# New Research in Nature Inspired Algorithms for Mobility Management in GSM Networks

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# Introduction

• Mobility Management becomes a crucial issue when designing infrastructure for wireless mobile GSM networks

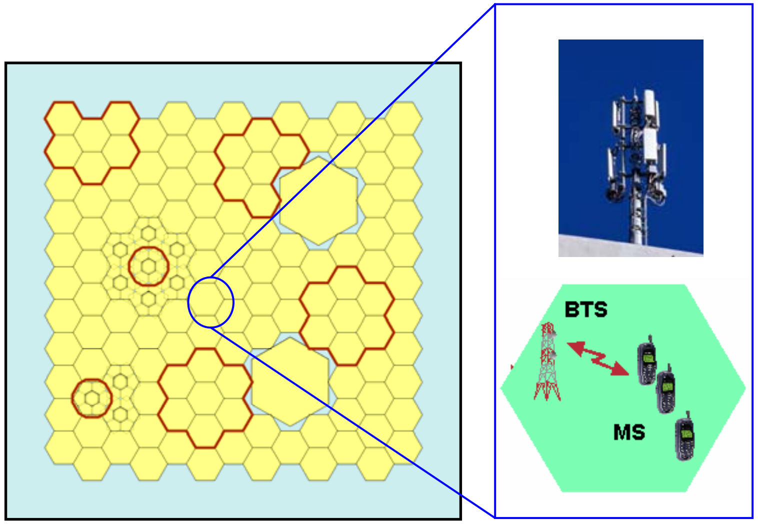
• The network must keep track of the location of each mobile terminal in order to route incoming calls

• Hundreds (even thousands) of communication transactions each minute in each cellular node which must be managed:

- **support a huge number of users**
- **bandwidth requirements**
- **quality of signal**

• Techniques for optimizing the network management are required:

- **Design scheme optimization**
- **Location of manager devices**
- **`Updating cost and paging cost**



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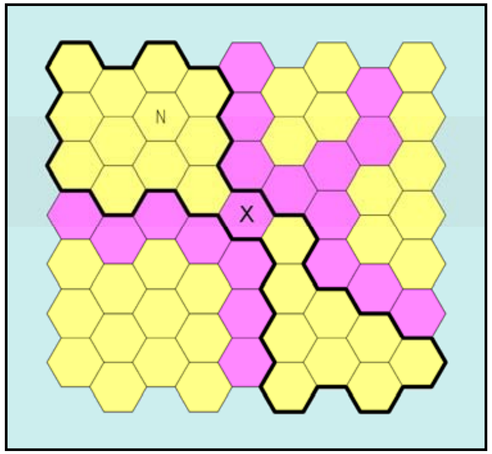
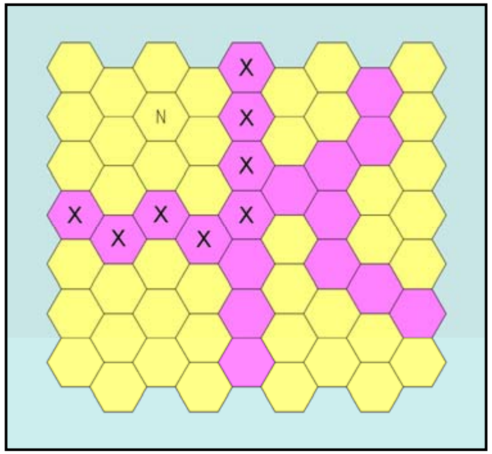
# The Mobility Management Problem

- Point of view:
  - Location Area (LA) scheme → Reporting Cells (RC) strategy
- Main Goal: reducing the total cost of managing a mobile cellular network
  - Updating cost
  - Paging cost
- Only an optimal set of cells must be RCs




- When a call arrives, the search is confined to the RC the user last reported and the neighboring bounded
- Vicinity factor : maximum number of neighbors for each cell that must page the user in case of incoming calls

# The Mobility Management Problem



- Total Cost function:

Number of location updates

$$Cost = \beta \times \sum_{i \epsilon S} N_{LU}(i) + \sum_{i=0}^{N} N_P(i) \times V(i)$$

Vicinity

Number of arrived calls

**N: Total number of cells in the network**
**S: Set of cells defined as RCs**
**β: Constant, cost ratio of a LU to a P transaction (β = 10)**

- P.R.L Gondim: finding an optimal set of reporting cells is NP-Complete

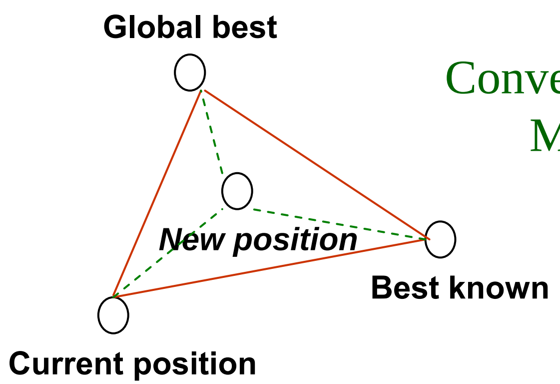
- Efficient optimization techniques are needed to solve it; bioinspired algorithms (GPSO & HNN)

