Filter Bank Based Multicarrier and Cognitive Radio

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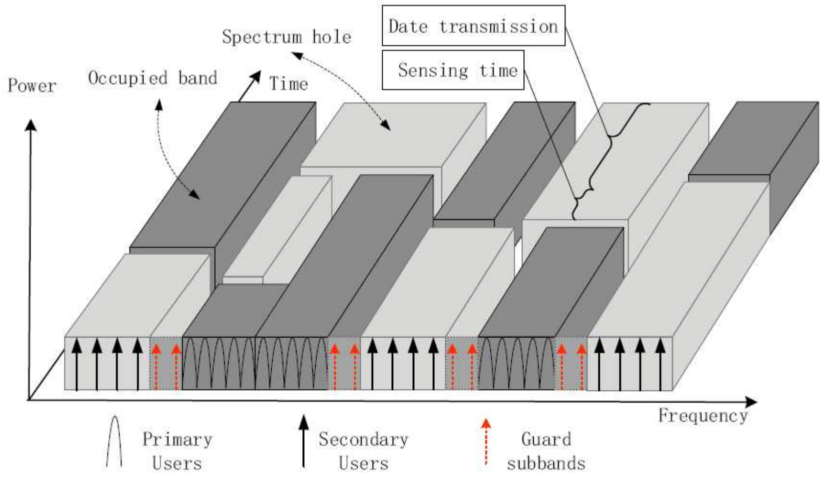
Outline

- Cognitive radio context
- Intercell Interference calculation
- Evaluation of the OFDM/FBMC system efficiency for CR
- Conclusion

Cognitive radio context

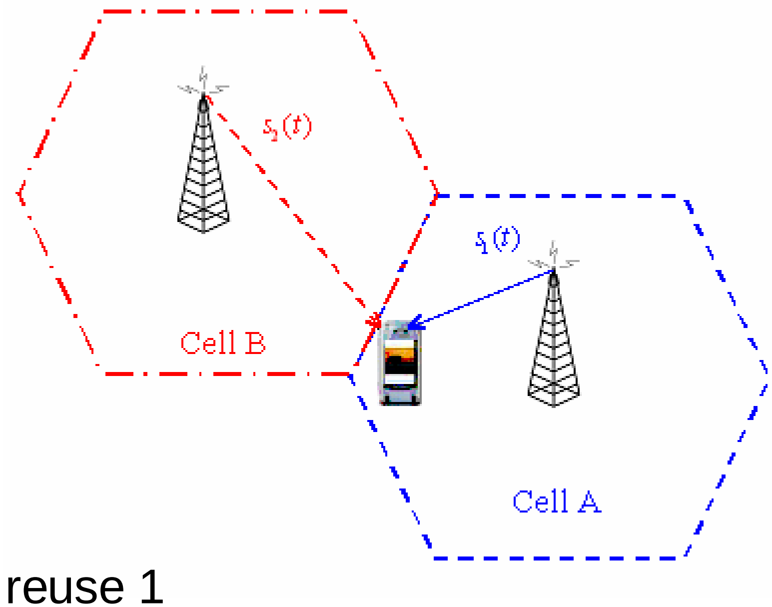
- Public space (open sharing model)
  - users compete for the resource
  - high spectral density
  - protection of other users
- White space in a licensed band (spectrum overlay)
  - protection of primary users
  - priority of primary users



Spectrum sensing

- Sensing sensibility (-116dBm for 802.22)
- Sensing latency
- Frequency resolution
- Spectrum sensing methods :
  - Matched filtered
  - Energy detector
  - Cyclostationnarity based detector
  - Covariance based detector
  - Cooperative sensing for reducing the shadowing effect

