Distributed Localized Interference Avoidance for Dynamic Frequency Hopping ad hoc Networks

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Outline

- CORASMA project overview
- CORASMA simulator
  - Basic Waveform
  - Network structure
  - Channels and Slots
- Interference Avoidance
  - Basic idea and example
  - Hopset adaption
  - Spectrum sensing
- Markov model and results
- Conclusion

Project overview

- **CORASMA**: <u>CO</u>gnitive <u>RA</u>dio for dynamic <u>S</u>pectrum <u>MA</u>nagement
  - Consortium: Thales (FR, GE, BE, IT), MUT, Saab, Selex, Tekever
  - Projected Duration: Nov. 2010 – Nov. 2013
  - Funded by the European Defense Agency (EDA)

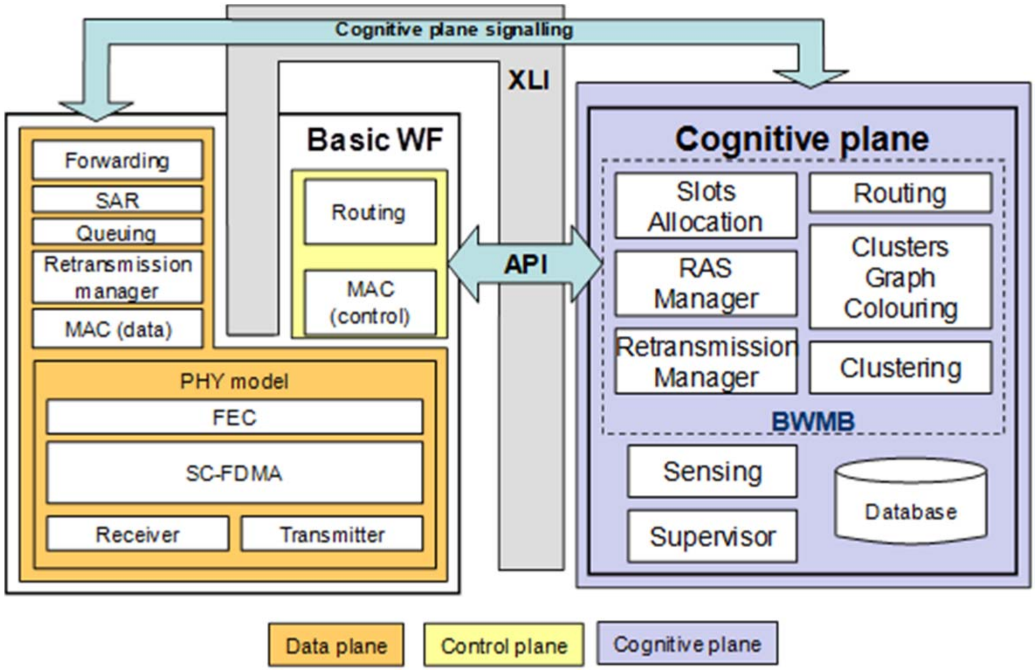
- Key topics addressed:
  - Cognitive radio in military context
  - Dynamic spectrum allocation
  - Spectrum usage optimization
  - High-fidelity system simulations

- Main objective: design of **a high-fidelity platform for tactical network simulation including PHY/MAC/NET protocol stack running in a realistic propagation environment**

CORASMA simulator

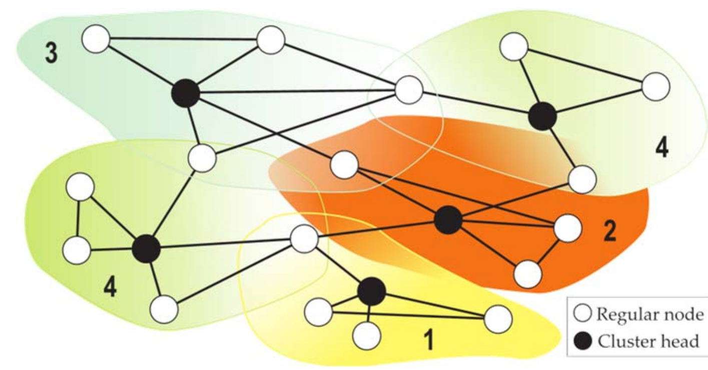
- Basic Waveform (BW)
  - Fully functional waveform (within the simulation framework)
  - Common basis for different cognitive solutions

