Secure Robust Resource Allocation in the Presence of Active Eavesdroppers using Full-Duplex Receivers

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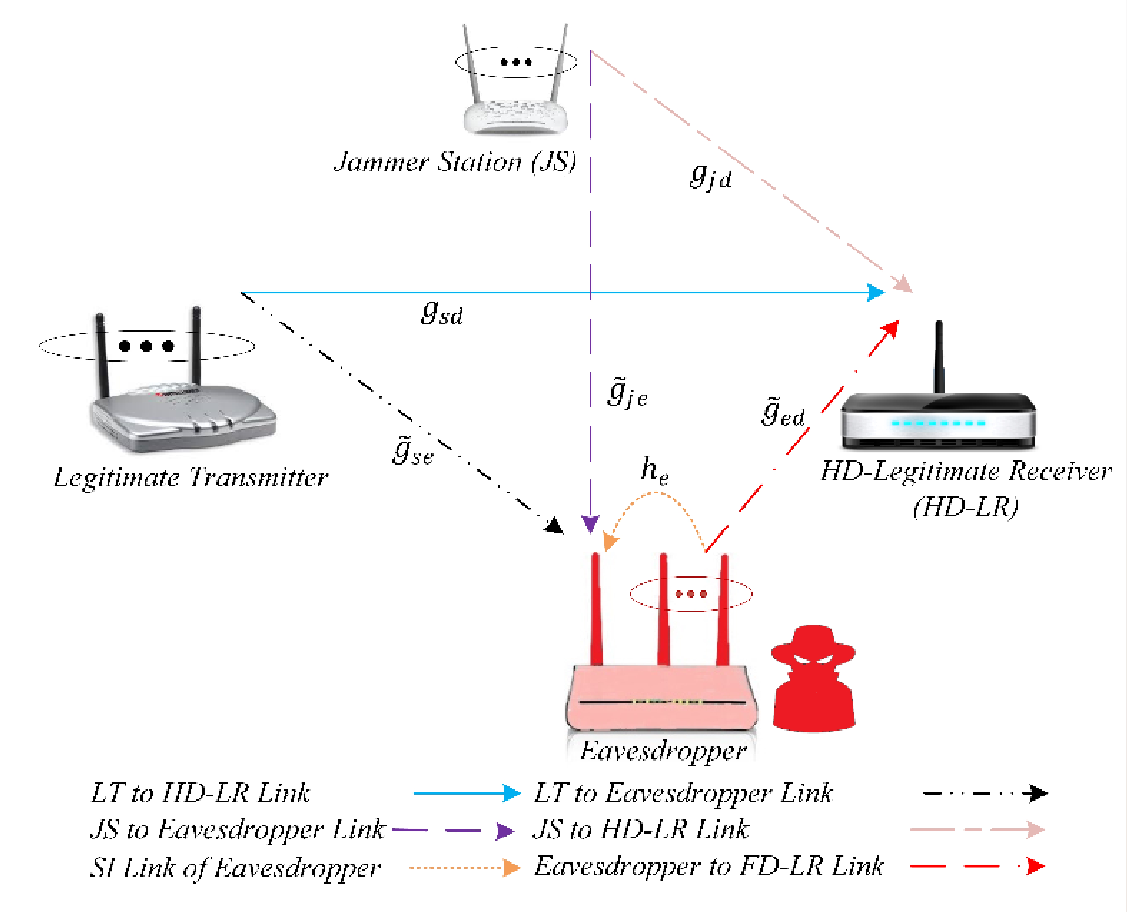
Physical layer security

- The security is provided at the PHY instead of application layer

- Secrecy rate is defined as the rate between Tx and Rx minus the rate between Tx and the eavesdropper

