Metaheuristic approaches for optimal broadcasting design in metropolitan MANETs

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THE OPLINK PROJECT
http://oplink.lcc.uma.es

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Outline of the talk

Optimal broadcasting in MANETs

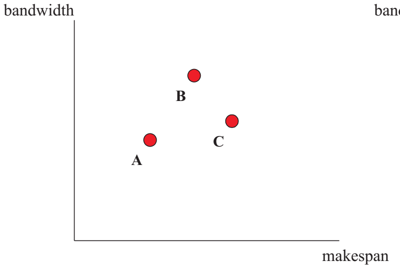
- Mobile devices interconnected without any pre-existing infrastructure
- Broadcasting on MANETs
  - Operation of capital importance for the network
  - Optimization of a broadcasting strategy is a multi-objective problem
    - Reach as many stations as possible
    - Minimize the network utilization
    - Reduce the makespan
  - Our proposal: tuning the broadcasting service for a particular network
- Collaboration developed in the OPLINK project (`http://oplink.lcc.uma.es`)

Contributions

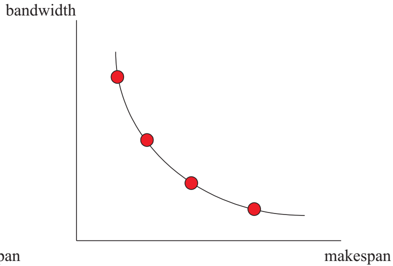
1. Broad study among six different multiobjective algorithms for optimal broadcasting in MANETs
2. Very realistic scenario: shopping mall

Basic concepts

- The solution of a MOP is a set of non-dominated solutions: Pareto Optimal Set $\Rightarrow$ Pareto Front
- Non-dominated solutions: how to deal with concept "A is better than B" in MO
  - Best solution concerning the network utilization
  - Best one concerning the makespan



A dominates B and C



Non-dominated points

Trajectory-based vs. Population-based Metaheuristics for Multiobjective Optimization

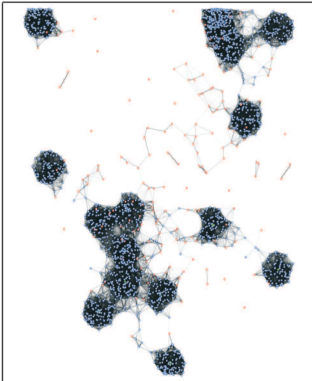
- Number of solutions used at the same time
- Population-based are very well suited to solve MOPs
  - They are naturally capable of computing a set of nondominated solutions in one single run

Six different population-based metaheuristics

- Evolutionary Algorithms
  - NSGA-II
  - SPEA2
  - ES
  - cMOGA
- Scatter Search (AbYSS)
- Particle Swarm Optimization (MOPSO)

Description

- MANETS
  - Stations usually are laptops, PDAs or mobile phones
  - Mobility of stations → dynamic topology of the network
- Metropolitan MANETs
  - Virtual Hot Spots (VHS): areas with high station density
  - VHSs can appear and disappear from the network
- Madhoc simulator
  - Network size: size of the simulation area
  - Node density: number of devices
  - Environment: mobility and wave propagation models



4km^2, 2000 stations ($500 \text{ stations/km}^2$)

The DFCN broadcasting protocol

DFCN: Delayed Flooding with Cumulative Neighborhood

- Neighbor-knowledge-based method: knowledge of the 1-hop neighborhood for its operation
- Active management of station mobility: it is able to take new broadcasting decisions on new neighbor discovery

DFCN Tunable Parameters

- Five different parameters for the decision making process on
  - New message reception
  - New neighbor connection

DFCNT: tuning DFCN in a given scenario

Objectives and constraints

- Objectives
  - Reach as many stations as possible
  - Minimize the network utilization
  - Reduce the duration of broadcasting operation
- Constraints
  - None

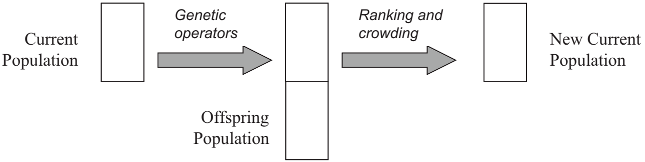
Offline process

- Prior to protocol deployment
- No mobile device is involved in the optimization procedure

NSGA-II

Non-dominated Sorting Genetic Algorithm

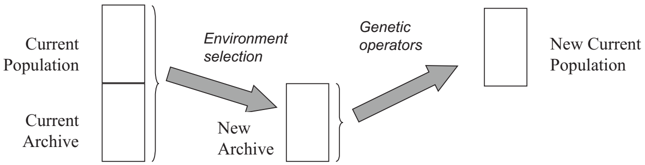
- Proposed by K. Deb (2002)
- The most popular metaheuristic for multi-objective optimization
- Features
  - Ranking using non-dominated sorting
  - Crowding distance as density estimator



SPEA2

Strength Pareto Evolutionary Algorithm

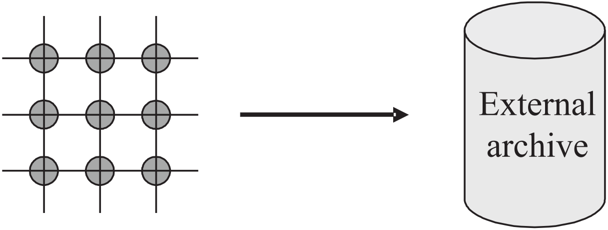
- Proposed by Zitzler, Laumanns y Thiele (2001)
- Features
  - Strength raw fitness
  - Density estimator based on the distance to the k-nearest neighbor



cMOGA

cellular MultiObjective Genetic Algorithm

- Adaptation of a canonical cGA model
- Features
  - It uses an external archive to store the non-dominated solutions
  - Adaptive Grid coming from PAES



