A GENETIC ALGORITHM FOR POWER AWARE MINIMUM CONNECTED DOMINATING SET PROBLEM ON WIRELESS AD HOC NETWORKS

COMP 6651 Project

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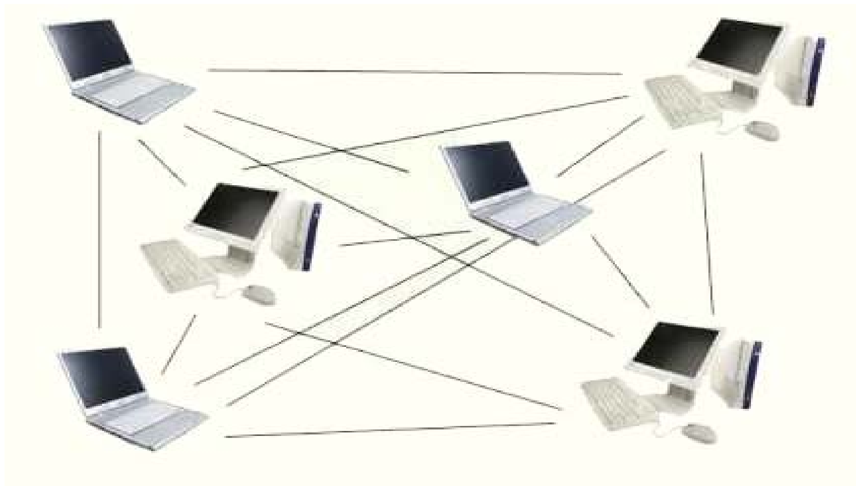
Outline

- Wireless AD HOC Network
- Broadcasting Problem in Wireless ADHOC Networks
- Unit Disk Graph
- DS, MDS and MCDS
- Genetic Algorithm’s Function
- A Simple Example of GA
- A GA for MCDS
- A GA for Power Aware MCDS

Wireless ADHOC Network

- Definition

Example: Automated battlefield, search and rescue, and disaster relief



- Limitations
  - No physical backbone infrastructure like wired network or cellular networks
  - Limited wireless bandwidth
  - Limited battery power
  - Multi-hop routing

Wireless ADHOC Networks (Cont'd)

- Challenge
  - Scalability
  - Power
    - Minimizing power consumption during the idle time
    - Minimizing power consumption during communication

- Operation
  - Broadcasting
  - Routing
  - Multicasting

Broadcasting

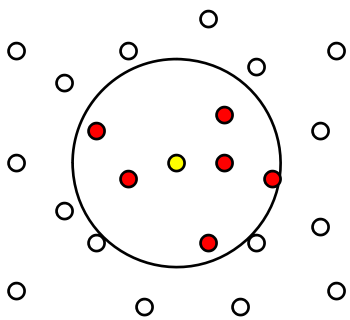
- Function:
  - paging a particular host
  - sending an alarm signal
  - finding a route to a particular host
- Objective:
  - Reliability

    (all nodes have received the broadcast packet)
  - Optimization

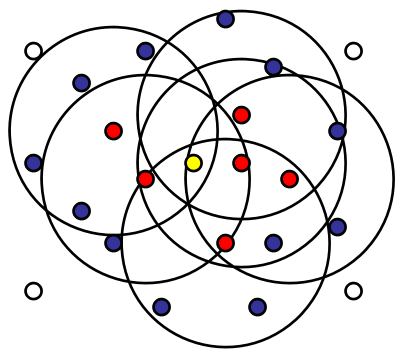
Broadcasting (Cont'd)

- Simple mechanism:
  - Flooding: Each node retransmits the message to its 1-hop neighbors

    Drawbacks: redundant transmission, collisions, contention and inefficient (Limitation of Node's Power)

