral efficiency than SFR and FFR. The suggested work will implement RFA in HetNets to alleviate ICI and deliberate jamming interference therefore improving uplink (UL) broadcasting recital in HetNets. This suggested network composition by alleviating ICI and deliberate jamming interference in HetNets yields higher network capacity

Table 1. List of abbreviations

Abbreviations	Description
HetNet	Heterogeneous Cellular Network
IJs	Deliberate Jammers
DJs-I	Deliberate Jammers Interference
ICI	Inter Cell Interference
sBS	Small Base Station
UL	Uplink
mBSs	Macro Base Stations
RFA	Reverse Frequency Allocation
U-HetNet	Uniform Heterogeneous Cellular Network
NU-HetNet	Non Uniform Heterogeneous Cellular Network
FFR	Fractional Frequency Reuse
SFR	Soft Frequency Reuse
DL	Downlink
M-EUs	MBS edge-users
SIR	Signal-to-interference ratio
LT	Laplace transform
IHPPP	Independent Homogeneous Poisson Point Process

1.1.1. Proposed Work

This suggested paper implements RFA in HetNets to alleviate DJs-I and ICI to enhance the broadcasting recital in HetNets. This network framework yields higher network capacity by efficiently alleviating DJs-I and ICI in HetNets. The used index of abbreviations in Table 1 and notations in Table 2 is given as:

1.2. Related Work

In [8] the author have studied different kinds of jamming attacks these jammers such as equalization jammers , automatic gain control jammers ,wide band jammers and partial band jammers have been thoroughly studied . In [9], the authors have studied multiple input and multiple output (MIMO) networks in residence of advanced jamming attacks. The results indicate that recital mortification in network recital because of jammers transmission power increment. The mBS coverage area has been splitted into two sub areas that is outer cell area and inner cell area in [10] for the better analysis of coverage probability in these areas. The users migrating in inner cell area faces severe interference because of proximity to mBS and the users located in outer cell area experience low SINR because of their far-flung position [10].Since mBS has strong signal transmission therefore sBSs situated in the inner cell area of mBS have truncated broadcasting region [10].

To utilize RFA in HetNets, two nonintersecting areas have been modeled from broadcasting area of mBs having inner and outer areas [10,11].The author in [10] implements RFA along with load balancing to reduce ICI. The outcome suggest notable broadcasting recital boost for mBS edge user. The authors have studied NU-HetNets accompanied by SFR in [9]. Authors have derived coverage probability expressions for U-HetNets as well as NU-HetNets. The result indicate notable boost in broadcasting area because of implicit reduction in ICI.

One of the interference reduction procedures includes fractional frequency reuse (FFR) [12], in which the whole available spectrum is partitioned into multiple sub spectra for reduction in ICI and to boost broadcasting recital. This method is ineffective because of partitioning of spectrum. The authors have proposed another procedure of Soft Fractional frequency reuse in [13] that is more coherent technique than FFR.

To utilize RFA in HetNets and its worthwhile recital assessment two non-intersecting areas have

Table 2. Symbols summary

Symbols	Explaination
$\varphi_S, \varphi_M, \varphi_u, \varphi_J$	IHPPPs of sBSs, mBSs, users, and DJs,
β	The path loss exponent $\forall\ \beta_M = \beta_S = \beta$,and $\beta > 2$
d_1, d_2	The radius of A^c_M and A^o_M respectively
φ_s, φ_m and φ_j	The densities of sBSs, mBSs and IJs
κ_M	SIR threshold
ν	Classical end User
$*$	Represents RFA deployment
$\gamma_\circ$	Ratio of $P_{t,M}$ and $P^{UL}_{t,\nu}$
γ_1	Ratio of $P_{t,S}$ and $P^{UL}_{t,\nu}$
γ_2	Ratio of $P_{t,J}$ and $P^{UL}_{t,\nu}$
γ_3	Ratio of $P^{DL}_{t,S}$ and $P^{UL}_{t,\nu}$

been established from broadcasting area of mBS, having central area, A^c_k, and outward region, A^o_k, $\forall k \in \{M, S\}$ [14,15]. The writers in [15], have utilized load balancing with RFA to alleviate ICI.By using the suggested setup, the results indicates the significant improvement in coverage performance for MBS edge user .

This suggested work differ in these ways:

1. In [7,16] authors have investigated disparate jamming attacks in disparate networks; however, their study lacks in assessment of deliberate jamming in HetNets. Hence deliberate jamming in HetNets has been discussed in this work.
2. In [4,5,8,10,17] the authors have explored RFA in HetNets and reduction of ICI. However their study lack lacks in assessment of RFA in reduction of deliberate jamming interference. Hence RFA is discussed in this work for the reduction of ICI and deliberate jamming interference.
3. In [4,17,18] downlink coverage has been investigated while this work focuses on analysis of factors that affect uplink coverage of mBS edge users.

1.3. Contributions and Objectives

This paper contributes in the following areas:

1. Study of interference originated by deliberate jamming in HetNets.
2. Use of RFA scheme to reduce ICI and deliberate jamming interference for enhancement of network recital gain.
3. Analysis of coverage probability and study of SINR threshold, signal to noise ratio SNR, mBS and sBS densities.
4. Study of Uplink coverage.
5. Study of RFA scheme with simulation scenarios.

The rest of the work is categorized in the following: Sec. 2 follows about system representation. The coverage probabilities derivations have been studied in Sec. 3. Sec. 4 discusses the results of the suggested system. The last Sec. 5, finishes the paper.

2. System Model

We will be implemented RFA while considering the deployment of sBS in the broadcasting region of mBS. Moreover interference mitigation in network layout schemes have been introduced along with

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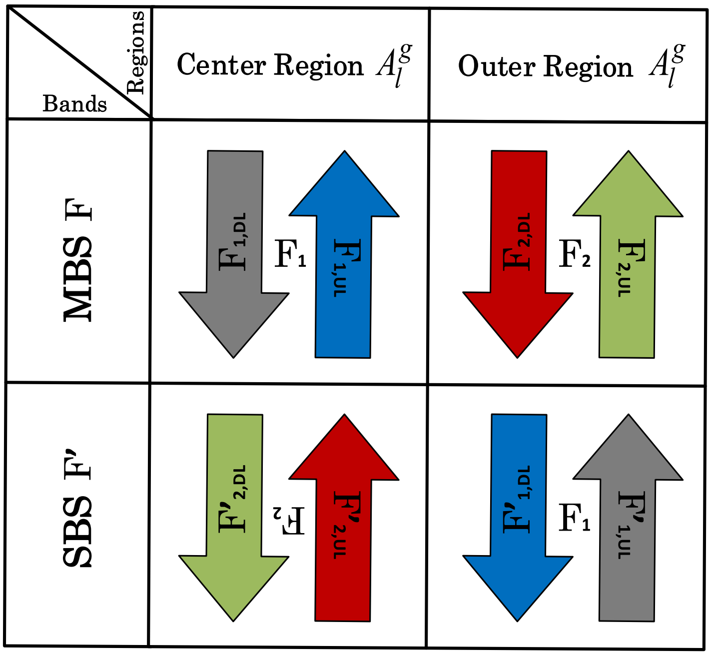

Figure 2. The two-tier HetNet representation along with RFA.

deliberate jamming mechanism. Moreover, mathematical preliminaries which are acquired here, are also utilized in Sec. 3 for derivation of coverage probabilities.

2.1. Network Layout and Assumptions

HetNets facsimile having two levels has been proposed having users, DJs, sBSs and mBSs. The users, DJs,sBSs and mBSs are modeled via IHPPPs with densities φ_{u}, φ_{J}, φ_S and φ_{M}, respectively.In the legitimate communication band DJs disseminate undesirable energies which abase network recital. .For the reduction of DJs-I and ICI, a dynamic interference reduction method RFA is enlisted. For the review, a classic user is supposed . β indicates path loss constant while $|h|$ represents Rayleigh fading gain. User interrelation has been achieved by using maximum power scheme technique [19].

