ITU KALEIDOSCOPE
NANJING 2017
Challenges for a data-driven society

Secrecy Energy Efficiency Optimization for Aritificial Noise Aided Physical-Layer Security in Cognitive Radio Networks

Yuhan Jiang
Nanjing University of Posts and Telecommunications
1016010430@njupt.edu.cn

Nanjing, China
27-29 November 2017

Framework

A joint zero-forcing (ZF) beamforming and power allocation problem is formulated to maximize the SEE under the constraints of the total transmit power, the secrecy rate (SR) of cognitive user (CU) and the quality-of-service (QoS) requirement of primary user (PU).

Underlay cognitive radio networks (CRNs)

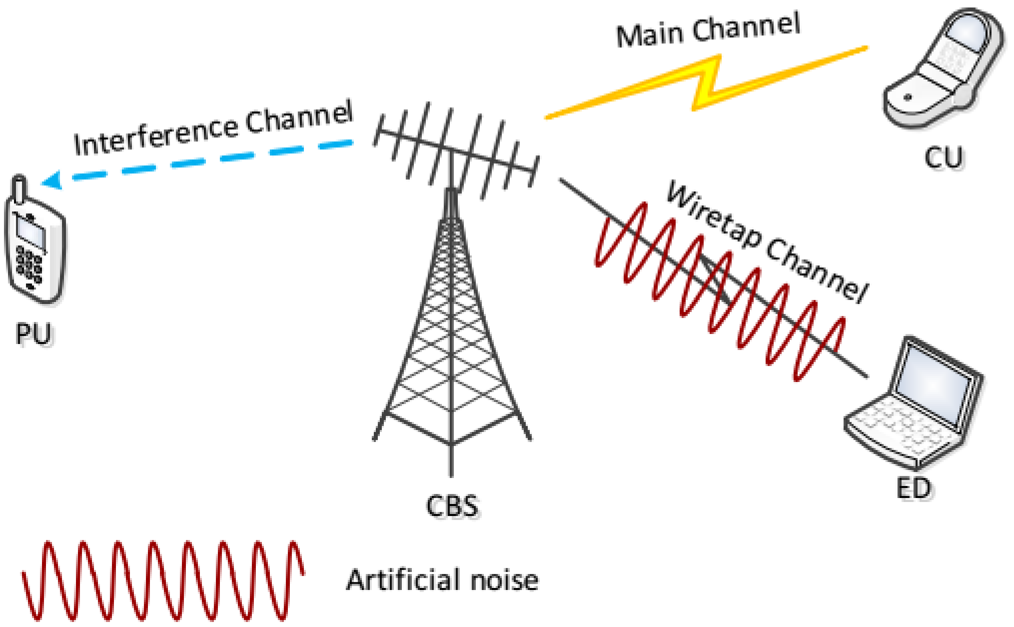
Artificial noise (AN)

Zero-forcing beamforming (ZF)

Transform the formulated non-convex optimization problem in fractional form into an equivalent one in subtractive form

Use the difference of two-convex functions (D.C.) approximation method to obtain an equivalent convex problem

System Model



System model for secure communication in CRNs

Problem Formulation

$$\max_{P_c, P_z} \eta_{\text{SEE}} = \frac{\log_2\left(1+\frac{\left|\mathbf{h}_c^H \mathbf{v}_c\right|^2 P_c}{\left|\mathbf{h}_c^H \mathbf{v}_z\right|^2 P_z + \sigma_c^2}\right) - \log_2\left(1+\frac{\left|\mathbf{h}_e^H \mathbf{v}_c\right|^2 P_c}{\left|\mathbf{h}_e^H \mathbf{v}_z\right|^2 P_z + \sigma_e^2}\right)}{P_c + P_z + P_b}$$

$$s.t. \quad \frac{\left|\mathbf{h}_p^H \mathbf{v}_c\right|^2 P_c}{\left|\mathbf{h}_p^H \mathbf{v}_z\right|^2 P_z + \sigma_p^2} \geq \gamma_p^{th}$$