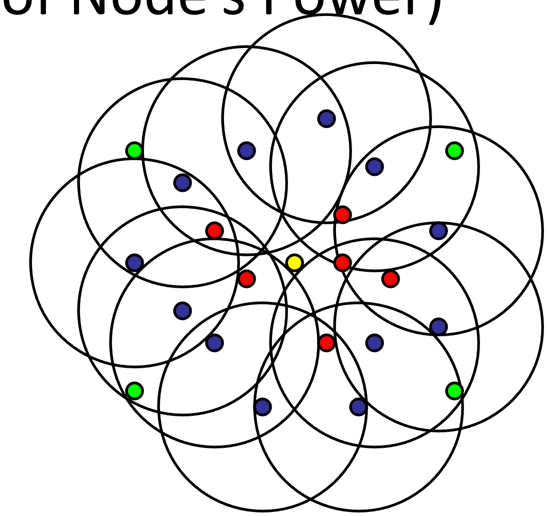


= Origin of message



= 1-hop adjacent to origin

= 2-hop adjacent to origin

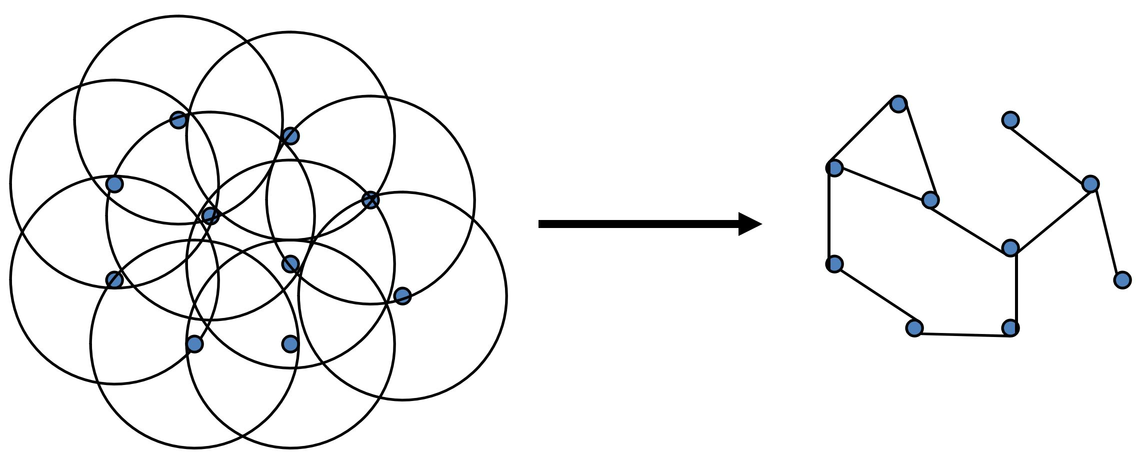


= 3-hop adjacent to origin

Wireless ADHOC Network's Graph Representation

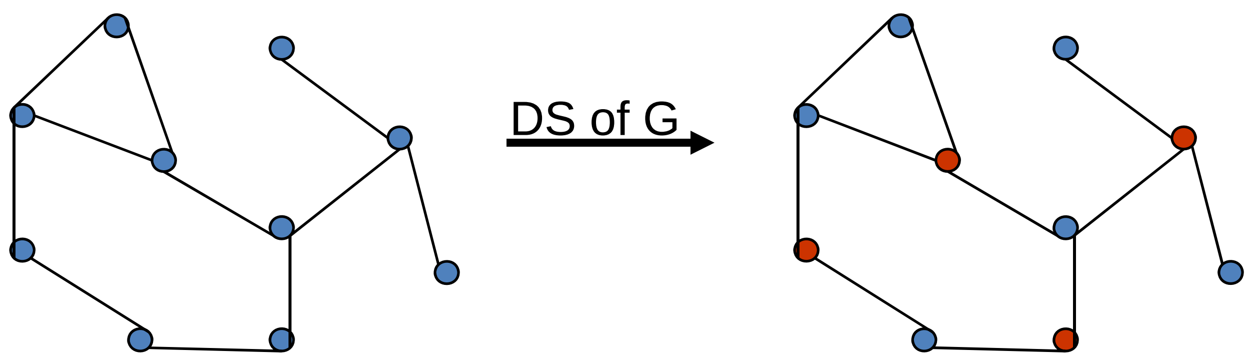
- Unit Disk Graph
  - All mobile hosts are homogeneous
    - The same transmission range
    - Unidirectional link

-Vertices with weights (Remaining Power)-



Dominating Set (DS)

- In Graph theory, a **dominating set** for a graph *G = (V, E)* is a subset *V'* of *V* such that every vertex not in *V'* is joined to at least one member of *V'* by some edge.