# Geometric Particle Swarm Optimization

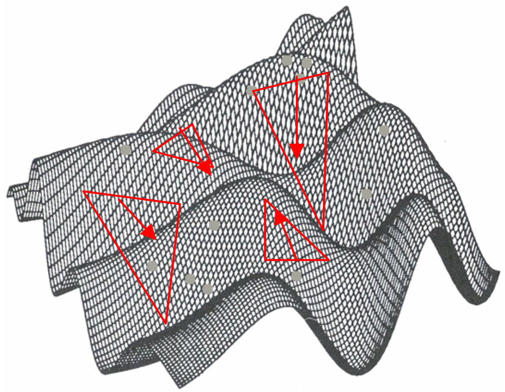


- Poli & Moraglio 2006; GPSO allows to generalize PSO virtually any solution representation (for us, binary representation), extending the search to richer spaces such as Euclidean, Manhattan and Hamming

- Key issue: multi-parental recombination of particles which leads
    - generalization of a mask-based crossover
    - being convex combination in Hamming spaces
- Operators:
    - Movement (updating velocity and position of particles) by means of three parent mask-based crossover
        - 3 parents: global best, current position, historical best known
    - Mutation (bit-flip)




Convex Combination
Metric Space



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# Geometric Particle Swarm Optimization

- GPSO Pseudocode

```
S ← SwarmInitialization()
while not stop condition do
    for each particle x_i of the swarm S do
        evaluate(x_i)
        if fitness(x_i) is better than fitness(h_i) then
            h_i ← x_i
        end if
        if fitness(h_i) is better than fitness(g_i) then
            g_i ← h_i
        end if
    end for
    for each particle x_i of the swarm S do
        x_i ← 3PMBCX((x_i, w_a), (g_i, w_b), (h_i, w_c))
        mutate(x_i)
    end for
end while
Output: best solution found
```

Canonical PSO

**Weight values**

**Movement operators: three parent mask-based crossover**

- Solution encoding: **binary vector representing RC network configuration**
    - **for each position (cell) '1' is RC and '0' is non-RC**

# Hopfield Neural Networks with Ball Dropping

- The Ball Dropping technique is used as backbone of the algorithms that employs Hopfield Neural Network as optimizer

- Inspired in the behavior of dropped balls onto a plate with troughs and crest
  - random positions of balls representing RCs

- Periodical drops increase the energy and the HNN tries to reduce it

```
1: Drop a predefined number of balls onto random positions
2: repeat
3:     Shake the plate
4:     Remove unnecessary balls
5: until location of balls does not lead to any better configuration
6: Output: best solution found
```

**HNN optimization process**

- HNN: the state vector considers two different components for location updates and call arrivals (being '***N***' the total number of cells)

$$X = [\underbrace{x_0 \;\; x_1 \;\; \wedge \;\; x_{N-1}}_{LU} \;\; \underbrace{x_N \;\; x_{N+1} \;\; \wedge \;\; x_{2N-1}}_{NP\ (call\ arrivals)}]^T$$

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# Experiments

- GSM Network Instances
  - 12 square instances with different dimension: 4x4,6x6,8x8 and 10x10
  - Generated according to realistic models (call arrivals and location updates)
  - Available in URL **http://oplink.lcc.uma.es/problems/mmp.html**

- Parameter Setting

| Instance | HNN+BD | | GPSO | | | |
|---|---|---|---|---|---|---|
| Dimension | N.DropBalls | N.Trials | N.Particles | Pcross | Pmut | wa+wb+wc |
| (4x4) | 7 | 3 | 20 | 0.9 | 0.1 | 0.33+0.33+0.33 |
| (6x6) | 10 | 5 | 50 | | | |
| (8x8) | 15 | 5 | 100 | | | |
| (10x10) | 15 | 5 | 120 | | | |

- For each algorithm and for each instance: 10 independent runs

# Experiments



- Results
  - GPSO obtains better results in terms of optimal and average cost
  - However, the differences are not significant
  - Robustness: GPSO obtains similar solutions in all executions (generally, std. dev. < 0.3)

| Instances | HNN+BD | | | GPSO | | |
|---|---|---|---|---|---|---|
| *Dimension* | *Best* | *Aver.* | *Std. Dev.* | *Best* | *Aver.* | *Std. Dev.* |
| 1 (4x4) | 98,535 | 98,627 | 0.09% | 98,535 | 98,535 | 0.00% |
| 2 (4x4) | 97,156 | 97,655 | 0.51% | 97,156 | 97,156 | 0.00% |
| 3 (4x4) | 95,038 | 95,751 | 0.75% | 95,038 | 95,038 | 0.00% |
| 4 (6x6) | 173,701 | 174,690 | 0.56% | 173,701 | 174,090 | 0.22% |
| 5 (6x6) | 182,331 | 182,430 | 0.05% | 182,331 | 182,331 | 0.00% |
| 6 (6x6) | 174,519 | 176,050 | 0.87% | 174,519 | 175,080 | 0.32% |
| 7 (8x8) | 308,929 | 311,351 | 0.78% | 308,401 | 310,062 | 0.53% |
| 8 (8x8) | 287,149 | 287,149 | 0.00% | 287,149 | 287,805 | 0.22% |
| 9 (8x8) | 264,204 | 264,695 | 0.18% | 264,204 | 264,475 | 0.10% |
| 10 (10x10) | 386,351 | 387,820 | 0.38% | 385,972 | 387,825 | 0.48% |
| 11 (10x10) | 358,167 | 359,036 | 0.24% | 359,191 | 359,928 | 0.20% |
| 12 (10x10) | 370,868 | 374,205 | 0.89% | 370,868 | 373,722 | 0.76% |