2.2. Deliberate Jamming Apparatus

Deliberate jammers (D-js) introduce interference in the permissible transmissions and thus reduced network coverage[7]. D-js distributed randomly using IHPPP in the mBS broadcasting area. Since mBS edge users are located at a great distance from mBS, thus experience critical degradation in network performance also ICI is a network degrading element. Thus D-js jam desired communication frequency. By increasing, D-js and their transmission range, UL of M-EUs in HetNets can entirely be jammed.

2.3. Use of Reverse Frequency Allocation

In SFR, the frequency band is further partitioned in two sub-bands. One of the sub band is assigned to the users and sBSs in mBS that located in center region and the second sub band assigned to sBS and the users in the outer region [5]. RFA is the advanced form of SFR having enhanced broadcast recital[20].In RFA frequency sub band are additionally divided into uplink and downlink frequency as compared to SFR. This permits notable interference mitigation as compared to SFR [17,20]. The radio relay direction of sBS are allocated in reverse direction as compared to mBS.The mBS DL frequencies are assigned to the UL of sBSs, while mBS UL frequencies are assigned to the DL of sBSs [21].The RFA significantly increases the network capacity of the mBS coverage area when this

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form of frequency allocation apparatus is used. As a result, RFA efficiently reduced the interference in this way and improves spectral efficiency as well as network coverage.The allocation of frequency resources is perfect, resulting in less co-tier and cross-tier interference and a higher data rate. [22].

In RFA no predetermined spectrum is allotted to sBS therefore it mitigates interference and increases coverage area. By introducing RFA the complete spectrum of mBS is made accessible to sBSs in non-intersecting areas but in reverse direction.

From the Fig. 2, For RFA, the sub bands are in reverse order used in mBSs and sBSs that is A_l^g $\forall\, l \in (\mathrm{M}, \mathrm{S})$ and $g \in (c, o)$[23].

For the implementation of RFA,the allotted frequency F, is further divided in two sub bands, F_1 and F_2, such that F = $\bigcup_{z\in(1,2)}$ Fz, as represented in Fig. 2. F1 and F2 are additionally partitioned in UL and DL sub-carriers. These sub bands are categorized as $\mathrm{F}_1 = \mathrm{F}_{1,\mathrm{UL}} + \mathrm{F}_{1,\mathrm{DL}}$ and $\mathrm{F}_2 = \mathrm{F}_{2,\mathrm{UL}} + \mathrm{F}_{2,\mathrm{DL}}$.

3. Analysis of Coverage Probability

Since ν is situated in A_{M}^c and A_{M}^o so here in this segment expression of coverage probabilities for cited below network frameworks are extricated.

1. Evaluation of UL in case of DJs without RFA in terms of coverage probabilities.
2. Evaluation of UL in case of DJs with RFA in terms of coverage probabilities.

3.1. Evaluation of UL in case of DJs without RFA in terms of coverage probabilities

For the disruption of uplink communication of M-EU in HetNets , DJ-s are positioned identically around mBS broadcasting region by using IHPPP. The limiting factors of efficiency in such networks are DJS-I and ICI. Thus the equation for uplink coverage probability , $P_{A_{\mathrm{M}}^c}^{\mathrm{UL}}(\kappa_{\mathrm{M}})$, for mBS accompanying ν in A_{M}^c without RFA and in the presence of DJ-s can be given as

$$P_{A_{\mathrm{M}}^c}^{\mathrm{UL}}(\kappa_{\mathrm{M}}) = P\left(\mathrm{SIR}_{\mathrm{M}}^{\mathrm{UL}} > \kappa_{\mathrm{M}}\right). \tag{1}$$

Here, κ_{M} is UL SIR threshold.Moreover $\mathrm{SIR}_{\mathrm{M}}^{\mathrm{UL}}$ represents the received UL SIR. $\mathrm{SIR}_{\mathrm{M}}^{\mathrm{UL}}$ from equation (1) it can be found as

$$\mathrm{SIR}_{\mathrm{M}}^{\mathrm{UL}} = \frac{P_{t,\nu}^{\mathrm{UL}}|h_{\mathrm{M}}|^2 r_{\mathrm{M}}^{-\beta}}{I_{\mathrm{M},A} + I_{\mathrm{S},A} + I_{J,A}},$$

$$= \frac{P_{t,\nu}^{\mathrm{UL}}|h_{\mathrm{M}}|^2 r_{\mathrm{M}}^{-\beta}}{\sum\limits_{l\in\phi_{\mathrm{M}}} P_{t,l}|h_l|^2 r_l^{-\beta} + \sum\limits_{k\in\phi_{\mathrm{S}}} P_{t,k}|h_k|^2 r_k^{-\beta} + \sum\limits_{j\in\phi_J} P_{t,j}|h_j|^2 r_j^{-\beta}}. \tag{2}$$

In eq(2), the interference of UL in A_{M}^c is the total number of mBS-tier interferences. $I_{\mathrm{M},A}$, sBS-tier $I_{\mathrm{S},A}$, and of DJs, $I_{J,A}$. $r_{(\cdot)}^{-\beta}$ represents the separation from either BS or DJs. However, $P_{t,\nu}^{\mathrm{UL}}$ represents the power transmitted in UL.While $P_{t,k}$, $P_{t,l}$ and $P_{t,j}$ represents the powers transmitted of sBSs, mBSs and DJs . φ_{S}, ϕ_{M} and φ_J represents the IHPPPs of sBSs, mBSs and DJs. However, A represents the mBS broadcasting region, $A = A_{\mathrm{M}}^c \bigcup A_{\mathrm{M}}^o$.Using (2), (1) can be written as

$$P_{A_{\mathrm{M}}^c}^{\mathrm{UL}}(\kappa_{\mathrm{M}}) \overset{(1)}{=} P\left(\frac{P_{t,\nu}^{\mathrm{UL}}|h_{\mathrm{M}}|^2 r_{\mathrm{M}}^{-\beta}}{I_{\mathrm{M},A} + I_{\mathrm{S},A} + I_{J,A}} > \kappa_{\mathrm{M}}\right)$$

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$$
\begin{aligned}
&\overset{(2)}{=} \mathrm{E}_{r_{\mathrm{M}}, I_{\mathrm{M},A}, I_{\mathrm{S},A}, I_{J,A}}\left[\exp\left(-\frac{r_{\mathrm{M}}^{\beta}\kappa_{\mathrm{M}}}{P_{t,v}^{\mathrm{UL}}}\left(I_{\mathrm{M},A}+I_{\mathrm{S},A}+I_{J,A}\right)\right)\right] \\
&\overset{(3)}{=} \mathrm{E}_{r_{\mathrm{M}}, I_{\mathrm{M},A}, I_{\mathrm{S},A}, I_{J,A}}\left[\exp\left(-s\left(I_{\mathrm{M},A}+I_{\mathrm{S},A}+I_{J,A}\right)\right)\right] \\
&\overset{(4)}{=} \mathrm{E}_{r_{\mathrm{M}}}\left[\mathrm{E}_{I_{\mathrm{M},A}}\exp\left(-s\left(I_{\mathrm{M},A}\right)\right)\times \mathrm{E}_{I_{\mathrm{S},A}}\exp\left(-s\left(I_{\mathrm{S},A}\right)\right)\times \mathrm{E}_{I_{J,A}}\exp\left(-s\left(I_{J,A}\right)\right)\right] \\
&\overset{(5)}{=} \mathrm{E}_{r_{\mathrm{M}}}\left[\mathcal{L}_{I_{\mathrm{M},A}}(s)\times \mathcal{L}_{I_{\mathrm{S},A}}(s)\times \mathcal{L}_{I_{J,A}}(s)\right]\Bigg|_{s=\frac{r_{\mathrm{M}}^{\beta}\kappa_{\mathrm{M}}}{P_{t,v}^{\mathrm{UL}}}}.
\end{aligned} \tag{3}
$$