If the eavesdropper is closer: zero secrecy rate

Cooperative Jamming



PHY security

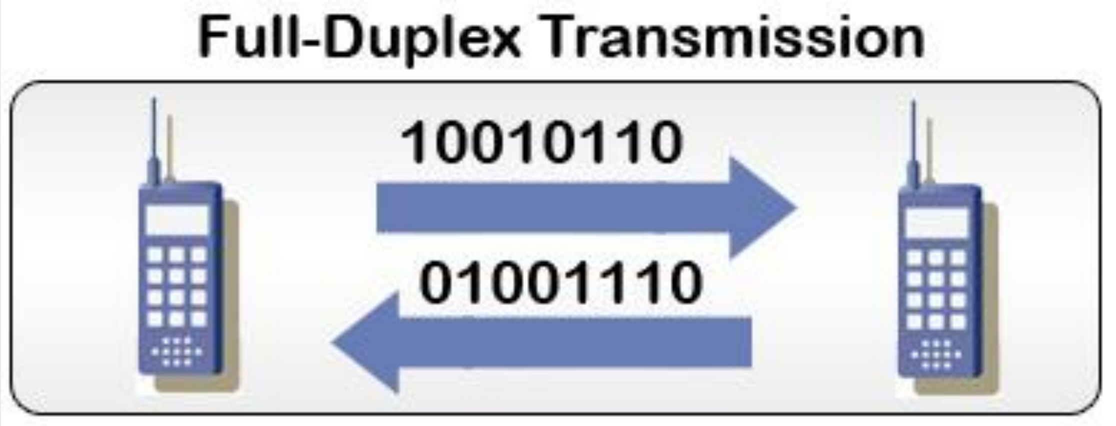
- CSI uncertainty: robust approaches

- passive or active eavesdroppers

  - passive eavesdroppers can only overhear signal

  - active eavesdroppers can also send jamming signals

Full-Duplex Receiver



Sender/Receiver Sender/Receiver

4 cases can be considered:

CASE 1: HD receivers + Passive Eavesdroppers

Main idea: using multiple antennas or relays to send jamming signals to the eavesdropper

Many works in this regard in the past few years such as:

S. Goel and R. Negi, "Guaranteeing secrecy using artificial noise," *IEEE Transactions on Wireless Communications*, vol. 7, no. 6, pp. 2180–2189, January 2008.

4 cases can be considered

CASE 2: HD receivers + Active eavesdroppers

G. T. Amariucai and S. Wei, “Half-duplex active eavesdropping in fast fading channels: A block-markov wyner secrecy encoding scheme,” *IEEE Transactions on Information Theory*, vol. 58, no. 7, pp. 4660–4677, July 2012 2180–2189, January 2008.

A. Chortiy, S. M. Perlazay, Z. Hanz, and H. V. Poory, “On the resilience of wireless multiuser networks to passive and active eavesdroppers,” *IEEE Journal on Selected Areas in Communications*, vol. 31, no. 9, pp. 1850–1863, September 2013.

A. Mukherjee and A. L. Swindlehurst, “A full-duplex active eavesdropper in MIMO wiretap channels: Construction and countermeasures,” in *Proceedings Asilomar Conference on Signals, Systems, and Computers*, pp. 265–269, Pacific Grove, CA, November 2011.

4 cases can be considered

CASE 3: FD receivers + Passive eavesdroppers

G. Zheng, I. Krikidis, J. Li, A. P. Petropulu, and B. Ottersten, “Improving physical layer secrecy using full-duplex jamming receivers,” *IEEE Transactions on Signal Processing*, vol. 61, no. 20, pp. 4962–4974, October 2013.

W. Li, M. Ghogho, B. Chen, and C. Xiong, “Secure communication via sending artificial noise by the receiver: Outage secrecy capacity/region analysis,” *IEEE Communications Letters*, vol. 16, no. 10, pp. 1628–1631, October 2012.

M. R. Abedi, N. Mokari, H. Saeedi, and H. Yanikomeroglu, “Secure robust resource allocation using full-duplex receivers,” *International Conference on Communications (ICC), Workshop on Wireless Physical Layer Security (WPLS), London, UK*, June 2015.

Y. Zhou, Z. Z. Xiang, Y. Zhu, and Z. Xue, “Application of full-duplex wireless technique into secure MIMO communication: Achievable secrecy rate based optimization,” *IEEE Signal Processing Letters*, vol. 21, no. 7, pp. 804–808, July 2014.

4 Cases can be considered

CASE 4: FD receiver + active eavesdropper:

No works on optimal power allocation is found to the best of out knowledge.

