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Spectrum Allocation Management in Cognitive Femtocell Networks for 5G Wireless Communication

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Abstract: *In 5G wireless communication, Cognitive Femtocell is modern technology that can satisfy the demand of cellular mobile communication in high density area (i.e. indoor , outdoor ,airport and home etc.) . In this network macro base station in macrocell and femto base station in femtocell are considered primary and secondary system. Macrocell User (MU) is called primary user and Femtocell User (FU) is called secondary user. One Macrocell cover more than one femtocells. Macrocell and Femtocell uses the same frequency channel. Spectrum allocation management function follows as : first determine which spectrum currently unused through spectrum sensing, secondly select the best available free channel through spectrum decision, thirdly assign to this channel with other femto users through spectrum sharing, and finally automatically release the channel when a macro user is detected. Actually we work on first part of spectrum allocation management, so in this paper we propose supper-allocation based cooperative spectrum sensing technique in cognitive femtocell networks for 5G wireless communication. In this technique FU use vacant channel if MU channel is idle in a fixed sensing time. During reporting time slot of FU, FU sends sensing time to the Cognitive Femtocell Access Point (CFAP). During reporting time of CFAP, CFAP forward sensing time of FU to the Fusion Center (FC) using the same radio channel for global decision. Reporting time slots of FUs and CFAPs combine with sensing time slots of FUs.*

Keywords: *Cognitive radio, 5G, Macrocell, Femtocell , Femto-User, Fusion Center.*

I. Introduction

The 4G wireless communication systems have been implemented in many countries. The Deployment of wireless mobile devices and services are facing some challenges that cannot be accomplished by 4G [1].

The increasing development of wireless communication services through mobile web browsing and smart device has caused of the 5G mobile network. The new 5G cellular networks will be installed on 2020. 5G networks will have different requirements including user service costs, reduced latency etc. [2]. Primary technologies for 5G are classified as Femtocell (small cell), peer-to-peer (P2P) communication, full-duplex (FD) communication, massive multiple-input multiple-output (massive-MIMO), cloud-based radio access network (C-RAN) and energy harvesting [3-4].

In 5G wireless communication, Cognitive Radio (CR) is a form of wireless communication in which a transceiver can intelligently identify which communication channels are free or not, if free then instantly move into vacant channels while avoiding occupied channels. The use of available radio-frequency (RF) spectrum while minimizing interference to other users [5] .

5G cognitive femtocell installation is used not only for indoor coverage (home) but also outdoor coverage (as airport, park). CFAP has two parts. One part is a closed access Femto zone, which provides private indoor user can access to the CFAP such as Wi-Fi device. Other part is an open access Femto zone that is authenticated by outdoor users who can access to the CFAP such as airports, railway stations and shopping centers.

Cognitive femtocell were suggested currently by which MBS and femtocell access points qualify as primary and secondary user or systems, respectively. Femtocells are assumed to have cognitive facilities that are able to detect the free channel hole and opportunistically use channel for data transmission [7-8]. Femtocell provides a low cost solution to increase indoor and outdoor coverage and capacity [8]. At first, a femtocell is known as a low power access point (Cognitive Femtocell Access Point - CFAP) for indoor environments. Then the implementation of femtocell is elaborated to outdoor where femtocells are used as conventional picocells [8]. In this case, Macro cell users (MUs) are PUs who have legacy rights over the spectrum band and must be protected from SU interference . On the other hand, femtocell users (FUs) are SUs that opportunistically access and use spectrum resources only when they are not used by MUs.

Cooperative Spectrum Sensing (CSS) consists of three main phases in cognitive radio such as local sensing, reporting, and data fusion [10]. CSS has some advantages such as the accuracy of the local sensing, reliability of the reporting channel, data fusion techniques, network overhead etc. [11]. The performance deduction case of multipath fading and shadowing can be removed by cooperative sensing through the receiver's sensitivity can be set to the same level of nominal path loss without increasing the implementation cost of CR devices [12]. The local sensing data send to the FC or is locally processed for local decision. Local processing is required for bandwidth reduction. In the processing calculate test statistics and a threshold device for local decision. When local decisions are ready, MAC access the control channel for reporting the sensing results [13]. FC is connected to MBS (PU) [13].

In superposition based cooperative spectrum sensing combines sensing duration and reporting duration for sensing cooperative secondary users. Secondary users acquire different sensing duration and superimpose different reporting duration [14]. In this scheme, large synchronization problem occur in data processing. CFAP or FAP are considered Fusion Center (FC) and its user are called FUs [15].

