Effective Combining Scheme for Channel Sensing in Multiuser Cognitive Radio Systems

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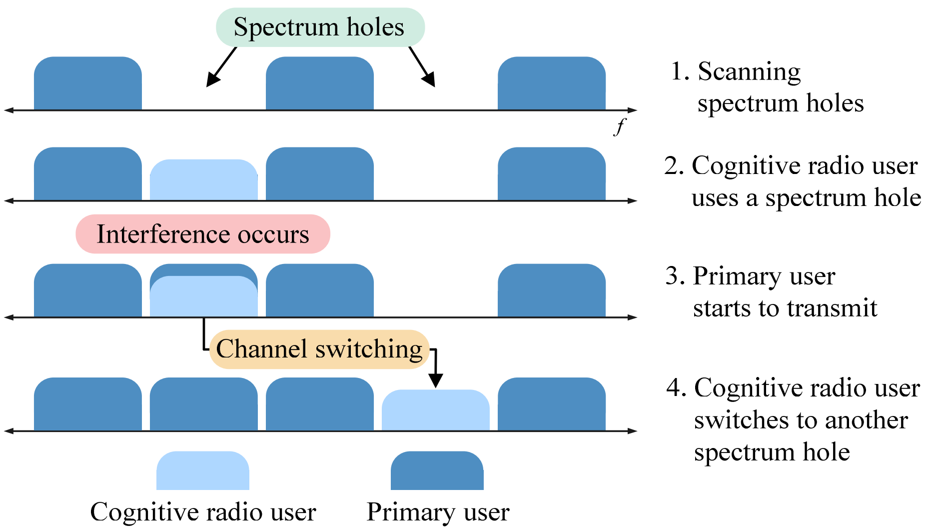
Concept of Cognitive Radio (CR) system

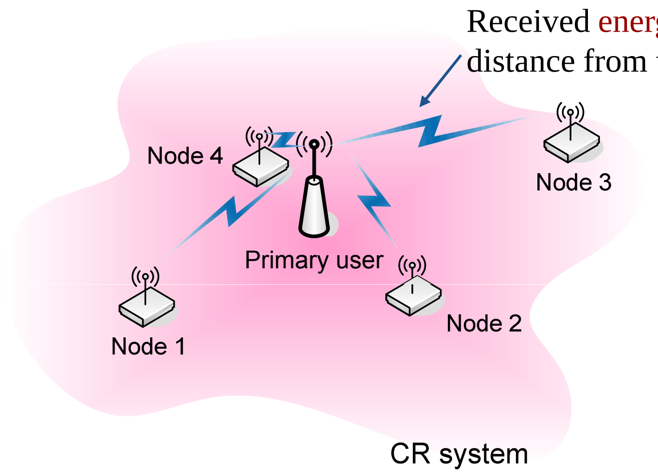
An example of CR system operation.

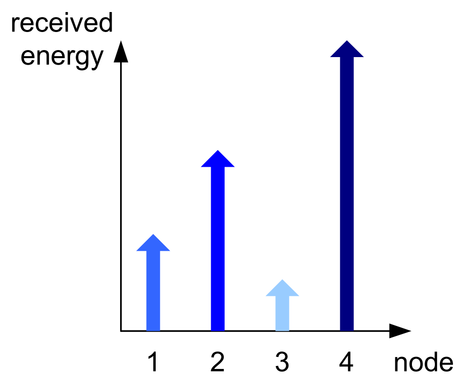


- Finding Spectrum hole by sensing
  - Channel sensing is very essential task in the practical CR system

Channel Fading Effect on Sensing Result

- When energy detection is considered





- CR nodes receive the very dissimilar energy with respect to each other according to the distance between CR and primary users (PU)

Basic of Energy Detection

- Test statistic X of received signal is tested with two hypotheses
  - PU absent, *H0*
    - $g(x) \sim N\{BT_S N_0, 4BT_S N_0^2\}$
  - PU present, *H1*
    - $f(x) \sim N\{BT_S N_0 + E, 4BT_S N_0^2 + 4EN_0\}$

Energy distribution depends on E

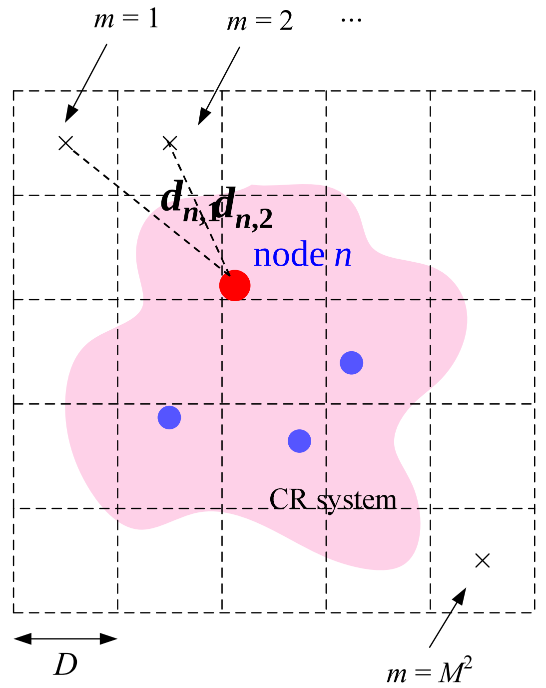
B: Bandwidth
T_S: Sensing time
N_0: Noise density
$N\{\}$: Gaussian PDF
E: Energy of signal received from PU