AIM: comparing CASE 4 with that of CASE 2 in a robust resource allocation framework

Assumptions: 1TX, 1RX, 1 Eavesdropper

Robustness against CSI Uncertainty

Channel Mismatch:

$$e_{\boldsymbol{g}_{se}} = \boldsymbol{g}_{se} - \tilde{\boldsymbol{g}}_{se} \qquad \mathcal{E}_{\mathbf{g}_{se}} = \left\{ \mathrm{e}_{\mathbf{g}_{se}} : \left\| \mathrm{e}_{\mathbf{g}_{se}} \right\|^2 \leq \varepsilon_{\mathbf{g}_{se}}^2 \right\}$$

$$e_{\boldsymbol{g}_{je}} = \boldsymbol{g}_{je} - \tilde{\boldsymbol{g}}_{je} \qquad \mathcal{E}_{\mathbf{g}_{je}} = \left\{ \mathrm{e}_{\mathbf{g}_{je}} : \left\| \mathrm{e}_{\mathbf{g}_{je}} \right\|^2 \leq \varepsilon_{\mathbf{g}_{je}}^2 \right\}$$

$$e_{\boldsymbol{g}_{de}} = \boldsymbol{g}_{de} - \tilde{\boldsymbol{g}}_{de} \qquad \mathcal{E}_{\mathbf{g}_{de}} = \left\{ \mathrm{e}_{\mathbf{g}_{de}} : \left\| \mathrm{e}_{\mathbf{g}_{de}} \right\|^2 \leq \varepsilon_{\mathbf{g}_{de}}^2 \right\}$$

$$e_{\boldsymbol{g}_{ed}} = \boldsymbol{g}_{ed} - \tilde{\boldsymbol{g}}_{ed} \qquad \mathcal{E}_{\mathbf{g}_{ed}} = \left\{ \mathrm{e}_{\mathbf{g}_{ed}} : \left\| \mathrm{e}_{\mathbf{g}_{ed}} \right\|^2 \leq \varepsilon_{\mathbf{g}_{ed}}^2 \right\}$$

The HD Scenario

$\boldsymbol{Problem\ \mathcal{O}^{HD}}$:

$$\max_{\boldsymbol{Q}_s \in \mathcal{Q}_s} \min_{\boldsymbol{Q}_e \in \mathcal{Q}_e,\ \boldsymbol{e}_{g_{se}} \in \mathcal{E}_{g_{se}},\ \boldsymbol{e}_{g_{ed}} \in \mathcal{E}_{g_{ed}}} R_s\ ,$$

