EDA ad hoc B program

CORASMA project
COgnitive RAdio for dynamic Spectrum MAnagement
Contract N° B-781-IAP4-GC

Learning algorithms for power and frequency allocation in clustered ad hoc networks

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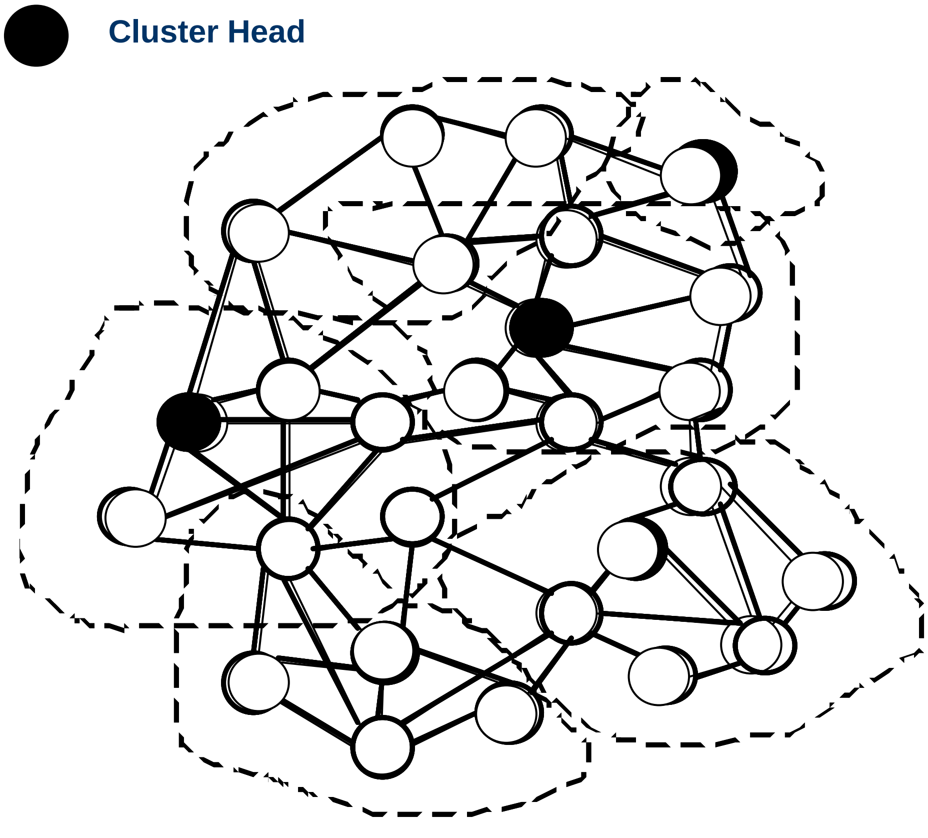
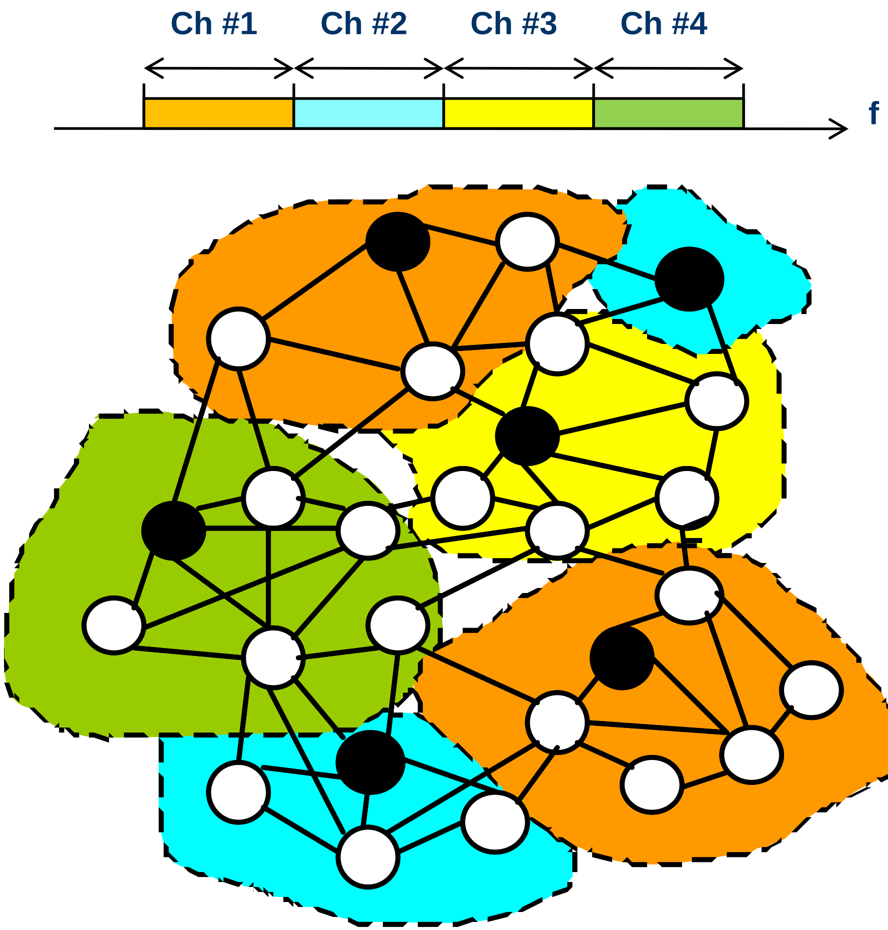
Overview: The problem