$$\log_2\left(1+\frac{\left|\mathbf{h}_c^H \mathbf{v}_c\right|^2 P_c}{\left|\mathbf{h}_c^H \mathbf{v}_z\right|^2 P_z + \sigma_c^2}\right) - \log_2\left(1+\frac{\left|\mathbf{h}_e^H \mathbf{v}_c\right|^2 P_c}{\left|\mathbf{h}_e^H \mathbf{v}_z\right|^2 P_z + \sigma_e^2}\right) \geq 0$$

$$0 \leq P_c + P_z \leq P_{CBS}^{\max}$$

Optimal Solution to SEE Maximization

- We design the normalized beamforming vector $\mathbf{v}_c$ in the null space of $\mathbf{h}_p$, meanwhile, $\mathbf{v}_z$ is designed at the null space of $\mathbf{h}_p$ and $\mathbf{h}_c$ to guarantee that the AN only degards the channel condition of eavesdropper.

$$\max_{P_c, P_z} \eta_{\text{SEE}} = \frac{\log_2\left(1+\frac{\left|\mathbf{h}_c^H \mathbf{v}_c\right|^2 P_c}{\sigma_c^2}\right) - \log_2\left(1+\frac{\left|\mathbf{h}_e^H \mathbf{v}_c\right|^2 P_c}{\left|\mathbf{h}_e^H \mathbf{v}_z\right|^2 P_z + \sigma_e^2}\right)}{P_c + P_z + P_b}$$

$$s.t. \quad \log_2\left(1+\frac{\left|\mathbf{h}_c^H \mathbf{v}_c\right|^2 P_c}{\sigma_c^2}\right) - \log_2\left(1+\frac{\left|\mathbf{h}_e^H \mathbf{v}_c\right|^2 P_c}{\left|\mathbf{h}_e^H \mathbf{v}_z\right|^2 P_z + \sigma_e^2}\right) \geq 0$$

$$0 \leq P_c + P_z \leq P_{CBS}^{\max}$$

Optimal Solution to SEE Maximization

- Dinkelbach's method

$$\max_{P_c, P_z} \; f\left(\eta_{\mathrm{SEE}}\right) = \log_2\left(1 + \frac{\left|\mathbf{h}_c^H \mathbf{v}_c\right|^2 P_c}{\sigma_c^2}\right) - \log_2\left(1 + \frac{\left|\mathbf{h}_e^H \mathbf{v}_c\right|^2 P_c}{\left|\mathbf{h}_e^H \mathbf{v}_z\right|^2 P_z + \sigma_e^2}\right) - \eta_{\mathrm{SEE}}\left(P_c + P_z + P_b\right)$$

$$s.t. \quad \log_2\left(1 + \frac{\left|\mathbf{h}_c^H \mathbf{v}_c\right|^2 P_c}{\sigma_c^2}\right) - \log_2\left(1 + \frac{\left|\mathbf{h}_e^H \mathbf{v}_c\right|^2 P_c}{\left|\mathbf{h}_e^H \mathbf{v}_z\right|^2 P_z + \sigma_e^2}\right) \geq 0$$

$$0 \leq P_c + P_z \leq P_{CBS}^{\max}$$

Optimal Solution to SEE Maximization

- D.C. approaches

$$f_1\left(P_c, P_z, \eta_{\mathrm{SEE}}\right) = \log_2\left(1 + \frac{\left|\mathbf{h}_c^H \mathbf{v}_c\right|^2 P_c}{\sigma_c^2}\right) + \log_2\left(\left|\mathbf{h}_e^H \mathbf{v}_z\right|^2 P_z + \sigma_e^2\right) - \eta_{\mathrm{SEE}}\left(P_c + P_z + P_b\right)$$

$$f_2\left(P_c, P_z\right) = \log_2\left(\left|\mathbf{h}_e^H \mathbf{v}_c\right|^2 P_c + \left|\mathbf{h}_e^H \mathbf{v}_z\right|^2 P_z + \sigma_e^2\right)$$

$$f_2\left(P_c, P_z\right) \approx f_2\left(\overline{P}_c, \overline{P}_z\right) + \frac{\left|\mathbf{h}_e^H \mathbf{v}_c\right|^2\left(P_c - \overline{P}_c\right) + \left|\mathbf{h}_e^H \mathbf{v}_z\right|^2\left(P_z - \overline{P}_z\right)}{\left(\left|\mathbf{h}_e^H \mathbf{v}_c\right|^2 \overline{P}_c + \left|\mathbf{h}_e^H \mathbf{v}_z\right|^2 \overline{P}_z + \sigma_e^2\right)\ln 2}$$