Interference Calculation



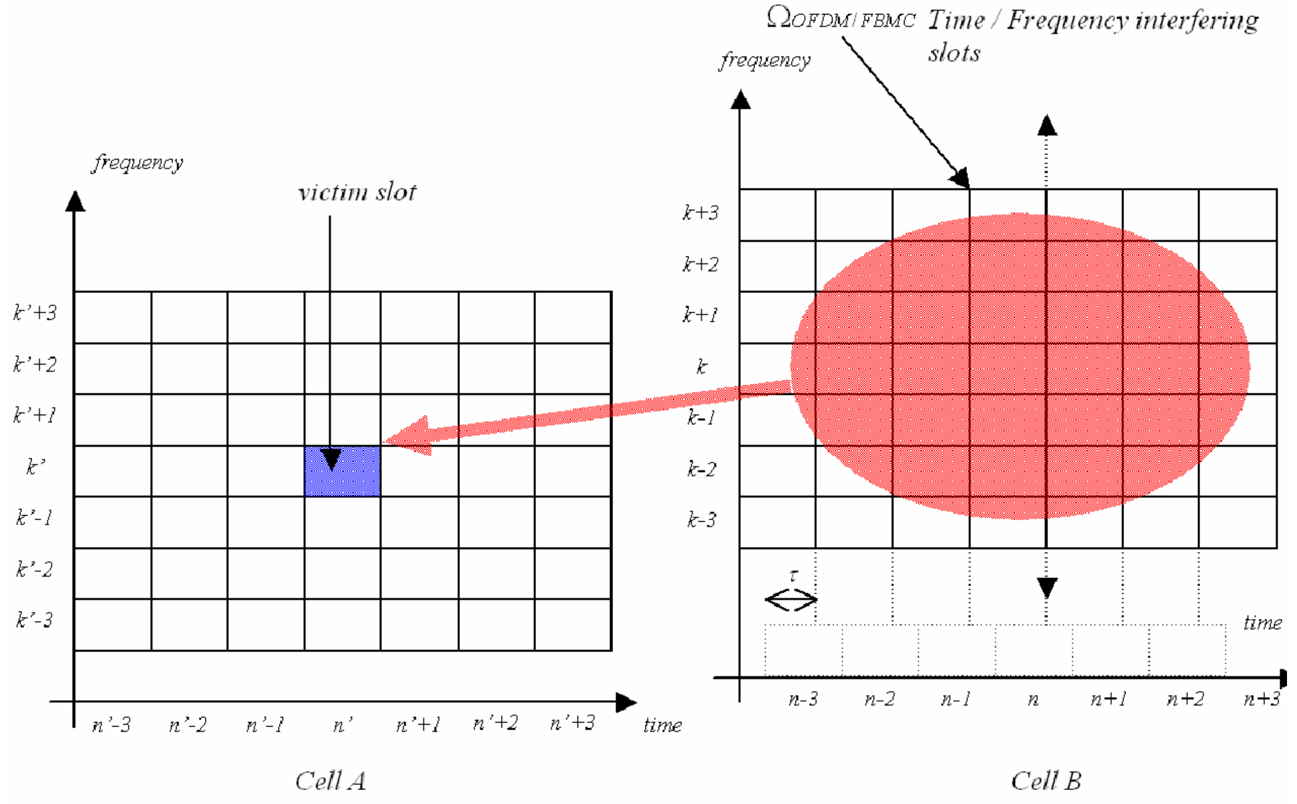
<u>Hypothesis</u>

- Frequency reuse 1
- Timing and frequency offsets τ,φ between the Cell B and the user (no synchronisation between the cells)

<u>How to compute the interference ?</u>

- Using Monte-Carlo simulations
- Out of band radiation using power spectrum density of the signals
- Using tables modeling the mean power interference