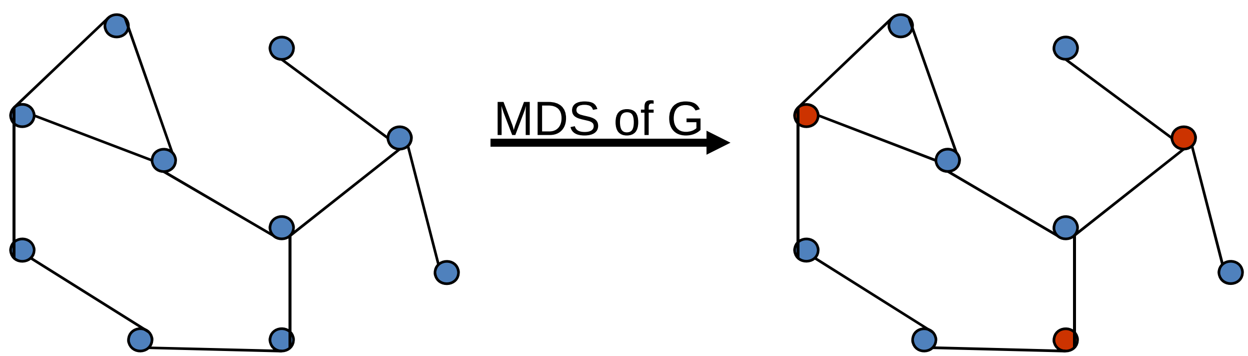


Minimum Dominating Set (MDS)

- The optimization version of the algorithm, that is finding the smallest | *V*' | such that *V*' is a dominating set, has approximation algorithm.

- The dominating set problem is NP-complete.
  Can be proved by reduction from **the Vertex Cover problem**

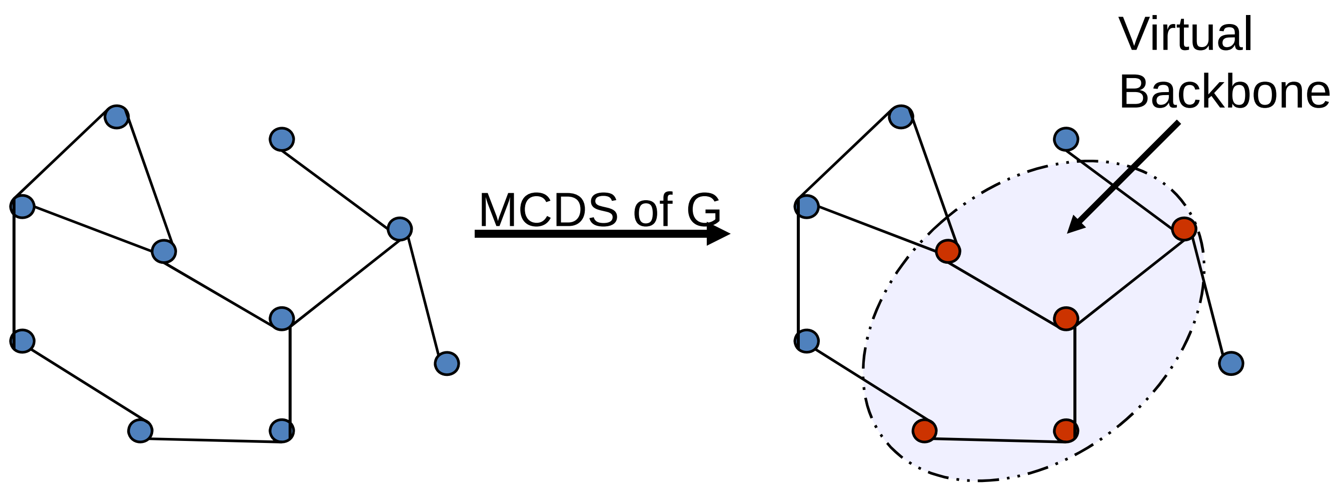
  its approximation is within a factor of **1 + log | *V* |** , but it doesn't have approximation within ***c*log | *V* |** for some ***c* > 0**



Minimum Connected Dominating Set (MCDS)

- **Connected Dominating Set (CDS)** is a dominating set which is also a connected sub graph of the original graph G

- **Minimum connected dominating set** is a connected dominating set such that removal of any node from that set makes it a Non-connected dominating set.