Cluster frequency « coloring »

Overview: The problem

- Optimization problem
  - Select the cluster frequency channel
    - That minimizes the total transmit power (all the clusters)
    - Subject to per-link SINR constraints
    - In a fully distributed way

- Several possible solutions
  - Multi-channels
    - Iterative Water-Filling
  - Single channel
    - GADIA
  - Game Theory-based
    - Reinforcement Learning
    - Trial and Error

Overview: Literature

- Iterative Water-filling
  - Individually optimum
  - No proof of convergence
  - Several results show its inefficiency in densely populated networks (Tragedy of the Commons)
- GADIA
  - Channel selected to minimize the global interference level
  - Convergence proved
  - Not adapt to set power and channel, requires distanced clusters
- Reinforcement Learning
  - Convergence proved
  - Slow convergence
  - Different training and exploitation periods

Trial and Error Learning

(H. Peyton Young, 2009)

Moods

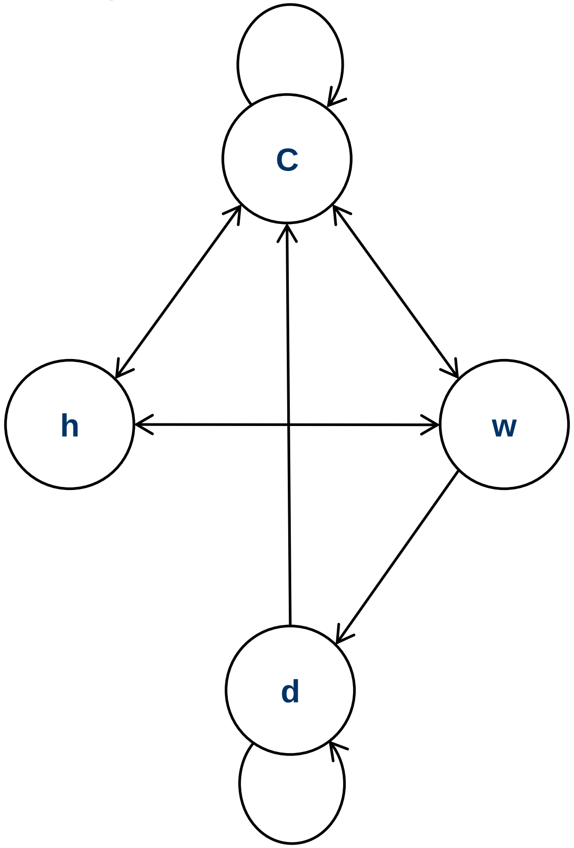
c: content

d: discontent

w: watchful

h: hopeful

- Content
  . Experiments new actions with probability ε
- Discontent
  . Experiments new actions