- Cognitive Manager(s)
  - One cognitive solution per partner
  - Each solution extends some part of the basic waveform by a cognitive process
  - Using a common spectrum sensing module

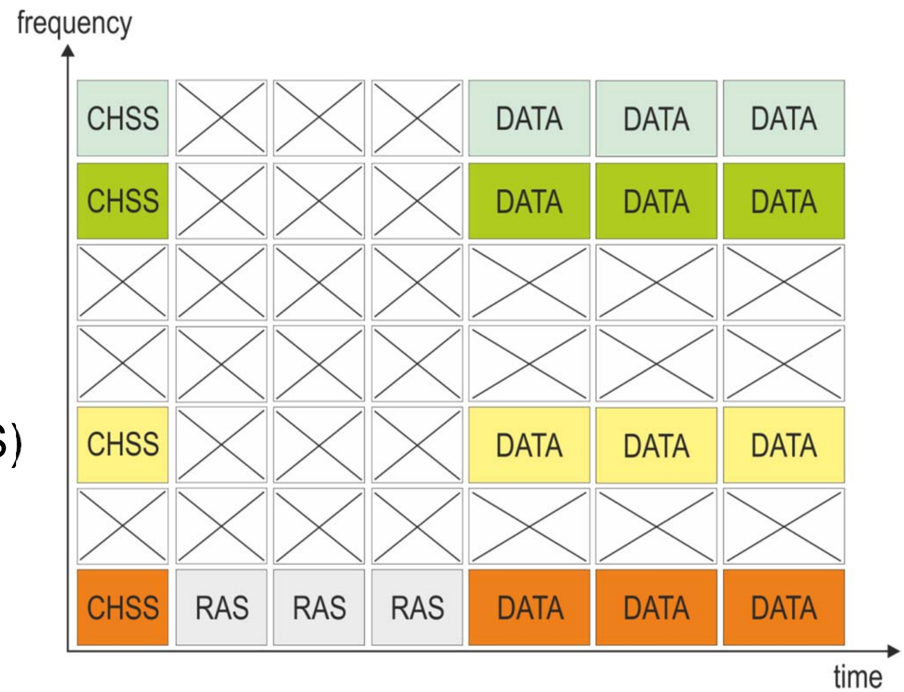


Basic Waveform

- Clustered network structure
  - Nodes are grouped into clusters
  - Operating on separate channels
  - Cluster heads manage access
  - Gateway nodes allow for inter-cluster communication



- Multi-channel MAC
  - Network-wide control channel (Random Access Slots, RAS)
  - Cluster-wide control channels (Cluster head signaling slot, CHSS)
  - Data Slots (DATA)