$$S.t. \quad tr(\boldsymbol{Q}_s) \leq P_s,$$

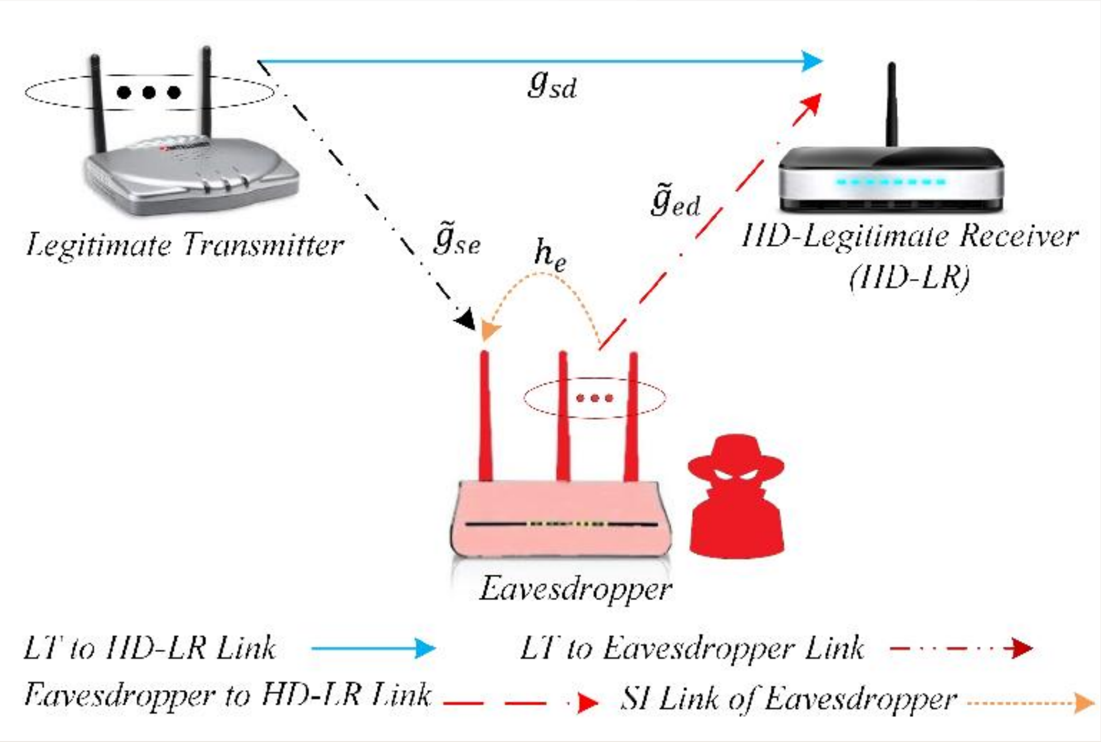
$$tr(\boldsymbol{Q}_e) \leq P_e,$$

$$\left\| \boldsymbol{e}_{g_{se}} \right\|^2 \leq \varepsilon^2_{g_{se}},$$

$$\left\| \boldsymbol{e}_{g_{ed}} \right\|^2 \leq \varepsilon^2_{g_{ed}},$$

$$\boldsymbol{Q}_s \succcurlyeq \boldsymbol{0},$$

$$\boldsymbol{Q}_e \succcurlyeq \boldsymbol{0}.$$



The HDJ Scenario

Problem $\mathcal{O}^{HDJ}$:

$$\max_{\mathbf{Q}_s\in\mathcal{Q}_s,\mathbf{Q}_j\in\mathcal{Q}_j}\ \min_{\mathbf{Q}_e\in\mathcal{Q}_e,\ \mathbf{e}_{g_{se}}\in\mathcal{E}_{g_{se}},\ \mathbf{e}_{g_{je}}\in\mathcal{E}_{g_{je}},\ \mathbf{e}_{g_{ed}}\in\mathcal{E}_{g_{ed}}} R_s,$$