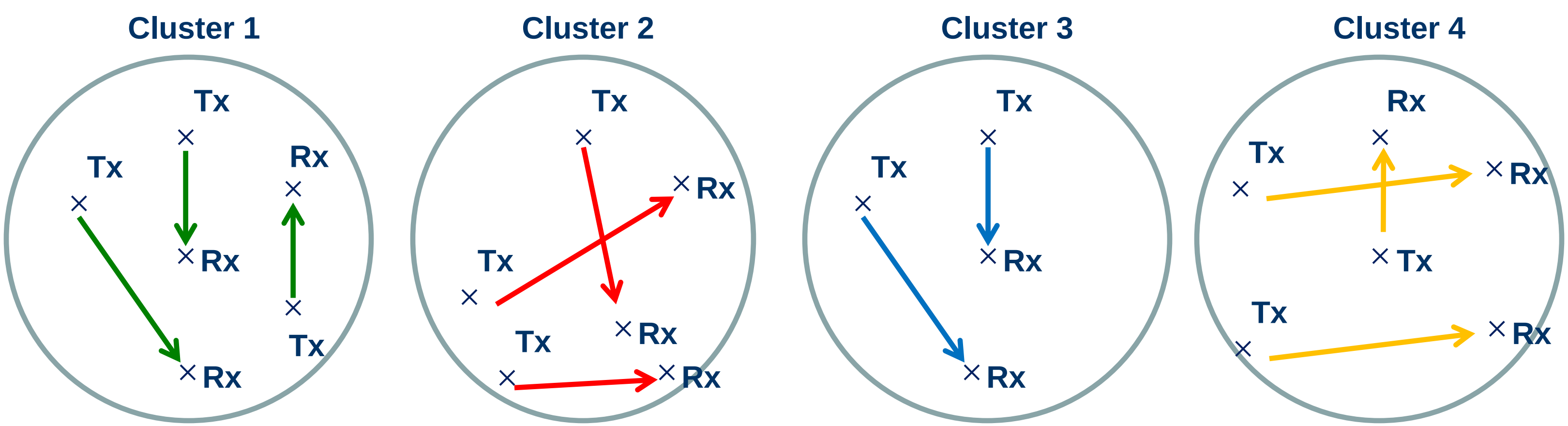


- C -> H: no experiment, utility increases
  . H -> C: if utility increases or equal
  . H -> W: if utility decreases
- C -> W: no experiment, utility decreases
  . W -> H: if utility increases
  . W -> C: if utility equal
  . W -> D: if utility decreases

From original TE to ad hoc networks…

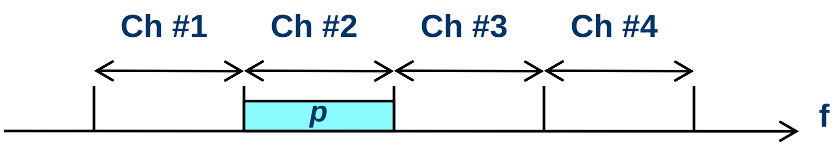
- First step

- To



Trial and Error: Utility function

- Proposed solution: Trial and Error algorithm
  - Players: CHs
  - Actions: powers/frequencies
  - Utility for CH #*k*:



$$u_k(\mathbf{p}) := \frac{1}{1+|L_k|\beta}\left(\underbrace{1-\frac{p_k}{p_{MAX}}}_{\text{Power minimization}} + \underbrace{\beta\sum_{\ell\in L_k} 1_{[\Gamma_\ell(\mathbf{p})>\Gamma_k]}}_{\text{SINR constraints}}\right)$$

Trial and Error: Theoretical Results

- Theorem
  - For , if ***a**** is a solution of the optimization problem and ***a**** is a NE, then TE converges to ***a****

- Theorem
  - For , the TE converges to the NE where the largest set of nodes are simultaneously satisfied

- Property
  - TE selects among all the NE the one maximizing the Social Welfare

Trial and Error: some issues

- Issues
  - Instability of the solution even if optimal
    - One parameter decides the experimentation frequency on both channels and power levels
    - Parameter fixed a priori
  - Slow convergence
  - Experimentation do not take “common sense” behavior

