Achievable Secrecy Sum-Rate in a Fading MAC-WT with Power Control and without CSI of Eavesdropper

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- Multiple Access Channel with Eavesdropper
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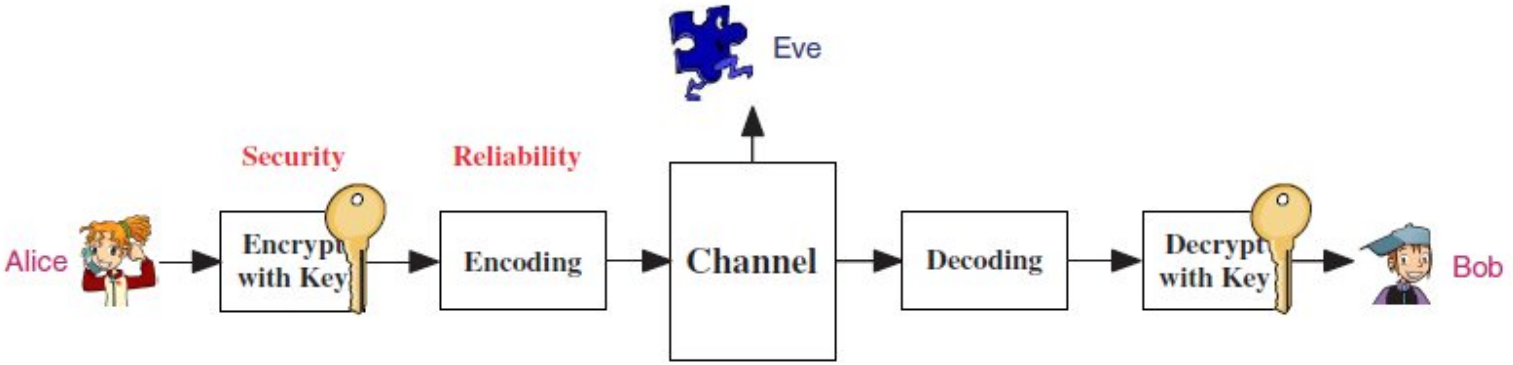
Introduction

- Security is important in transmission of information
- Conventional technique is Cryptography
  - Assumes limited computational capacity of Eavesdropper.
- Information theoretic security.
  - Assumes unlimited computational capacity of Eavesdropper.
- Wyner introduced Wiretap channel in his seminal paper in 1974.

