Genetic Algorithms for Mobile and Satellite Telecommunications Systems

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Contents

- Summary of existing GA applications in mobile telecommunications systems
  - Frequency assignment
  - Fixed channel assignment
  - Dynamic channel assignment
  - Base station location
- Potential of GAs/EC in the design of satellite telecommunications systems

Frequency assignment

- Calegari, Guidec, Kuonen & Kobler (1997)
- Chang & Potter (1994)
- Crompton, Hurley & Stephens (1993)
- Crompton, Hurley & Stephens (1994)
- Hurley & Smith (1995)
- Kapsalis, Rayward-Smith & Smith (1995)
- Kapsalis & Smith (1996)
- Valenzuela, Jones & Hurley (1997)
- Valenzuela, Hurley & Smith (1998)

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Mobile network-FCA

- Typically, the design of a cellular radio network starts with
  - a geographic region over which the network must operate
  - an estimated traffic demand and
  - a limited portion of the radio spectrum
- The first stage is to locate base stations across the region and derive what is known as a propagation model.
- The estimated traffic demand is used to determine the number of channels required by each base station.

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The model

- A network of n cells, each to be assigned a number d_i of channels, i = 1 to n.
- An n x n compatibility matrix C, derived from the propagation model, which incorporates the interference constraint information (co-channel, adjacent channel and co-site).
- This could be a single matrix whose entries are minimum frequency separation between and within cells/sectors.
- Other features may be incorporated such as constraint priority levels (CELAR, RCM_2)

The objectives

- To assign a set of channels to each cell in the network so as to
  - satisfy the interference constraints (feasible solution)
  - make effective use of the available frequency band(s) (cost element)
  - meet traffic demands

  and all in a "reasonable" computation time.
- There will likely be a trade-off between these objectives for real problems.

GA/EC approaches

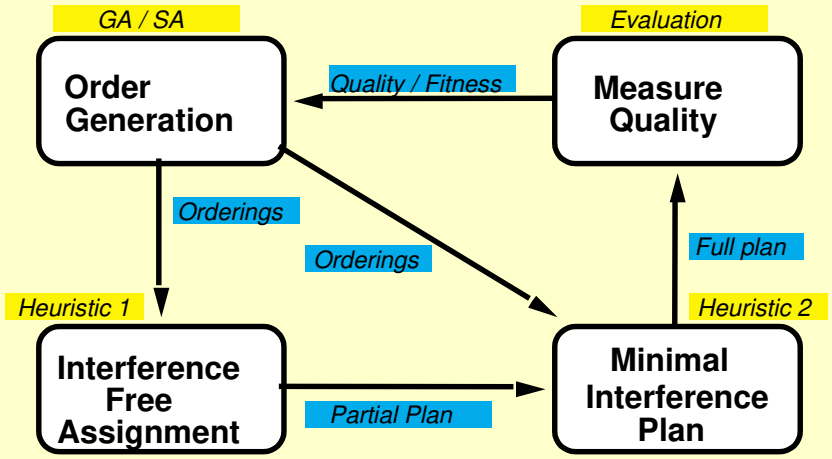
- Cuppini (1994)
- Lai & Coghill (1996)
- Clark & Smith (1998)
- Ngo & Li (1998)
- Crisan & Mühlenbein (1998)
- Ryan, Debuse, Smith & Whittley (1999)

- These use either indirect or direct representations, e.g.

Clark & Smith(1998)

- In ICANNGA97
- Use an indirect representation
  - SA or GA generates orders of cells for a pair of greedy heuristics (hybrid approach)

Ordering hybrids



- Frequency plan sent back to Nortel Matra in Paris and evaluated on a commercial design tool.
- Colours signify the levels of interference

- Improvement in computation time (from 2 days to 5 minutes)
- Improvement in solution quality
  - mean C/I level (from 24dB to 37 dB)
  - Interference free area (from 94.3% to 98.8%)

Ryan et al. (1999)

- Use a GA in which partial evaluation is possible due to crossover type and representation chosen - gives 90 times speed up.
- Uses a direct representation in which there is a gene for each channel requirement in each cell.