Here, $\mathcal{L}_{I_{\mathrm{M},A}}(s), \mathcal{L}_{I_{\mathrm{S},A}}(s)$, and $\mathcal{L}_{I_{J,A}}(s)$ represents the laplace transform (LT) of $I_{\mathrm{M},A}$, $I_{\mathrm{S},A}$, and $I_{J,A}$. $\mathrm{E}[\bullet]$ represents the expectation of LTs.
From the above equation (3), step (1) is acquired by the coverage probability defination [15]. And the step (2) is acquired from the definition of void probability of independent homogenous poisson point process.Step (3) is derived by substituting the value of s into step (2) where s is $\frac{r_{\mathrm{M}}^{\beta}\kappa_{\mathrm{M}}}{P_{t,v}^{\mathrm{UL}}}$. However, step (4) is derived from the defination of exponential property , i.e., $\exp(a+b)=\exp(a)\times\exp(b)$. Step (5) is eventually inferred from Step (4) via the LT defination (see (2.12) of [24]).
The Laplace transform obtained by the mbs tier looks like this., $\mathcal{L}_{I_{\mathrm{M},A}}(s)$, in A, is calculated

$$
\begin{aligned}
\mathcal{L}_{I_{\mathrm{M},A}}(s) = \exp\Bigg(&\frac{\varphi_{\mathrm{M}}\pi\gamma_{\circ}\kappa_{\mathrm{M}}d_2^{(2-\beta)}r_{\mathrm{M}}^{\beta}}{\beta/2-1}\,{}_2F_1\left(1,1-\frac{2}{\beta},2-\frac{2}{\beta},-\gamma_{\circ}\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{d_2}\right)^{\beta}\right) - \\
&\frac{\varphi_{\mathrm{M}}\pi\gamma_{\circ}\kappa_{\mathrm{M}}y^{(2-\beta)}r_{\mathrm{M}}^{\beta}}{\beta/2-1}\,{}_2F_1\left(1,1-\frac{2}{\beta},2-\frac{2}{\beta},-\gamma_{\circ}\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{y}\right)^{\beta}\right)\Bigg).
\end{aligned} \tag{4}
$$

Proof: The proof of (4)is given in Appendix A . In equation (4), $\gamma_{\circ}$ is the correlation of $P_{t,\mathrm{M}}$ and $P_{t,v}^{\mathrm{UL}}$, where $P_{t,\mathrm{M}}$ represents the power transmitted by mBS-tier.

By applying the similar method in (4), A is calculated by using the interference LT obtained from the sBS, $\mathcal{L}_{I_{\mathrm{S},A}}(s)$

$$
\begin{aligned}
\mathcal{L}_{I_{\mathrm{S},A}}(s) = \exp\Bigg(&\frac{\varphi_{\mathrm{S}}\pi\gamma_{1}\kappa_{\mathrm{M}}x_2^{(2-\beta)}r_{\mathrm{M}}^{\beta}}{\beta/2-1}\,{}_2F_1\left(1,1-\frac{2}{\beta},2-\frac{2}{\beta},-\gamma_{1}\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{x_2}\right)^{\beta}\right) - \\
&\frac{\varphi_{\mathrm{S}}\pi\gamma_{1}\kappa_{\mathrm{M}}x_1^{(2-\beta)}r_{\mathrm{M}}^{\beta}}{\beta/2-1}\,{}_2F_1\left(1,1-\frac{2}{\beta},2-\frac{2}{\beta},-\gamma_{1}\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{x_1}\right)^{\beta}\right)\Bigg).
\end{aligned} \tag{5}
$$

Here, γ_1 is ratio of $P_{t,\mathrm{S}}$ and $P_{t,v}^{\mathrm{UL}}$, where $P_{t,\mathrm{S}}$ is the power transmitted by sBS.
By applying the similar technique of (4), the interference LT obtained from the DJs, $\mathcal{L}_{I_{J,A}}(s)$, in A, can be represented as follows

$$
\begin{aligned}
\mathcal{L}_{I_{J,A}}(s) = \exp\Bigg(&\frac{\varphi_{J}\pi\gamma_{2}\kappa_{\mathrm{M}}z_2^{(2-\beta)}r_{\mathrm{M}}^{\beta}}{\beta/2-1}\,{}_2F_1\left(1,1-\frac{2}{\beta},2-\frac{2}{\beta},-\gamma_{2}\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{z_2}\right)^{\beta}\right) - \\
&\frac{\varphi_{J}\pi\gamma_{2}\kappa_{\mathrm{M}}z_1^{(2-\beta)}r_{\mathrm{M}}^{\beta}}{\beta/2-1}\,{}_2F_1\left(1,1-\frac{2}{\beta},2-\frac{2}{\beta},-\gamma_{2}\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{z_1}\right)^{\beta}\right)\Bigg).
\end{aligned} \tag{6}
$$

Here, γ_2 is the ratio of $P_{t,J}$ and $P_{t,v}^{\mathrm{UL}}$ where $P_{t,J}$ is transmitted power of DJs and z_1 and z_2 represents the jamming areas of the jammers, s.t., $z_1 \leq z_2$.

$$P^{\mathrm{UL}}_{A^c_{\mathrm{M}}}(\kappa_{\mathrm{M}}) = \frac{2\pi\varphi_{\mathrm{M}}}{1-\exp(-\varphi_{\mathrm{M}}\pi d_1^2)}\int_y^{d_1}\exp\left(\frac{\pi\kappa_{\mathrm{M}} r_{\mathrm{M}}^{\beta}}{\beta/2-1}\left[\varphi_{\mathrm{M}}\gamma_{\circ}d_2^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_{\circ}\left(\frac{r_{\mathrm{M}}}{d_2}\right)^{\beta}\right)-\varphi_{\mathrm{M}}\gamma_{\circ}y^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_{\circ}\left(\frac{r_{\mathrm{M}}}{y}\right)^{\beta}\right)+\right.\right.$$
$$\varphi_{S}\gamma_1 x_2^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_1\left(\frac{r_{\mathrm{M}}}{x_2}\right)^{\beta}\right)-\varphi_{S}\gamma_1 x_1^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_1\left(\frac{r_{\mathrm{M}}}{x_1}\right)^{\beta}\right)+\varphi_{J}\gamma_2 z_2^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_2\left(\frac{r_{\mathrm{M}}}{z_2}\right)^{\beta}\right)-$$
$$\left.\left.\varphi_{J}\gamma_2 z_1^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_2\left(\frac{r_{\mathrm{M}}}{z_1}\right)^{\beta}\right)\right]-\varphi_{\mathrm{M}}\pi r_{\mathrm{M}}^2\right) r_{\mathrm{M}}dr_{\mathrm{M}}. \tag{11}$$

$$P^{\mathrm{UL}}_{A^o_{\mathrm{M}}}(\kappa_{\mathrm{M}}) = \frac{2\pi\varphi_{\mathrm{M}}}{\exp(-\varphi_{\mathrm{M}}\pi d_1^2)}\int_{d_1}^{d_2}\exp\left(\frac{\pi\kappa_{\mathrm{M}} r_{\mathrm{M}}^{\beta}}{\beta/2-1}\left[\varphi_{\mathrm{M}}\gamma_{\circ}d_2^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_{\circ}\left(\frac{r_{\mathrm{M}}}{d_2}\right)^{\beta}\right)-\varphi_{\mathrm{M}}\gamma_{\circ}y^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_{\circ}\left(\frac{r_{\mathrm{M}}}{y}\right)^{\beta}\right)\right.\right.$$
$$+\varphi_{S}\gamma_1 x_2^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_1\left(\frac{r_{\mathrm{M}}}{x_2}\right)^{\beta}\right)-\varphi_{S}\gamma_1 x_1^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_1\left(\frac{r_{\mathrm{M}}}{x_1}\right)^{\beta}\right)+\varphi_{J}\gamma_2 z_2^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_2\left(\frac{r_{\mathrm{M}}}{z_2}\right)^{\beta}\right)-$$
$$\left.\left.\varphi_{J}\gamma_2 z_1^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_2\left(\frac{r_{\mathrm{M}}}{z_1}\right)^{\beta}\right)\right]-\varphi_{\mathrm{M}}\pi r_{\mathrm{M}}^2\right) r_{\mathrm{M}}dr_{\mathrm{M}}. \tag{12}$$