Objective of this paper, supper allocation cooperative spectrum sensing in cognitive femocell networks sense spectrum more efficiently for 5G wireless communication. In this technique fusion center is centralized coordination of the femtocell, each FU get longer sensing time for MU signal, FUs and CFAPs are super-allocated to different reporting time slots. FUs and CFAPs reporting time are fixed case of removing synchronization problem in FC. FUs are covered by some femtocell, each FU reports its local decision to CFAP and then reports to FC for Global decision.

The rest of this paper is organized as follows. The system model assumed in this paper is described in Section II. The proposed supper allocation based spectrum sensing technique is described in Section III. The performance of the proposed scheme is verified by computer simulation in Section IV. Finally, conclusions are given in Section V.

II. System Model

We assume that a group of W hexagonal Networks based on macro cells. The frequency band in this network are divided W sub-channel, each cell is allocated different sub-channels. Each cell is covered by six cells (7 cell patterns) [15]. Mobile RAN Management System (MRMS) has periodical information exchange. FMS and MRMS can do handover procedures such as handover decision, cell selection and resource allocation [6].

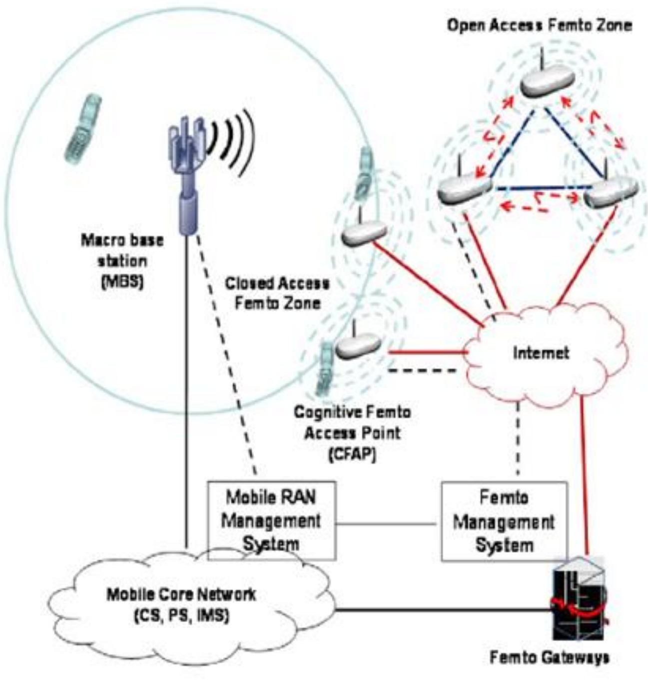

Fig. 1. Cognitive femtocell architecture for 5G wireless communication [6]

Femtocell is installation and randomly changing location within macrocell coverage area. In one macrocell contains N FUs, F femtocell, one Fusion Center (FC) and Macro user's m=1, 2, 3…. M.

In this network , N FUs are divided into F femtocells, in which every femotcell contains N FUs and the Cognitive Femto Access Points $CFAP_f$, f=1,2,3.…,F.

It is collected sensing result from all FUs at the same femtocell . Cooperative spectrum sensing in the cognitive femtocell network is shown in Fig.2. In sensing time duration, at first, each FU calculate the received energy from the Macro user (MU) in the frequency channel of interest. Local sensing, decision is transmitted to the nearest CFAP through a control channel, that will merge local sensing decision to make a femtocell decision .Then secondly all femtocell decisions will be passed to the FC through a control channel. All femtocell decisions from CFAPs will be merged to make global decisions about presence and absence the Macro user signal.

