Capacity Analysis of OFDM / FBMC based Cognitive Radio Networks with Estimated CSI

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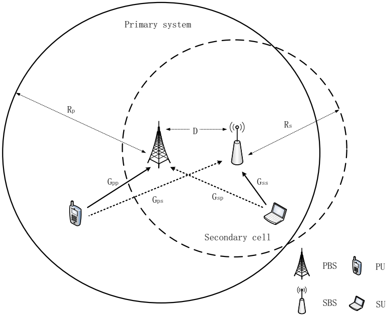
Outline

- Much of attention in broadband CR literature emphasized on the use of OFDM modulation
- Filter bank based modulation (FBMC) has been proposed as an alternative scheme Farhang-Boroujeny, com. mag 2008, PHYDYAS FP7 european project
- When using OFDM in asynchronous communication systems Inter-Cell Interference (ICI) exists between PUs and SUs Hamdi, trans. wireless 2009 Y. Medjahdi et al., SPAWC 2009
- In this work, we will consider capacity analysis of a CR Network using OFDM and FBMC

The considered Cognitive radio network :



We have the following assumptions:

- Primary system and secondary cell apply the same multicarrier modulation scheme (OFDM or FBMC)
- SUs in the secondary cell are synchronized, and secondary base station can perfectly sense the free bands of the licensed system
- Primary system and secondary cell are assumed to be unsynchronized, so Inter-Cell Interference (ICI) exists between PUs and SUs

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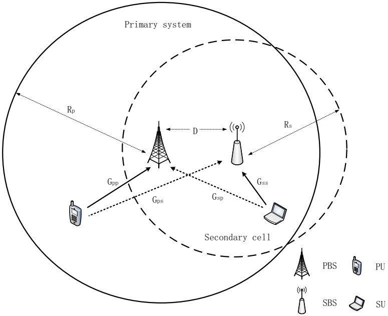

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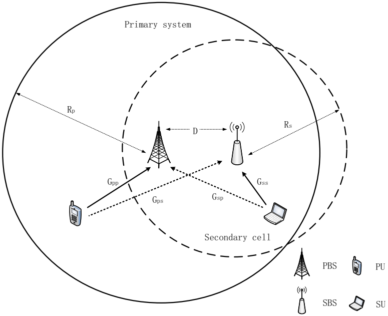

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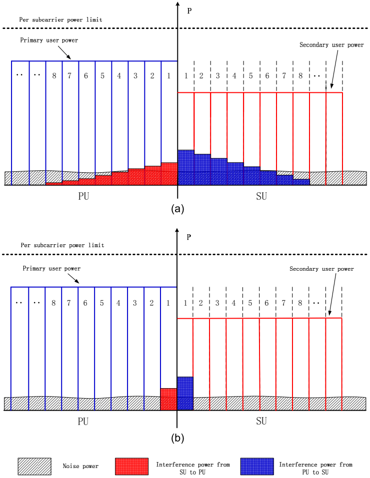
Illustration of ICI between PU and SU
(a) OFDM based CR networks (b) FBMC based CR networks



- The secondary cell wants to maximize the sum data rate by allocating power into the detected spectrum holes for its users
- This problem can be formulated as follows :

$$\max_{\mathbf{p}} : C(\mathbf{p}) = \sum_{m=1}^{M}\sum_{k=1}^{K}\sum_{f=1}^{F_k} \theta_m^{kf} log_2\left[1 + \frac{p_m^{kf} G_{ss}^{mkf}}{\sigma^2 + I_f^k}\right]$$

s.t.

$$\begin{cases} \sum_{k=1}^{K}\sum_{f=1}^{F_k} \theta_m^{kf} p_m^{kf} \leqslant P_{th}, \quad \forall m; \\ 0 \leqslant p_m^{kf} \leqslant P_{sub}; \\ \sum_{m=1}^{M}\sum_{n=1}^{N} \theta_m^{k_{l(r)}n} p_m^{k_{l(r)}n} G_{sp}^{mk_{l(r)}} \sum_{i=1}^{N-n+1} V_{N-i+1} \leqslant I_{th}, \quad \forall k; \end{cases}$$

where M is the number of secondary users, K is the number of spectrum holes and F_k is the number of SC in the k^{th} spectrum hole

$$I_f^k = \begin{cases} \sum_{n=f}^{N} P_p^{k_l} G_{ps}^{k_l f} V_n, & f = 1, 2, \cdots N \\ \sum_{n=F_k-f+1}^{N} P_p^{k_r} G_{ps}^{k_r f} V_n, & f = F_k - N + 1, \cdots F_k \\ 0, & otherwise \end{cases}$$

- Practically, the channel gain between SU and PBS "G_{sp}" cannot be perfectly estimated
- A channel gain margin G_m is added on the estimated pathloss gain

$$\overline{G_{sp}} = (1 + G_m)G_{pl}$$

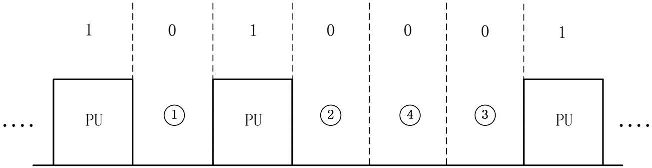
where G_m depends on the prescribed outage probability

$$P_{out} = P(G_{sp} > \overline{G_{sp}}) = P(|H_{sp}|^2 > 1 + G_m)$$

- Given an acceptable outage probability P_{out}, the added channel gain margin G_m can be obtained

$$G_m = 2\mu^2 log_e(\frac{1}{P_{out}}) - 1$$

- The optimization problem is an integer programming problem
- Suboptimal solution : first assign the bandwidth, then the clusters and finally allocate the power
- The bandwidth assignment algorithm increments the number of clusters N_u for user u which exhibits the smallest channel capacity Lengoumbi et al., VTC 2006



Four types of clusters in available spectrum holes

- The Hungarian algorithm is used to implement the cluster assignment

- After the cluster assignment, the power allocation of multi-user system can be virtually regarded as a single-user system

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- Rosen's Gradient Projection Method (GPM) can be applied to obtain the optimal power allocation for this simple CR uplink scenario in a low computational complexity.