Optimal Solution to SEE Maximization

- D.C. approaches

$$\max_{P_c, P_z} \left\{ f_1(P_c, P_z, \eta_{SEE}) - f_2(\overline{P}_c, \overline{P}_z) - \frac{\left|\boldsymbol{h}_e^H \boldsymbol{v}_c\right|^2 (P_c - \overline{P}_c) + \left|\boldsymbol{h}_e^H \boldsymbol{v}_z\right|^2 (P_z - \overline{P}_z)}{\left(\left|\boldsymbol{h}_e^H \boldsymbol{v}_c\right|^2 \overline{P}_c + \left|\boldsymbol{h}_e^H \boldsymbol{v}_z\right|^2 \overline{P}_z + \sigma_e^2\right) \ln 2} \right\}$$

$$s.t. \quad P_z \geq \frac{\left|\boldsymbol{h}_e^H \boldsymbol{v}_c\right|^2 \sigma_c^2 - \left|\boldsymbol{h}_c^H \boldsymbol{v}_c\right|^2 \sigma_e^2}{\left|\boldsymbol{h}_c^H \boldsymbol{v}_c\right|^2 \left|\boldsymbol{h}_e^H \boldsymbol{v}_z\right|^2}$$

$$0 \leq P_c + P_z \leq P_{CBS}^{\max}$$

The Proposed Algorithm to Solve SEEM Problem

Function *Outer_Iteration*

Step 1: Initialize the maximum number of iterations $i_{\max}$ and the maximum tolerance ε .

Step 2: Set maximum SEE $\eta_{\mathrm{SEE}}^{0} = 0$ and iteration index $i = 0$.

Step 3: Call **Function** *Inner_Iteration* with η_{SEE}^{i} to obtain the optimal solution (P_c^i, P_z^i).

Step 4: Update

$$\eta_{\mathrm{SEE}}^{i+1} = \frac{\log_2\left(1+\frac{cP_c^i}{\sigma_c^2}\right)-\log_2\left(1+\frac{eP_c^i}{fP_z^i+\sigma_e^2}\right)}{P_c^i+P_z^i+P_b}$$

Step 5: Set $i = i + 1$.

Step 6: **if** $\left|\eta_{\mathrm{SEE}}^{i} - \eta_{\mathrm{SEE}}^{i-1}\right| \geq \varepsilon$ or $i \leq i_{\max}$

Step 7: **goto** Step 3.

Step 8: **end if**

Step 9: **return** P_c^i and P_z^i.

Step 10: Obtain the optimal solution $P_c^* = P_c^i$ and $P_z^* = P_z^i$ for problem (12).

end

Function *Inner_Iteration* (η_{SEE})

Step 11: Initialize $(\overline{P}_c^0, \overline{P}_z^0) = (0, 0)$ and $f^0 = 0$.

Step 12: Set $i = 0$.

Step 13: Find the optimal solution (P_c, P_z) of (22) for given $(\overline{P}_c^i, \overline{P}_z^i)$ and η_{SEE} by using CVX.

Step 14: Compute

$$f^{i+1} = f_1(P_c^{i+1}, P_z^{i+1}, \eta_{\mathrm{SEE}}) - f_2(P_c^{i+1}, P_z^{i+1}).$$

Step 15: Set $i = i + 1$.

Step 16: **if** $\left|f^i - f^{i-1}\right| \geq \varepsilon$ or $i \leq i_{\max}$