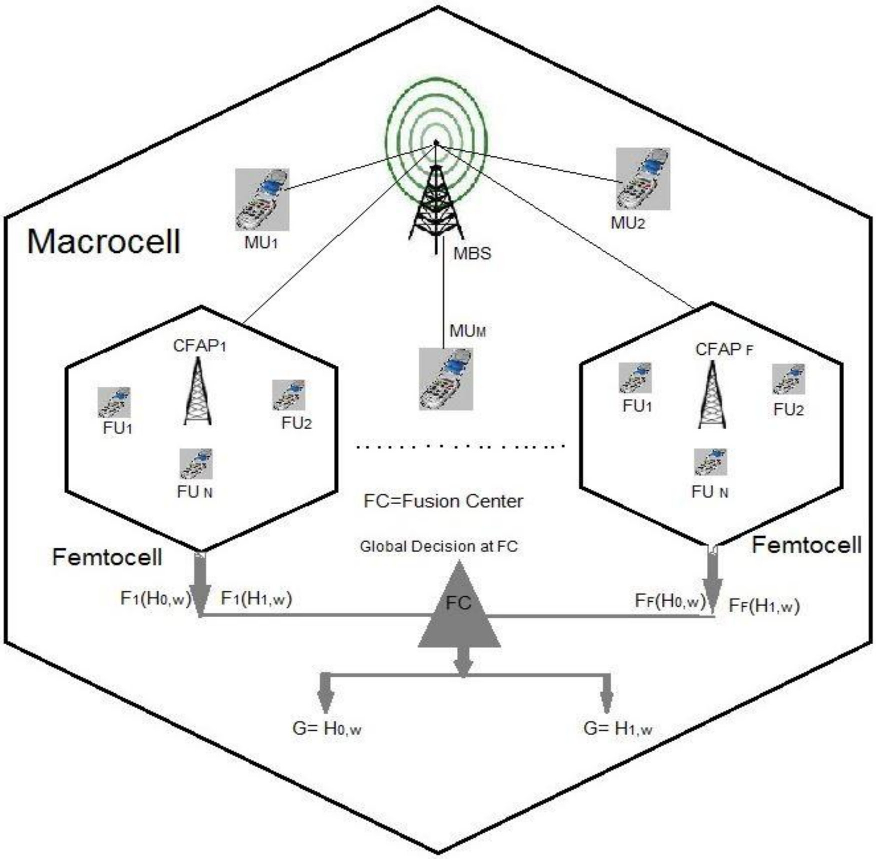

Fig. 2. Femtocell based cooperative spectrum sensing in 5G

The Femto-users and macro-users introduce interference from other CFAPs and MBSs. We consider that the macro network is M MBSs and F CFAPs are installed within the macro-cell coverage. The received signal of macro-user from macro base station MBS t (As macro-user t) through the *w*-th sub-channel can be formulated [7]:

$$r_t = \sqrt{\sigma_t} g_t^w x_t + \sum_{m=1\neq t}^{\mathrm{M}} \sqrt{\sigma_{m,t}}\ g_{m,t}^w x_m + \sum_{f=1}^{F} \eta_f^w \sqrt{\sigma_{f,t}}\, g_{f,t}^w s_f + \upsilon_t \tag{1}$$

Where σ_t,$\sigma_{m,t}$ and $\sigma_{f,t}$ denotes path loss from serving MBS ,the adjacent MBS m and CFAP f to macro-user t , g_t^w, $g_{m,t}^w$ and $g_{f,t}^w$ respectively channel from serving MBS, the adjacent MBS m and CFAT f to macro-user t, x_t and s_f respectively denote the signal transmitted to macro-user t and transmitted to femto-user f , η_f^w denote utility function of femocell f through w sub-channel ,υ_t denote zero mean additive white Gaussian noise (AWGN) of the macro-user t .

A. Signal- to- Interference and Noise Ratio (SINR) for Macro-User

The SINR value for *t*- Macro-User through w sub-channel using equation (1) can be formulated as[7]:

$$\Psi_t^w = \frac{\sigma_t |g_t^w|^2 \rho_t}{\sum_{m=1\neq t}^{\Phi} \sigma_{m,t} \left|g_{m,t}^w\right|^2 \rho_m + \sum_{f=1}^{F} \eta_f^w \sigma_{f,t} \left|g_{f,t}^w\right|^2 \rho_f + \chi_{w,t}^2}$$

$$\Psi_t^w = \frac{|g_t^w|^2 \Upsilon_t}{\sum_{m=1\neq t}^{\Phi} \left|g_{m,t}^w\right|^2\ \Upsilon_{m,t} + \sum_{f=1}^{F} \eta_f^w \left|g_{f,t}^w\right|^2 \Upsilon_{f,t} + 1} \tag{2}$$

Where ρ_t, ρ_m and ρ_f respectively represents the transmit signal power of the MBS M, the adjacent MBS m, and the CFAP f *signal* ,Υ_t , $\Upsilon_{m,t}$, *and* $\Upsilon_{f,t}$ respectively the average received SNR of macro-user *t* for the serving MBS, the adjacent MBS m, and CFAP f , and $\chi^2_{w,t}$ denote the variance of υ_t .
In the same way, the received signal of Femto-user provided by CFAP *n* (As Femto-user n) through the *w*-th sub-channel can be formulated as [7].