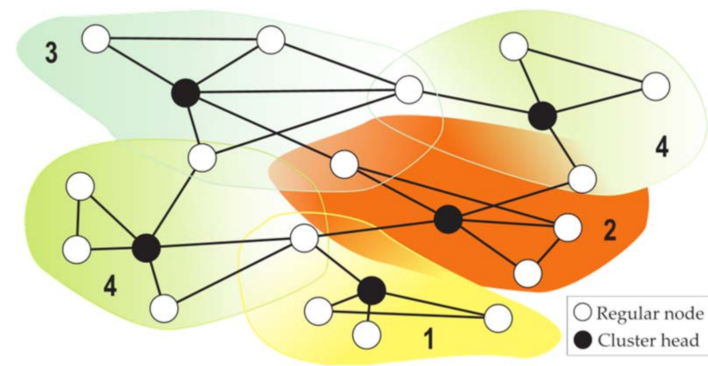


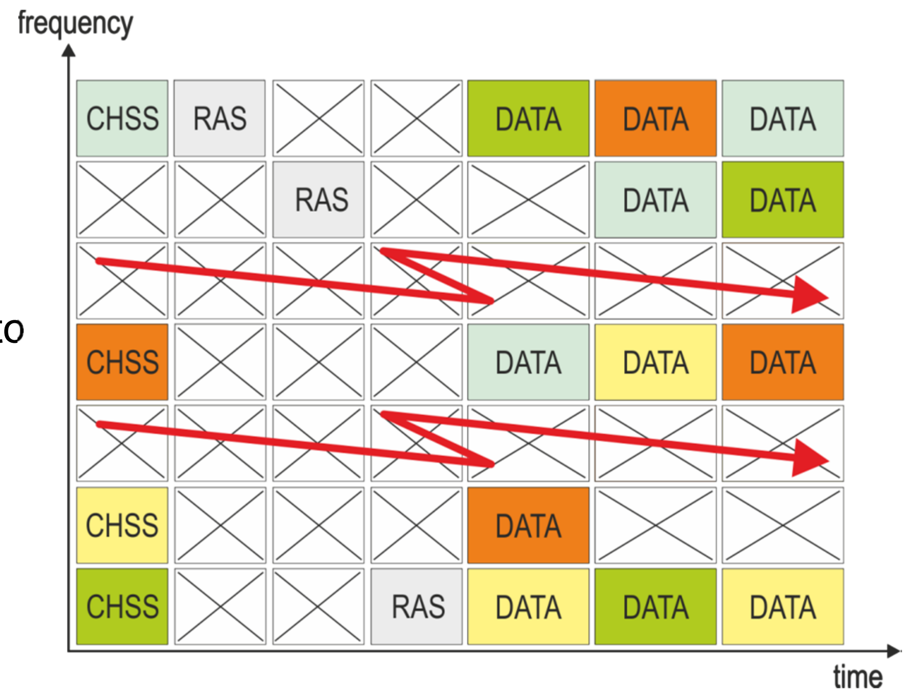
Interference Avoidance: Basic idea

- Cognitive extension of the Basic WF

- Frequency hopping over K channels
  - Cluster-based frequency hopping improves robustness and increases security
  - Local orthogonality is preserved

- Dynamic frequency hopping:
  Do not hop on bad channels
  - Local decision for each cluster
  - Find a different locally unused hopset to substitute a bad channel
  - Coordinate with neighboring clusters

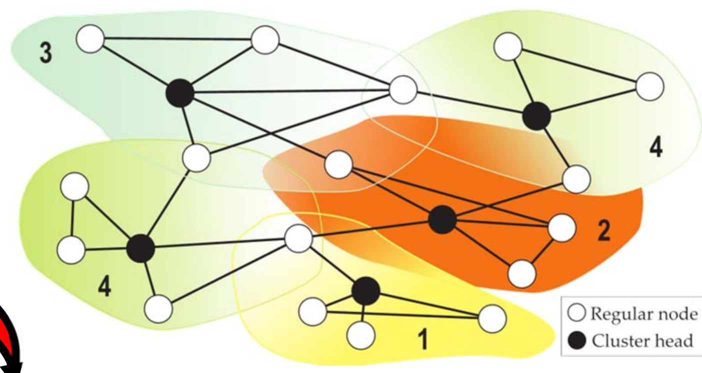




Interference Avoidance: Example

channel	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10
c11	9	7	8	4	3	11	8	5	8	2
c10	1	5	7	11	2	6	7	6	11	9
c9	10	2	10	3	11	8	6	1	9	7
c8	2	8	9	1	4	10	5	3	7	11
c7	5	6	4	5	9	1	10	2	3	8
c6	4	3	1	8	10	3	11	9	2	3
c5	8	11	5	9	5	4	1	10	4	6
c4	3	10	6	7	1	9	2	4	5	5
c3	6	9	3	2	6	7	4	8	1	10
c2	11	4	2	10	8	5	3	7	6	1
c1	7	1	11	6	7	2	9	11	10	4