- Solution: enhanced Trial and Error (ETE)
  - Two different experimentation frequency
    - sets the experimentation frequency on the power levels
    - sets the experimentation frequency on the channels
    - is time-varying:

$$\varepsilon_c(t) = \begin{cases} \max\left(\frac{\varepsilon_c(t-1)}{2}, \varepsilon_{\min}\right) & \text{if } \sum_{\ell \in L_k} 1_{[\Gamma_\ell(\mathbf{p}) > \Gamma_k]} = |L_k| \\ \varepsilon_c(0) & \text{otherwise} \end{cases}$$

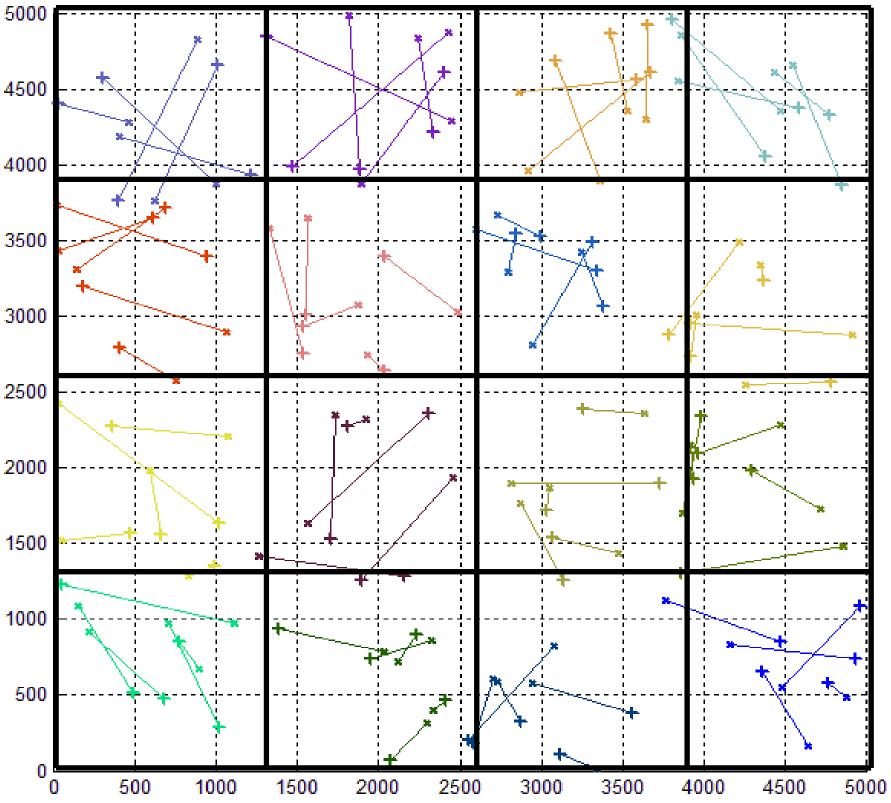
    - “Small” makes the channel-cluster association scheme stable

Enhanced Trial and Error

- Solution: enhanced Trial and Error (ETE)
  - Smart probability distribution for power experimentation
    - Content and $\sum_{\ell \in L_k} 1_{[\Gamma_\ell(\mathbf{p}) > \Gamma_k]} = |L_k|$: experiment only levels below
    - Content and $\sum_{\ell \in L_k} 1_{[\Gamma_\ell(\mathbf{p}) > \Gamma_k]} < |L_k|$: experiment all levels
    - Discontent: $p_k = \begin{cases} p_{\mathrm{MAX}} & \text{with prob.} \quad \min\left(\frac{\mathrm{C}}{\mathrm{K}}, 1\right) \\ 0 & \text{with prob.} \quad \max\left(1 - \frac{\mathrm{C}}{\mathrm{K}}, 0\right) \end{cases}$