$$r_n = \sqrt{\sigma_n} g_n^w s_n + \sum_{m=1}^{\Phi} \sqrt{\sigma_{m,n}}\ g_{m,n}^w x_n + \sum_{f=1\neq n}^{F} \eta_f^w \sqrt{\sigma_{f,n}}\, g_{f,n}^w s_f + \upsilon_n \qquad (3)$$

Where σ_n, $\sigma_{m,n}$ and $\sigma_{f,n}$ represents a path loss from serving CFAP, the MBS *m* and the adjacent CFAP f to Femto-user *n*, g_n^w, $g_{m,n}^w$ and $g_{f,n}^w$ respectively channel from serving CFAP, the MBS m and the adjacent CFAT f to Femto-user *n*, and υ_n represents an AWGN of Femto-user *n*.

B. Signal- to- Interference and Noise Ratio (SINR) for Femto-User

The SINR value for *n*- Femto-user through w-th sub-channel using equation (3) can be formulated as [7]:

$$\Psi_n^w = \frac{\sigma_n |g_t^w|^2 \rho_n}{\sum_{m=1}^{\Phi} \sigma_{m,n} |g_{m,n}^w|^2 \rho_m + \sum_{f=1}^{F} \eta_f^w \sigma_{f,n} |g_{f,n}^w|^2 \rho_f + \chi^2_{w,n}}$$

$$\Psi_n^w = \frac{|g_t^w|^2 \Upsilon_n}{\sum_{m=1}^{\Phi} |g_{m,n}^w|^2\ \Upsilon_{m,n} + \sum_{f=1}^{F} \eta_f^w |g_{f,n}^w|^2 \Upsilon_{f,n} + 1} \qquad (4)$$

Where ρ_n, ρ_m and ρ_f represents the transmit signal power of the serving femto-user *n* ,the MBS *m*, and the adjacent CFAP f *signal* ,Υ_n , $\Upsilon_{m,n}$, *and* $\Upsilon_{f,n}$ respectively represents the average received SNR of Femto-user *n* for the serving CFAP, the MBS *m*, and the adjacent CFAP f, and $\chi^2_{w,n}$ represent the variance of υ_n.
We use simple hypothesis testing for the presence or absence of macro-user signal where $H_{1,w}$ and $H_{0,w}$, we represent hypothesis to the absence and presence of the macro-user signal, respectively. The received signal of the CFAP can be represented in the time domain over w-the sub channel as:

$$Y_{w,n} = \begin{cases} \alpha_{w,n} & : H_{0,w} \quad Absence\ MU\ Signal \\ x_{w,n}\beta_{w,n} + \alpha_{w,n} & : H_{1,w} \quad Present\ \ MU\ Signal \end{cases} \qquad (5)$$

Where w=1,2,3,…………W is the sub-channel of the receiving signal of CFAP and $Y_{w,n}$is the receiving signal of n-th FU, $\beta_{w,n}$ is the channel gain from MU to n-th FU,$x_{w,n}$ is the transmitted MU QPSK signal with variance $\chi^2_{w,n}$, $\alpha_{w,n}$ is Additive White Gaussian Noise (AWGN) with zero mean and variance ${\chi_{\alpha,n}}^2$ at n-th FU. $x_{w,n}$ And $\alpha_{w,n}$ are assumed to be independent of each other and the noises are also independent of each other between FUs.
The summation of all received FUs signal are given bellow [16]

$$E_w^n = \frac{1}{L} \sum_{t=0}^{N} (Y_w^n(t))^2 \qquad (6)$$

Where Y_w^n is *t* sample of n-th FU signal for cooperative networks over a sensing duration τ_s and bandwidth where $L = \tau_s F_s$
The Signal E_w^n can be modeled as a central and non-central Chi-square distributed random variable with $2T$ degrees of freedom under hypothesis $H_{0,w}$ and $H_{1,w}$,respectively.
The detection performance is considered on two things:

C. Probability of detection (P_d) for Femtocell

One is the probability of detection (P_d), that denotes the probability of a CR user declaring that a Macro-user (PU) is present when the spectrum is occupied by the Macro-user. Decision statistics E_w^n depend on sensing time τ_s of j-th femto-user (FU) and decision threshold λ_j, so probability of false alarm for j-th Femto-user as[16]:

$$P_{d,w}^n(\tau_s\,, \lambda^n\,) = P\left(E_w^n > \left(\lambda^n \middle| H_{1,w}\right)\right) = Q_L\left(\sqrt{2L\Upsilon}, \sqrt{2L\lambda^n}\right)$$

$$= Q\left((\lambda^n - \Upsilon - 1)\sqrt{\frac{L}{2\Upsilon + 1}}\right)$$
$$\simeq Q\left((\lambda^n - \Upsilon - 1)\sqrt{\frac{\tau_s F_s}{2\Upsilon+1}}\right) \quad (7)$$

D. Probability of False Alarm (P_d) for Femtocell:

On the other Probability of false alarm (P_f), that denotes the probability of a CR user declaring which a Macro-user (PU) is present when the spectrum is free such as:

$$P^n_{f,w}(\tau_s, \lambda^n) = P\left(E^n_w > \left(\lambda^n \middle| H_{0,w}\right)\right) = \Gamma\frac{(L,L\lambda^n)}{\Gamma(L)}$$
$$\simeq Q\left((\lambda^n - 1)\sqrt{L}\right)$$
$$\simeq Q\left((\lambda^n - 1)\sqrt{\tau_s F_s}\right) \quad (8)$$

Where Γ(·,·), Q(·) and Q_U(·,·) are the incomplete gamma function, Q-function and generalized Marcum Q-function , respectively [17]. Υ is a non-centrality parameter defined as SNR (signal-to-noise power ratio) of the receive macro-user signal at CFAP.

E. Conventional Cooperative Spectrum sensing for cognitive radio

In conventional cooperative spectrum sensing as shown in Fig. 3. [17]

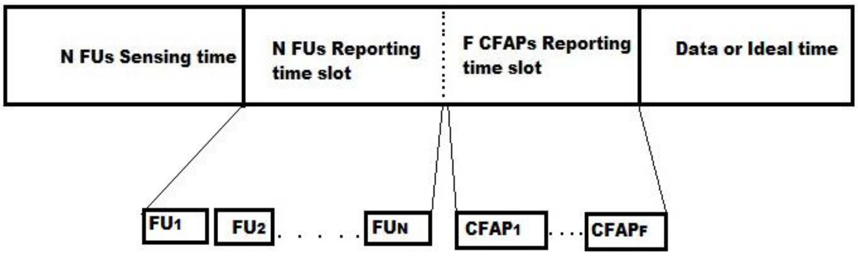

Fig. 3. Conventional cooperative spectrum sensing

N FUs conventional sensing time τ_s^{con} get from equation (8) and (7) .We get λ^n from equation (8) as:

$$\lambda^n = \frac{Q^{-1}(P^n_{f,w})}{\sqrt{\tau_s F_s}} + 1$$

Putting in equation (7) .Finally we get conventional sensing time τ_s as:

$$\tau_s^{con} = \frac{1}{F_s}\left[Q^{-1}\left(P^n_{f,w}\right) - Q^{-1}\left(P^n_{d,w}\right)(2\Upsilon + 1)\right]^2 \quad (9)$$

Where τ_s^{con} is used in improve supper-allocation cooperative spectrum sensing for femtocell. We can see in equation (9) sensing time i.e. probability of false alarm and detection depend on SNR of a Femto-user (FU).

III. Proposed Supper Allocation Based Cooperative Spectrum Sensing Technique In Femtocell

In the paper, Femto-user (FU) reporting times and Cognitive Femto Access Point (CFAP) reporting times are combined with sensing time of FU as a result sensing time of FU will increase. In fig.3. describe N FUs in F femtocell networks. In this scheme, FU_{FN} is F-th femtocell and N-th Femto-user. Here sensing time and reporting time of femtocell are τ_s and τ_r . Sensing the time of first Femto-user of first femtocell is FU_{11}, which is same to sensing time of conventional sensing time slot $\tau_s^{11} = \tau_s$ that is calculated above. Except for FU_{11}, other FUs can sense spectrum during reporting time slot of FUs and CFAPs. As an example, we can sensing time of FU_{12} is $\tau_s^{12} = \tau_s + \tau_r^{11}$,then sensing time of FU_{13} is $\tau_s^{13} = \tau_s^{12} + \tau_r^{12}$, where reporting time is same for all FUs and CFAPs .So we can write sensing time expression for others next Femto-user $FU_{F(n+1)}$ such as:

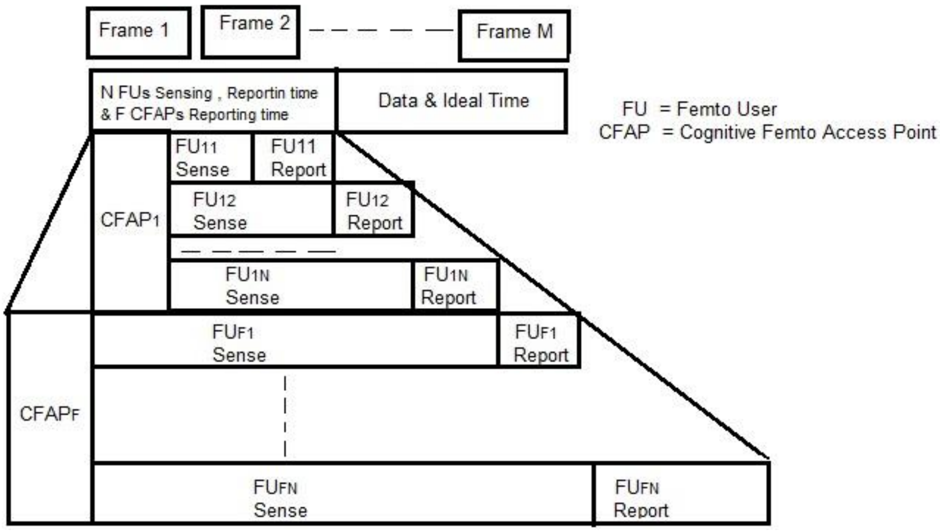

Fig.4. Proposed super-allocation based cooperative spectrum sensing technique in Femtocell

$$\tau_s^{f(n+1)} = \tau_s + \sum_{n=1}^{N} \tau_r^{fn} \tag{10}$$

Where *f= 1,2,3,…………F* and n=1,2,3…………N are the number of femtocells and the number of femto-users (FUs) . In first femtocell is

$$\tau_s^{1n} = \tau_s + (n-1)\tau_r \tag{11}$$

So total sensing time of F femtocell within N femto- users are denoted by

$$\begin{aligned}\tau_s^{FN} &= \sum_{n=1}^{F-1} \tau_s^{nN} + \sum_{n=1}^{N} \tau_r^{Fn} \\ &= (\tau_s + N * \tau_{r,FU}^{fem} + \tau_{r,CFAP}^{fem})(F-1) + \tau_s + (n-1)\tau_r \end{aligned} \tag{12}$$

Where $\tau_{r,FU}^{fem}$ is femto- user reporting time and $\tau_{r,CFAP}^{fem}$ is Cognitive Femto Access Points Decision reporting time.

A. Femto Users Decision (local)

Using equation (7) ,the probability of detection $P_{d,w}^{n}$ depends on the threshold value λ^n , signal-to-noise ratio Υ, and finally sensing time τ_s and channel bandwidth F_s .In improving supper allocation based cooperative spectrum sensing in femtocell has N Femto-users no-fixed sensing time slot. The no-fixed sensing time is greater than conventional sensing time slot, so $\tau_s^{FN} \geq \tau_s^{con}$ in equation (13) to sense Femto-users (FUs).

Let us consider the probability of detection for conventional sensing time to be $P_{d,w(con)}^{n}$ and probability of detection for proposed no fixed sensing time is $P_{d,w(fem)}^{n}$. When FU belongs to the first femtocell, the CFAP reporting time slot is not included in its sensing time. Substituting the value of τ_s and τ_s^{1n} in equation (6) .So we get

$$P_{d,w(con)}^{n}(\tau_s, \lambda^n) = Q\left((\lambda^n - \Upsilon - 1)\sqrt{\frac{\tau_s F_s}{2\Upsilon+1}}\right) \tag{13}$$

$$P_{d(fem)}^{1n}(\tau_s^{1n}, \lambda^n) = Q\left((\lambda^n - \Upsilon - 1)\sqrt{\frac{\tau_s + (n-1)\tau_r * F_s}{2\Upsilon+1}}\right) \tag{14}$$

Where $P_{d,w(fem)}^{1n} \geq P_{d,w(con)}^{n}$ because is sensing time of τ_s^{1n} is larger than τ_s^{con} $, so\ (\tau_s + (n-1)\tau_r) \geq \tau_s^{con}$ for n=1,2,3………N .When n=1 we get $P_{d,w(fem)}^{1n} = P_{d,w(con)}^{n}$.

