Evolutionary Algorithms for Real-World Instances of the Automatic Frequency Planning Problem in GSM Networks

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F. Luna[1] E. Alba[1] A.J. Nebro[1] S. Pedraza[2]

[1] Department of Languages and Computer Science, University of Málaga

[2] Optimi Corp.

{flv,eat,antonio}@lcc.uma.es, salvador.pedraza@optimi.com

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Outline of the talk

Frequency Assignment Problem (FAP)

- Well-known problem in OR: many mathematical models have been proposed (extension of graph coloring)
- Current real-world frequency planning: GSM networks
- Advanced technologies are used (e.g. frequency hopping) for increasing the network capacity
  - Subscribers: Quality of Service (QoS)
  - Operators: Income

Why are we still interested in solving FAP problems?

1. 77% of the world's cellular market is GSM
2. UMTS will be coexisting with GPRS and EDGE
3. Current GSM operators
   1. Subsequent expansions/modifications of the network
   2. Solve unpredicted interference reports
   3. Handle anticipated scenarios

Problem Definition

- Allocate frequencies (few dozens) to elementary transceivers (TRXs) of the network (thousands)
- Frequency reuse is a unavoidable → this provokes interference → QoS degradation

Our approach: using Evolutionary Algorithms (EAs) → (1,λ) EA

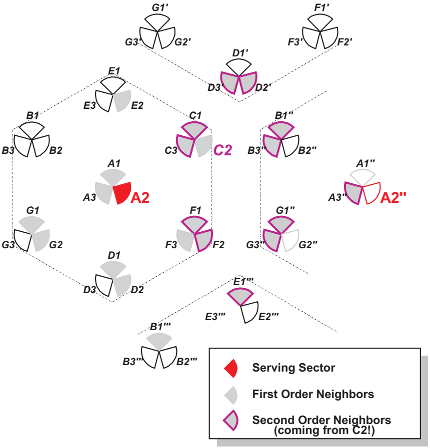
- No recombination is required
- Population-based algorithm with low cost per iteration

Contributions

1. Using a real-world GSM network instance → frequency plans are evaluated with a commercial tool
2. Specialized genetic operators using accurate network information
3. Frequency plans can be directly deployed in the real network

GSM components and interferences

GSM network architecture



Components relevant to AFP

- Base Transceiver Station (BTS)
- Sectors
- Transceiver (TRX)

Interferences

- Co-channel
- Adjacent-channel

Main features

- No recombination
- Simple
- Non elitist

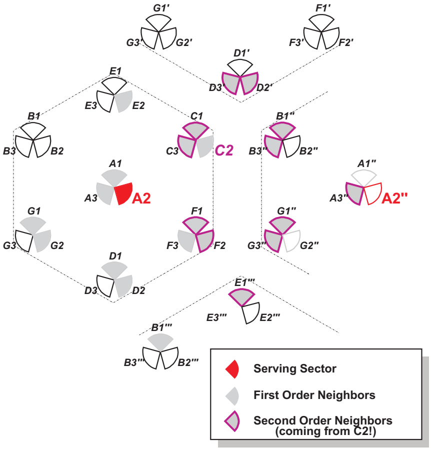
(1,λ) EA

```
current = new Solution();
offsprings = new Population(λ);
init(current);
evaluate(current);
for iter = 0 to NUMBER_OF_ITERATIONS do
  for i = 1 to λ do
    perturbation = perturb(current);
    evaluate(perturbation);
    offsprings[i] = perturbation;
  end for
  current = bestSolution(offsprings);
end for
```

Fitness function

- Evaluation of factors like Frame Erasure Rate, Block Error Rate, etc.
- All the aspects of network configuration (BCCHs, TCHs, etc.)
- Implementation of interference reduction techniques (e.g. frequency hopping)

A representation for a frequency plan



Solution ***p***

146	137	· · ·	150	134
A1	A2		G2'''	G3'''