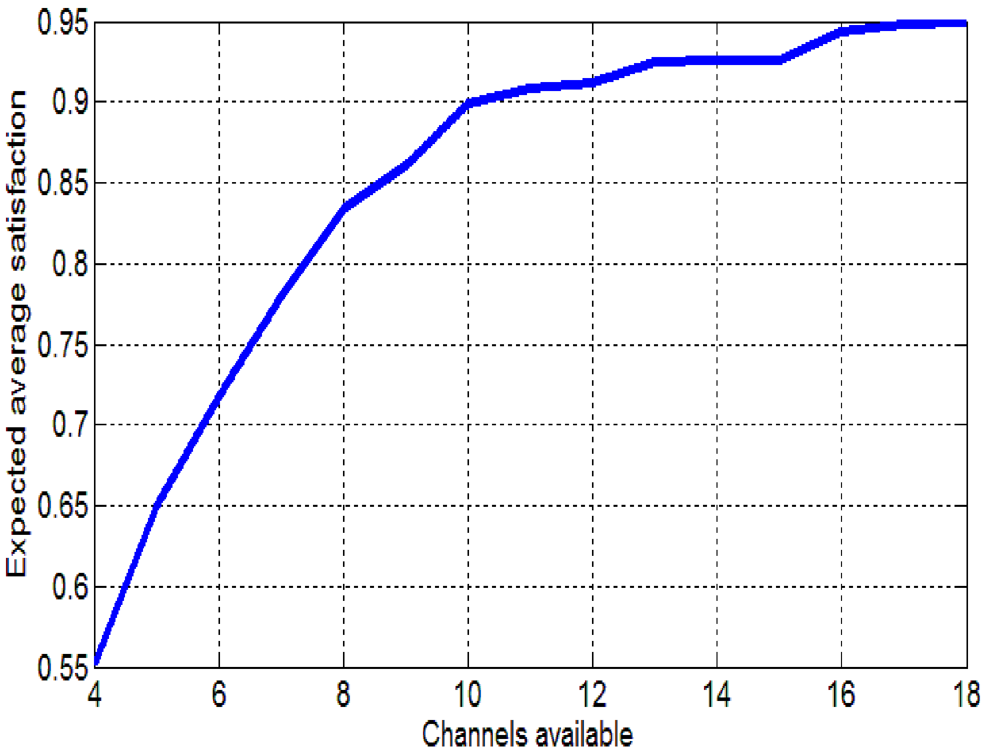
Numerical Simulations

- Static dense scenario
  - Nodes fixed in a square area
  - 16 “square” clusters
  - 4 links per cluster
  - Channel-range: 2-18
  - Block fading channels
  - Rayleigh fading channels