If Femto-user are not first femtocell . In this case sensing time slot includes CFAP reporting time slots.

Substituting τ_s^{FN} in equation (6), we get

$$P_{d,w(fem)}^{FN}(\tau_s^{FN}, \lambda^n) = Q\left((\lambda^n - \Upsilon - 1)\sqrt{\frac{((F-1)(\tau_s + N * \tau_{r,FU}^{fem} + \tau_{r,CFAP}^{fem}) + \tau_s + (n-1)\tau_r) * F_s}{2\Upsilon+1}}\right) \tag{15}$$

Each Femto-user local decision Ld_n as follows

$$Ld_n = \begin{cases} 1 \ , if \ P_{d,w(fem)}^{FN} > P_{f,w(fem)}^{FN} \\ 0 \quad Otherwise \end{cases}$$

B. Cognitive Femto Access Points Decision (femtocell)

All F-th CFAP take all local decision Ld_n from all FUs will be merged to make a femtocell decision $Fd_{d,F}^{fem}$ are given:

$$Fd_{d,F}^{fem} = \begin{cases} 1 \ , if \ Ld_n^N > \phi \\ 0 \ Otherwise \end{cases}$$

Where ϕ is a threshold value of femtocell decision.

C. Femtocell Global Decision (Global):

At the fusion center of femtocell (FC) combine all femtocell decision $Fd_{d,F}^{fem}$ to make Global decion F_G using ϑ-out- N rule as follows.

$$F_G = \begin{cases} 1 \ if \ \sum_{f=1}^{F} Fd_{d,F}^{fem} > \vartheta \\ 0 \ \ Otherwise \end{cases}$$

Where ϑ is global decision threshold value.

IV. Simulation

In the performance evaluation of supper-allocation based cooperative spectrum sensing in cognitive femtocell networks using Monte Carlo Simulating and following Table 1: parameter is used for simulation:

Table 1: Simulation Parameter

Parameters Name	**Value**
Femto-Users(FUs)	6
Femtocell number	3
Femto-users number per femtocell	2
Sensing time of FUs	2ms
Average SNR	-10
Macro-users signal	QPSK
Numbers samples	1000

Sensing time of conventional scheme is shown in Fig. 5.

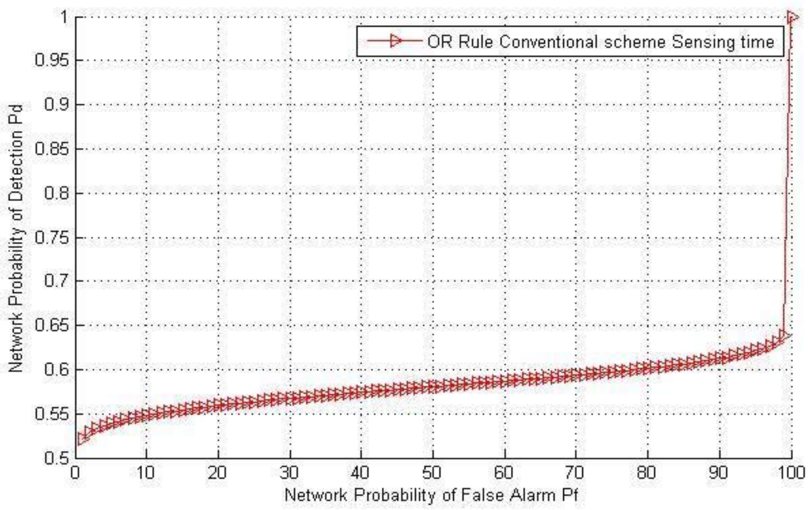

Fig. 5. ROC curve of probability of false alarm (P_f) vs probability of detection (P_d) of conventional scheme sensing time

In fig.5. and fig.6. Shows ROC curves for the proposed supper allocation based cooperative spectrum sensing femtocell, without and with femtocell RT. RT means reporting time. My proposed supper allocation based cooperative spectrum sensing compared with the conventional sensing time scheme in femtocell, in which the proposed technique can have greater sensing time than the conventional sensing time scheme. Probability of detection in Eq. (14) was assumed for the proposed sensing technique without reporting time for the Cognitive Femto access point (CFAP) decision. Probability of detection in Eq. (15) was assumed for the proposed sensing time technique with reporting time for the femtocell decision. Our Scheme increase probability of detection, sensing time τ_s^{FN} also increase as well as.