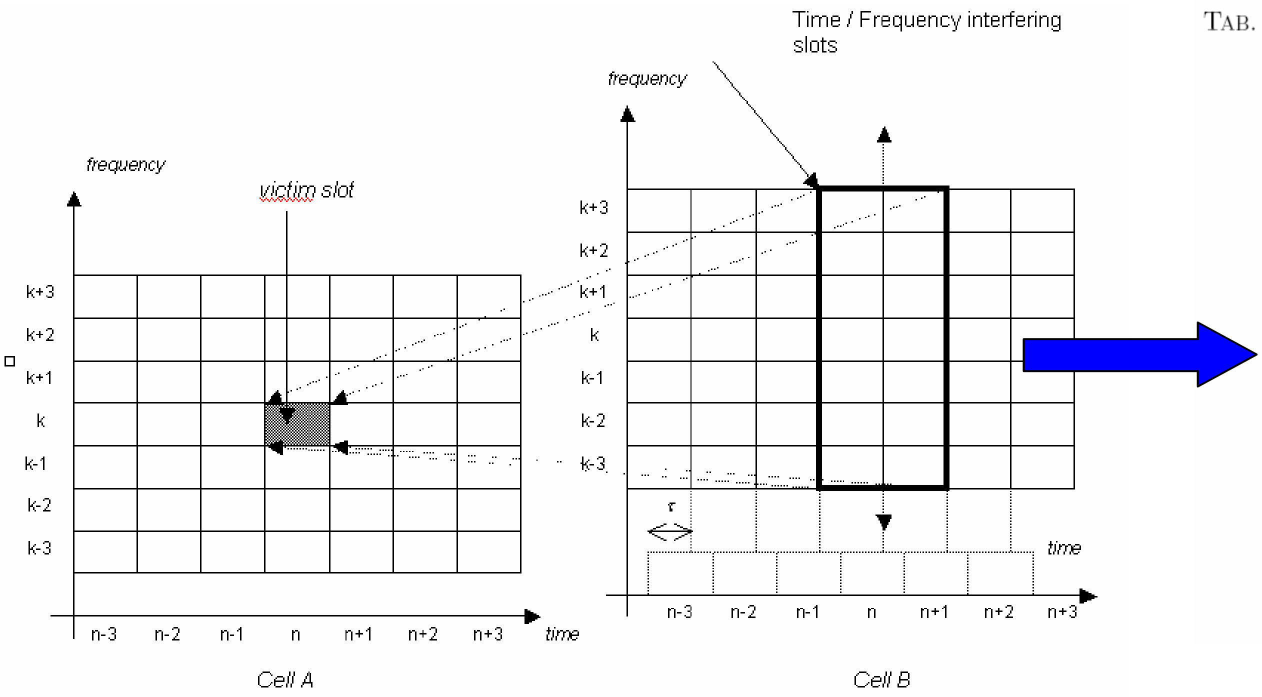
Interference Calculation



Determination of the set of interfering slots and their associated interference power for OFDM and FBMC systems

Interference Calculation

CP-OFDM=> CP-OFDM



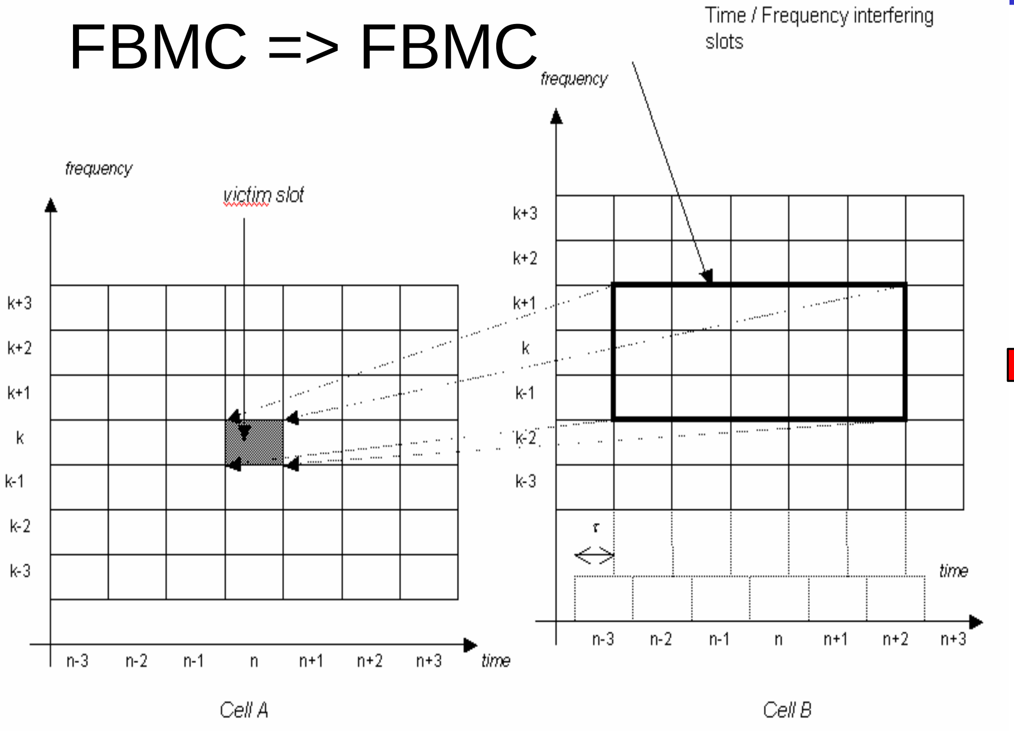
TAB. 1 – CP-OFDM mean interference power table

$f \setminus t$	n	$n+1$
$k-7$	9.19E-04	9.19E-04
$k-6$	1.25E-03	1.25E-03
$k-5$	1.80E-03	1.80E-03
$k-4$	2.81E-03	2.81E-03
$k-3$	5.00E-03	5.00E-03
$k-2$	1.13E-02	1.13E-02
$k-1$	4.50E-02	4.50E-02
k	3.52E-01	3.52E-01
$k+1$	4.50E-02	4.50E-02
$k+2$	1.13E-02	1.13E-02
$k+3$	5.00E-03	5.00E-03
$k+4$	2.81E-03	2.81E-03
$k+5$	1.80E-03	1.80E-03
$k+6$	1.25E-03	1.25E-03
$k+7$	9.19E-04	9.19E-04

- Only the slots whose interference powers are larger than 10^{-4} are considered