time

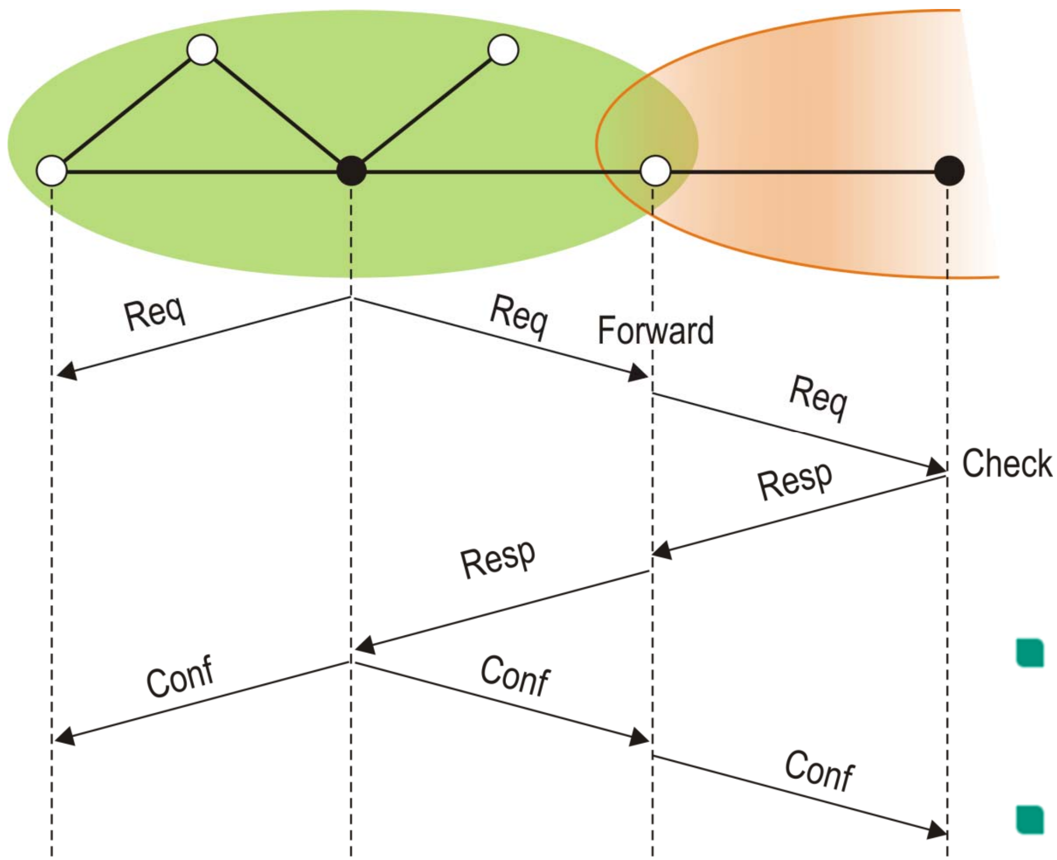


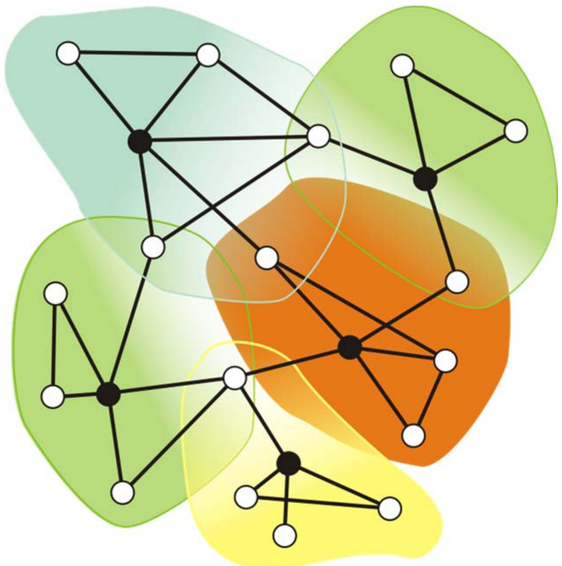
- Channels: c1 - c11
- Time steps: t1 - t10
- Hopsets: 1 – 11
- Cluster colors:
- Bad channels:

We substitute bad channels with hopsets!