Genetic Algorithms (GAs)

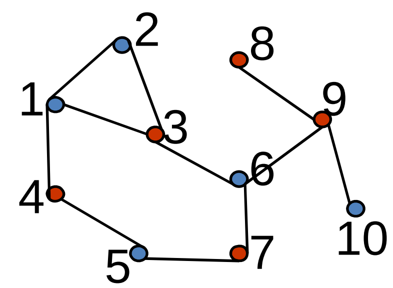
- A particular class of evolutionary algorithms
- Use techniques inspired by biology such as inheritance, mutation, selection, and crossover (recombination)
- Used for finding true or approximate solutions to:
  - Optimization Problems
  - Search Problems (huge size)

GA's function

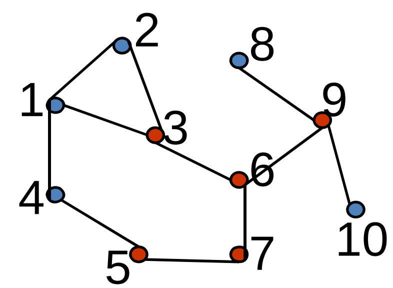
- Trying to evolve a population of candidate solutions (chromosomes) to get "better and better" population.

- Candidate solutions (Chromosome)
  - Potential answers of the problem.
  - Initially generated randomly.

- What is a good chromosome?
  - A "Fitness Function" which is a criteria for evaluating chromosomes (potential answer) is defined.
  - "Evolution" means making the populations with higher fitness.



ch1= < 3 4 7 8 9 >
(A potential MCDS answer)



ch2 = < 3 5 6 7 9 >
(A potential answer which is the final answer)

GA's function (cont'd)

- To "evolve population" two operations are defined:
  - Crossover
    - Two chromosomes are randomly selected as parents and are combined to compose a new chromosome (offspring).
  - Mutation
    - A single chromosome is selected and a random change is applied to it to generate a new chromosome.
  - The size of population
    - a fixed number
    - After each stage the chromosomes with lower fitness are removed from population (a new Generation is created)

- Termination condition
  - Having a chromosome (solution) with a large enough fitness