ν is situated in A^c_{M} or in A^o_{M} (represented as $\nu_{A^c_{\mathrm{M}}}$ and $\nu_{A^o_{\mathrm{M}}}$, respectively), whereas corresponding the distance of mBS $r_{\mathrm{M},\nu}$, having PDFs of distances as (7) and (8) [25] [20]

$$f_{r_{\mathrm{M}}|\nu_{A^c_{\mathrm{M}}}}(r_{\mathrm{M}}) = \frac{2\pi\varphi_{\mathrm{M}} r_{\mathrm{M}}\exp(-\varphi_{\mathrm{M}}\pi r_{\mathrm{M}}^2)}{1-\exp\left(-\varphi_{\mathrm{M}}\pi d_1^2\right)}, \tag{7}$$

and

$$f_{r_{\mathrm{M}}|\nu_{A^o_{\mathrm{M}}}}(r_{\mathrm{M}}) = \frac{2\pi\varphi_{\mathrm{M}} r_{\mathrm{M}}\exp(-\varphi_{\mathrm{M}}\pi r_{\mathrm{M}}^2)}{\exp\left(-\varphi_{\mathrm{M}}\pi d_1^2\right)}. \tag{8}$$

Without RFA utilization UL coverage probability expression, $P^{\mathrm{UL}}_{A^c_{\mathrm{M}}}(\kappa_{\mathrm{M}})$, for MBS associated ν in A^c_{M} whereas contemplating uniform IJs distribution, given as

$$P^{\mathrm{UL}}_{A^c_{\mathrm{M}}}(\kappa_{\mathrm{M}}) = \int_y^{d_1}\mathcal{L}_{I_{\mathrm{M},A}}(s)\times\mathcal{L}_{I_{\mathrm{S},A}}(s)\times\mathcal{L}_{I_{J,A}}(s)\, f_{r_{\mathrm{M},\nu}|\nu_{A^c_{\mathrm{M}}}}(r_{\mathrm{M},\nu})\, dr_{\mathrm{M},\nu}. \tag{9}$$

By putting values of (4), (5), (6) and (7) into (9), $P^{\mathrm{UL}}_{A^c_{\mathrm{M}}}(\kappa_{\mathrm{M}})$ is written as (11).

Likewise,without RFA utilization for he uniformly distributed DJs , the UL coverage probability equation, $P^{\mathrm{UL}}_{A^o_{\mathrm{M}}}(\kappa_{\mathrm{M}})$, for mBS corresponded ν in A^o_{M} can be obtained as

$$P^{\mathrm{UL}}_{A^o_{\mathrm{M}}}(\kappa_{\mathrm{M}}) = \int_{d_1}^{d_2}\mathcal{L}_{I_{\mathrm{M},A}}(s)\times\mathcal{L}_{I_{\mathrm{S},A}}(s)\times\mathcal{L}_{I_{J,A}}(s)\, f_{r_{\mathrm{M},\nu}|\nu_{A^o_{\mathrm{M}}}}(r_{\mathrm{M},\nu})\, dr_{\mathrm{M},\nu}. \tag{10}$$

By putting (4), (5), (6) and (8) in (10), $P^{\mathrm{UL}}_{A^o_{\mathrm{M}}}(\kappa_{\mathrm{M}})$ is written as (12).

3.2. *Evalution of UL in presence of Djs with RFA in terms of coverage probability*

The equation of UL coverage probability, $P^{\mathrm{UL},*}_{A^c_{\mathrm{M}}}(\kappa_{\mathrm{M}})$, with DJs and RFA whereas supposing ν in A^c_{M} is written as

$$P^{\mathrm{UL},*}_{A^c_{\mathrm{M}}}(\kappa_{\mathrm{M}}) = P\left(\mathrm{SIR}^{\mathrm{UL}}_{\mathrm{M}} > \kappa_{\mathrm{M}}\right). \tag{13}$$

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While deploying RFA the experienced UL interference consist of mixture of UL interference by the mBS-tier in A_{M}^{c}, i.e., $I_{\phi_{\mathrm{M}},A_{\mathrm{M}}^{c}}^{\mathrm{UL}}$,interference by the sBS-tier DL in A_{M}^{o}, i.e., $I_{\phi_{i},A_{\mathrm{M}}^{o}}^{\mathrm{DL}}$, and DJs interference, i.e., $I_{J,A}$. Hence, $\mathrm{SIR}_{\mathrm{M}}^{\mathrm{UL}}$ from (13) can be obtained as

$$\mathrm{SIR}_{\mathrm{M}}^{\mathrm{UL}} = \frac{P_{t,\nu}^{\mathrm{UL}}|h_{\mathrm{M}}|^{2}r_{\mathrm{M}}^{-\beta}}{I_{\phi_{\mathrm{M}},A_{\mathrm{M}}^{c}}^{\mathrm{UL}} + I_{\phi_{\mathrm{S}},A_{\mathrm{M}}^{o}}^{\mathrm{DL}} + I_{J,A}}. \tag{14}$$

Equation (14) can be expanded as

$$\mathrm{SIR}_{\mathrm{M}}^{\mathrm{UL}} = \frac{P_{t,\nu}^{\mathrm{UL}}|h_{\mathrm{M}}|^{2}r_{\mathrm{M}}^{-\beta}}{\sum\limits_{l\in\phi_{\mathrm{M}}} P_{t,l}^{\mathrm{UL}}|h_{l}|^{2}r_{l}^{-\beta} + \sum\limits_{k\in\phi_{\mathrm{S}}} P_{t,k}^{\mathrm{DL}}|h_{k}|^{2}r_{k}^{-\beta} + \sum\limits_{j\in\phi_{J}} P_{t,j}|h_{j}|^{2}r_{j}^{-\beta}}. \tag{15}$$

