Joint Optimization of Access Point Placement and Frequency Assignment in WLAN

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ENSEEIHT / IRIT, Toulouse

A. Gondran – A. Caminada
O. Baala – H. Mabed
Agenda

1. Problem
2. Frequency channel assignment
3. Our approach
4. ACP and AFP combination
5. Conclusion/Perspectives
1. Problem

WLAN Planning

1. selecting a *location* for each transmitter
2. *setting* the parameters of all transmitters

Objectives:

- providing users wireless access to their local network.
- respecting *financial requirements*
- guarantying a given *quality of service*. 
1. Overlapped Problems

Transmitter Location + Frequency Assignment
(Coverage + Interferences)

+ Access Points + Access Points
+ coverage area + interference
- coverage area

Automatic Cell Planning
Set covering problem

Automatic Frequency Planning
Graph coloring problem
1. Overlapped Problems

Transmitter Location + Frequency Assignment (Coverage + Interferences)

Successively : most studies
  – Constraints are added to the location problem in order to ease the frequency channel assignment
  – The global problem is over-constrained

Simultaneously : very rare
  – Only three channels with co-channel interference (Wertz04)
2. Frequency assignment

- Share the resources: frequency channels
- IEEE 802.11b/g: 13 channels (3 non-overlapping)
2. Frequency Assignment

- 3 non-overlapping channels
  - More than 3 antennas => interferences
  - Interference: computation of SINR (*Signal-to-Interference-plus-Noise-Ratio*)
  - Spreading interference over the whole area

- 2 approaches
  - Global view: interference at cell level
  - Local view: interference at user level
  => Adding of constraints to ease frequency channel assignment
2. Global view

3-Graph colouring

- Sites are fixed
- Assigning a colour (frequency channel) to each zone (cell) such that two adjacent zones do not share the same colour.
- We have 3 available colours (non-overlapping channels)
2. Global view

3-Graph colouring

a solution
2. Global view

3-Graph colouring

• If we add a new cell then 3-graph colouring problem is impossible

=> We must add constraints in ACP problem:
  – Graph of incompatible sites (Rodrigues00, Lee02, Mathar00)
2. Global view

T-coloration with 13 colours

- **Resources:** Using 13 available frequency channels
- **Objective:** Satisfying the distance of frequency channel between neighbour transmitters
- **QoS:** Spreading interferences on all cells
2. Global view

T-coloration with 13 colours

- **Resources**: Using 13 available frequency channels
- **Objective**: Satisfying the distance of frequency channel between neighbour transmitters
- **QoS**: Spreading interferences on all cells
2. Local view

Calculation of signal to interference ratio

- One user receives several signals
  - Best signal
  - Interfering signals

- Measurement

\[
SINR = \frac{P_{\text{best signal}}}{\sum P_{\text{interfering}} \gamma(\Delta f) + N}
\]

- Maximising the SINR
2. Local view

Other approaches: addition of constraints during the transmitters location

– Overlapping penalty (Mathar00, Amaldi04a/b)
– Penalizing the 4th overlapping
– Signal deviation between interfering transmitters (Reininger00, Runser05)
– Evaluation of frequency reuse rate (Bahri05)
3. New approach: unifying both problems and both criteria

Transmitter Location + Frequency Assignment (Coverage + Interferences)

real bit rate

- The bit rate provided by the network is unique and takes into account all variables (location, setting and frequency)
- Require calculus – higher computation time
### 3. Our fitness

\[
\sum_{a \in AP} (c_s + c_a) + \beta \times \sum_{t \in users} \max(0, -\Delta_t)
\]

Deviation between the bit rate desired by the user and the real bit rate provided by the network on downlink interference basis

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3. Our fitness

\[ \sum_{a \in AP} (c_s + c_a) + \beta \times \sum_{t \in \text{users}} \max(0, -\Delta_t) \]

Sum of all network users bit rate lack (in kbps) weighted by a financial cost \( \beta \)

Optimisation under constraints of coverage (minimum bit rate for all users)
4. Joint ACP and AFP

• **Originality**
  – tackling both problems in the same time
  – multiple interfering signals are used to compute SINR
  – 13 available channels (not only 3)
  – Large-scale combinatorial !!!

• **Comparing 3 strategies**
  – strategy 1: ACP without channel and 13-channels AFP successively
  – strategy 2: 3-channels ACP and 13-channels AFP successively
  – strategy 3: 13-channels ACP and AFP together
4. Joint ACP and AFP

Optimisation process
- Local search
- 20mn on Pentium 4
- 1 run

Testbed
- 2 floor building
- 94 candidate sites
- 2 antenna patterns
- 4 levels of emitted power

\[ \sum_{p=0}^{93} C_{93}^p (408)^p \approx 10^{242} \] configurations

- demand:
  600 users (300 on each floor)
  500kbps => 300Mbps
  8800 test point (SINR)
4. Joint ACP and AFP

**Optimisation process**
- Local search
- 20mn on Pentium 4
- 1 run

**Testbed**
- 2 floor building
- 94 candidate sites
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$$\sum_{p=0}^{93} C_{93}^p (408)^p \approx 10^{242}$$ configurations

- demand:
  - 600 users (300 on each floor)
  - 500kbps => 300Mbps
  - 8800 test point (SINR)
4. ACP and AFP combination

– strategy 1: ACP without channel and 13-channels AFP successively
– strategy 2: 3-channels ACP and 13-channels AFP successively
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![Diagram showing TP uncovered and unsatisfied for different strategies]
Floor 1

1. Problem
2. Frequency Assignment Problem
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Strategy 1

- 150 m
- 40 m

Strategy 2

Strategy 3
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**Floor 2**

**strategy 1**

- Diagram of strategy 1

**strategy 2**

- Diagram of strategy 2

**strategy 3**

- Diagram of strategy 3
5. Conclusion/Perspectives

• First results
  – simultaneous ACP/AFP is convincing
  – feasible solution found quickly (minimum service)
  – about 250 networks are evaluated per second (for 8800 test points)

• To do: comparison
  – with results from others groups (model / algorithm / test)
  – with manual deployment
  – with others successive approach

• Further algorithmic steps…