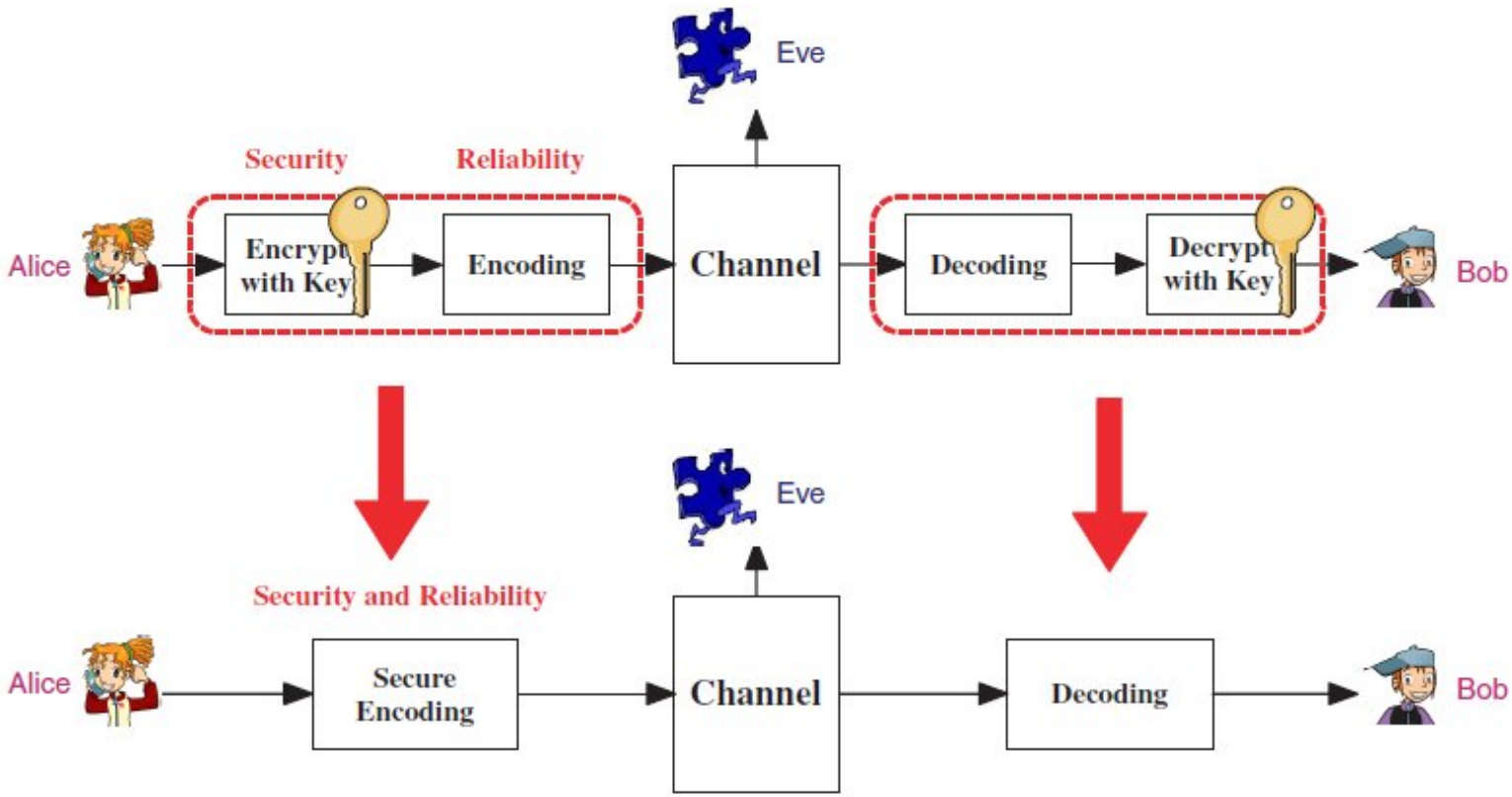
Model



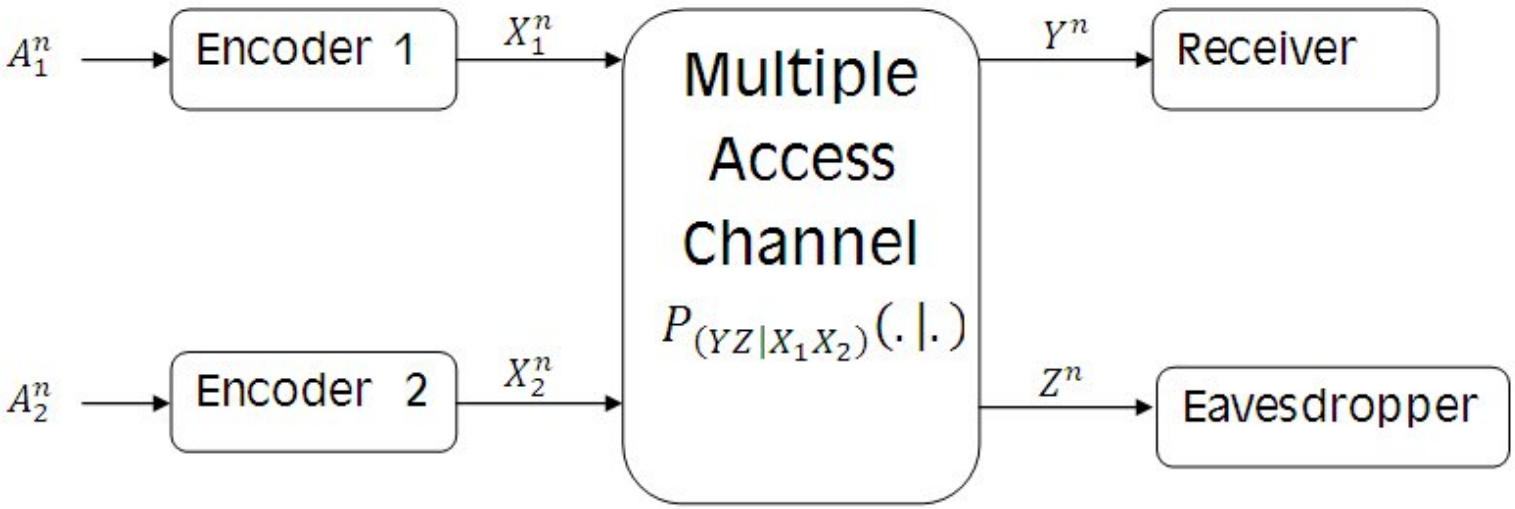
Encryption with channel coding

Information Theoretic Security

- Security issues include confidentiality, integrity, authentication, and non-repudiation
- Two basic types of attacks: passive attacks and active attacks.