In the above expression, the transmitted power of ν in mBS UL is, $P_{t,l}^{\mathrm{UL}}$, the transmitted power in SBS DL is $P_{t,k}^{\mathrm{DL}}$, and the transmitted power of IJs is $P_{t,j}$. Further more, by substituting equation (14) in equation (13), the value of $P_{A_{\mathrm{M}}^{c}}^{\mathrm{UL},*}(\kappa_{\mathrm{M}})$ can be obtained as

$$\begin{aligned} P_{A_{\mathrm{M}}^{c}}^{\mathrm{UL},*}(\kappa_{\mathrm{M}}) &= P\left(\frac{P_{t,\nu}^{\mathrm{UL}}|h_{\mathrm{M}}|^{2}r_{\mathrm{M}}^{-\beta}}{I_{\phi_{\mathrm{M}},A_{\mathrm{M}}^{c}}^{\mathrm{UL}} + I_{\phi_{\mathrm{S}},A_{\mathrm{M}}^{o}}^{\mathrm{DL}} + I_{J,A}} > \kappa_{\mathrm{M}}\right) \\ &= \mathrm{E}_{r_{\mathrm{M}},I_{\phi_{\mathrm{M}},A_{\mathrm{M}}^{c}}^{\mathrm{UL}},I_{\phi_{\mathrm{S}},A_{\mathrm{M}}^{o}}^{\mathrm{DL}},I_{J,A}}\left[\exp\left(-\frac{r_{\mathrm{M}}^{\beta}\kappa_{\mathrm{M}}}{P_{t,\nu}^{\mathrm{UL}}}\left(I_{\phi_{\mathrm{M}},A_{\mathrm{M}}^{c}}^{\mathrm{UL}} + I_{\phi_{\mathrm{S}},A_{\mathrm{M}}^{o}}^{\mathrm{DL}} + I_{J,A}\right)\right)\right] \\ &= \mathrm{E}_{r_{\mathrm{M}}}\left[\mathcal{L}_{I_{\phi_{\mathrm{M}},A_{\mathrm{M}}^{c}}^{\mathrm{UL}}}(s) \times \mathcal{L}_{I_{\phi_{\mathrm{S}},A_{\mathrm{M}}^{o}}^{\mathrm{DL}}}(s) \times \mathcal{L}_{I_{J,A}}(s)\right]\Bigg|_{s=\frac{r_{\mathrm{M}}^{\beta}\kappa_{\mathrm{M}}}{P_{t,\nu}^{\mathrm{UL}}}}. \end{aligned} \tag{16}$$

The laplace transformation of UL interference in mBS in A_{M}^{c}, which is, $\mathcal{L}_{I_{\phi_{\mathrm{M}},A_{\mathrm{M}}^{c}}^{\mathrm{UL}}}$, can be obtained as

$$\begin{aligned} \mathcal{L}_{I_{\phi_{\mathrm{M}},A_{\mathrm{M}}^{c}}^{\mathrm{UL}}} = \exp\Bigg(&\frac{\varphi_{\mathrm{M}}\pi\kappa_{\mathrm{M}}d_{1}^{(2-\beta)}r_{\mathrm{M}}^{\beta}}{\beta/2-1}\,{}_{2}F_{1}\left(1,1-\frac{2}{\beta},2-\frac{2}{\beta},-\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{d_{1}}\right)^{\beta}\right) - \\ &\frac{\varphi_{\mathrm{M}}\pi\kappa_{\mathrm{M}}y^{(2-\beta)}r_{\mathrm{M}}^{\beta}}{\beta/2-1}\,{}_{2}F_{1}\left(1,1-\frac{2}{\beta},2-\frac{2}{\beta},-\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{y}\right)^{\beta}\right)\Bigg). \end{aligned} \tag{17}$$

Proof: The proof of (17) is given in Appendix B .
However,DL interference LT of the sBS region in A_{M}^{o}, i.e., $\mathcal{L}_{I_{\phi_{\mathrm{S}},A_{\mathrm{M}}^{o}}^{\mathrm{DL}}}$, may be obtained likewise as in (17), and is written as

$$\begin{aligned} \mathcal{L}_{I_{\phi_{\mathrm{S}},A_{\mathrm{M}}^{o}}^{\mathrm{DL}}} = \mathcal{L}_{I_{\phi_{\mathrm{S}},A_{\mathrm{M}}^{c}}^{\mathrm{DL}}} = \exp\Bigg(&\frac{\varphi_{\mathrm{S}}'\pi\gamma_{3}\kappa_{\mathrm{M}}x_{2}^{(2-\beta)}r_{\mathrm{M}}^{\beta}}{\beta/2-1}\,{}_{2}F_{1}\left(1,1-\frac{2}{\beta},2-\frac{2}{\beta},-\gamma_{3}\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{x_{2}}\right)^{\beta}\right) - \\ &\frac{\varphi_{\mathrm{S}}'\pi\gamma_{3}\kappa_{\mathrm{M}}x_{1}^{(2-\beta)}r_{\mathrm{M}}^{\beta}}{\beta/2-1}\,{}_{2}F_{1}\left(1,1-\frac{2}{\beta},2-\frac{2}{\beta},-\gamma_{3}\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{x_{1}}\right)^{\beta}\right)\Bigg). \end{aligned} \tag{18}$$

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$$P^{\mathrm{UL},*}_{A^c_{\mathrm{M}}}(\kappa_{\mathrm{M}}) = \frac{2\pi\varphi_{\mathrm{M}}}{1-\exp\left(-\varphi_{\mathrm{M}}\pi d_1^2\right)}\int_y^{d_1} \exp\left(\frac{\pi\kappa_{\mathrm{M}} r_{\mathrm{M}}^{\beta}}{\beta/2-1}\left[\varphi_{\mathrm{M}} d_1^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{d_1}\right)^{\beta}\right)-\varphi_{\mathrm{M}} y^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{y}\right)^{\beta}\right)+\right.\right.$$
$$\varphi'_{\mathrm{S}}\gamma_3 d_2^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_3\left(\frac{r_{\mathrm{M}}}{d_2}\right)^{\beta}\right)-\varphi'_{\mathrm{S}}\gamma_3 d_1^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_3\left(\frac{r_{\mathrm{M}}}{d_1}\right)^{\beta}\right)+\varphi_J\gamma_2 d_2^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_2\left(\frac{r_{\mathrm{M}}}{d_2}\right)^{\beta}\right)-$$
$$\left.\left.\varphi_J\gamma_2 y^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_2\left(\frac{r_{\mathrm{M}}}{y}\right)^{\beta}\right)\right]-\varphi_{\mathrm{M}}\pi r_{\mathrm{M}}^2\right) r_{\mathrm{M}} dr_{\mathrm{M}}. \tag{20}$$

$$P^{\mathrm{UL},*}_{A^o_{\mathrm{M}}}(\kappa_{\mathrm{M}}) = \frac{2\pi\varphi_{\mathrm{M}}}{\exp\left(-\varphi_{\mathrm{M}}\pi d_1^2\right)}\int_{d_1}^{d_2} \exp\left(\frac{\pi\kappa_{\mathrm{M}} r_{\mathrm{M}}^{\beta}}{\beta/2-1}\left[\varphi_{\mathrm{M}} d_2^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{d_2}\right)^{\beta}\right)-\varphi_{\mathrm{M}} d_1^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{d_1}\right)^{\beta}\right)+\right.\right.$$
$$\varphi'_{\mathrm{S}}\gamma_3 d_1^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_3\left(\frac{r_{\mathrm{M}}}{d_1}\right)^{\beta}\right)-\varphi'_{\mathrm{S}}\gamma_3 y^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_3\left(\frac{r_{\mathrm{M}}}{y}\right)^{\beta}\right)+\varphi_J\gamma_2 d_2^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_2\left(\frac{r_{\mathrm{M}}}{d_2}\right)^{\beta}\right)-$$
$$\left.\left.\varphi_J\gamma_2 y^{(2-\beta)}\mathcal{J}\left(\beta,-\kappa_{\mathrm{M}}\gamma_2\left(\frac{r_{\mathrm{M}}}{y}\right)^{\beta}\right)\right]-\varphi_{\mathrm{M}}\pi r_{\mathrm{M}}^2\right) r_{\mathrm{M}} dr_{\mathrm{M}}. \tag{21}$$

Here, $\mathcal{L}_{I^{\mathrm{DL}}_{\varphi_{\mathrm{S}},A^o_{\mathrm{M}}}} = \mathcal{L}_{I^{\mathrm{DL}}_{\varphi_{\mathrm{S}},A^c_{\mathrm{M}}}}$ because φ_{S} in A^c_{M} is nearly equal to φ_{S} in A^o_{M}. γ_3 is ratio of $P^{\mathrm{DL}}_{t,\mathrm{S}}$ and $P^{\mathrm{UL}}_{t,\nu}$ where $P^{\mathrm{DL}}_{t,\mathrm{S}}$ is the DL power transmitted in SBSs.

