ARES 2008 Presentation

Providing Fault Tolerance in Wireless Backhaul Network Design with Path Restoration

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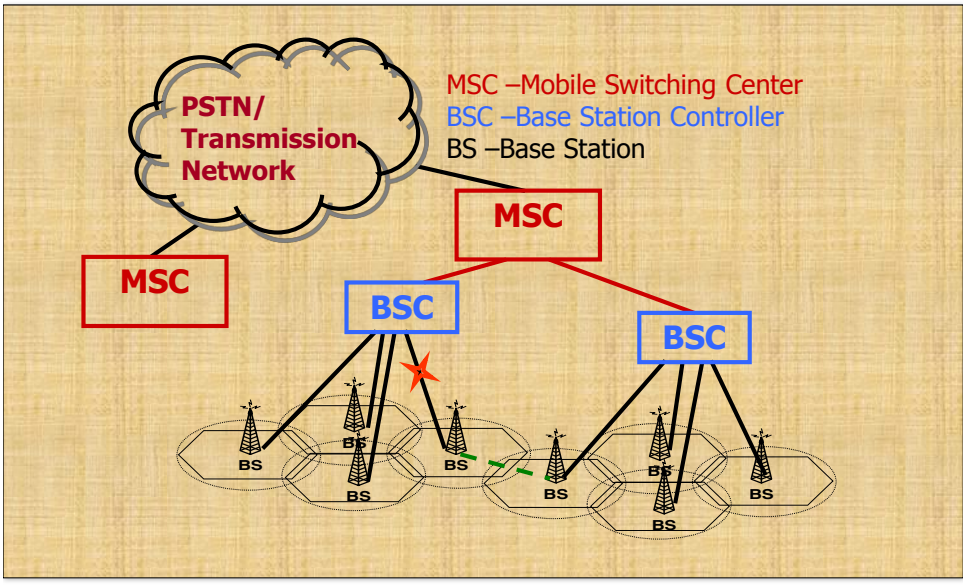
Content

- Introduction
- Research Consideration
  - Phase 1: Minimum Cost Network Design with Hierarchical Network, Tree Topology
    - Network Design Problem & Model
    - Genetic Algorithm Approach
    - Simulation Results
  - Phase 2: Survivability Network Design with Path Restoration
    - Network Design Problem & Model
    - Genetic Algorithm Approach
    - Simulation Results
- Conclusion

Introduction



Research Consideration

- Phase 1: Minimum Cost Network Design with Hierarchical Network, Tree Topology
  - Network Design Problem & Model
  - Genetic Algorithm Approach
  - Simulation Results
- Phase 2: Survivability Network Design with Path Restoration
  - Network Design Problem & Model
  - Genetic Algorithm Approach
  - Simulation Results

Phase 1: Minimum Cost Network Design with Hierarchical Network, Tree Topology

- Network Design Problem & Model
- Genetic Algorithm Approach
- Simulation Results

Network Design Problem & Model

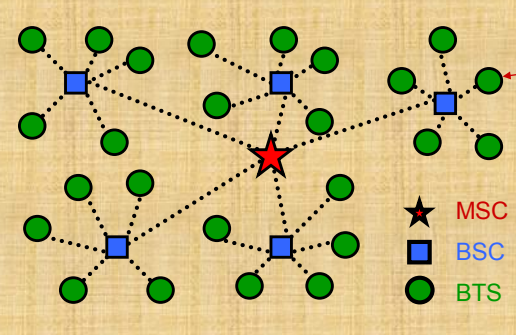
- Objective:

$$\min_{v,w,x,y,z} C_L(v,w,z) + C_N(x,y) \quad \text{Equation 1}$$

- where C_L is the cost of the link and interface cards, and C_N is the cost of the allocated BSCs and MSCs.

Network Design Problem & Model

- Assumption : Network Floor plan is given
  Location of each BTS
  Possible location of BSC, MSC
- Problem : to select BSC, MSC and their link types to connect to any other BTSs and other networks (such as PSTN)



Each BTS communicates with other BTSs in a communication demand units (Capacity, or Erlang).