Distributed hopset adaptation protocol

- Coordination / notification of hopset adaptations necessary





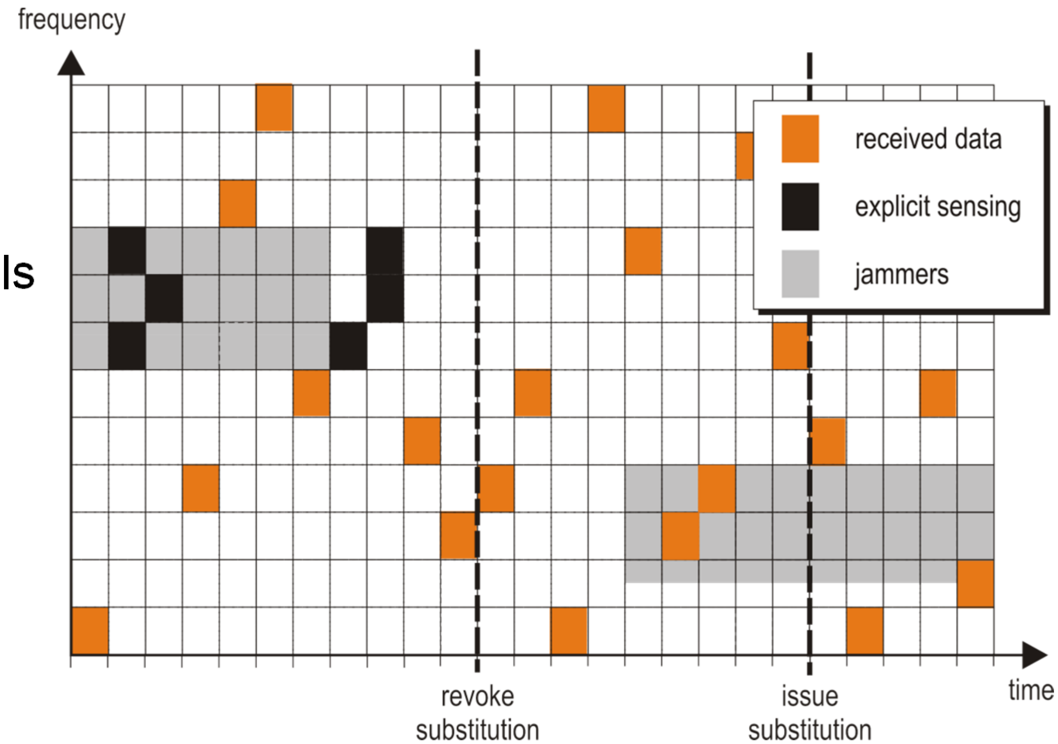
- Cluster heads inform their neighbors when adapting their hopsets
- …and possibly allow them to object (avoiding conflicts)

Spectrum sensing

- Channel exclusion (re-inclusion) by issuing (revoking) substitutions based on the results of spectrum sensing

- Implicit Sensing:
  - During message reception
  - Based on PER or SNR
  - Used to detect bad channels

- Explicit Sensing:
  - While idle / upon request
  - Energy Detection
  - Used to explore excluded channels



- Sensing is performed in collaboration with peer nodes

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Performance modeling

- A simple simulative model describing the dependencies and the possible gains of dynamic frequency hopping as proposed
  - Qualitative insight for Cognitive Manager design
  - Simple way to verify the behavior of the CORASMA simulator

- Chosen here: Markov model
  - What gains can be expected compared to random hopping?