$T = 84$

$F_{A1} = \{134, 135, ..., 151\}$

$F_{A2} = \{134, 135, ..., 151\}$

$\vdots$

$F_{G3'''} = \{134, 135, ..., 151\}$

Initial solutions are generated in two phases

Phase 1: constructive greedy heuristic

```
trxs = frequencies = ∅;
trxs = TRXsFromSite(s);
random_shuffle(trxs);
for t in trxs do
  f = chooseInterferenceFreeFrequency(t,frequencies);
  assign(t,f);
  frequencies = insert(frequencies,t);
end while
```

- Operate site by site
- Aimed at avoiding intra-site co- and adj-channel interference

Phase 2: local search

- Similar to Dsatur with Costs
  1. TRXs are ranked according a “hardest to deal with metric”
  2. TRXs are allocated a frequency provoking minimal interference
- Goal: reaching “good” solutions in very short times

Updating the frequencies of several TRXs

Phase 1: selecting the TRXs to be perturbed

- It works on one single site
- The site is chosen by selecting one out of its installed TRXs
- Two strategies has been used:
  1. Binary Tournament: the “hardest to deal with” wins
  2. Random

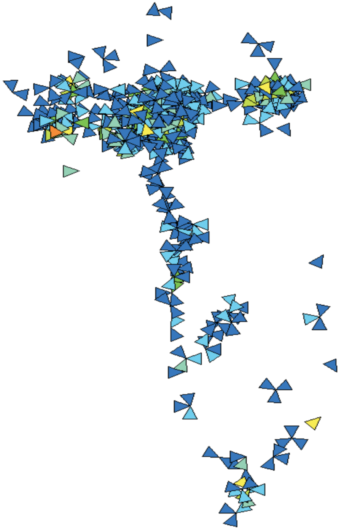
Phase 2: updating the frequencies

- It operates in two steps:
  1. Computing an intra-site interference-free plan for the site
  2. Refining this plan by considering interference from neighbors
- Strong intensification features

```
trxs = TRXsFromSite(s);
applySimpleGreedyHeuristic(s);
trxs = rank(trxs);
for t in trxs do
  f = minInterfFrequency(t,N(s));
  assign(t,f);
end for
```

Instance details

- GSM parameters
  - 711 sectors
  - 2,612 TRXs
  - the same 18 frequencies for all the TRXs
- Network topology (average over all sectors)
  - 25.08 first order neighbors
  - 96.60 second order neighbors
  - No classical hexagonal cell shapes



Parameterization

- (1,λ) EA: $\lambda = 10$ and $\lambda = 20$. For each λ
  - λ_1 perturbations generated by using Tournament Selection
  - λ_2 perturbations generated by using Random

  $\rightarrow$ $\lambda_1 + \lambda_2 = \lambda$
- Stopping condition: computing 100,000 function evaluations

Algorithm	Config		Costs	
	λ_1	λ_2	$\tilde{x}$	*IQR*
(1,10) EA	0	10	4701	88
	3	7	4688	91
	5	5	4708	104
	7	3	4705	113
	10	0	4680	148
(1,20) EA	0	20	4725	141
	5	15	4741	100
	10	10	4763	138
	15	5	4743	115
	20	0	4787	151

Discussion

1. (1,10) EA with $\lambda_1 = 10$ achieved the best (lowest) cost
2. This strategy largely promotes intensification because
   1. (1,10) EA iterates twice longer than (1,20) EA $\rightarrow$ more exploitation
   2. $\lambda_1 = 10$: all the offsprings are generated using Binary Tournament
3. All the configs with $\lambda = 10$ outperform the $\lambda = 20$ settings
4. Low IQR $\rightarrow$ robustness

Conclusions

1. We have used $(1,\lambda)$ EAs to solve the AFP problem in a real world GSM network
   - No classical mathematical formulation
   - Commercial tool to evaluate the tentative frequency plans
2. Advanced operators for initializing and perturbing solutions
   - They use accurate network information
3. Different configurations have been tested: those promoting intensification reached the best planning costs $\longrightarrow$ lowest interference in the network

Future Work

1. New metaheuristics for solving the problem
2. Using more instances to evaluate the optimizers
3. Formulating the AFP problem as a multiobjective problem

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Questions?