$$S.t.\quad tr(\mathbf{Q}_s)\leq P_s,$$

$$tr(\mathbf{Q}_e)\leq P_e,$$

$$tr(\mathbf{Q}_j)\leq P_j,$$

$$\|\mathbf{e}_{g_{se}}\|^2\leq \varepsilon^2_{g_{se}},$$

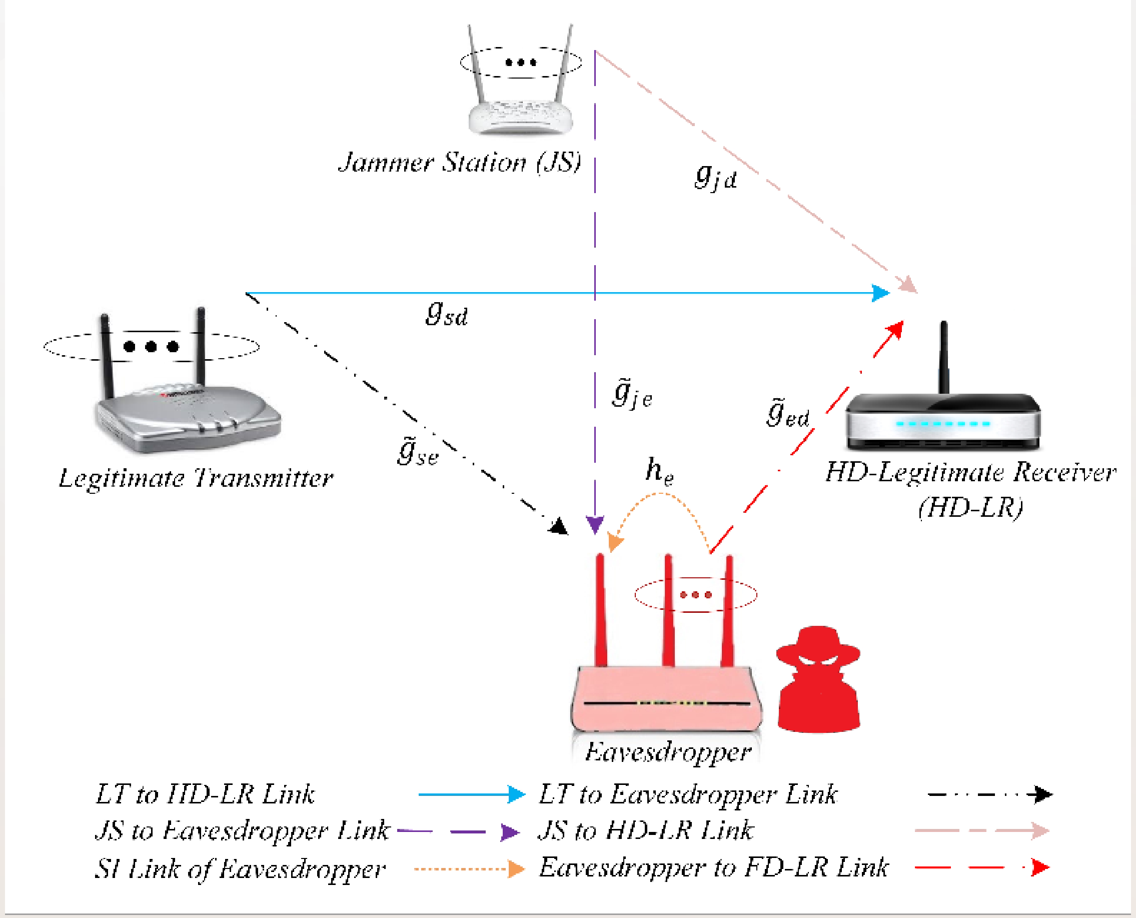
$$\|\mathbf{e}_{g_{ed}}\|^2\leq \varepsilon^2_{g_{ed}},$$

$$\|\mathbf{e}_{g_{je}}\|^2\leq \varepsilon^2_{g_{je}},$$

$$\mathbf{Q}_s\succcurlyeq \mathbf{0},$$

$$\mathbf{Q}_{je}\succcurlyeq \mathbf{0},$$

$$\mathbf{Q}_j\succcurlyeq \mathbf{0}.$$



The FD Scenario

$\boldsymbol{Problem\ \mathcal{O}^{FD}}$:

$$\max_{\boldsymbol{Q}_s \in \boldsymbol{\mathcal{Q}}_s, \boldsymbol{Q}_d \in \boldsymbol{\mathcal{Q}}_d} \ \min_{\boldsymbol{Q}_e \in \boldsymbol{\mathcal{Q}}_e, e_{g_{se}} \in \mathcal{E}_{g_{se}}, e_{g_{de}} \in \mathcal{E}_{g_{de}}, e_{g_{ed}} \in \mathcal{E}_{g_{ed}}} R_s,$$