Multiple Access Channel with Eve



Multiple Access Channel with Eve

- This model has been studied under the asumption of independent sources
- Gaussian MAC with eavesdropper studied by Yener and Tekin(IEEE trans 2008)
- Fading MAC with full CSI of eavesdropper studied by Yener and Tekin

Definitions

- Security if measured by the equivocation rate for each user
- $R_{1e}^{(n)} = \frac{1}{n} H(W_1|Z^n)$
- $R_{2e}^{(n)} = \frac{1}{n} H(W_2|Z^n)$
- $R_{1e}^{(n)} + R_{2e}^{(n)} = \frac{1}{n} H(W_1 W_2|Z^n)$
- Reliability: $P_{e1}^{(}n) = Pr\{\tilde{W}_1 \neq W_1\}, P_{e1}^{(}n) = Pr\{\tilde{W}_1 \neq W_1\}$
- A rate-equivocation pair $(R_1, R_2, R_{1e}, R_{2e})$ is achievable if $\exists$ a sequence of message sets $\mathcal{W}_{1n}$ and $\mathcal{W}_{2n}$ and encoder-decoder pairs (f_{1n}, f_{2n}, g_n) s.t. $P_e^{(n)} \to 0$ as $n \to \infty$ and equivocation rates satisfy $R_{1e} \leq \liminf_{n\to\infty} R_{1e}^{(n)}, R_{2e} \leq \liminf_{n\to\infty} R_{2e}^{(n)}$,

MAC with eavesdropper: Secrecy rate region

- The best known rate region for DM - MAC is as follows

$$R_1 \leq [I(U_1; Y \mid U_2) - I(U_1; Z)]^+$$
$$R_2 \leq [I(U_2; Y \mid U_1) - I(U_2; Z)]^+$$
$$R_1 + R_2 \leq [I(U_1, U_2; Y) - I(U_1, U_2; Z)]^+$$

  - where $p(x_1, x_2, u_1, u_2, y, z) = p(u_1)p(x_1 \mid u_1)p(u_2)p(x_2 \mid u_2)p(y, z \mid x_1, x_2)$
  - The rate region for Gaussian MAC and fading MAC can be obtained from this rate region.

Fading MAC: Secrecy rate region with perfect CSIT of Bob and Eve

- Rate region for fading MAC is as follows(Yener and Tekin)

$$R_1 \leq \mathrm{E}_{h,g}\left\{\left[log\frac{(1+h_1P_1(h,g))(1+g_2P_2(h,g))}{1+g_1P_1(h,g)+g_2P_2(h,g)}\right]^+\right\},$$

$$R_2 \leq \mathrm{E}_{h,g}\left\{\left[log\frac{(1+g_1P_1(h,g))(1+h_2P_2(h,g))}{1+g_1P_1(h,g)+g_2P_2(h,g)}\right]^+\right\},$$