- Received energy from PU
  - $E = T_S P_t y(d)$
  - However, to obtain the information about the distance d in real time can generally be difficult
    - Especially, when CR nodes have a mobility

P_t: Transmission power of PU
$y(d)$: path loss gain when distance between CR user and PU is d

→ Using a *grid structure* to exploit the heterogeneity of received energy from PU, with the minimal prior information

Grid Structure



1. Formulate the grid

2. For CR node n, distance from the PU located at all squares in grid is estimated ($d_{n,m}$ is calculated for all m)

3. For CR node n, received energy from the PU located at all squares in grid is estimated by using $d_{n,m}$ ($E_{n,m}=T_S P_t y(d_{n,m})$ for all m)

Decision Making

- Using the grid, PDF of test statistic for node n and PU at square m is modified as
  - $f_{n,m}(x) \sim N\{BT_S N_0 + E_{n,m}, 4BT_S N_0^2 + 4E_{n,m} N_0\}$
- Using the LRT (likelihood ratio test) based on Neyman-Pearson criterion
  - It is known as the optimal decision rule
  - $\mathbf{x}:=(x_1,x_2,\ldots,x_N)$ where x_n denotes the test statistic measured at node n
  - Likelihood ratio is

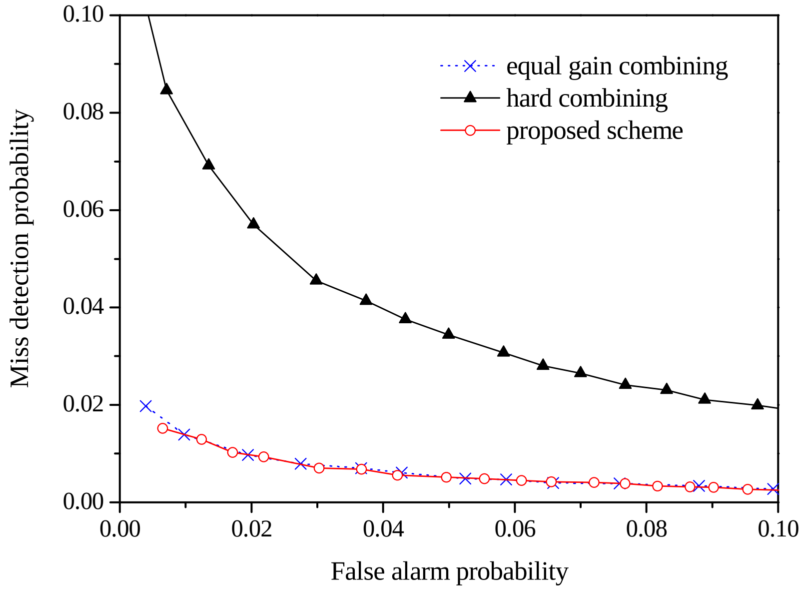
$$L(x) := \frac{\sum_{m=1}^{M^2} p_m \prod_{n=1}^{N} f_{n,m}(x_n)}{\prod_{n=1}^{N} g(x_n)}$$

M^2: Number of squares in grid
N: Number of CR nodes
p_m: Probability that a PU is activated at the square m

  - If $L(\mathbf{x}) > e$, where e is threshold value, the CR system decides the presence of PU

Numerical Results

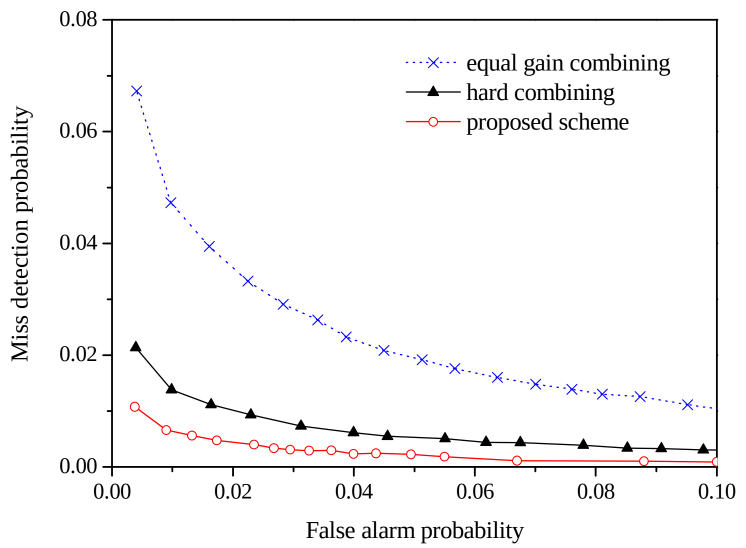
N=9, M=10, p_m=0.01 for all m, N_0=-163 dBm/Hz. T_S = 100 $u$sec, B=1 MHz, D=7 km, P_t=70 dBm/Hz



When TX power of PU is strong so that it covers the entire area of CR system

Numerical Result

N=9, M=10, p_m=0.01 for all m, N_0=-163 dBm/Hz. T_S = 100 $u$sec, B=1 MHz, D= 250 m, P_t= 5 dBm/Hz



When only a part of CR nodes can receive enough energy from the PU
(i.e., TX power of PU is very weak)

Conclusion

- Effective combining method is investigated

- The proposed scheme
  - considers the fact that the received energy from the PU can be very dissimilar among CR nodes according to their geographical location
  - Numerical results show that it improves the detection performance significantly in comparison with other schemes