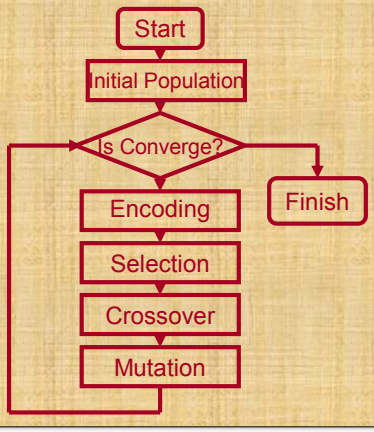
Network Design Problem & Model

Constraints:

- BSC Capacity Constraints → # of circuit & # of interface
- BSC Type → Cost(# of circuit, # of interface)
  - » Type A
  - » Type B
  - » Type C
- MSC Capacity Constraints → # of circuit & # of interface
- MSC Type → Cost(# of circuit, # of interface)
  - » Type A
  - » Type B
  - » Type C
- Link Capacity → # of circuit & # of interface
  - – Cost(# of circuit, # of interface)

Genetic Algorithm Approach

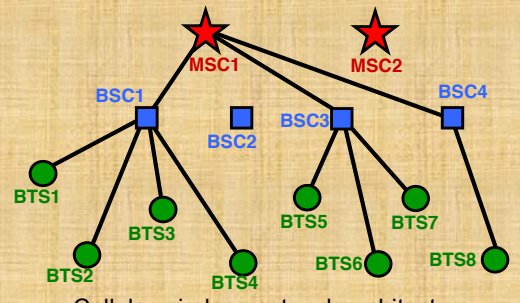
- Genetic Algorithm, stochastic optimization technique that uses the biological paradigm of evolution.
- The good chromosome has a better potential of being carried to the next generation.
- There are 4 Operators:
  - Encoding
  - Selection
  - Crossover
  - Mutation



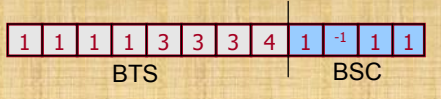
Genetic Algorithm Approach

- Encoding

Example : A simple Cellular Wireless Network Design with 8 BTS, 4 BSC, and 2 MSC.



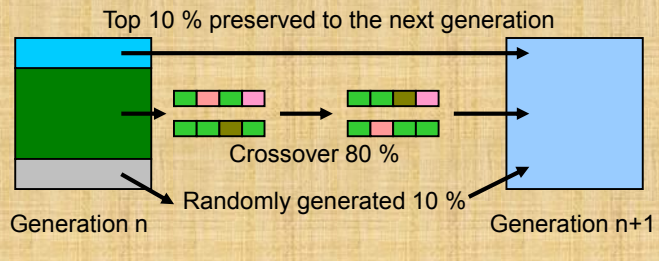
Cellular wireless network architecture



Encoding string of cellular wireless network architecture

Genetic Algorithm Approach

- Selection



Selection process in GA

Genetic Algorithm Approach

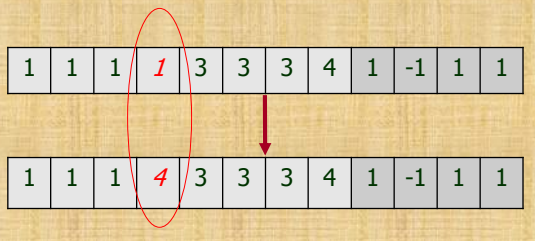
- Crossover

Example :

1	1	***1***	1	***3***	3	3	4	|	1	-1	1	1	Parents1
2	2	***3***	1	***2***	2	1	3	|	1	0	0	1	Parents2
1	1	***3***	1	***2***	3	3	4	|	1	-1	1	1	Offspring1
2	2	***1***	1	***3***	2	1	3	|	1	0	0	1	Offspring2