Interference Calculation

FBMC => FBMC



TAB. 2 – PHYDYAS/OQAM mean interference power table

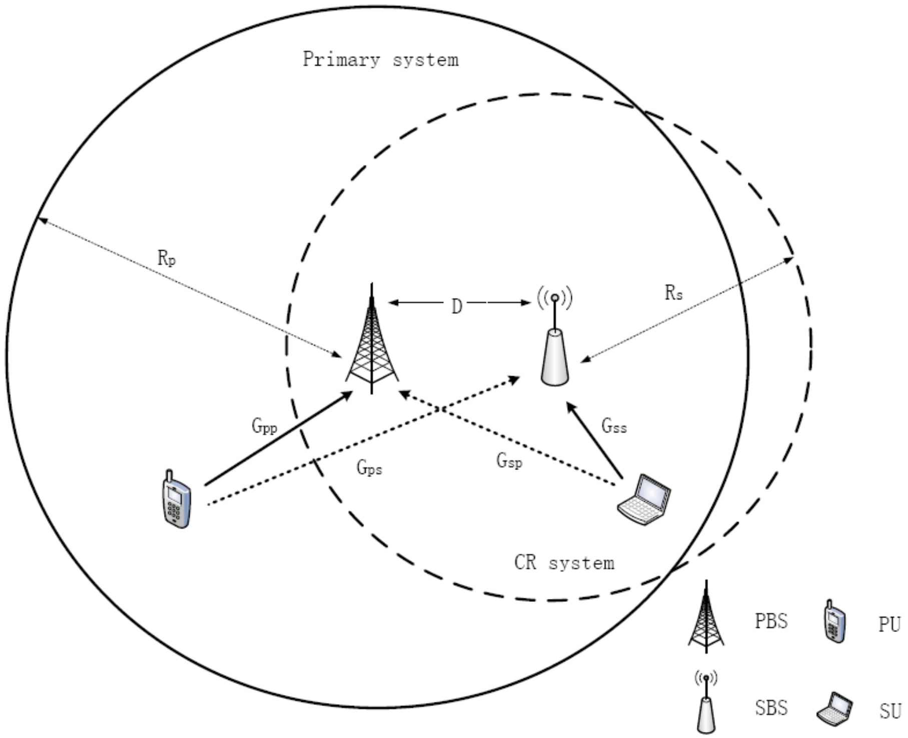
$f \setminus t$	n-2	n-1	n	n+1	n+2
k-1	1.08E-03	1.99E-02	4.60E-02	1.99E-02	1.08E-03
k	1.05E-03	1.26E-01	5.69E-01	1.26E-01	1.05E-03
k+1	1.08E-03	1.99E-02	4.60E-02	1.99E-02	1.08E-03

- The number of interfering slots is reduced in FBMC (15) compared to OFDM(30)
- The interference tables can easily be used for the derivation of spectrum efficiency of multicarrier based cognitive radio system

Y. Medjahdi, M. Terre, D. Le Ruyet, D. Roviras, J.A. Nossek and L. Baltar,
« Inter-cell interference analysis for OFDM/FBMC systems », SPAWC 2009

System efficiency

- Hypothesis :
  - Uplink scenario with path loss and Rayleigh channel
  - We considerer a cognitive radio network with one primary and one secondary system