By using equation (17), LT of mBS DL interference in A^o_{M},that is , $\mathcal{L}_{I^{\mathrm{UL}}_{\varphi_{\mathrm{M}},A^o_{\mathrm{M}}}}$, is obtained as

$$\mathcal{L}_{I^{\mathrm{UL}}_{\varphi_{\mathrm{M}},A^o_{\mathrm{M}}}}(s) = \exp\left(\frac{\varphi_{\mathrm{M}}\pi\kappa_{\mathrm{M}} d_2^{(2-\beta)} r_{\mathrm{M}}^{\beta}}{\beta/2-1}\,{}_2F_1\left(1,1-\frac{2}{\beta},2-\frac{2}{\beta},-\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{d_2}\right)^{\beta}\right)-\right.$$
$$\left.\frac{\varphi_{\mathrm{M}}\pi\kappa_{\mathrm{M}} d_1^{(2-\beta)} r_{\mathrm{M}}^{\beta}}{\beta/2-1}\,{}_2F_1\left(1,1-\frac{2}{\beta},2-\frac{2}{\beta},-\kappa_{\mathrm{M}}\left(\frac{r_{\mathrm{M}}}{d_1}\right)^{\beta}\right)\right). \tag{19}$$

UL coverage probability expression, $P^{\mathrm{UL},*}_{A^c_{\mathrm{M}}}(\kappa_{\mathrm{M}})$, for correlated ν in mBS A^c_{M} whereas imagining uniform deployment of DJs and RFA can be obtained as

$$P^{\mathrm{UL},*}_{A^c_{\mathrm{M}}}(\kappa_{\mathrm{M}}) = \int_y^{d_1} \mathcal{L}_{I^{\mathrm{UL}}_{\varphi_{\mathrm{M}},A^c_{\mathrm{M}}}}(s)\times\mathcal{L}_{I^{\mathrm{DL}}_{\varphi_{\mathrm{S}},A^o_{\mathrm{M}}}}(s)\times\mathcal{L}_{I_{J,A}}(s)\, f_{r_{\mathrm{M},\nu}|\nu_{A^c_{\mathrm{M}}}}(r_{\mathrm{M},\nu})\, dr_{\mathrm{M},\nu}. \tag{22}$$

By putting values from (6), (7), (17) and (18), in (22), $P^{\mathrm{UL},*}_{A^c_{\mathrm{M}}}(\kappa_{\mathrm{M}})$ is expressed as (20).

Therefore, UL coverage probability equation, $P^{\mathrm{UL},*}_{A^o_{\mathrm{M}}}(\kappa_{\mathrm{M}})$, for ν correlated with mBS in A^o_{M}, with uniform deployment of DJs and RFA , can be obtained as

$$P^{\mathrm{UL},*}_{A^o_{\mathrm{M}}}(\kappa_{\mathrm{M}}) = \int_{d_1}^{d_2} \mathcal{L}_{I^{\mathrm{UL}}_{\varphi_{\mathrm{M}},A^o_{\mathrm{M}}}}(s)\times\mathcal{L}_{I^{\mathrm{DL}}_{\varphi_{\mathrm{S}},A^c_{\mathrm{M}}}}(s)\times\mathcal{L}_{I_{J,A}}(s)\, f_{r_{\mathrm{M},\nu}|\nu_{A^o_{\mathrm{M}}}}(r_{\mathrm{M},\nu})\, dr_{\mathrm{M},\nu}. \tag{23}$$

By placing the (6), (8), (18) and (19) in (23), $P^{\mathrm{UL},*}_{A^o_{\mathrm{M}}}(\kappa_{\mathrm{M}})$ is represented as (21).

4. Results and Discussion

We discusses the conclusions of UL coverage probability in this portion for the user ν ,assuming (i) Using RFA to cover a DJ's distribution region, the Uplink coverage against radius and (ii)Without using RFA to cover a DJ's distribution region, the Uplink coverage against radius.The results obtained

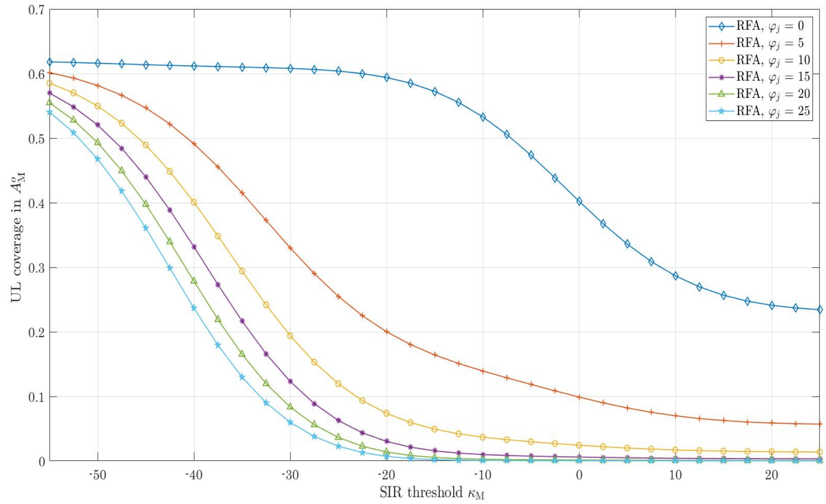

Figure 3. UL coverage versus κ_{M} and φ_J in A^o_{M}.

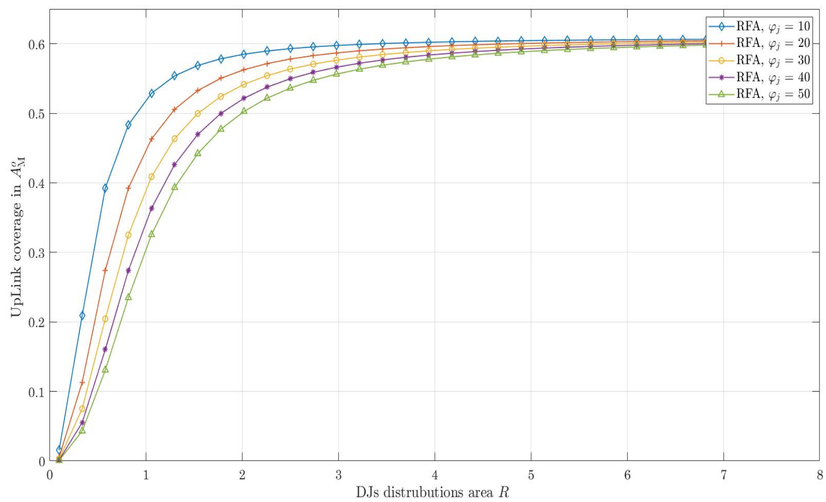

Figure 4. Using RFA to cover a DJ's distribution region, the Uplink coverage against radius .

by using the Matlab 2019b.The sBSs, mBSs and users are considered as $A = \pi(2000\ \mathrm{m})^2$,such that, $A = A^c_{\mathrm{M}} \mathrm{U} A^o_{\mathrm{M}}$. Additionally, the transmitted powers of sBS, mBS, DJs,and ν are considered as 20 dBm, 30 dBm, 10 dBm, and 10 dBm, respectively. While assuming ν in A^o_{M} the consequences of network parameters such as $P^{\mathrm{UL}}_{t,\nu}$, φ_J, φ_{M}, φ_{S}, κ_{M}, and $P_{t,J}$, are examined for the coverage in UL.The parameters for the simulation for the suggested network are catalogued in Table 3.