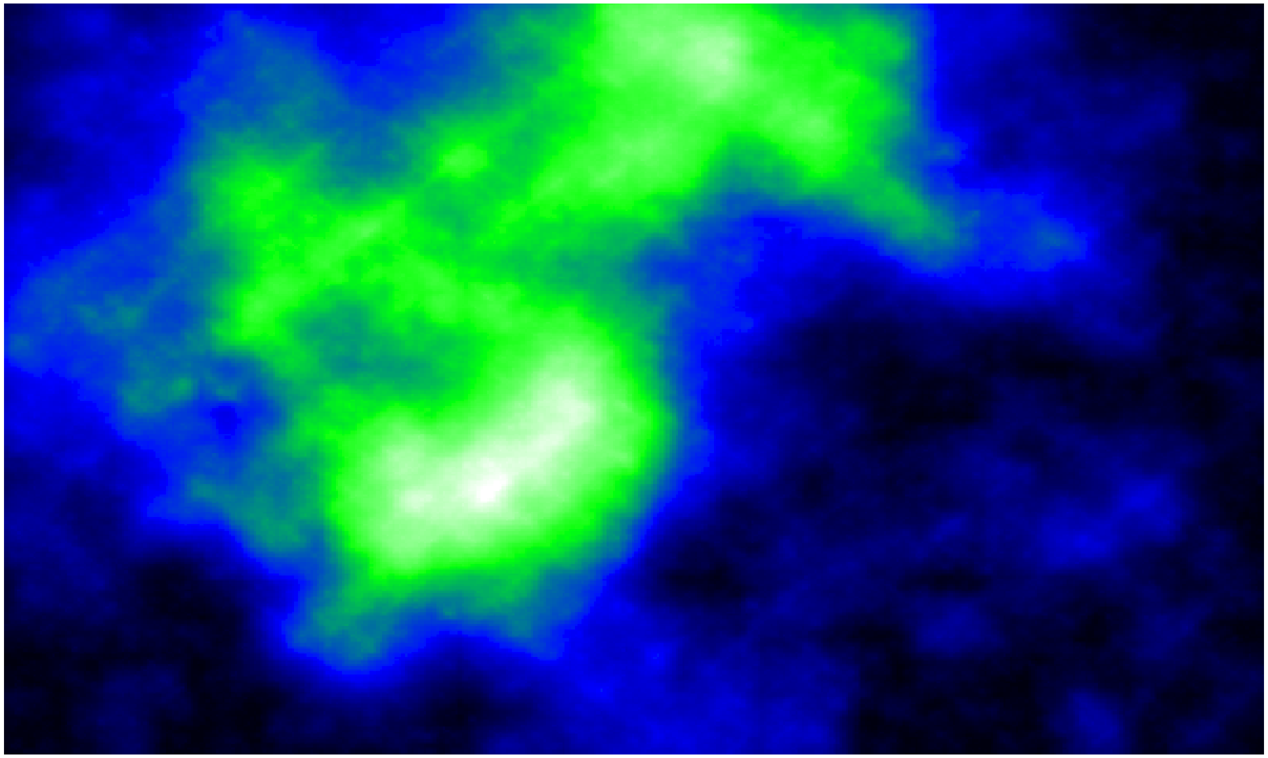
  Or

  - The number of stages passes a certain number.

GA Procedure (Review)

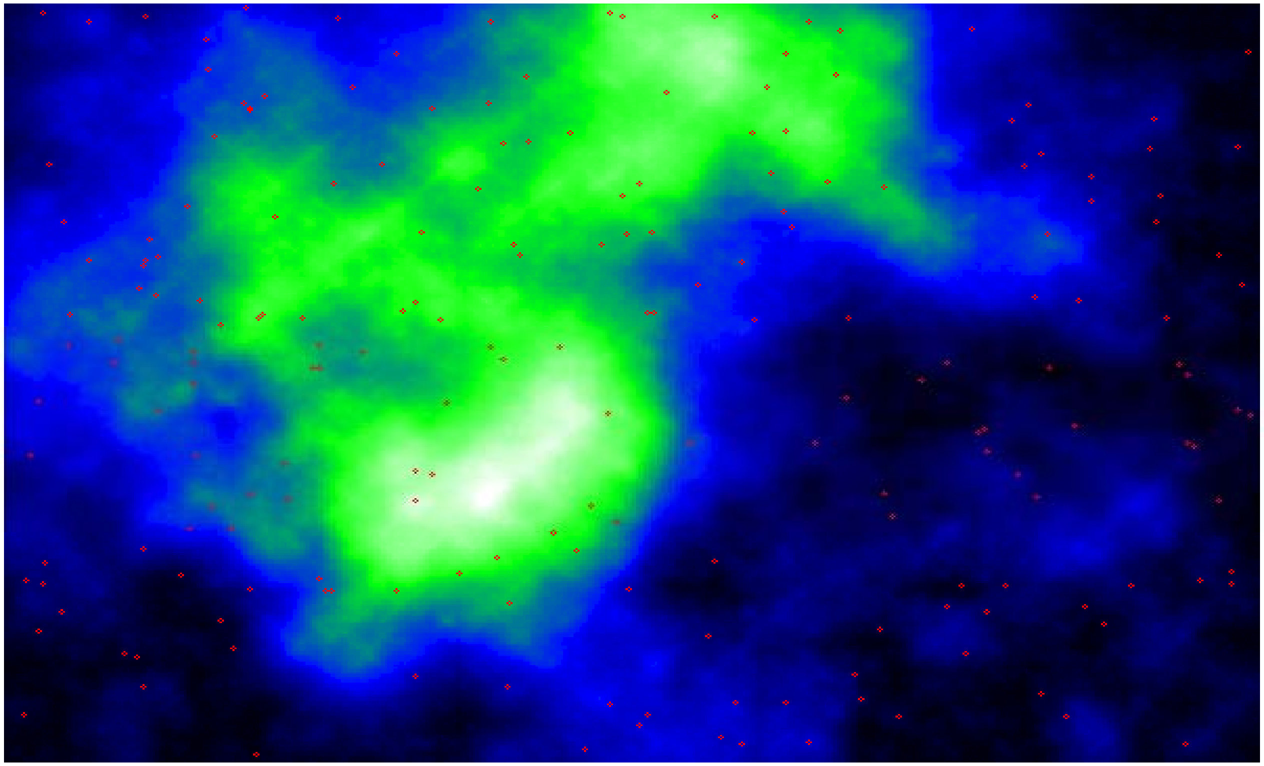
- Initialising
  - start with a randomly generated population of chromosomes (candidate solutions).
- Evolution process
  - crossover (applied in a random number of times)
  - mutation (applied in a random number of times)
  - removing bad chromosomes (low fitness) to have a new generation
- Termination
  - Maintaining a good solution
  - After n generation