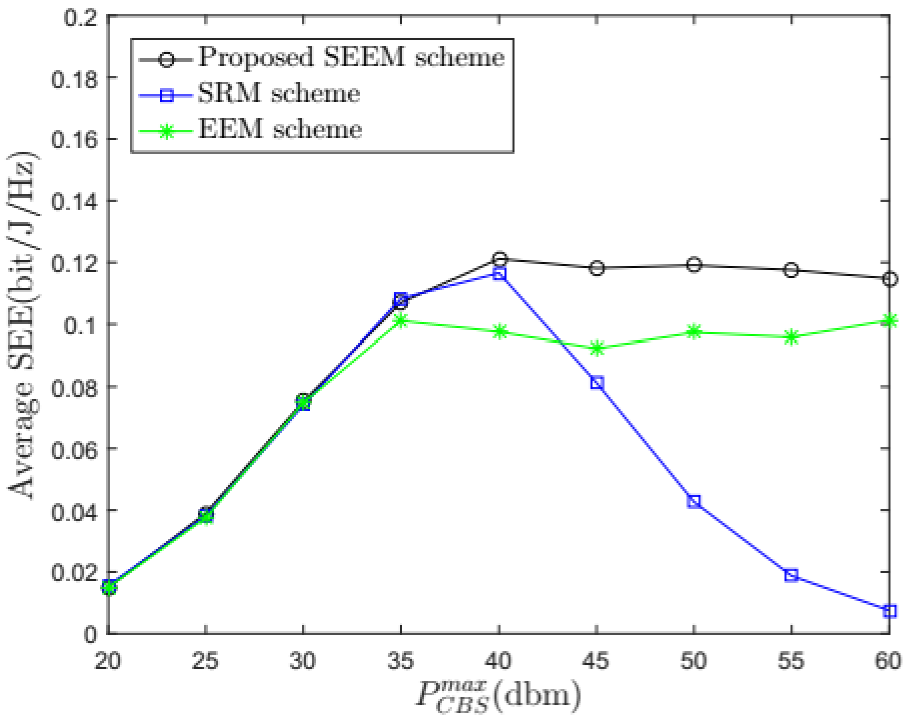
Step 17: **goto** Step 13.

Step 18: **end if**

Step 19: **return** P_c and P_z.

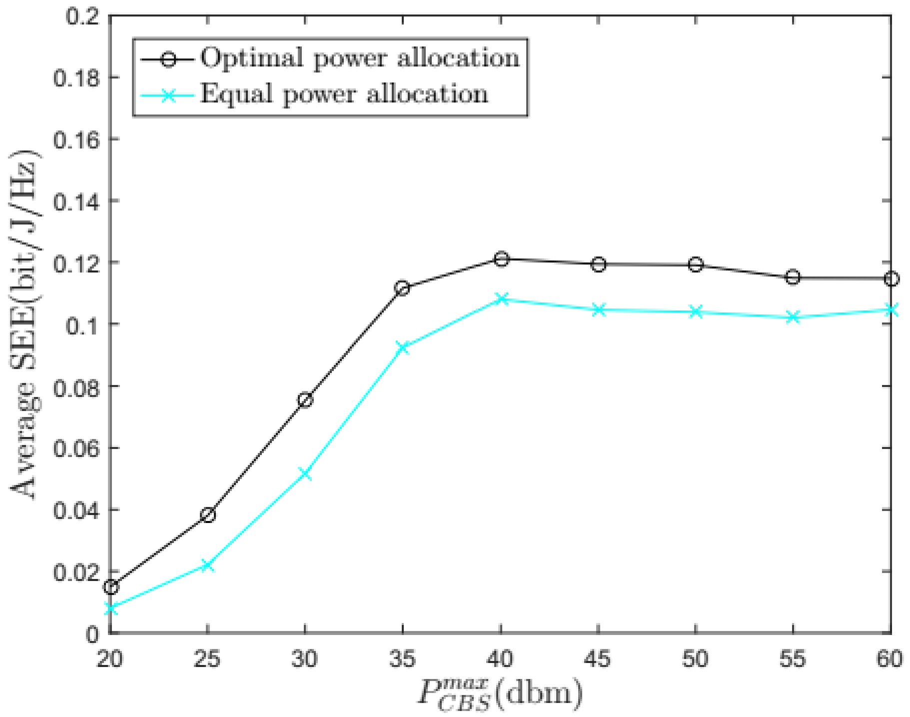
end

Simulation Results



Average SEE versus $P_{CBS}^{\max}$ of the proposed SEEM and convential SRM and EEM schemes

Simulation Results



Average SEE versus $P_{CBS}^{\max}$ of the proposed SEEM scheme with the optimal power allocation and simple equal power allocation strategies.

Thank you for listening!