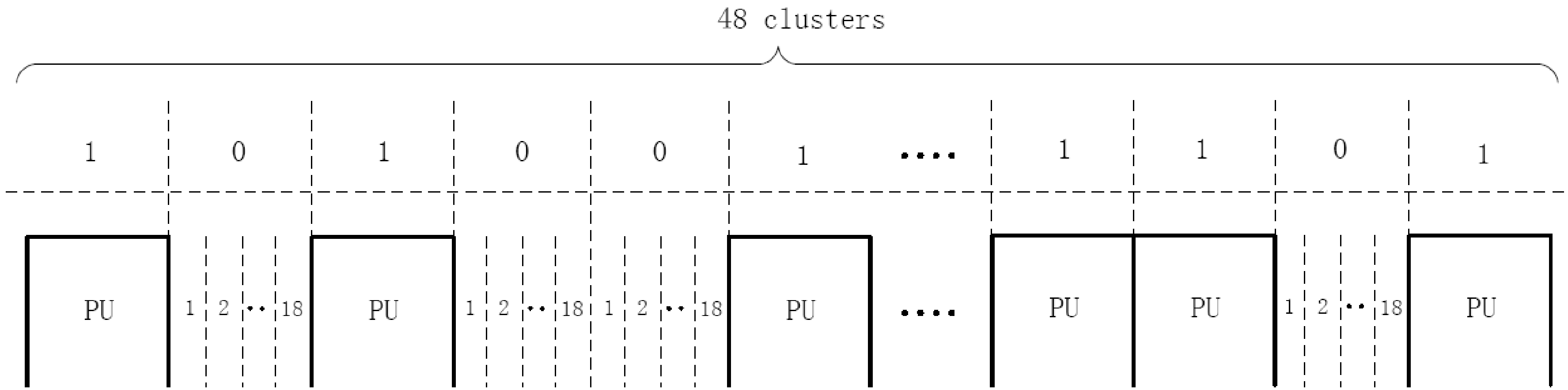
ICI power interference

cases / f	OFDM	FBMC	PS
k+8	1.12E-3	0	0
k+7	1.84E-3	0	0
k+6	2.50E-3	0	0
k+5	3.59E-3	0	0
k+4	5.60E-3	0	0
k+3	9.95E-3	0	0
k+2	2.23E-2	0	0
k+1	8.94E-2	8.81E-2	0
k	7.05E-1	8.23E-1	1
k-1	8.94E-2	8.81E-2	0
k-2	2.23E-2	0	0
k-3	9.95E-3	0	0
k-4	5.60E-3	0	0
k-5	3.59E-3	0	0
k-6	2.50E-3	0	0
k-7	1.84E-3	0	0
k-8	1.12E-3	0	0

- These tables are different from the ones obtained using the power spectrum density of the signals

System efficiency

- first case : one secondary user - *K* holes of size F_k



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

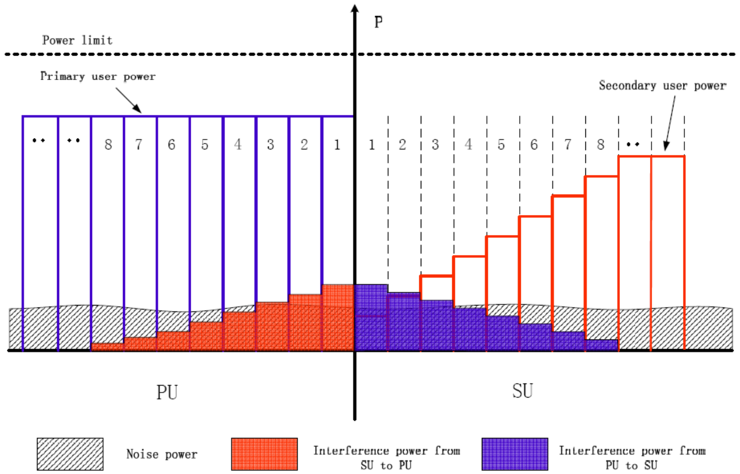
$s.t.$

$$\begin{cases} \sum_{k=1}^{K}\sum_{f=1}^{F_k} p^{kf} \le P_{th} \\ p^{kf} \ge 0 \\ p^{kf} \le P_{sub} \\ \sum_{n=1}^{N} p^{k_{l(r)}n} G_{sp}^{k_{l(r)}} V_n \le I_{th}, \quad \forall k \end{cases}$$

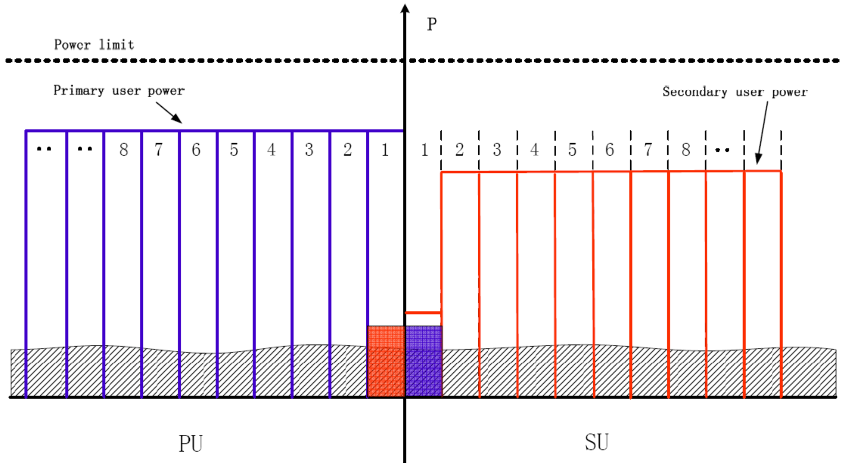
$$I_f^k = \begin{cases} \sum_{n=f}^{N} P_p^{k_l} G_{ps}^{k_l f} V_n, & f = 1, 2, \cdots N \\ \sum_{n=F_k-f+1}^{N} P_p^{k_r} G_{ps}^{k_r f} V_n, & f = F_k - N + 1, \cdots F_k \\ \sigma^2, & others \end{cases}$$