Table: system simulation parameters

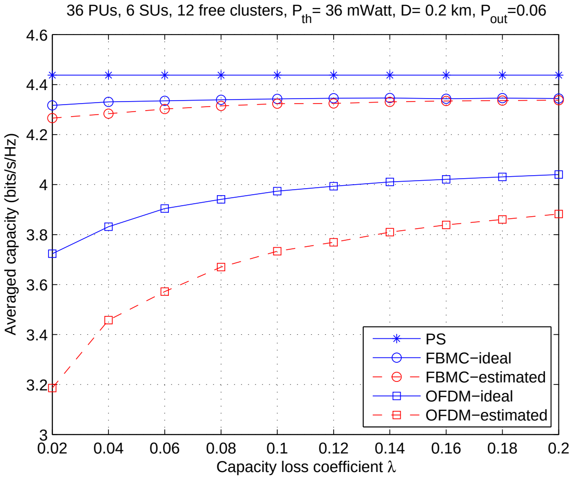
Parameter	Value	Unit
Total bandwidth B	10	MHz
Center frequency	2.5	GHz
Number of sub-carriers	1024	-
Number of sub-carriers per cluster L	18	-
Power limit per subcarrier P_{sub}	5	mWatt
Noise power per subcarrier	-134.10	dBm
Channel delays	$10^{-9}[0, 110, 190, 410]$	s
Channel powers	$[0, -9.7, -19.2, -22.8]$	dB
Channel realizations	200	-

- We assume that the received primary signal in PBS always has a desired $SNR = \frac{P_p G_{pp}}{L\sigma^2} \approx 10$. The capacity on each cluster occupied by PU is

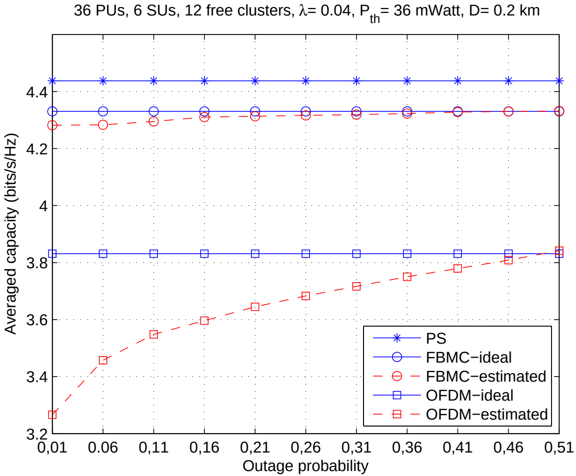
$$C = log_2(1 + \frac{P_p G_{pp}}{L\sigma^2})$$

- The value of interference threshold I_{th} can be automatically generated by defining a tolerable capacity loss coefficient λ according to

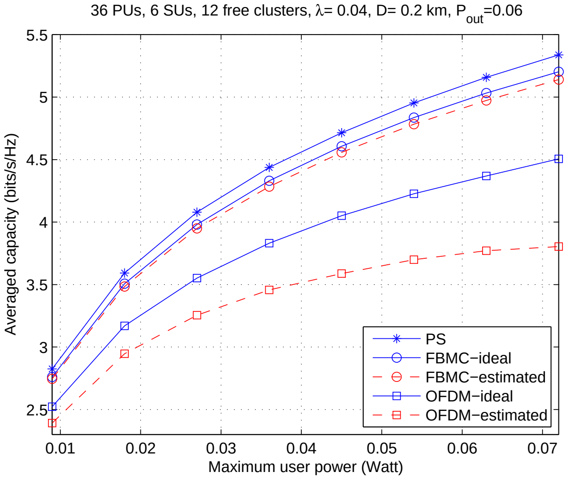
$$(1-\lambda)C = log_2(1 + \frac{P_p G_{pp}}{L\sigma^2 + I_{th}})$$



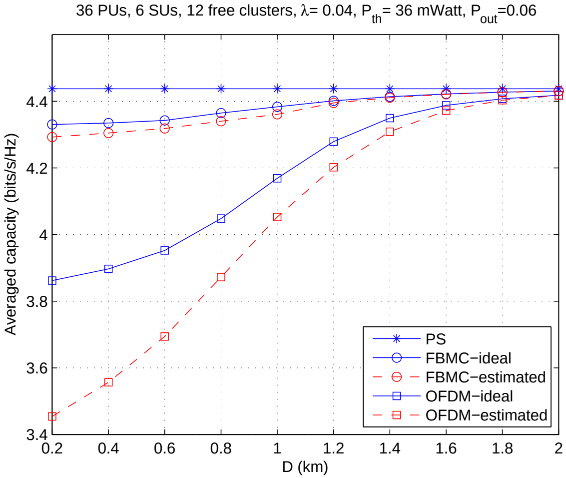
Averaged capacity *vs.* interference level.



Averaged capacity *vs.* outage probability.



Averaged capacity *vs.* maximum user power.



Averaged capacity *vs.* distance between SBS and PBS.

- In this work we have evaluated the spectrum efficiency of a simple CR network considering both OFDM and FBMC
- Compared to OFDM based CR network, FBMC based CR network can offer higher channel capacity
- FBMC scheme achieves better performance gain if only rough estimated channel information is available
- FBMC is a good candidate for physical layer data communication in CR context

THANK YOU FOR YOUR ATTENTION