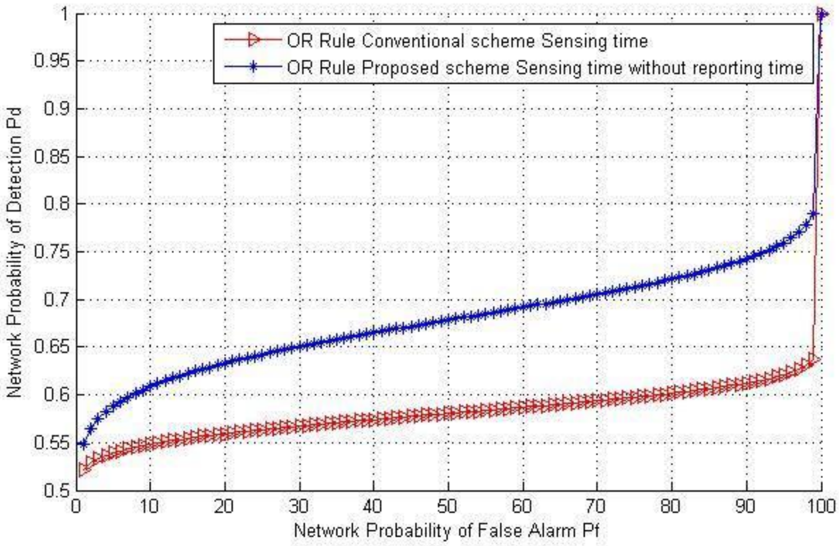

Fig. 6. ROC curve of probability of false alarm (P_f) vs probability of detection (P_d) of conventional sensing time scheme and proposed sensing time technique without reporting time

In fig. 6. and fig. 7. Shows ROC curves for the Femtocell global decision at the Fusion Center (FC) for the proposed sensing time technique and conventional sensing time scheme with and without Femtocell reporting time. Above figures OR-rule-based [18] is the more efficient rule of the proposed sensing time scheme with better performance, with and without femtocell reporting time. So, the OR-rule is the best efficiency, compared with other Data fusion decisions (Majority-rule, AND-rule) [19].

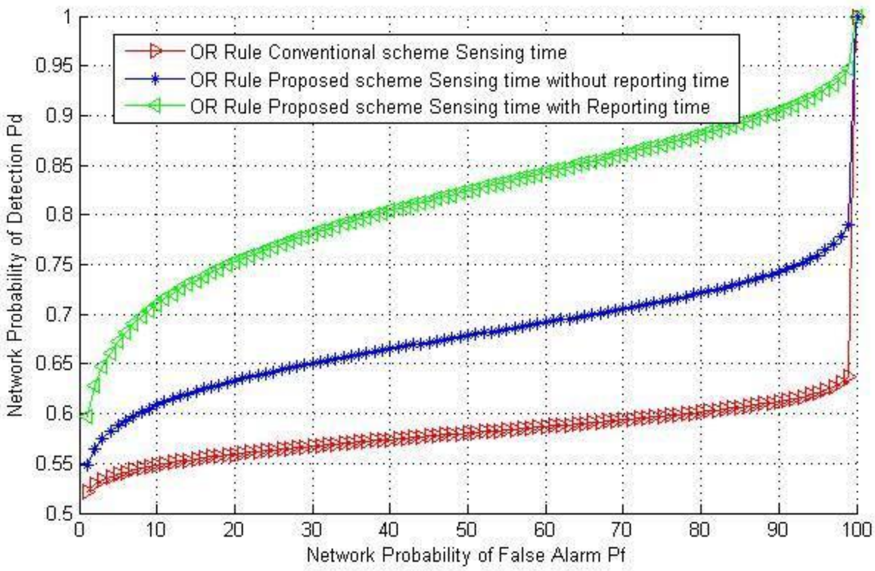

Fig. 7. ROC curve of probability of false alarm (P_f) vs probability of detection (P_d) of conventional sensing time scheme and proposed sensing time technique without and with reporting time

V. Conclusion

In this paper, we proposed super allocation based cooperative spectrum sensing in cognitive femtocell networks for 5G wireless communication in HetNet interference environment. In this paper describe about supper allocation spectrum sensing ,we will work others part of spectrum allocation management for Femtocell in future. By sensing sub-channel that is un-used nearby macro-user and allocating to Femto-user. In proposed sensing technique performance is greater than conventional spectrum sensing scheme. Here by re-scheduling reporting time slots of FUs and CFAPs, get greater sensing duration than conventional scheme.

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