System efficiency

CP-OFDM



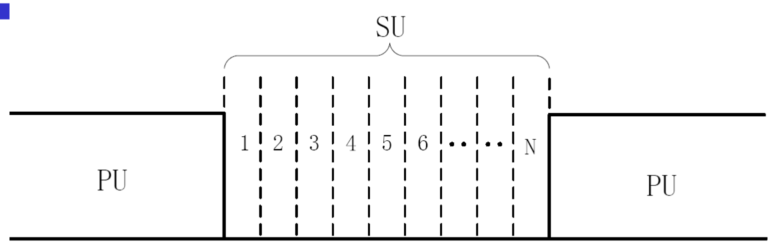
FBMC

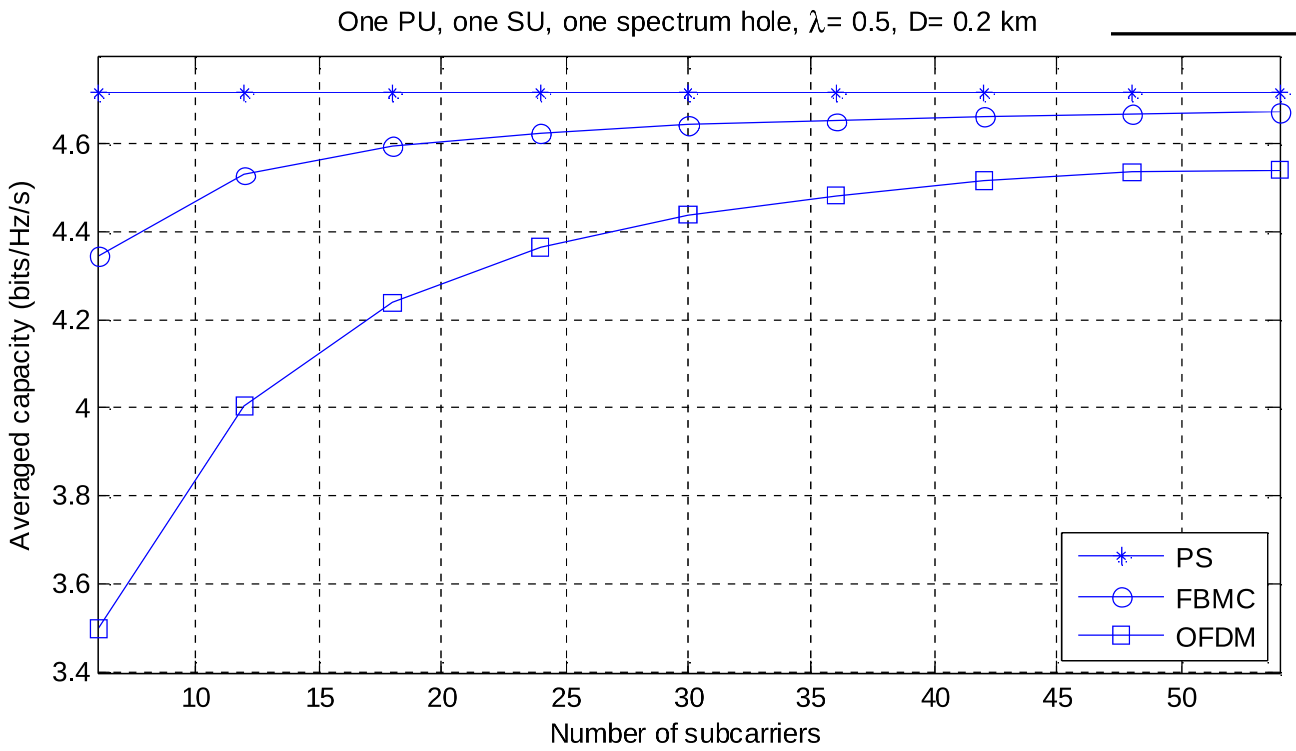


- problem solved using the Rosen’s gradient projection method

Simulation Results

- only one hole of size F_k

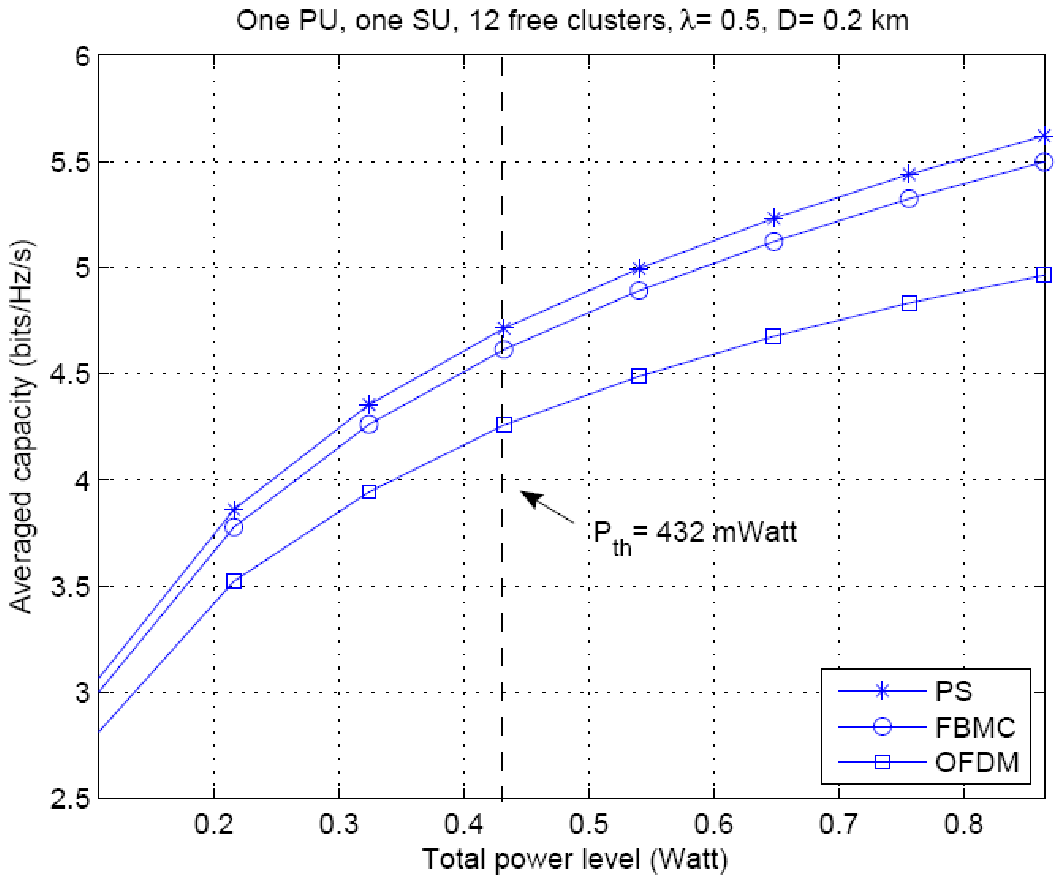




25% of gain for a hole of 6 subcarriers ; 10 % gain for a hole of 18 subcarriers