$$S.t. \quad tr(\boldsymbol{Q}_s) \le P_s,$$

$$tr(\boldsymbol{Q}_e) \le P_e,$$

$$tr(\boldsymbol{Q}_j) \le P_j,$$

$$tr(\boldsymbol{Q}_d) \le P_d,$$

$$\|e_{g_{se}}\|^2 \le \varepsilon^2_{g_{se}},$$

$$\|e_{g_{ed}}\|^2 \le \varepsilon^2_{g_{ed}},$$

$$\|e_{g_{je}}\|^2 \le \varepsilon^2_{g_{je}},$$

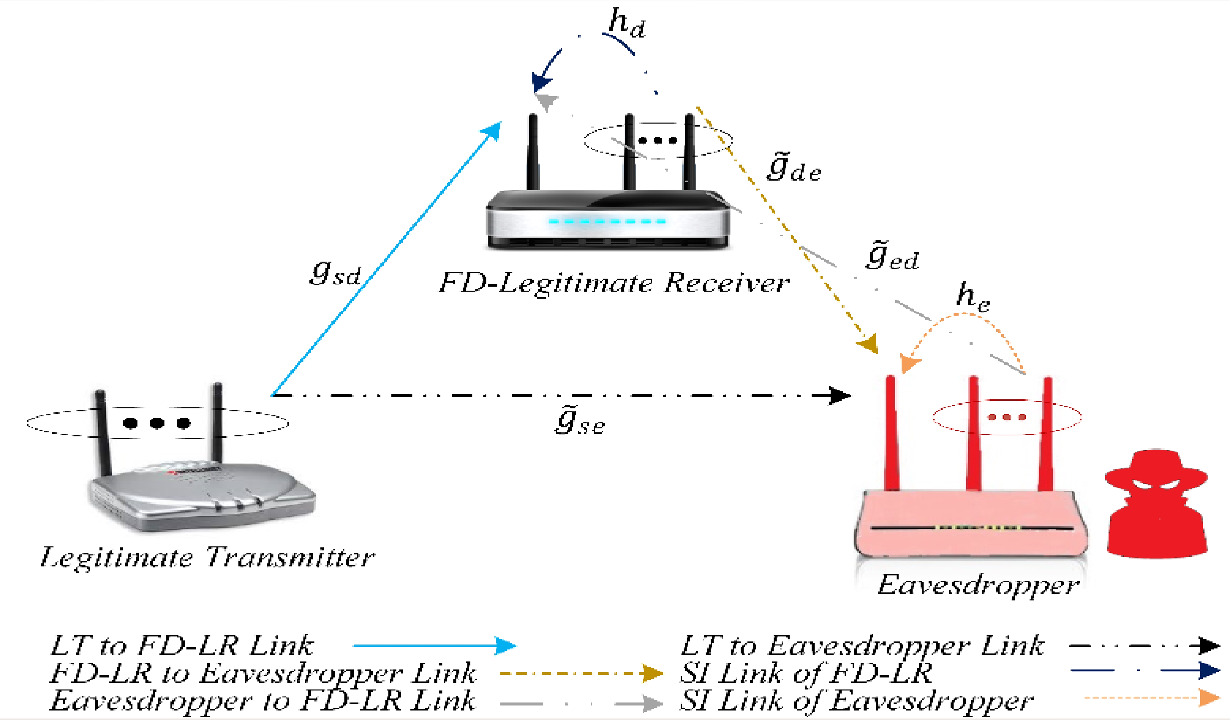
$$\|e_{g_{de}}\|^2 \le \varepsilon^2_{g_{de}},$$

$$\boldsymbol{Q}_s \succcurlyeq \boldsymbol{0},$$

$$\boldsymbol{Q}_{je} \succcurlyeq \boldsymbol{0},$$

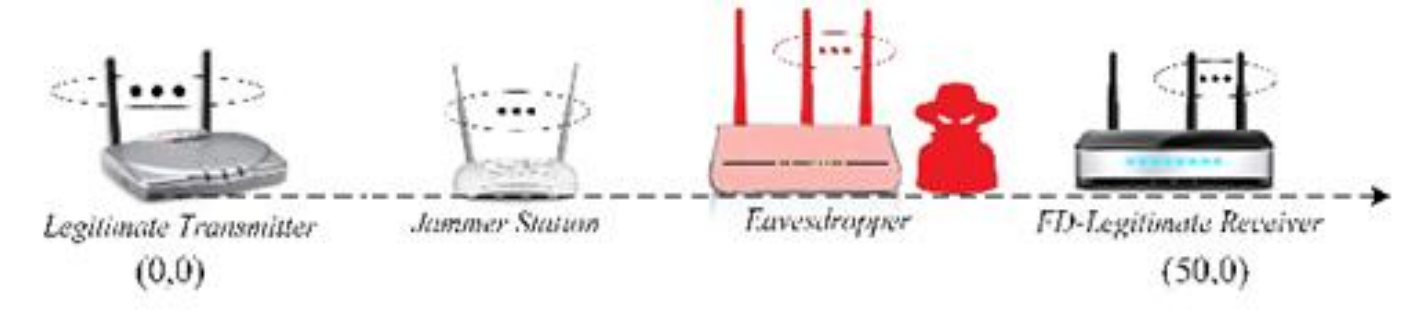
$$\boldsymbol{Q}_j \succcurlyeq \boldsymbol{0}$$