A simple application of GA



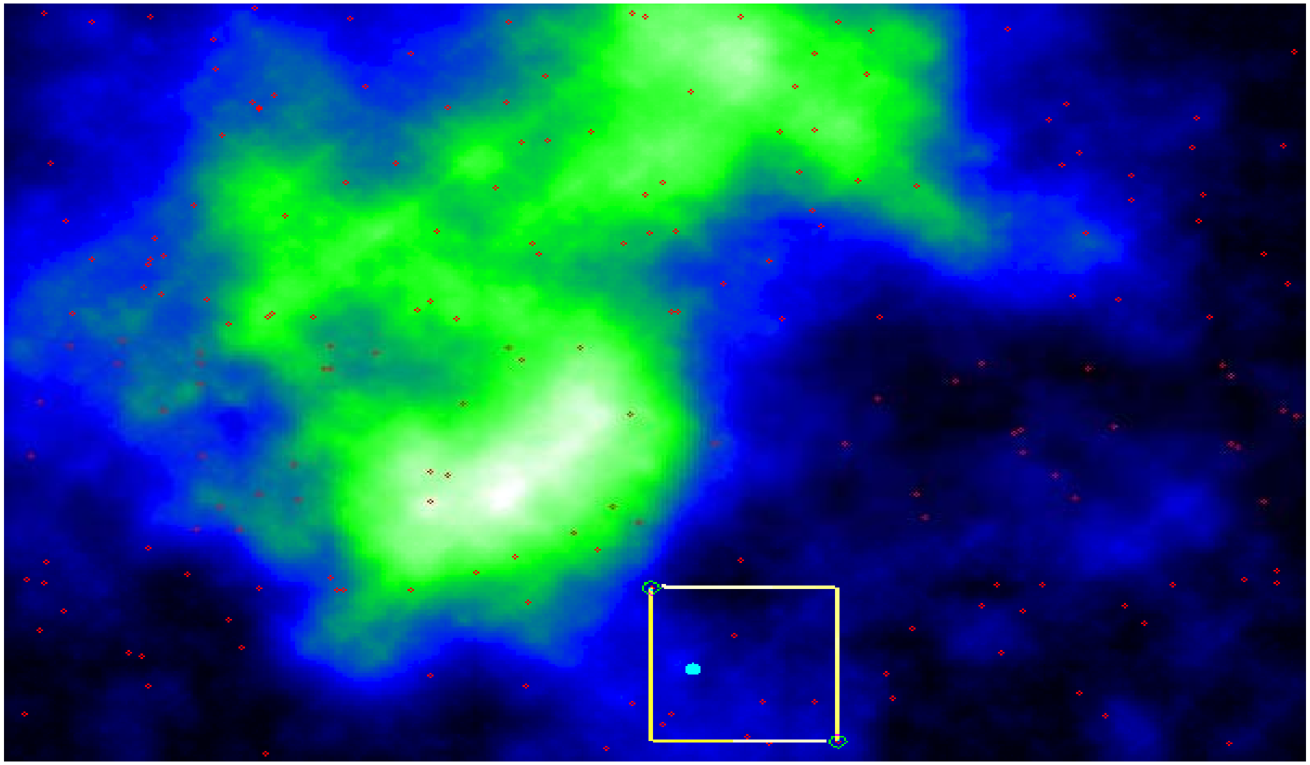
- Light colors shows the higher pixels
- The goal is to find the highest pixel (lightest color)
- Not very easy !