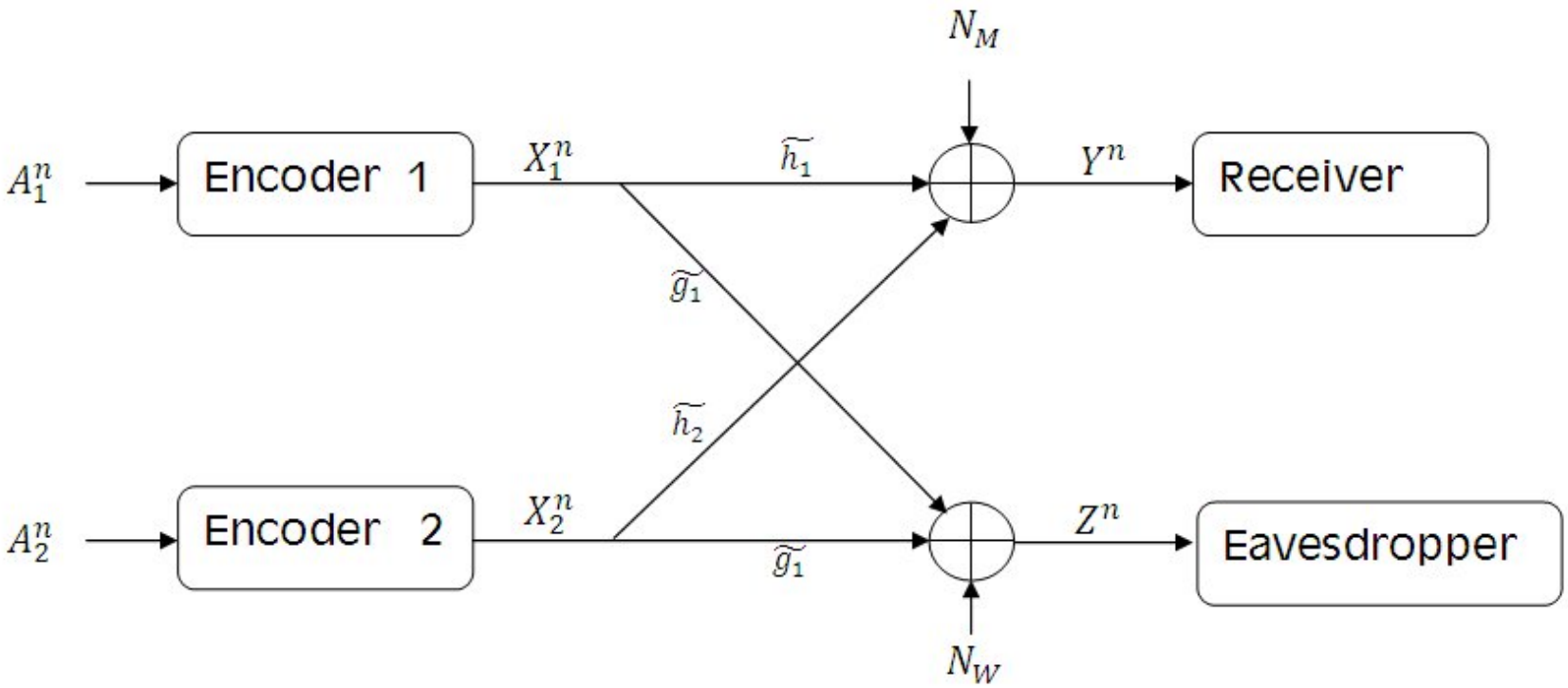
$$R_1+R_2 \leq \mathrm{E}_{h,g}\left\{\left[log\frac{1+h_1P_1(h,g)+h_2P_2(h,g)}{1+g_1P_1(h,g)+g_2P_2(h,g)}\right]^+\right\},$$

- where $h=(h_1,h_2), g=(g_1,g_2)$ are channel gains of Bob and Eve and $P_1(h,g)$ and $P_2(h,g)$ are the transmit powers satisfying power constraints and Gaussian signalling is used.

Fading MAC without CSI of eve

- In passive attack of Eavesdropper, CSI cannot be estimated
- Single user wiretap channel without CSI studied in H.E Elgamal(IEEE trans 2008)and Mathew Bloch et. al(IEEE trans 2008)
- We propose the power control scheme for fading MAC to optimize Secrecy sum-rate.

Fading MAC without CSI of eve: Channel Model



- $\tilde{h}_{k,i}$, $\tilde{g}_{k,i}$ Complex channel gains
- we define $|\tilde{h}_{k,i}|^2 = h_{k,i}$ and $|\tilde{g}_{k,i}|^2 = g_{k,i}$, for $k = 1, 2$.
- $\phi^s_{x_1,x_2} = 1 + s_1 x_1 + s_2 x_2$ where s is the channel state (h or g) and x_k is the power used.
- Let $A_1 \triangleq \{h_1 > \tau_1,\ h_2 < \tau_2\}$, $A_2 \triangleq \{h_1 < \tau_1,\ h_2 > \tau_2\}$ and $A_{12} \triangleq \{h_1 > \tau_1,\ h_2 > \tau_2\}$

Fading MAC without CSI of eve: Optimal power allocation

Theorem

For a given power control policy $\{P_k(h)\},\ k = 1, 2$, *the following secrecy sum-rate*

$$\mathrm{E}_{h,g}\left\{\left[log\left(\frac{\phi^{h}_{P_1,P_2}}{\phi^{g}_{P_1,P_2}}\right)\right]^{+}\right\} \tag{1}$$

is achievable, subject to power constraint
$\mathrm{E}_{h,g}[P_k(h)] \leq \bar{P}_k,\ k = 1, 2.$

- Optimal policy computed numerically.