The simulated and numerical results for UL coverage probability are shown in Fig. 3 which compares different values of A^o_{M} versus κ_{M}. The results indicate that higher valus of φ_J causes higher DJs-I and lower UL coverage. RFA reduces effective interference of sBSs Moreover, the results indicate that by the deployment of RFA, the network significantly improves coverage either in presence or absence of DJs.

The chance of coverage probabilities in A^o_{M} versus various values of SIR threshold κ_{M} and φ_J are compared in Fig. 3 .It is generated for $\varphi_J = 0$,5,10,15, 20, 25. This figure shows by deploying RFA, coverage improves. This is because of efficient use of resource and effective reduction of interference

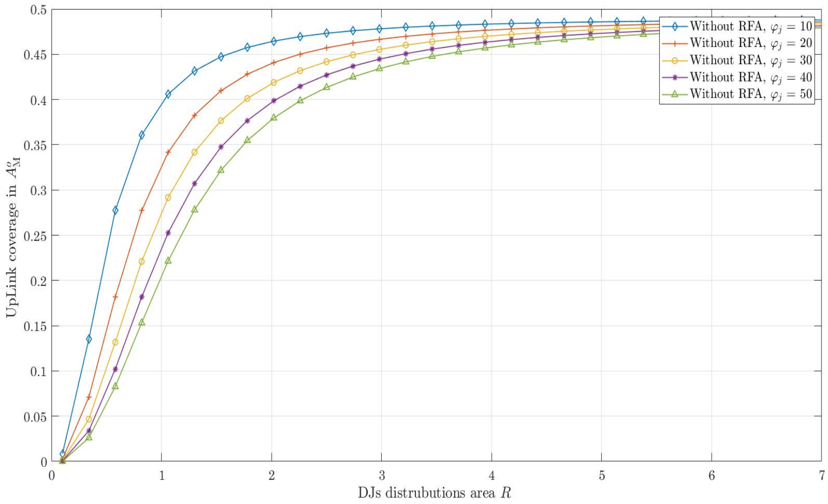

Figure 5. Without using RFA to cover DJ's distribution region,the Uplink coverage against radius .

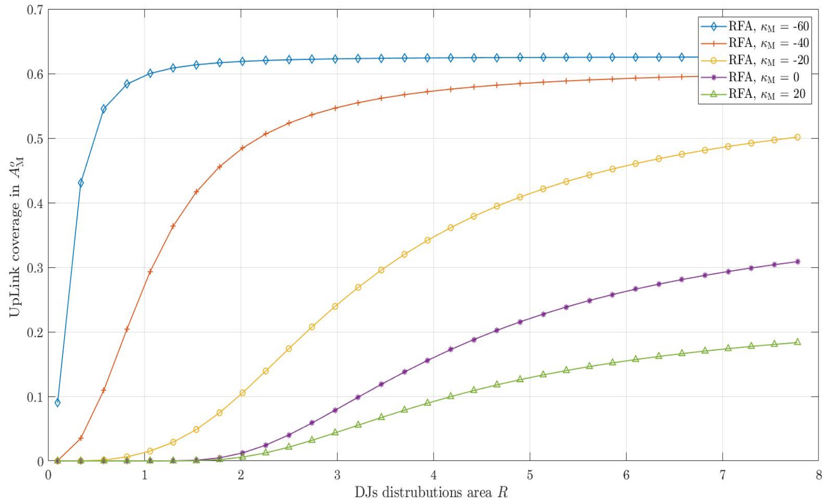

Figure 6. DJs distribution area, with the deployment of RFA,the UL coverage versus radius

due to RFA. By improving the value of φ_J UL coverage severely degrades because of significant increase in DJS-I.

The coverage probabilities of UL in A_M versus DJs distribution area,considering κ_M = -40 dB and φ_J = 10, 20, 30, 40 and 50,have been shown in Figs. 4 and 5.The result indicates Improved UL coverage by increasing distribution area of DJs because of less DJs number per unit area. Thus, creating the DJs less efficient while considering their power transmission constant. Moreover, by efficient resource allocation with the employment of RFA, hence improves the UL coverage.

Similarly, the coverage probabilities of UL in A^o_M against different DJs distribution area radius, considering φ_J = 60 and κ_M = -60, -40, 0 and 20 dB have been shown in the Figs. 6 and 7. The result shows improved UL coverage because of lower DJs-I and increased in distribution areas of φ_J.Hence the results indicate higher value ofκ_M significantly reduces UL coverage because of lower user associations.

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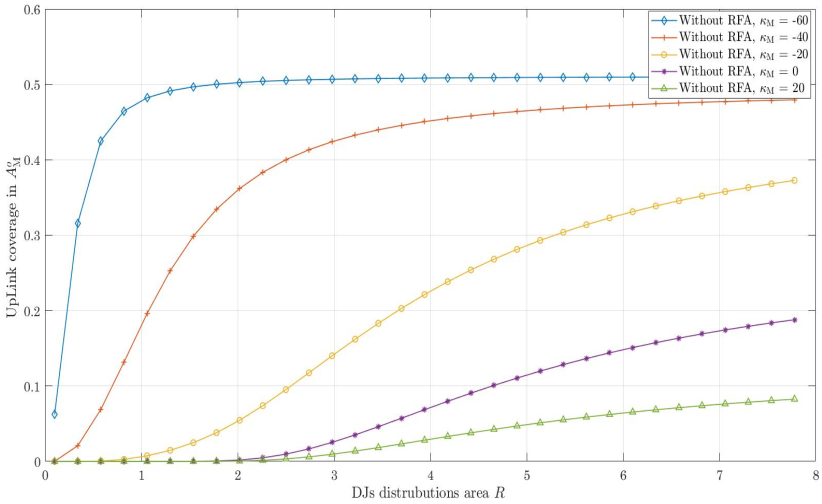

Figure 7. DJs distribution area, without RFA,the UL coverage versus radius

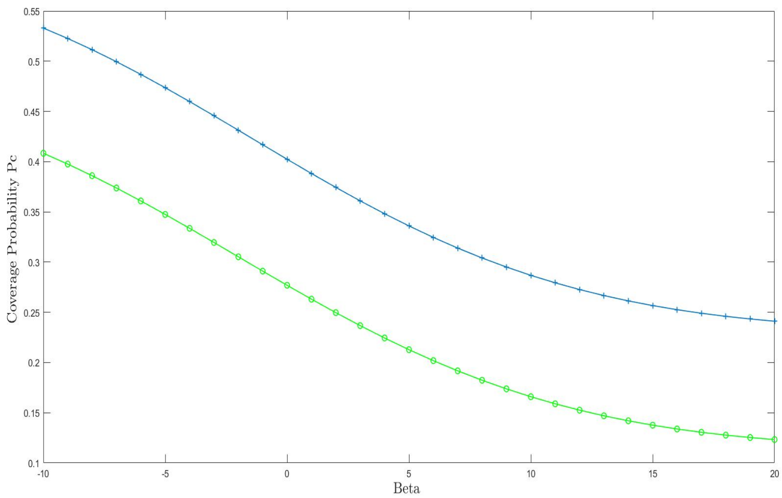

Figure 8. Path loss exponent vs Coverage Probability.

The β is the path loss exponent while PC is the coverage probability. The Figs. 8 represents as the path loss exponent increases the coverage probability decreases while when the value of path loss decreases the coverage probability increases.

5. Conclusion

In HetNets ICI is the main element that restrict system recital. The situation worsens because of existence of deliberate jamming. In this paper deliberate jammers are placed around the vicinity of target. The results are originated by scrutinizing disparate network parameters including user transmit power ,radius of jammers ,transmitter power of sBS and mBS and SINR threshold in case of deploying RFA and not deploying RFA. The results suggest that UL coverage is notably lessen by deliberate jammers density and transmission power. The results indicate a substantial improvement in UL coverage by applying RFA.