Simulation Results

• 1 secondary user – 12 free clusters among 48 clusters (18 subcarriers per cluster)



System efficiency

- second case : 12 secondary users – 12 free clusters

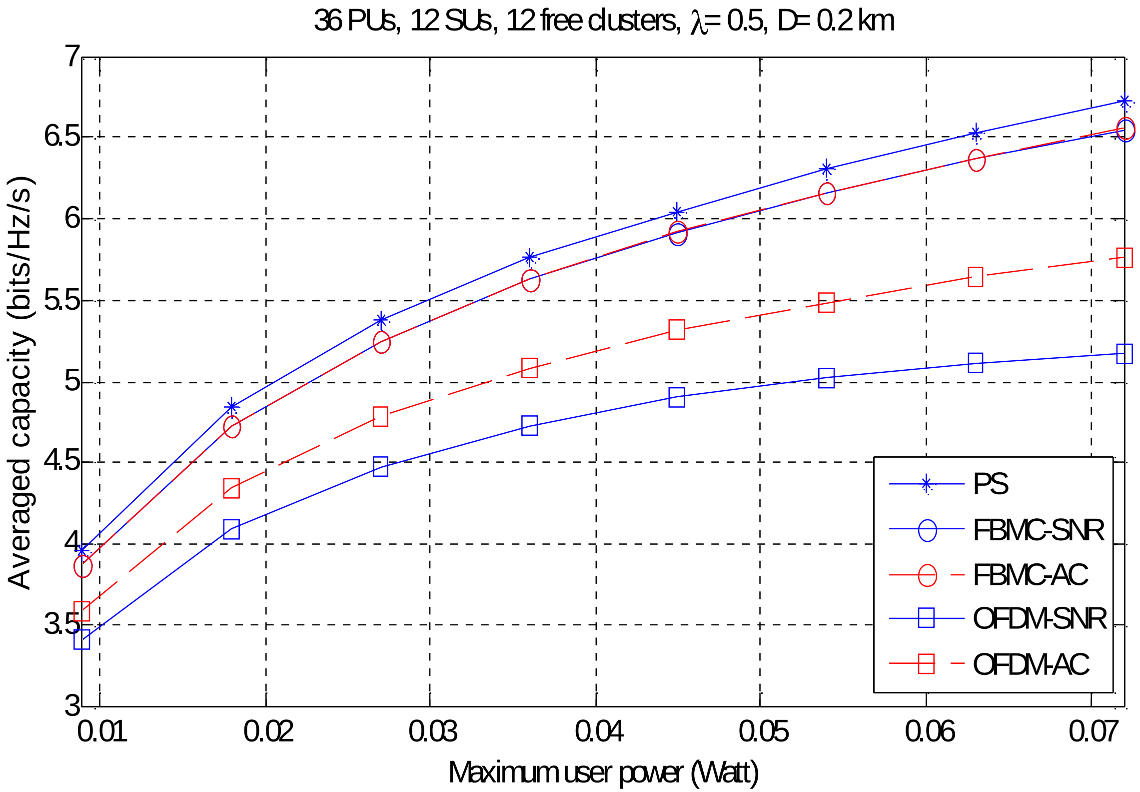
$$\max_{\mathbf{p}} : C(\mathbf{p}) = \sum_{m=1}^{M} \sum_{k=1}^{K} \sum_{f=1}^{F_k} \theta_m^{kf} \cdot log_2[1 + \frac{p_m^{kf} G_{ss}^{mkf}}{I_f^k}]$$