Markov model

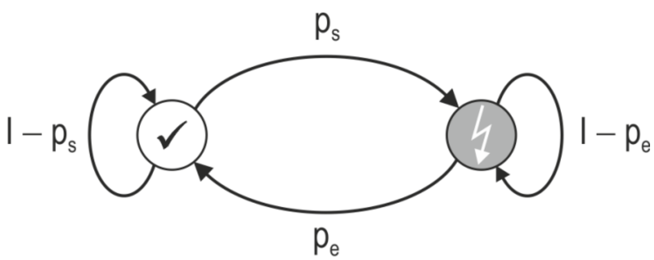
- Goal: A simple simulative model describing the dependencies and the possible gains of dynamic frequency hopping as proposed

- Model assumptions
  - Describes only a one-hop cluster neighborhood
  - Interference is the same in all clusters
  - Substitution protocol works as described, channel is substituted with hopset right away (ideal, fast reaction)

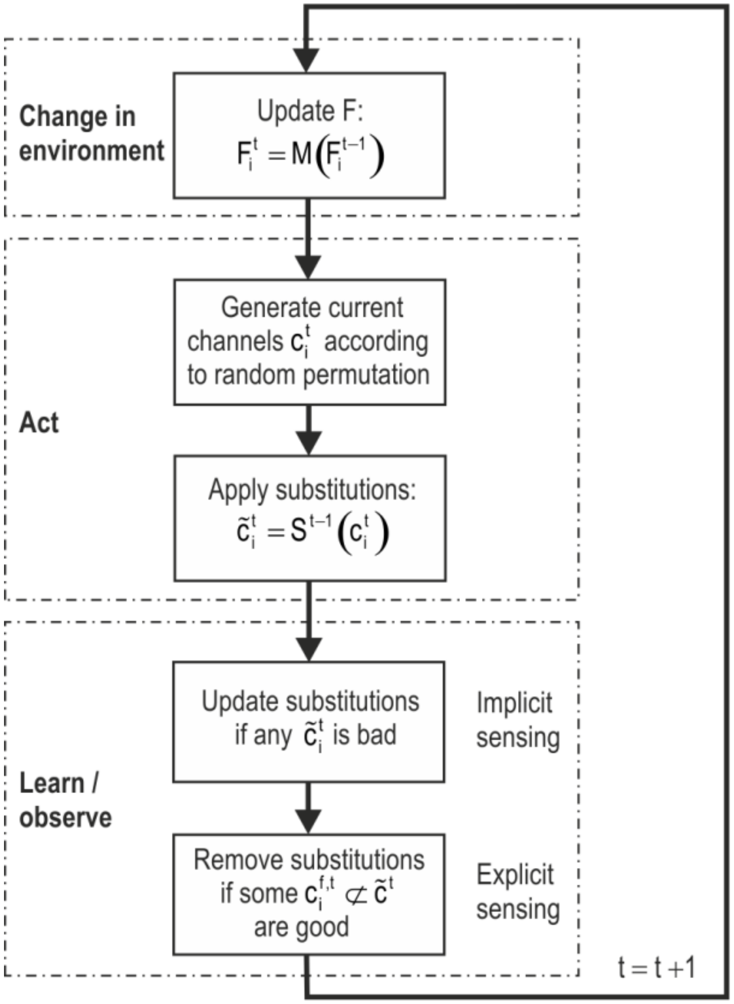
- Model parameters
  - N clusters in K channels
  - Interference starts with probability p_s, ends with probability p_e
  - Success probability for sensing p_d
  - N_e channels can be explicitly sensed in each time step
  - State vectors: **F** (Currently bad channels), **S** (list of substitution hopsets)

Markov model

- The interference model for each channel is based on a simple Markov chain M:

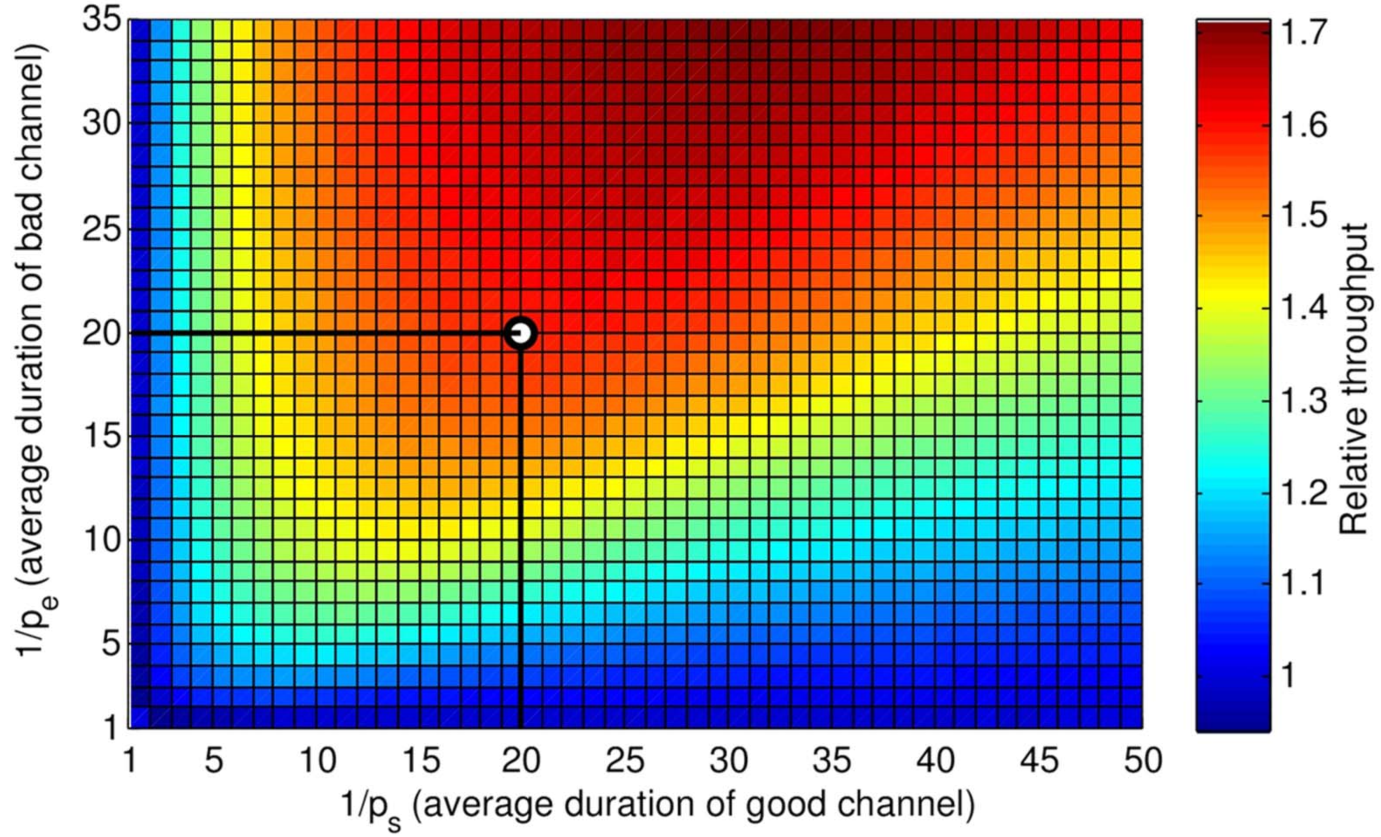


- The simulation states F and S only depend on the last step and also have the Markov property