Genetic Algorithm Approach

- Mutation



Mutation process in GA

Simulation Results

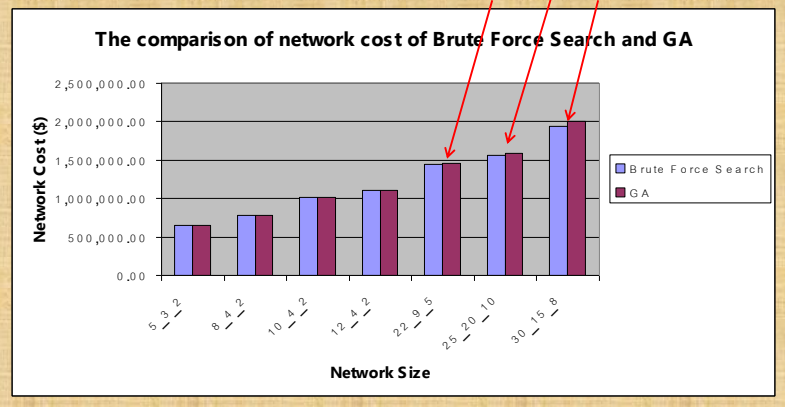
The result comparisons between Brute Force Search approach and GA

Problem Size (bts_bsc_msc)	Brute Force Search		Genetic Algorithm	
	Cost	CPU Time (sec)	Best Cost	CPU Time (sec)
5_3_2	683,206.4	1.0	683,206.4	1.0
8_4_2	989,271.5	9.0	989,271.5	3.5
10_4_2	1,066,101.6	206.2	1,066,101.6	3.0
12_4_2	1,211,395.8	5,016.2	1,211,395.8	4.2
22_9_5	1,664,949.6	84,387.0	1,664,949.6	63.0
25_20_10	1,557,714.4	702,733.2	1,643,869.9	135.8
30_15_8	2,237,392.4	714,929.2	2,343,875.9	69.7

Simulation Results

In small to moderate network size, evaluated by Brute Force Search

The differences are less than 4%

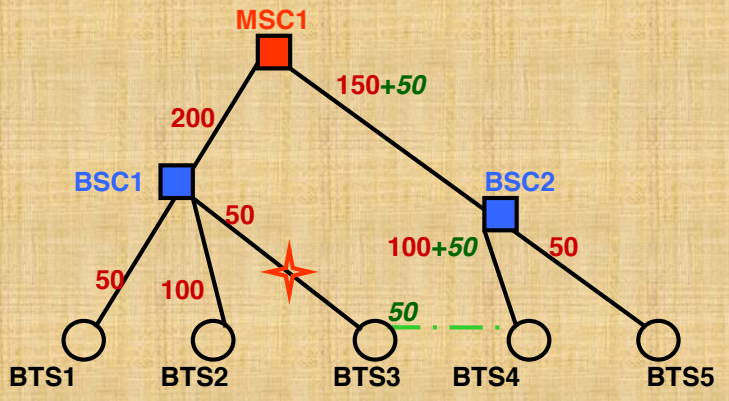


The comparison of network cost of brute force search algorithm (BFS) and GA

Phase 2: Survivability Network Design with Path Restoration

- Network Path Restoration Design Problem & Model
- Genetic Algorithm Approach
- Simulation Results

Network Path Restoration Design Problem and Model



A snapshot of the network design to protect BTS-BSC link failure with path restoration approach

