# Frequency and Waveform Adaptation Strategies for Countering Smart Adversaries in Satellite Systems

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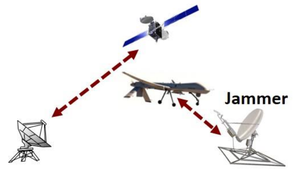
## Frequency Hopping (FH) and Waveform Adaptation Games

### Transmitter Model

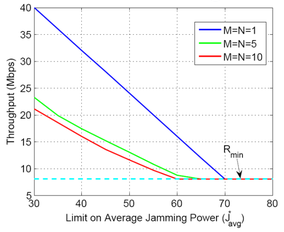
- Transmitter may transmit over any of *K* available channels
- For each channel, transmitter can select one of *M* waveforms

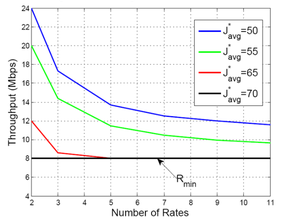



### Jammer Model

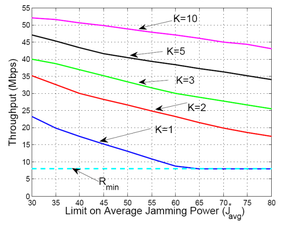
- Jammer may jam any/all of the *K* channels subject to an average power constraint
- Jammer has *N* jamming power levels

### Single channel (*K* = 1)



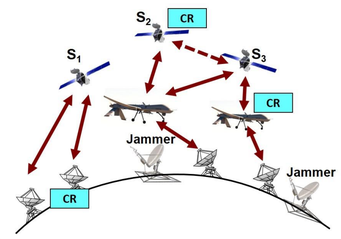

### Multi-channel (*K* > 1)




## Motivation

### Unique SATCOM Characteristics

- Highly dynamic network topology
- Long time to detect interference
- Beamforming (frequency reuse)
- Different uplink and downlink bands
- Ease of jamming

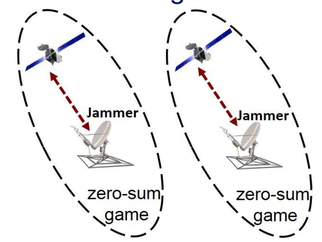



## 2-stage Hierarchical Frequency and Waveform Adaptation Games

### First Stage (zero-sum game between each SAT-jammer pair):

SAT:
- Select the interference margin in each of the *K* channels
- Instruct the ground stations within its spot beams about its selection

Jammer:
- Select the jamming power in each of the *K* channels
- Instruct the colluding UAV about its selection




### Second Stage:

Ground stations and UAVs use outcome of first stage to allocate channels and associate SATs by either:

1. Competing (noncooperative game)
2. Cooperating (cooperative game)
3. Bargaining with heterogeneous rate demands

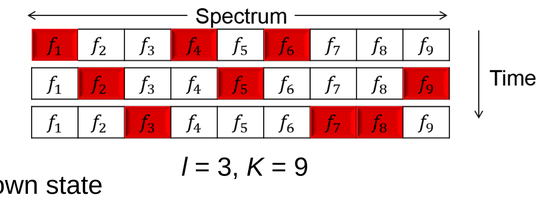

## MDP-based FH to Combat Sweep Jammers

### Jammer Model

Random sweep (jam *l* out of *K* channels at a time)

### Transmitter Model

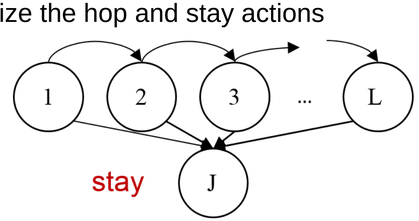
Transmitter can only observe its own state

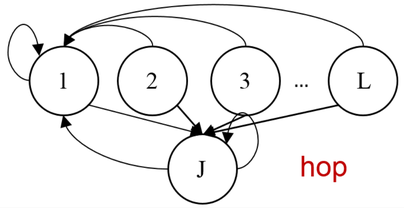



*l* = 3, *K* = 9

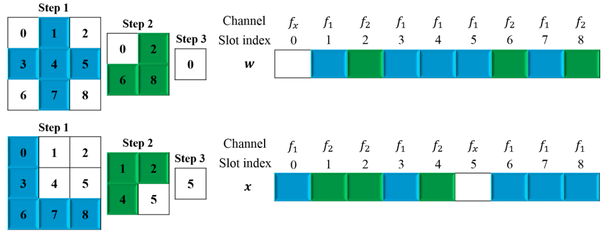
### Transmitter Strategy

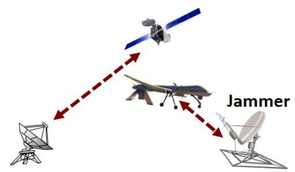
- Follow a Markov decision process (MDP)-based FH approach
- Optimize the hop and stay actions



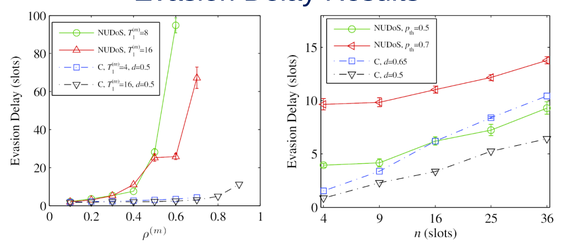




## FH Rendezvous for Link Re-establishment




### Evasion Delay Results




### Hamming Distance Results