ADAPTIVE CLUSTERING ALGORITHM FOR COOPERATIVE SPECTRUM SENSING IN MOBILE ENVIRONMENTS

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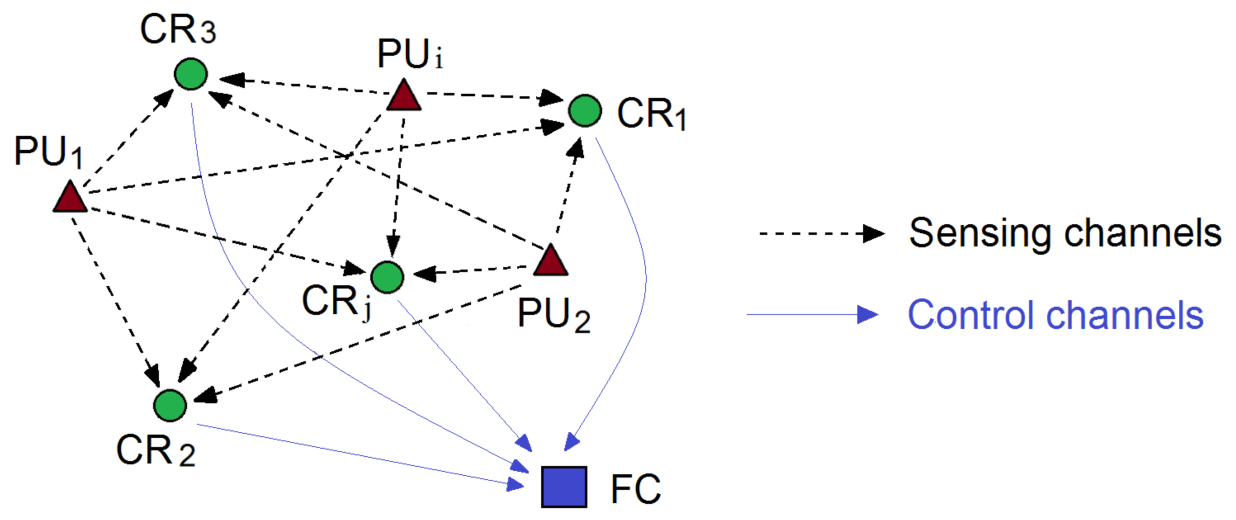
Centralized cooperative spectrum sensing



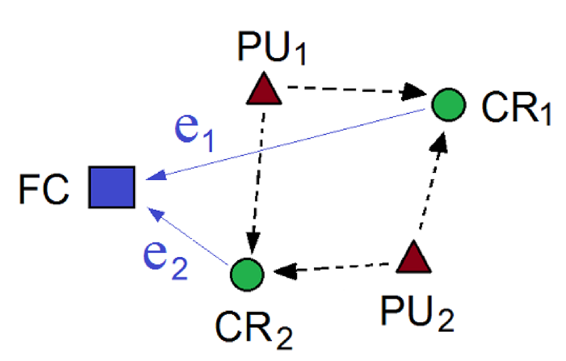
- Energy detection at the CR's: $\mathbf{e} = \{e_j\}_{j=1}^{Ns}$
- FC makes a decision on the presence (H_1) or absence (H_0) of PU signals.

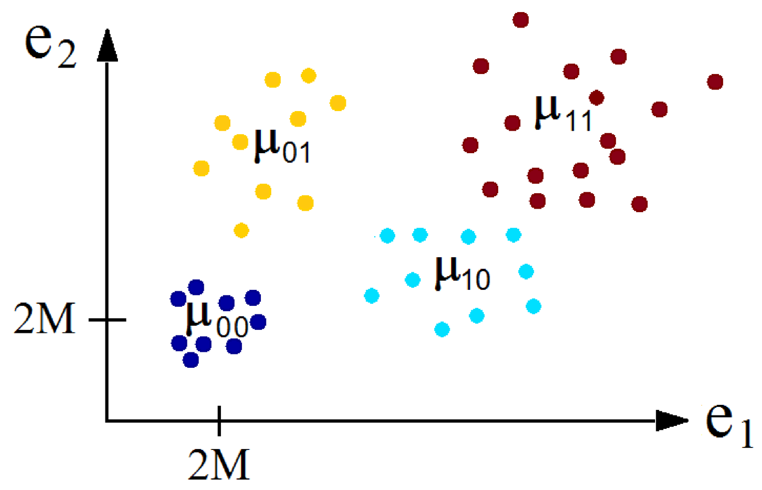
System model

- Primary network state: $\mathbf{s} = [\, s_1 \; s_2 \; \cdots \; s_{Nu} \,],\; s_i \in \{0, 1\}$
- Distribution of the energy vector estimates: $\mathbf{e}|\mathbf{s} \sim \mathcal{N}(\boldsymbol{\mu}_\mathbf{s}, \boldsymbol{\Sigma}_\mathbf{s})$

$$\mu_{\mathbf{s},j} = 2M\left(1 + \sum_{i=1}^{Nu} s_i\,\gamma_{i,j}\right), \qquad \boldsymbol{\Sigma}_\mathbf{s} = 4\,\mathrm{diag}(\boldsymbol{\mu}_\mathbf{s} - \mathbf{1}M)$$