GA/EC approaches

- Cuppini (1994) - 12 cells
- Lai & Coghill (1996) - 25 cells (d=167)
- Clark & Smith (1998) - 48 cells (d=107)
- Ngo & Li (1998) - 25 cells (167-470)
- Crisan & Mühlenbein (1998) - (670--5500)
- Ryan, Debuse, Smith & Whittley (1999) - 100-718 cells (d: 677-5101)
- However, despite improvements, a GA may not be the most suitable approach!

RCM_2 P1-718

373 channels available
5101 channels required

	CSC violations	ACC/CCC violations	Channels supplied/ used	Times
Benchmark	0	0	5101 / ?	?
SA	0	0	5101 / 373	1,500
GA	0	12	5101 / 373	30,000
Heuristic A	0	0	5091 / 363	1
Heuristic B	0	0	5101 / 310	1

Conclusions

- General heuristics such as GAs can lead to reasonable solutions in a reasonable time, providing thought is given to the problem representation and move operators.
- Problem specific heuristics are still worth investing time and effort into.

Mobile network-DCA

- In dynamic channel assignment, the whole pool of channels is available to all cells and a strategy must be adopted to allocate channels to calls as they arrive to minimise blocking.
- Sandalidas & Stavroulakis (1998) have applied a GA to the dynamic channel assignment problem.

Satellite networks

- Iridium system 'launched' in 1997, now fully operational.
- A number of LEO/MEO systems are under various stages of operation and development (Teledesic, Global Star, ICO, Orbcomm, Elipsat, and others)
- These are high risk ventures due to cost and competition.

Satellite networks

- The configuration, operation and management of such a system will determine its viability and survival.
- Due to the large range of design issues involved, it is not possible to mathematically model and solve exactly the complete design.
- Heuristics can play a key part in the determination of an optimal design.

Satellite networks

- WWW search for GAs in satellite/space systems did not yield very much:
  - Bishop, J.A., Striz, A.G., Design of Vibration Suppression System in Space Trusses using a Genetic Algorithm. Proceedings of the 1996 37th AIAA/ASME/ASCE/AHS Structures, Structural Dynamics and Material Conference Apr 15-17 1996 v3 1996 Salt Lake City p 1868-1873.
  - Gage, P.J., Kroo, I.M., Interplanetary Trajectory Optimization using a Genetic Algorithm. Journal of the Astronautical Sciences v 43 n 1 Jan-Mar 1995 American Astronautical Soc San Diego CA USA p 59-75.
  - Benton, Ryan Gene. Using Genetic Algorithms to Improve Interpretation of Satellite Data. Proceeding of the Annual Southeast Conference, Mar 17-18 1995 Clemson, CA p 143-145

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Design Issues

- Configuration issues:
  - The number of orbits
  - The number of satellites per orbit
  - The types of orbits (polar, rosette, equatorial, polyhedral, mixed)
  - The trajectories (circle, elliptic)
  - The altitude of each orbit
- These issues are not independent, choice of one affects options in others

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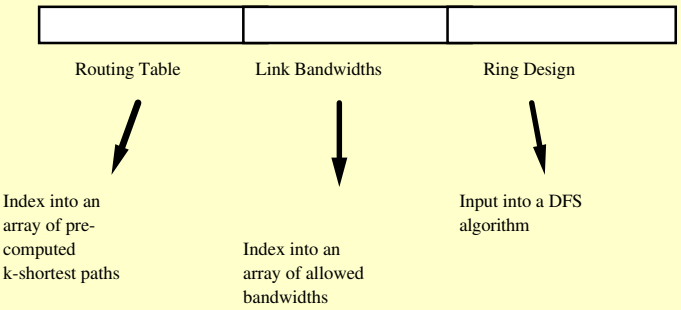
Design Issues

- The number and types of antennas used for direct user communication
- Space-based or ground-based routing?
- Maintenance and upgrade

All to ensure a certain quality of service.

Potential of GAs

- GAs can be used to attack the complete design problem. An example of this is the design of survivable telecommunications networks, e.g. White, Mann & Smith (1999), in which all parts of the design question were encoded.



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- Ryan, Debuse, Smith & Whittley (1999), GECCO'99.
- Sandalidas & Stavroulakis (1998), A combinatorial evolution strategy for dynamic channel assignment in cellular radio, ACM Symposium on Applied Computing.
- White, Mann & Smith (1999), GAs and network ring design, Annals of Operations Research, 86, 347--371.