ES

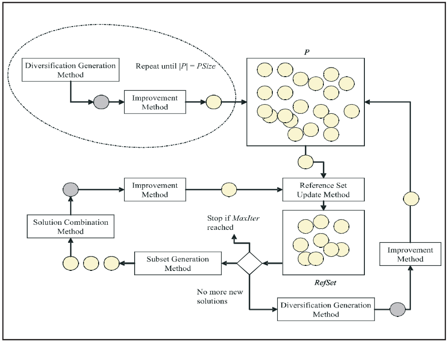
Evolution Strategy

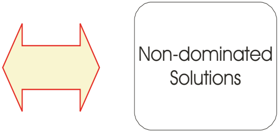
- Hybrid algorithm between ES and NSGA-II
  - NSGA-II selection scheme: ranking and crowding
- No crossover, only mutation is applied to generate the offspring
- The variance of the mutation is updated depending on the successful replacements in the last *n* generations
  - The new variation is used for generating the new offspring

AbYSS

Archive-based hYbrid Scatter Search

- Adaptation of the scatter search template to MO optimization
- Features
  - It uses an external archive + feedback in the restart
  - Different density estimators from NSGA-II and SPEA2

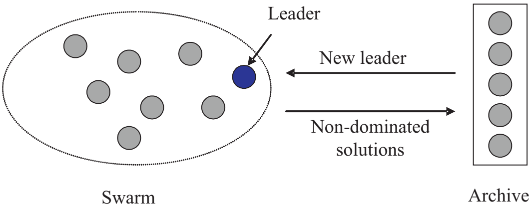




MOPSO

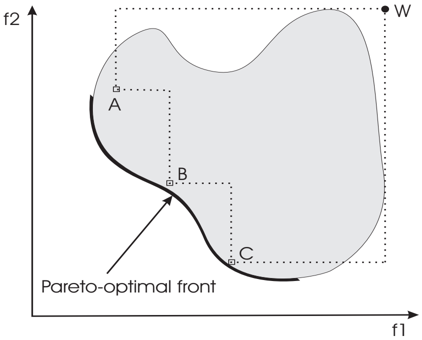
MultiObjective PSO

- Uses an external archive to store the non-dominated solutions
- Leader selection from non-dominated individuals
- No mutation is used here



Hypervolume

- Volume covered by members of the non-dominated set of solutions
- Measures both convergence and diversity in the Pareto front
- Larger values are better



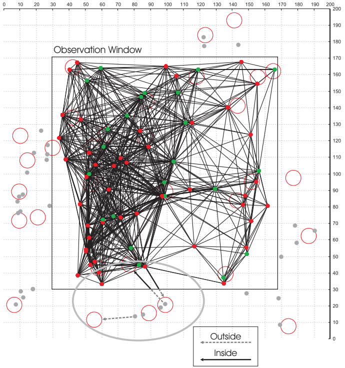
Parameters used in Madhoc and the solvers

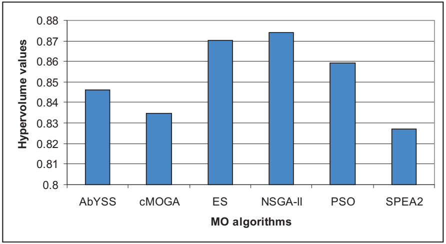
Solvers

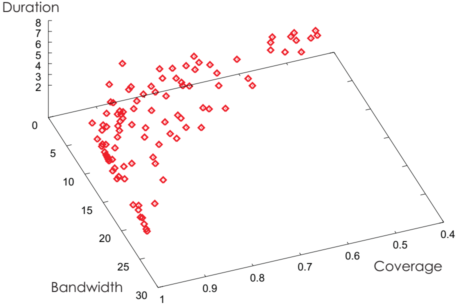
- Stopping condition: 25,000 evaluations
- Find 100 non-dominated solutions at most
- Five simulations per function evaluation

Madhoc

- Environment: Mall
- Observation window: 70%
- Simulation area: 200 x 200 m^2
- Node density: 2000 stations/km^2







Results

- NSGA-II and ES are the best, but with little differences
- Higher HV values result in a more accurate and more diverse set of DFCN configurations
- Execution times $\sim$ 2 days each independent run $\Rightarrow$
  6 algorithms $\times$ 30 executions $\times$ 2 days $\sim$ 360 days $\Rightarrow$
  Collaboration is a must

Conclusions

1. Six different multiobjective algorithms have been used to optimally tuning a broadcasting strategy (DFCN) in MANETs
2. The optimization problem, DFCNT, considers 3 objectives
   - Minimizing makespan
   - Maximizing broadcasting coverage
   - Minimizing bandwidth
3. Comparing the resulting Hypervolume values
   - NSGA-II and ES are the best algorithms
   - They all generate a wide set of non-dominated solutions

Future Works

1. Thorough evaluation of the algorithms over different, maybe larger scenarios, e.g., a highway
2. Parallelizing the algorithms to reduce the execution times