Initializing



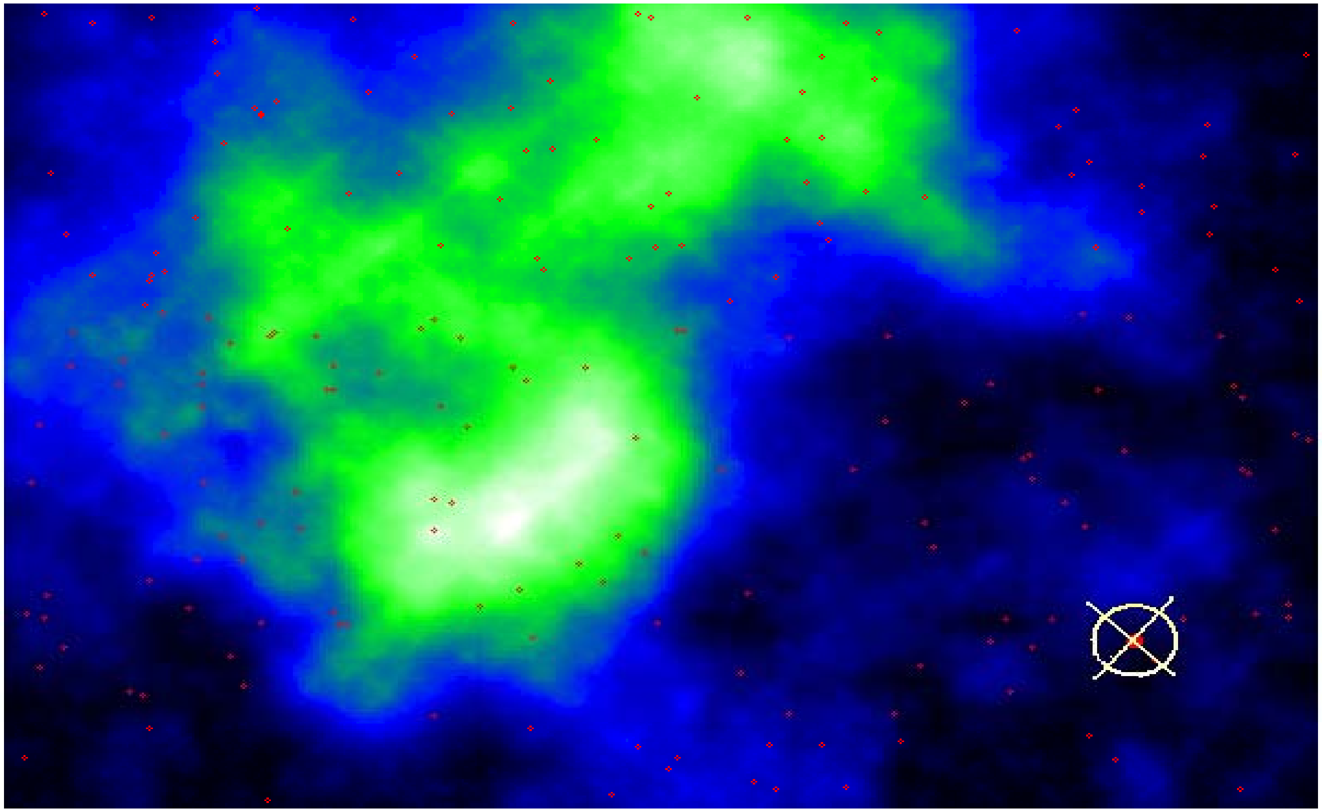
- A population of random points (chromosomes) are generated as the initial population.

Crossover



- Two chromosomes (points) are selected randomly (parents)
- The offspring (child) chromosome is a point in the rectangle bounded by parents

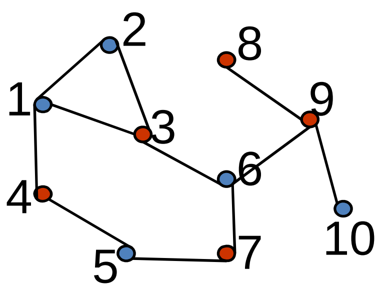
Removing



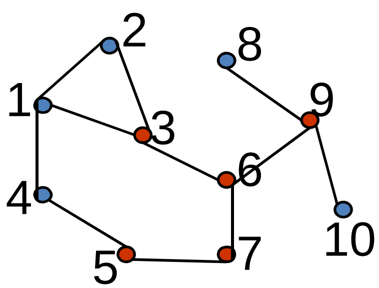
- Fitness of each chromosome (point) is its height.
- Chromosomes (points) with lower height (fitness) are removed.