$$\boldsymbol{Q}_d \succcurlyeq \boldsymbol{0}$$

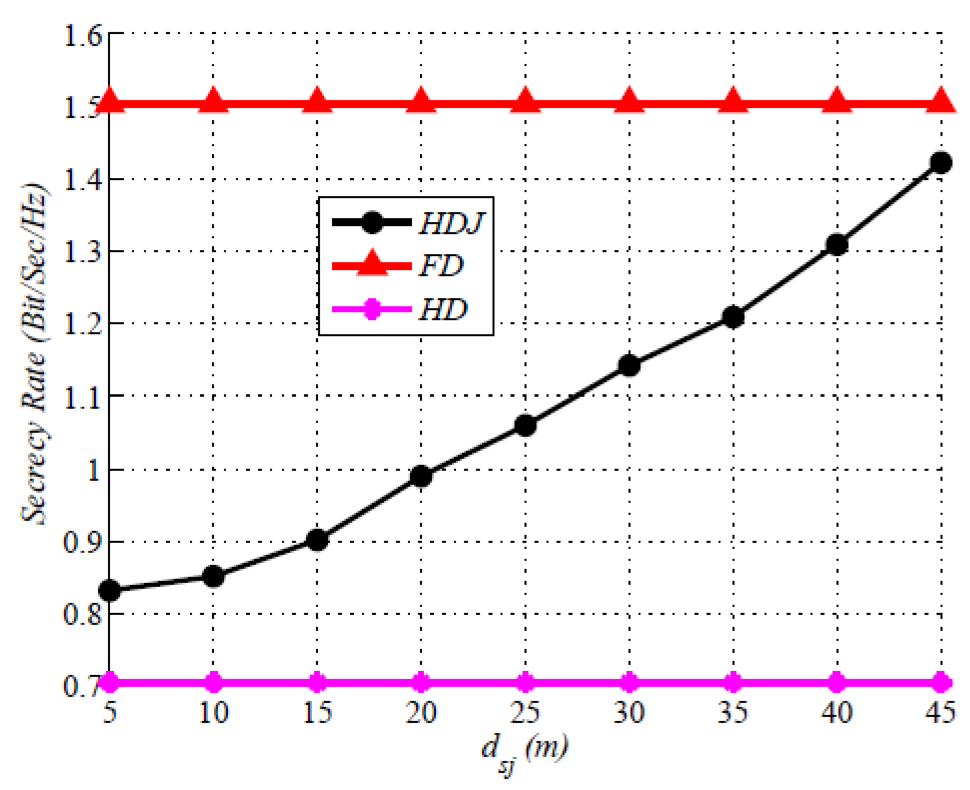


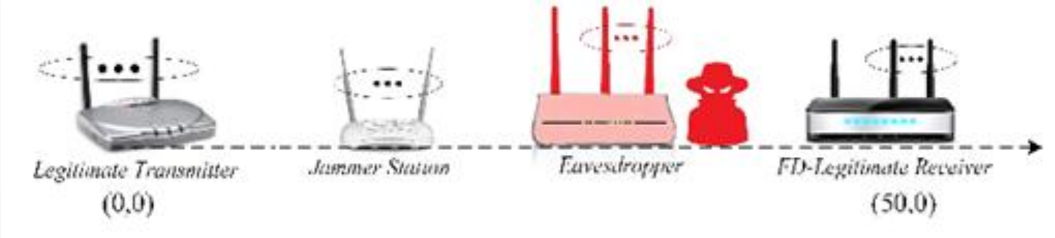
Simulation Setup

Parameter	Value
$N_s = N_d = N_j = N_e$	4
$\sigma_d^2 = \sigma_e^2$	$0\ dB$
$\mathcal{E}_{g_{se}}^2 = \mathcal{E}_{g_{de}}^2 = \mathcal{E}_{g_{je}}^2 = \mathcal{E}_{g_{de}}^2$	0.5