Markov model results

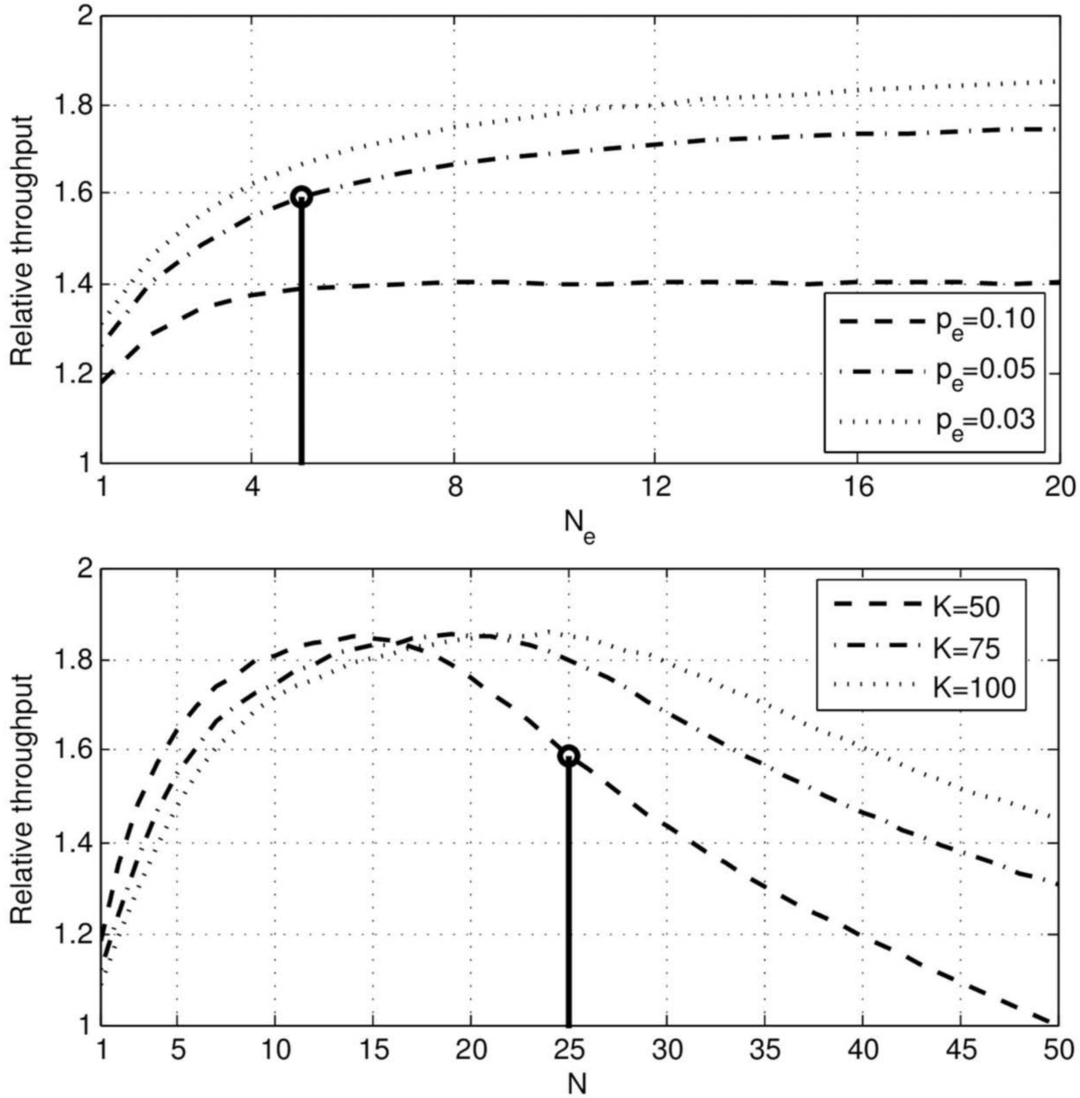
- Performance gain of hopset adaption vs. random hopping for different interference statistics ($N = 25$, $K = 50$, $N_e = 5$, $p_d = 0.95$)



Markov model results

- Impact of explicit sensing parameter N_e ($N = 25$, $K = 50$, $p_d = 0.95$)

- Impact of the network size / node density ($p_s = p_e = 0.05$, $N_e = 5$, $p_d = 0.95$)



Conclusion

- Overview of the CORASMA project
- Combating localized interference in a clustered ad hoc network using Dynamic Frequency Hopping
- Distributed hopset adaption algorithm allowing each cluster to best utilize the available channels
- Simplified Markov model yields a maximal performance gain of two compared to random hopping (for the presented scenarios)

Thank you for your attention. Questions?

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