$$s.t.$$

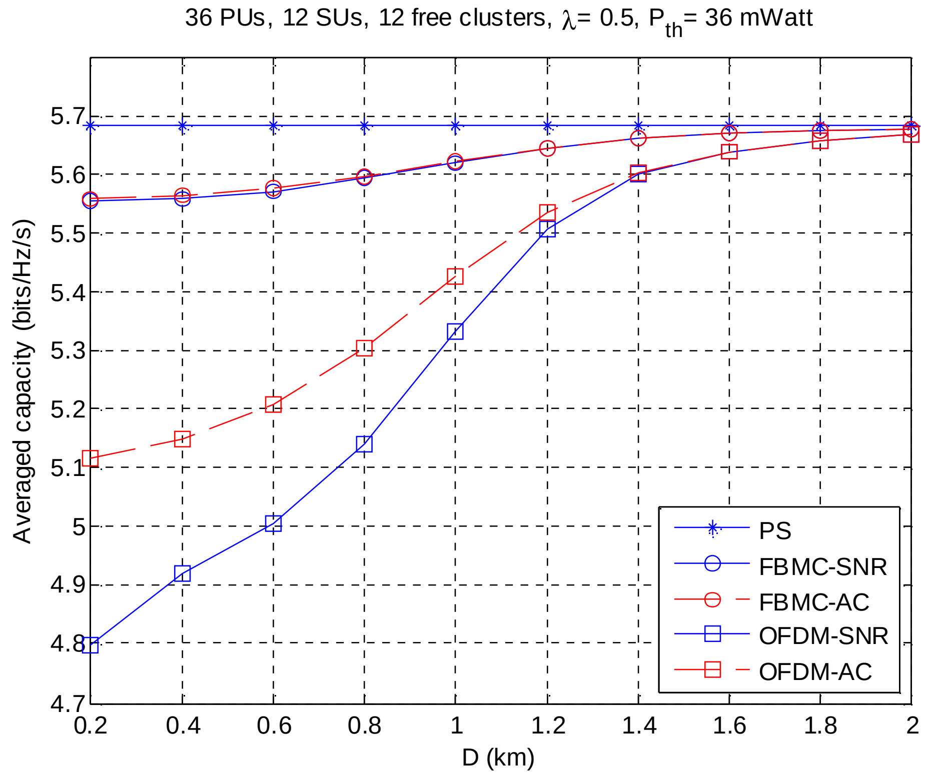
$$\begin{cases} \sum_{k=1}^{K} \sum_{f=1}^{F_k} \theta_m^{kf} p_m^{kf} \leq P_{th}, & \forall m \\ 0 \leq p_m^{kf} \leq P_{sub} \\ \sum_{m=1}^{M} \sum_{n=1}^{N} \theta_m^{k_{l(r)} n} p_m^{k_{l(r)} n} G_{sp}^{m k_{l(r)}} V_n \leq I_{th}, & \forall k \end{cases}$$

- Heuristic solution : we first allocate the secondary users to the free clusters using the Hungarian algorithm then we allocate the power

Simulation Results



Simulation Results



Conclusions

- The mean power intercell interference tables have been derived for FBMC and OFDM systems
- We have shown that the number of interfering slots is reduced in FBMC with respect to OFDM due to the time/frequency response of the prototype filter
- We have evaluated the spectrum efficiency of FBMC/OFDM system for cognitive radio assuming no synchronisation between primary and secondary users
- The gain achieved using FBMC system strongly depends on the size of the holes and the distance between the 2 BS stations

QUESTIONS ?