Appendix A Proof of the Laplace Transform of (4)

Proof of (4):

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Table 3. The Parameters of Simulation

Parameters	Configuration
mBS, sBSs, DJs	IHPPPs
Channel bandwidth	10 MHz
Code iterations	1000
φ_S	$20\ /\ \pi(2000\text{m})^2$
φ_M	$4\ /\ \pi(2000\text{m})^2$
φ_J	$20\ /\ \pi(200\text{m})^2$
A	$\pi \times (2000\text{m})^2$
The powers transmitted by mBS, sBS, ν , and DJs	35 dBm, 30 dBm, 25 dBm, and 20 dBm

From MBS-tier the LT of interference received , $\mathcal{L}_{I_{\mathrm{M},A}}(s)$, in A, is given below

$$\mathcal{L}_{I_{\mathrm{M},A}}(s) \overset{(a)}{=} \mathrm{E}_{I_{\mathrm{M},A}}\left[\exp\left(-I_{\mathrm{M},A}s\right)\right]\Big|_{s=\frac{r_{\mathrm{M}}^{\beta}\kappa_{\mathrm{M}}}{P_{t,\nu}^{\mathrm{UL}}}}$$

$$\overset{(b)}{=} \mathrm{E}_{I_{\mathrm{M},A},|h_l|^2}\left[\exp\left(-s\sum_{l\in\phi_{\mathrm{M}}} P_{t,\mathrm{M}}|h_l|^2 r_l^{-\beta}\right)\right]$$

$$\overset{(c)}{=} \mathrm{E}_{I_{\mathrm{M},A},|h_l|^2}\left[\prod_{l\in\phi_{\mathrm{M}}} \exp\left(-|h_l|^2\gamma_\circ\kappa_{\mathrm{M}} r_{\mathrm{M}}^{\beta} r_l^{-\beta}\right)\right]$$

$$\overset{(d)}{=} \mathrm{E}_{I_{\mathrm{M},A}}\left[\prod_{l\in\phi_{\mathrm{M}}} \mathrm{E}_{|h_l|^2}\exp\left(-|h_l|^2\gamma_\circ\kappa_{\mathrm{M}} r_{\mathrm{M}}^{\beta} r_l^{-\beta}\right)\right]$$

$$\overset{(e)}{=} \mathrm{E}_{I_{\mathrm{M},A}}\left[\prod_{l\in\phi_{\mathrm{M}}} \frac{1}{1+\gamma_\circ\kappa_{\mathrm{M}}\left(\frac{r_l}{r_{\mathrm{M}}}\right)^{-\beta}}\right]$$

$$\overset{(f)}{=} \exp\left(-2\pi\varphi_{\mathrm{M}}\int_{y}^{d2} \frac{r_l dr_l}{1+\left(\frac{r_l}{(\gamma_\circ\kappa_{\mathrm{M}})^{1/\beta} r_{\mathrm{M}}}\right)^{\beta}}\right)$$

$$\overset{(g)}{=} \exp\left(-\pi\varphi_{\mathrm{M}}\left(\gamma_\circ\kappa_{\mathrm{M}}\right)^{2/\beta} r_{\mathrm{M}}^2 \int_{\left(\frac{y}{(\gamma_\circ\kappa_{\mathrm{M}})^{1/\beta} r_{\mathrm{M}}}\right)^2}^{\left(\frac{d_2}{\gamma_\circ\kappa_{\mathrm{M}}^{1/\beta} r_{\mathrm{M}}}\right)^2} \frac{du}{1+(u)^{\beta/2}}\right)$$

The step (a) is acquired by defination of Laplace Transform [24], step (b) is derived from putting the value of $I_{\mathrm{M},A} = \sum_{l\in\phi_{\mathrm{M}}} P_{t,\mathrm{M}}|h_l|^2 r_l^{-\beta}$, into step (a). Step (c) Step (c) is achieved by putting the value of s, Step (e) is acquired from the Laplace transform with respect to h_j, of Step (d) Step (f) is acquired by applying the probability generating functional (PGFL) of IHPPP [19], Step (g) is acquired from putting the value of $u = \left(\frac{r_l}{(\gamma_\circ \kappa_{\mathrm{M}})^{1/\beta} r_{\mathrm{M}}}\right)^2$ in step (f). Finally, computing Gauss hypergeometric functions approximation of Step (g) (4) is obtained .

Appendix B Proof of the Laplace transform of (17)

Proof of (17):

$$
\begin{aligned}
\mathcal{L}_{I^{\mathrm{UL}}_{\phi_{\mathrm{M}},A^c_{\mathrm{M}}}}(s) &= \mathrm{E}_{I^{\mathrm{UL}}_{\phi_{\mathrm{M}},A^c_{\mathrm{M}}}}\left[\exp\left(-I^{\mathrm{UL}}_{\phi_{\mathrm{M}},A^c_{\mathrm{M}}} s\right)\right]\Bigg|_{s=\frac{r^{\beta}_{\mathrm{M}}\kappa_{\mathrm{M}}}{P^{\mathrm{UL}}_{t,v}}} \\
&= \mathrm{E}_{I^{\mathrm{UL}}_{\phi_{\mathrm{M}},A^c_{\mathrm{M}}},|h_l|^2}\left[\exp\left(-s\sum_{l\in\phi_{\mathrm{M}}} P^{\mathrm{UL}}_{t,v}|h_l|^2 r_l^{-\beta}\right)\right] \\
&= \mathrm{E}_{I^{\mathrm{UL}}_{\phi_{\mathrm{M}},A^c_{\mathrm{M}}},|h_l|^2}\left[\prod_{l\in\phi_{\mathrm{M}}}\exp\left(-|h_l|^2\kappa_{\mathrm{M}} r^{\beta}_{\mathrm{M}} r_l^{-\beta}\right)\right] \\
&= \mathrm{E}_{I^{\mathrm{UL}}_{\phi_{\mathrm{M}},A^c_{\mathrm{M}}}}\left[\prod_{l\in\phi_{\mathrm{M}}}\mathrm{E}_{|h_l|^2}\exp\left(-|h_l|^2\kappa_{\mathrm{M}} r^{\beta}_{\mathrm{M}} r_l^{-\beta}\right)\right] \\
&= \mathrm{E}_{I^{\mathrm{UL}}_{\phi_{\mathrm{M}},A^c_{\mathrm{M}}}}\left[\prod_{l\in\phi_{\mathrm{M}}}\frac{1}{1+\kappa_{\mathrm{M}}\left(\frac{r_l}{r_{\mathrm{M}}}\right)^{-\beta}}\right] \\
&= \exp\left(-2\pi\varphi_{\mathrm{M}}\int_{y}^{d_1}\frac{r_l dr_l}{1+\left(\frac{r_l}{\kappa_{\mathrm{M}}^{1/\beta} r_{\mathrm{M}}}\right)^{\beta}}\right) \\
&= \exp\left(-\pi\varphi_{\mathrm{M}}\kappa_{\mathrm{M}}^{2/\beta} r_{\mathrm{M}}^2\int_{\left(\frac{y}{\kappa_{\mathrm{M}}^{1/\beta} r_{\mathrm{M}}}\right)^2}^{\left(\frac{d_1}{\kappa_{\mathrm{M}}^{1/\beta} r_{\mathrm{M}}}\right)^2}\frac{du}{1+(u)^{\beta/2}}\right)
\end{aligned}
$$

Finally, by computing the Gauss hypergeometric approximation of Step (f) we arrive at (17) .

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