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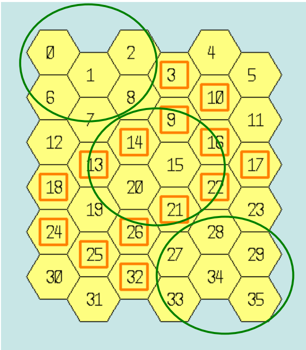
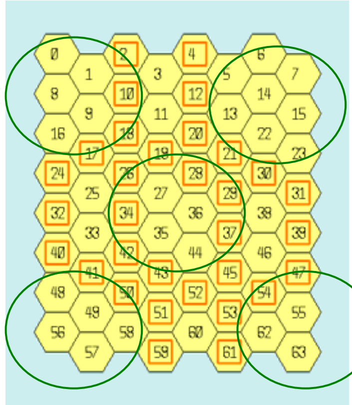
# Experiments

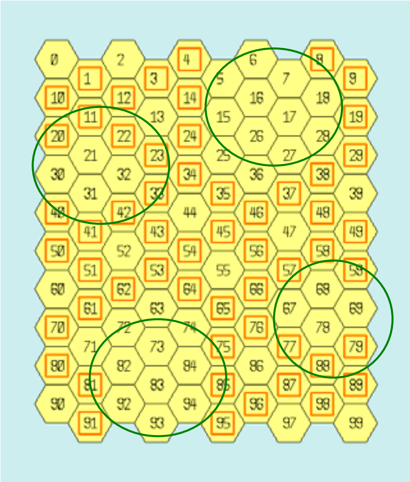
- Results
  - Cluster organization of reporting cells constituting neighborhoods
  - Examples (6x6, 8x8 and 10x10)



Test Network 6
Best Cost: 174,519
Alg: HNN+BD & GPSO

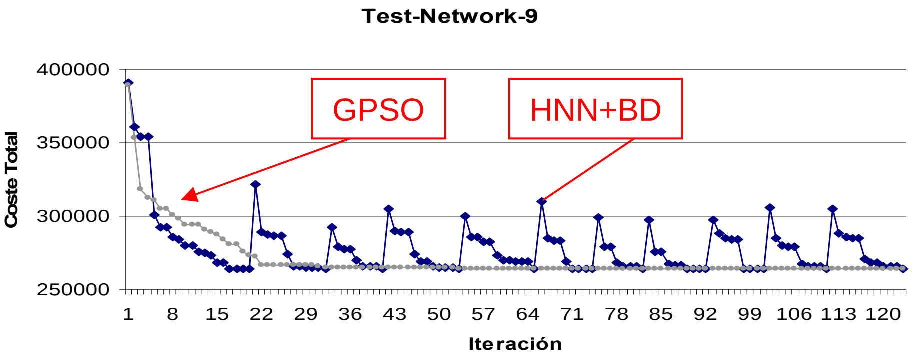


Test Network 8
Best Cost: 287,149
Alg: HNN+BD & GPSO



Test Network 12
Best Cost: 370,868
Alg: HNN+BD & GPSO

- Different behavior
  - Dropping effects vs.
  - Monotonous decreasing



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# Experiments

- Comparison with other optimizers
  - Genetic Algorithm (Subatra & Zomaya 2003)
    - Parameters:

| | |
|---|---|
| Population $m$ | 100 |
| Best cloned $\sigma$ | 5 |
| Tournament selection $p_s$ | 0.8 |
| Two-point crossover $p_c$ | 0.8 |
| Gene mutation $p_m$ | 0.001 |
| Max stale period $T_{stale}$ | 20 |
| Escape mutation $p_{mm}$ | 0.2 |

  - Instance: 6x6 square dimension
  - Results

| *Algorithm* | *Total Cost* | *Number of RCs* |
|---|---|---|
| **GA** | 229,556 | 26 |
| **GPSO** | 214,313 | 23 |
| **HNN+BD** | 211,278 | 24 |

- Both algorithms beat the GA
- Different possibilities concerning the making decision process

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# Conclusions



- We solved the Mobility Management using two new nature inspired techniques: GPSO and HNN+BD

- Twelve new realistic instances were used in experiments

- Simulation results show that the proposed algorithms outperform existing methods in the literature

- Comparisons reveal that GPSO performs more robust. However, final results are quite similar in both algorithms

- In addition, GPSO can be more easily adapted to other GSM network schemes and configurations (different to RCs)

- We are interested in evaluating new instances under different conditions of topology and larger dimensions

- Further work will involved new techniques and comparisons