Jamming MANETs

Pierre Moulin and Muriel Médard
Dept. of Electrical and Computer Engineering
University of Illinois at Urbana-Champaign

in collaboration with Ralf Koetter and Todd Coleman
Graduate Student: Victor Wu

January 25, 2007
— 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

\[ E\|X\|^2 = SNR \quad E\|Z\|^2 = J\, SNR \]

- 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 \( l = SNR^{-2\nu} \), \( \nu > 0 \).

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

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

- Capacity

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

is achievable using Peaky Gaussian signaling.

- At best, jammer has $O(SNR^{1+\min(1,v)})$ effect.
Error Exponent in the Presence of a Jammer

\[ P_e(R) \leq \exp\{-E_t(R, SNR, J)\} \]

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

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

- If \( q \) is isotropic then optimal \( v \) is also isotropic.
- \( E_t(\rho, q, v) \) admits a saddle point for every \( \rho \).
- 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