Genetic Algorithm Approach

String encoding for network path restoration

P_1	P_2	P_3	P_4	P_5	P_6	...	P_r
2	7	5	4	1	9	...	4

$r = 1, 2, \ldots, T;$
$P_r = 0, 1, 2, \ldots, 9;$

String encoding for network design with path restoration

Genetic Algorithm Approach

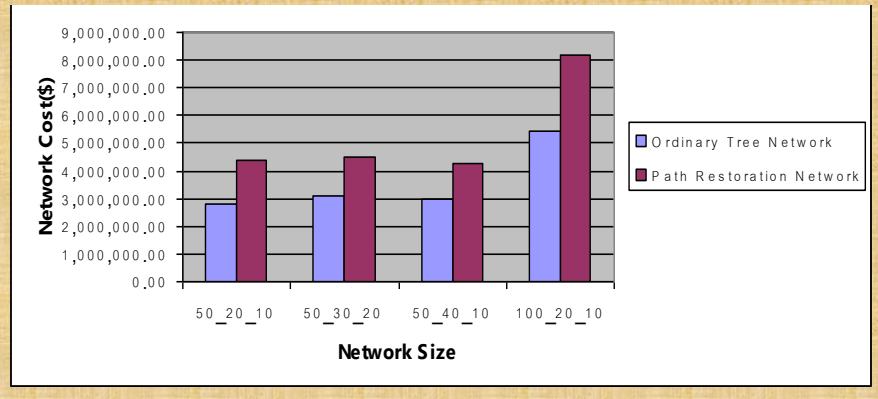
Crossover, (15% of chromosome)

Example :

1	0	**1**	1	**3**	3	3	4	7	0	Parents1
2	7	**3**	1	**2**	2	1	3	6	2	Parents2

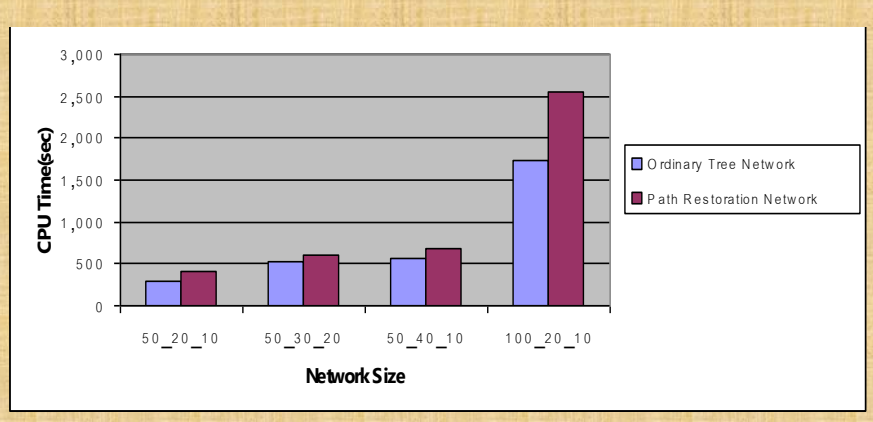
1	0	**3**	1	**2**	3	3	4	7	0	Offspring1
2	7	**1**	1	**3**	2	1	3	6	2	Offspring2

Simulation Results



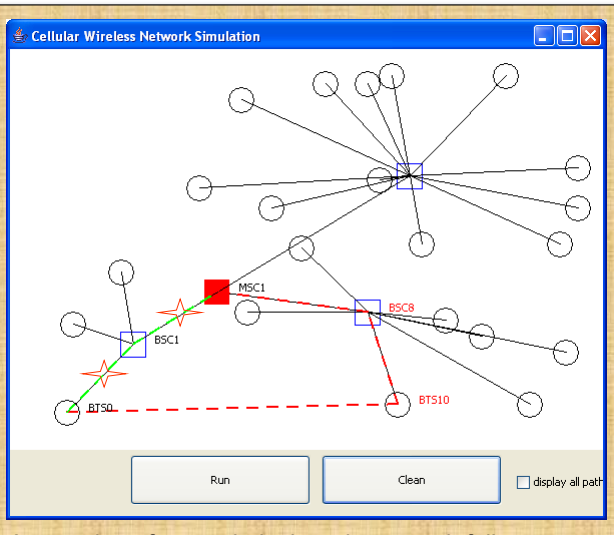
Network cost comparison between phases 1 & 2

Simulation Results



CPU time comparison between phases 1 & 2

An Example of Simulation Result



A snapshot of network design when a path failure occurs

Conclusion

From our experiments

- Genetic Algorithm (GA) is effective in solving cellular wireless network design problem as verified by a brute force search approach where all possible solutions are considered.
- For path restoration coverage, the network design requires even higher cost due to extra network equipments and communication bandwidth to cover the network from link failure event.

Q&A

Any suggestion?

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