Jamming MANETs

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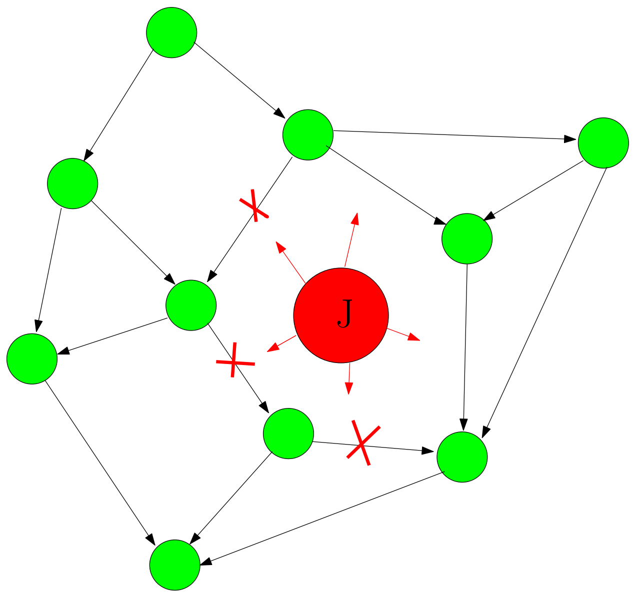
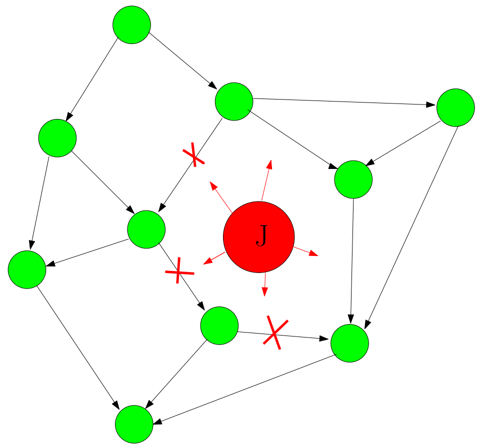


- Applications:
  - Emergency operations
  - Battlefield
  - Surveillance systems
- Related thrusts: network coding, resource allocation

Basic Problem

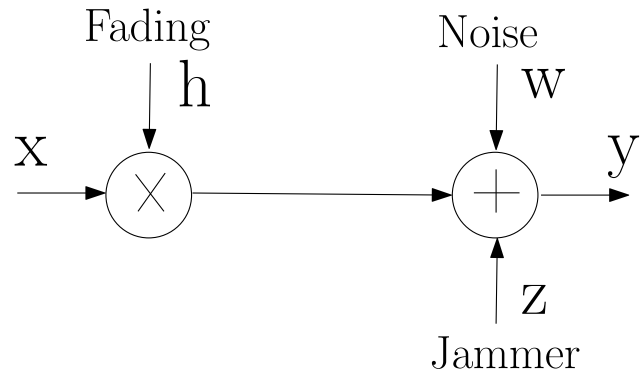


- Fundamental limits of resistance to jamming?
- Network coding: Ho, Koetter, Médard, Karger and Effros 03
- Link coding: Ray, Moulin and Médard 06
  for wideband fading channels
- Large # of degrees of freedom improves resistance to jamming
- What is the best coding strategy?

Jamming for Wideband Fading Channels

- Use of large bandwidth improves the **power efficiency** of time-varying channels
- A jammer has no effect on the wideband capacity limit.
- What effect does a jammer have on the error exponent?
- What are the optimal transmission and jamming strategies?

Model



$$E\|\mathbf{X}\|^2 = SNR \qquad E\|\mathbf{Z}\|^2 = J\,SNR$$

- Assume single-antenna system
- Wideband channel: Set of parallel indep. narrowband channels.
- Each narrowband channel is in the low SNR regime.
- The channel state is unknown at the transmitter and receiver.
- Block fading $\Rightarrow$ channel coherence length of l symbols.
- Jammer's signal is independent of the transmitter's signal.

Capacity in the Absence of a Jammer

- Capacity [Zheng, Tse, Médard 03]

$$C(SNR) = SNR + SNR^{1+\min(1,\nu)} + o(SNR^{1+\min(1,\nu)})$$

where $l \doteq SNR^{-2\nu}$, $\nu > 0$.

- Peaky Gaussian signaling
  - Transmit in only $\delta(SNR) = SNR^{1-\min(1,\nu)}$ fraction of the blocks.
  - Transmit Gaussian signals in blocks chosen for transmission.

Capacity in the Presence of a Jammer

- Input distribution: $q \in \mathcal{Q}$
- Jammer + AWGN distribution: $v \in \mathcal{V}$.

$$C(SNR, J) = \sup_{q \in \mathcal{Q}} \inf_{v \in \mathcal{V}} I(q, v)$$

- Capacity

$$C(SNR) = SNR + O(SNR^{1+\min(1,\nu)})$$

is achievable using Peaky Gaussian signaling.

- At best, jammer has $O(SNR^{1+\min(1,\nu)})$ effect.

Error Exponent in the Presence of a Jammer

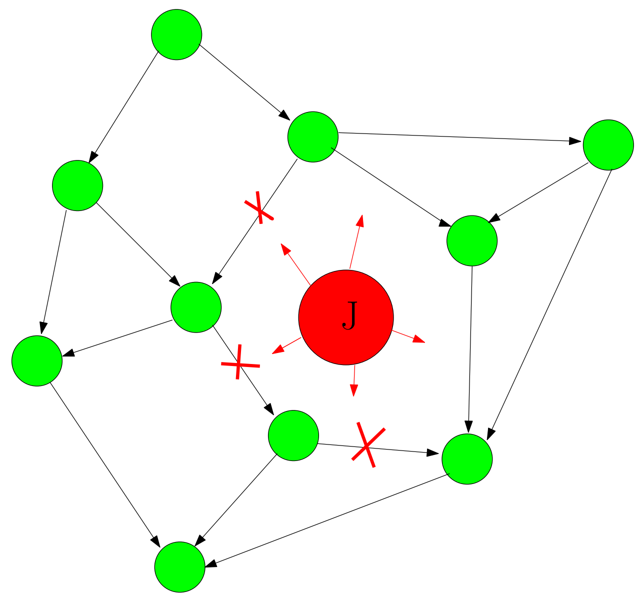
$$P_e(R) \leq \exp\{-E_r(R, SNR, J)\}$$

$$E_r(R, SNR, J) = \max_{0\leq\rho\leq 1} \sup_{q\in\mathcal{Q}} \inf_{v\in\mathcal{V}} [E_0(\rho, q, v) - \rho R]$$

$$E_0(\rho, q, v) = -\log \int \left[\int q(\mathbf{x}) v(\mathbf{y}|\mathbf{x})^{\frac{1}{1+\rho}} \, d\mathbf{x} \right]^{1+\rho} d\mathbf{y}$$

- If q is isotropic then optimal v is also isotropic.
- $E_r(\rho, q, v)$ admits a saddle point for every ρ.
- If q is Gaussian, the effect of the jammer vanishes with increasing bandwidth

Returning to MANET Jamming



- Combine network coding with physical-layer coding to exploit capacity of threatened link
- Power efficiency *vs* bandwidth resources
- Mobility (of nodes and jammer)

Related MANET Security Topics

- Resistance to eavesdroppers
- Authentication problems – ID capacity
- Data-hiding capacity – application to tracking of transactions and byzantine node ID (traitor tracing)
- Steganography – application to network monitoring, leaking byzantine nodes