- Example: $Nu = 2, Ns = 2$





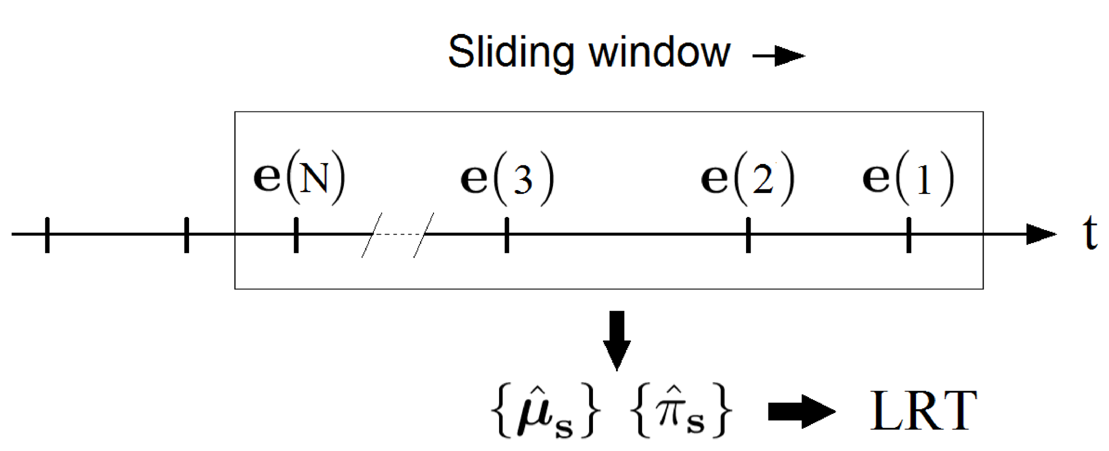
LRT detector

- Likelihood ratio test: $\dfrac{p(\mathbf{e}|H_1)}{p(\mathbf{e}|H_0)} \underset{H_0}{\overset{H_1}{\gtrless}} \gamma,$

$$p(\mathbf{e}|H_0) = f(\mathbf{e}|\boldsymbol{\mu}_\mathbf{0}), \qquad p(\mathbf{e}|H_1) = \sum_{\mathbf{s}\neq\mathbf{0}} \frac{\pi_\mathbf{s}}{1-\pi_\mathbf{0}} f(\mathbf{e}|\boldsymbol{\mu}_\mathbf{s})$$

- $f(\mathbf{e}|\boldsymbol{\mu}_\mathbf{0})$ is known.
- Unknown parameters (time-varying): $\{\boldsymbol{\mu}_\mathbf{s}, \pi_\mathbf{s}\}_{\mathbf{s}\neq\mathbf{0}}$
- The FC must maintain an updated estimate of the unknown parameters from the data it regularly receives through the control channels.

Adaptive parameter estimation



- **Clustering algorithm with missing data**

$$J(\mathbf{r}, \boldsymbol{\mu}) = \sum_{n=1}^{N} \sum_{\mathbf{s}} r_\mathbf{s}(n)\, b_\mathbf{s}(n), \qquad b_\mathbf{s}(n) = \sum_{j=1}^{Ns} v_j(n)(e_j(n) - \mu_{\mathbf{s},j})^2$$

$$\hat{\mathbf{r}}, \hat{\boldsymbol{\mu}} = \underset{\mathbf{r},\boldsymbol{\mu}}{\mathrm{argmin}}\; J(\mathbf{r}, \boldsymbol{\mu}), \qquad \hat{\pi}_\mathbf{s} = \frac{1}{N}\sum_{n=1}^{N} \hat{r}_\mathbf{s}(n)$$

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Initialize μ̂ with the result of the last clustering
repeat
  ——- Minimization with respect to r ———
  for n = 1 to N do
    b_s(n) = Σ_{j=1}^{Ns} v_j(n)(e_j(n) − μ̂_{s,j})², ∀s
    initialize r̂_s(n) = 0, ∀s
    r̂_s(n) = 1, where s = argmin_t {b_t(n)}
  end for
  ——- Minimization with respect to μ ——-
    μ̂_{s,j} = Σ_{n=1}^{N} v_j(n) r̂_s(n) e_j(n) / Σ_{n=1}^{N} v_j(n) r̂_s(n),   ∀j, ∀s ≠ 0
until r̂ converges
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Numerical results

- Sensing channels: independent time-varying Rayleigh fading, $\bar{\gamma}_{i,j} = -5$ dB, $f_D = 25$ Hz $\Rightarrow T_C \approx 16$ ms, $W = 5$ MHz.
- Sensing: $T_F = 1$ ms, $\tau = 20\,\mu$s, $N = 16$, $No = \sum_{n=1}^{N}\sum_{j=1}^{Ns} v_j(n)$
- PU's activity modeled as independent two-states Markov chains with $p_{0,0} = 2/3$, $p_{1,1} = 1/2$, and identical transmit power.