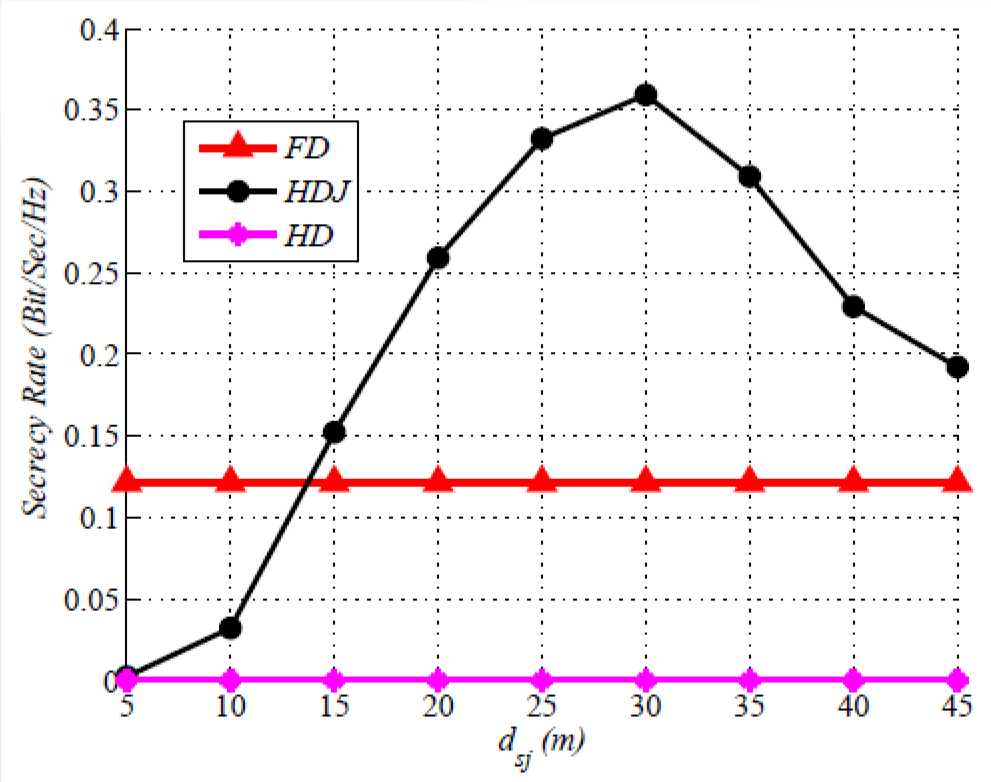
Simulation Results: Effect of Source-Jammer Distance on the performance

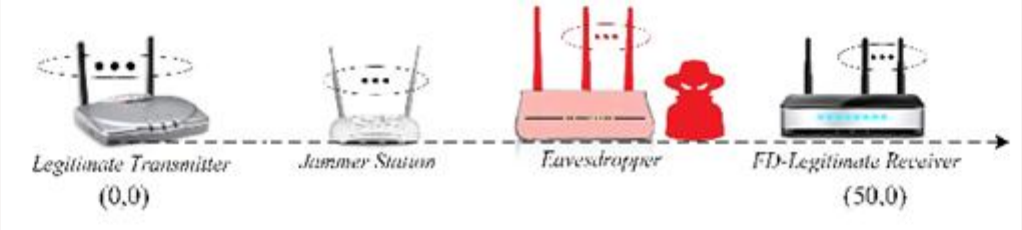




Eavesdropper location is fixed at (70,0)

Simulation Results: Effect of Source-Jammer Distance on the performance





Eavesdropper location is fixed at (30,0)

Conclusion

- Preference of deploying the FD scenario over CJ, or vice versa, highly depends on where the jammer and eavesdropper are located.
- If the jammer can be placed close enough to the eavesdropper, a better performance is achieved compared to the FD system.
- Otherwise, the FD scenario can generally take over which is very favorable from practical point of view as we can remove the need for an extra network node.

Thanks for your attention