Fading MAC without CSI of eve: Optimal power control with Cooperative Jamming

- A user when not transmitting information can jam the eve.
- $\{P_k(h)\},\ k=1,2$, power when transmitting information
  $\{Q_k(h)\},\ k=1,2$, power when jamming,

Theorem

With the above power control policies secrecy sum-rate

$$\mathrm{E}_{h,g}\left\{\left[log\left(\frac{\phi^{h}_{P_1,P_2}+\phi^{h}_{Q_1,Q_2}-1}{\phi^{g}_{P_1,P_2}+\phi^{g}_{Q_1,Q_2}-1}\right)\left(\frac{\phi^{g}_{Q_1,Q_2}}{\phi^{h}_{Q_1,Q_2}}\right)\right]^{+}\right\} \tag{2}$$

is achievable, subject to power constraint
$\mathrm{E}_{h,g}[P_k(h)+Q_k(h)]\leq \bar{P}_k,\ k=1,2.$

Without CSI of Eve: ON/OFF power control

- ON/OFF power control is a simple threshold based scheme as follows:
  - $h_1 > \tau_1$, $h_2 > \tau_2$: Both transmit;
  - $h_1 > \tau_1$, $h_2 < \tau_2$: User-1 transmits;
  - $h_1 < \tau_1$, $h_2 > \tau_2$: User-2 transmits;
  - $h_1 < \tau_1$, $h_2 < \tau_2$: No user transmits.
- Then secrecy sum-rate is given by:

$$R_B = \mathrm{E}_{h,g}\left\{\left[log\left(\frac{\phi^h_{P_1,P_2}}{\phi^g_{P_1,P_2}}\right)1_{A_{12}}\right]^+\right\} + \mathrm{E}_{h,g}\left\{\left[log\left(\frac{\phi^h_{P_1,0}}{\phi^g_{P_1,0}}\right)1_{A_1}\right]^+\right\} + \mathrm{E}_{h,g}\left\{\left[log\left(\frac{\phi^h_{0,P_2}}{\phi^g_{0,P_2}}\right)1_{A_2}\right]^+\right\} \quad (3)$$

where $1_{\{\}}$ is the indicator function.