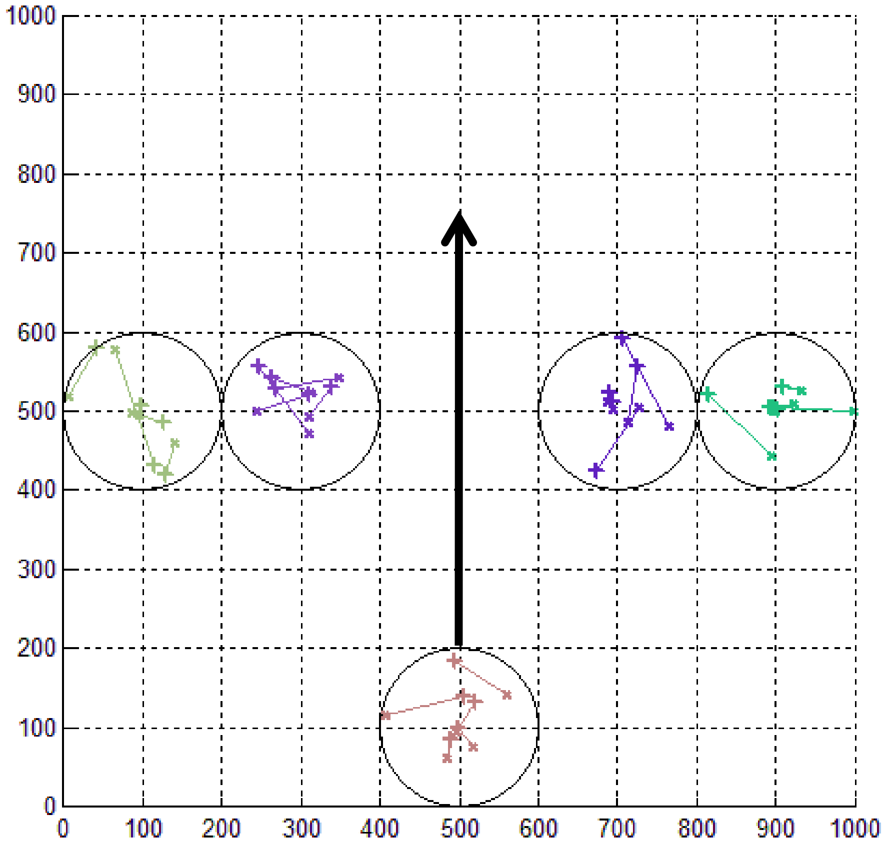
Simulation results

- Dense scenario



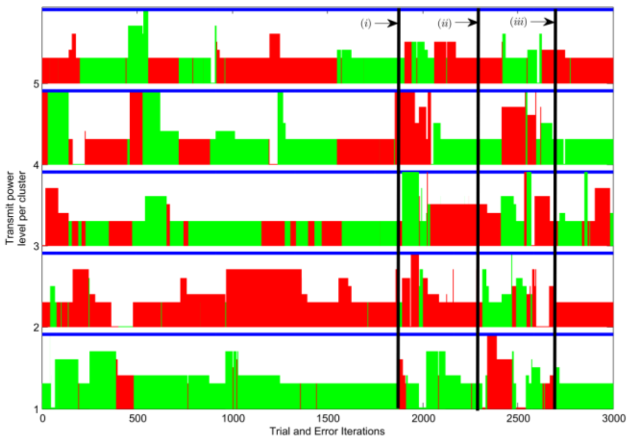
Numerical Simulations

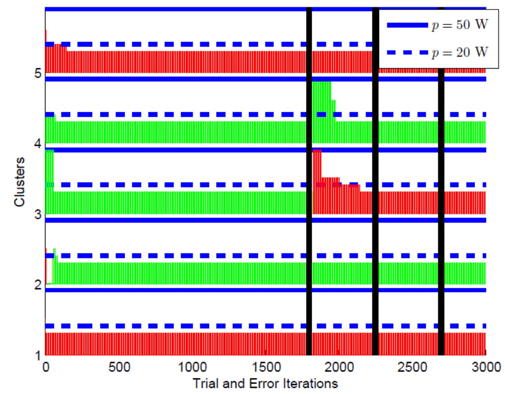
- Mobility scenario
  - 4 clusters fixed
  - 1 moving cluster
  - 2 frequency channels

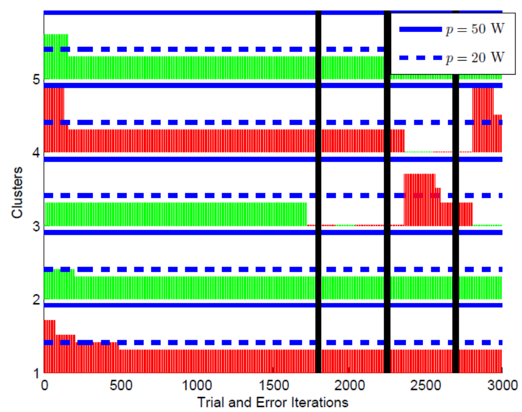


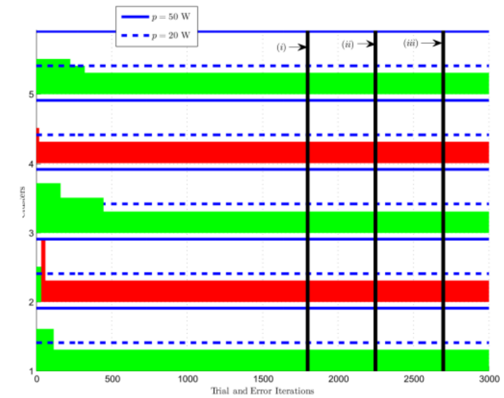
Channels and power levels – Mobility scenario

- Standard TE
- Enhanced TE









Enhanced Trial and Error - Conclusions

- Sets efficiently channel and power levels
- Requires only intra-cluster information
- Quickly adapts to changes in the network topology
- Quickly adapts to fading

- Thus looks adapted from a theoretical point of view
- And validated by simulations

Using Matlab simulations!

- Next challenge: make it work into a real system
- Ongoing implementation in a HiFi network simulator…