A GA for MCDS

- **Representation**
  - Each chromosome is a simply a “Set” of vertices
    - No Duplicate vertices!
    - No ordering among vertices.



ch1= { 3 4 7 8 9 }



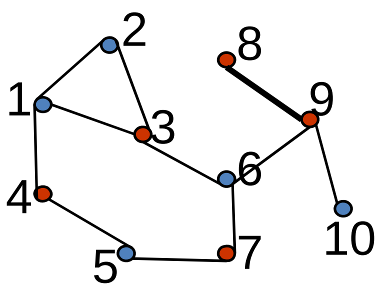
ch2 = { 3 5 6 7 9 }

A GA for MCDS

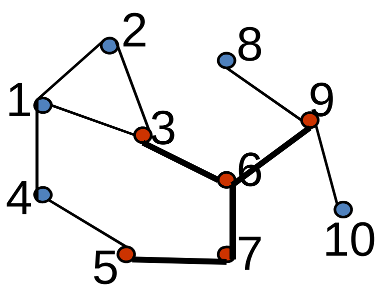
- **Fitness Function (Not Power Aware)**
  - for each chromosome *ch* we define

$$fit(ch) = 0.8 \times X(ch) + 0.2 \times Y(ch)$$

- *X*(*ch*) is the number of vertices covered by *ch* (contained or dominated by *ch*).
- *Y*(*ch*) is the max size of connected components of *ch*.



ch1= { 3 4 7 8 9 }
X = 10 Y = 2
fit (ch1) =8.4



ch2 = { 3 5 6 7 9 }
X = 10 Y=4
fit(ch2) = 8.8

A GA for MCDS

- **Fitness function for Power Aware MCDS**
  - Each vertex has a weight (battery)
  - We prefer the vertices which have higher battery.
  - Remember fitness function without power was:

$$fit(ch) = 0.8 \times X + 0.2 \times Y$$

- A fitness function with power applied:

$$fitP1(ch) = \sum_{v_i \in ch} batt(v_i) \times fit(ch)$$

- A better fitness function with power

$$fitP2(ch) = \left(\mu(batt(v \in ch))^2 / \operatorname{var}(batt(v \in ch))\right) \times fit(ch)$$

A GA for MCDS (Evolution)

- **Crossover**

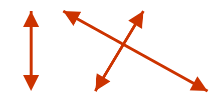
  - Select two chromosomes p1 , p2 randomly as parents.

$$G(23,180)$$
$$p1 = \{1,2,3,4,5,6,7\}$$
$$p2 = \{2,5,7,9,10,12,20\}$$

  - Define Exchange Vectors

$$evP1 = P1 - P1 \cap P2$$
$$evP2 = P2 - P1 \cap P2$$

$$evP1 = \{1,3,4,6\}$$



$$evP2 = \{9,10,12,20\}$$

  - generate random number *r*

$$r = 3 \rightarrow \langle 1 \le r \le 4 \rangle$$
$$evP1' = \{9,20,4,10\}$$
$$evP2' = \{1,6,12,3\}$$

  - swap *r* vertices of *evP1* with *evP2. (randomly select vertices)*

$$off\,1 = evP1' \cup (p1 \cap p2) = \{9,2,20,4,5,10,7\}$$
$$off\,2 = evP2' \cup (p1 \cap p2) = \{2,5,7,1,6,12,3\}$$

A GA for MCDS

- **Mutation**
  - Lots of techniques
  - "Simple" Mutation
    - Select a chromosome randomly.
    - A random vertex of that chromosome is replaced by another random vertex
    - Ex:
      - ch1 = {2,5,6,3,15,16,12}
      - ch2 = {2,14,6,3,15,16,12}.

A GA for MCDS

- **Termination**
  - The algorithm terminates if
    - A chromosome represents a solution (for the decision problem)
    - A connected subset of vertices that dominate all vertices (X=n) is find.
  - Or if
    - GA finds no solution after a particular number of generations.
    - Probably there is no solution for decision problem
    - There are approximate results.

Thanks for your patience

Any Questions ?