- We then optimize the secrecy sum-rate over τ_1, τ_2

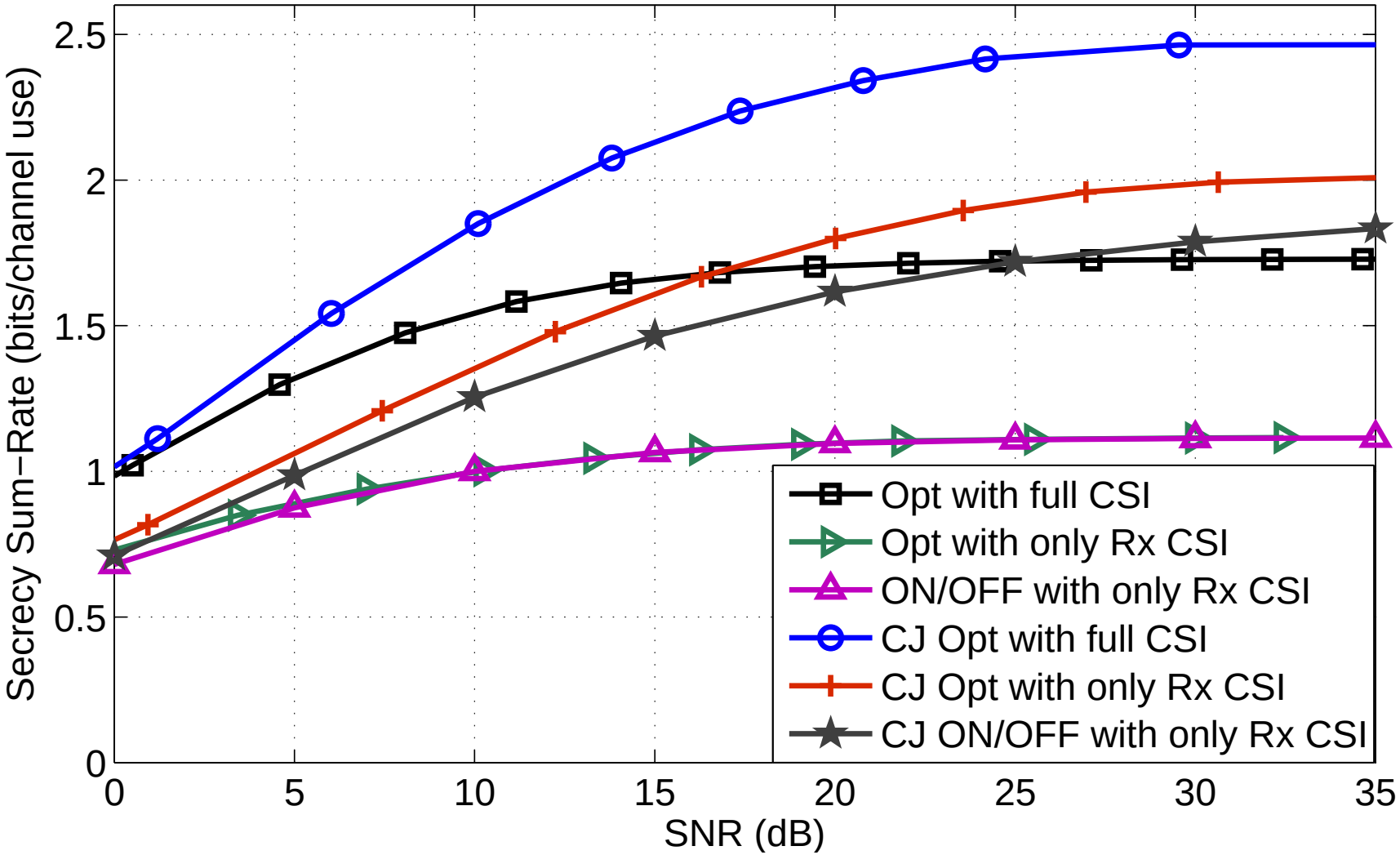
ON/OFF power control with cooperative Jamming

- Here we employ co-operative jamming over ON/OFF scheme
  - $h_1 > \tau_1$, $h_2 > \tau_2$: Both transmit with power P_{1a}, P_{2a};
  - $h_1 > \tau_1$, $h_2 < \tau_2$: User-1 transmits with power P_{1b}, user-2 jams with power Q_2;
  - $h_1 < \tau_1$, $h_2 > \tau_2$: User-2 transmits with power P_{2b}, user-1 jams with power Q_1;
  - $h_1 < \tau_1$, $h_2 < \tau_2$: None transmits or jams.

$$R_B^{CJ} = \mathrm{E}_{h,g}\left\{\left[log\left(\frac{\phi^h_{P_{1a},P_{2a}}}{\phi^g_{P_{1a},P_{2a}}}\right)1_{A_{12}}\right]^+\right\} + \mathrm{E}_{h,g}\left\{\left[log\left(\frac{\phi^h_{P_{1b},Q_2}}{\phi^g_{P_{1b},Q_2}}\right)1_{A_1}\right]^+\right\}$$
$$+ \mathrm{E}_{h,g}\left\{\left[log\left(\frac{\phi^h_{Q_1,P_{2b}}}{\phi^g_{Q_1,P_{2b}}}\right)1_{A_2}\right]^+\right\} \quad (4)$$

When $\tilde{h}_k$ and $\tilde{g}_k$ have Rayleigh distribution

Fading MAC Without CSI of Eve: Simulation results



Summary

- Studied optimal power control for fading Gaussian MAC when CSI of Eve not available.
- Obtained simple ON-OFF scheme
- Considered schemes with Cooperative Jamming

Future Work

- Correlated sources over Gaussian MAC with eavesdropper
- Fading MAC with eve: Fast and Slow fading
- Functions of correlated input sequences over MAC
- All above cases with side-information

Thanks !

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