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Routing and Frequency Selection in Mesh Network using Genetic Algorithms

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Overview

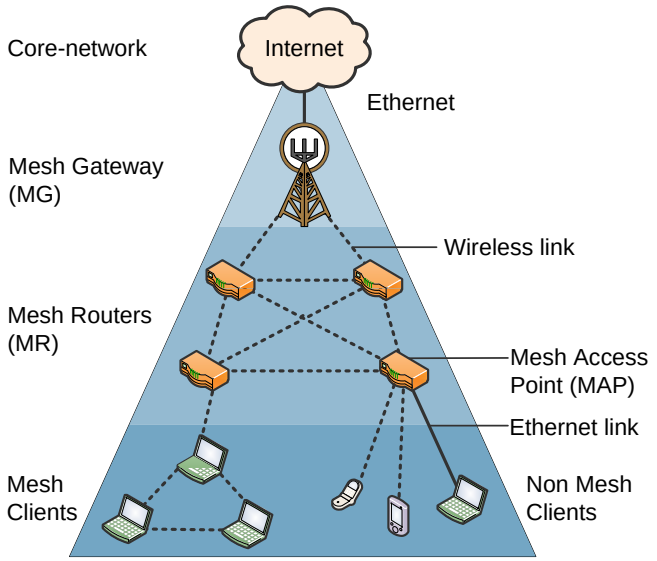
- Motivation
- Problem Formulation
- Genetic Algorithms
  - Introduction
  - Application to Mesh Networks
- Numerical Results
- Outlook and Conclusion

Mesh Network Planning

- Context: Characteristics of mesh networks
  - Multi*
  - Self-organized: routing, resource allocation, medium access
  - Static mesh routers

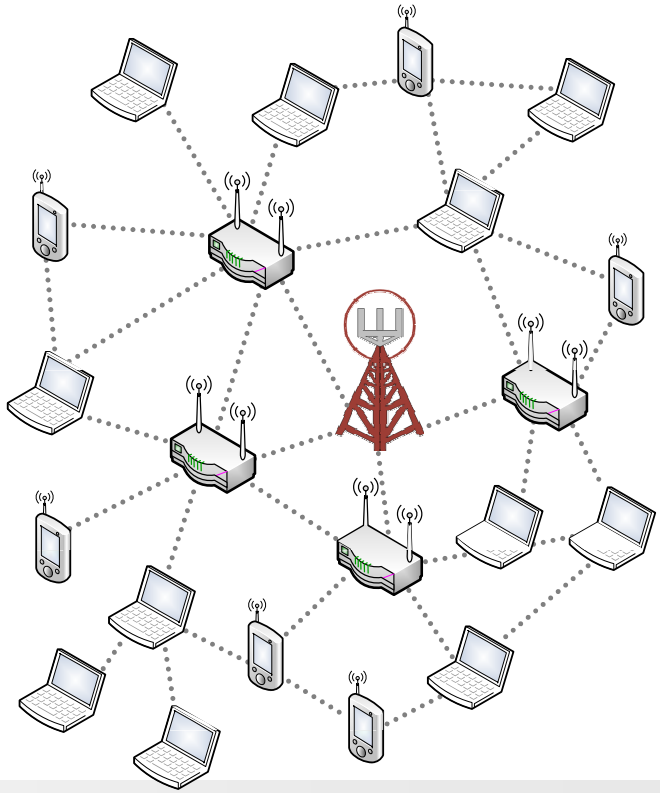
- Problem for commercial mesh network
  - Mesh routers have to be installed
  - Good service quality

- Planning of a self-organized network
  - fast evaluation of network quality possible solution:
    - plan static and idealistic
    - operate self-organized, dynamic



Problem Formulation

- Starting point:
  - optimization of routing and channel allocation
- Given:
  - set of mesh nodes (with number of interfaces)
  - set of gateways with access speeds
  - connectivity and pair-wise collision matrix
  - link rate matrix
  - number of parallel channels
- Output:
  - routing
  - channel allocation
- Objective:
  - maximize minimal or total throughput



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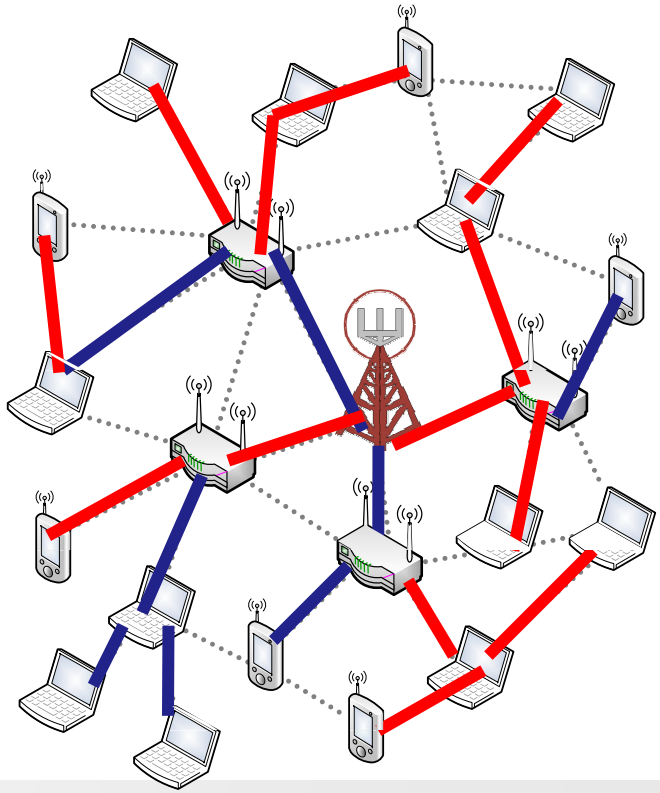
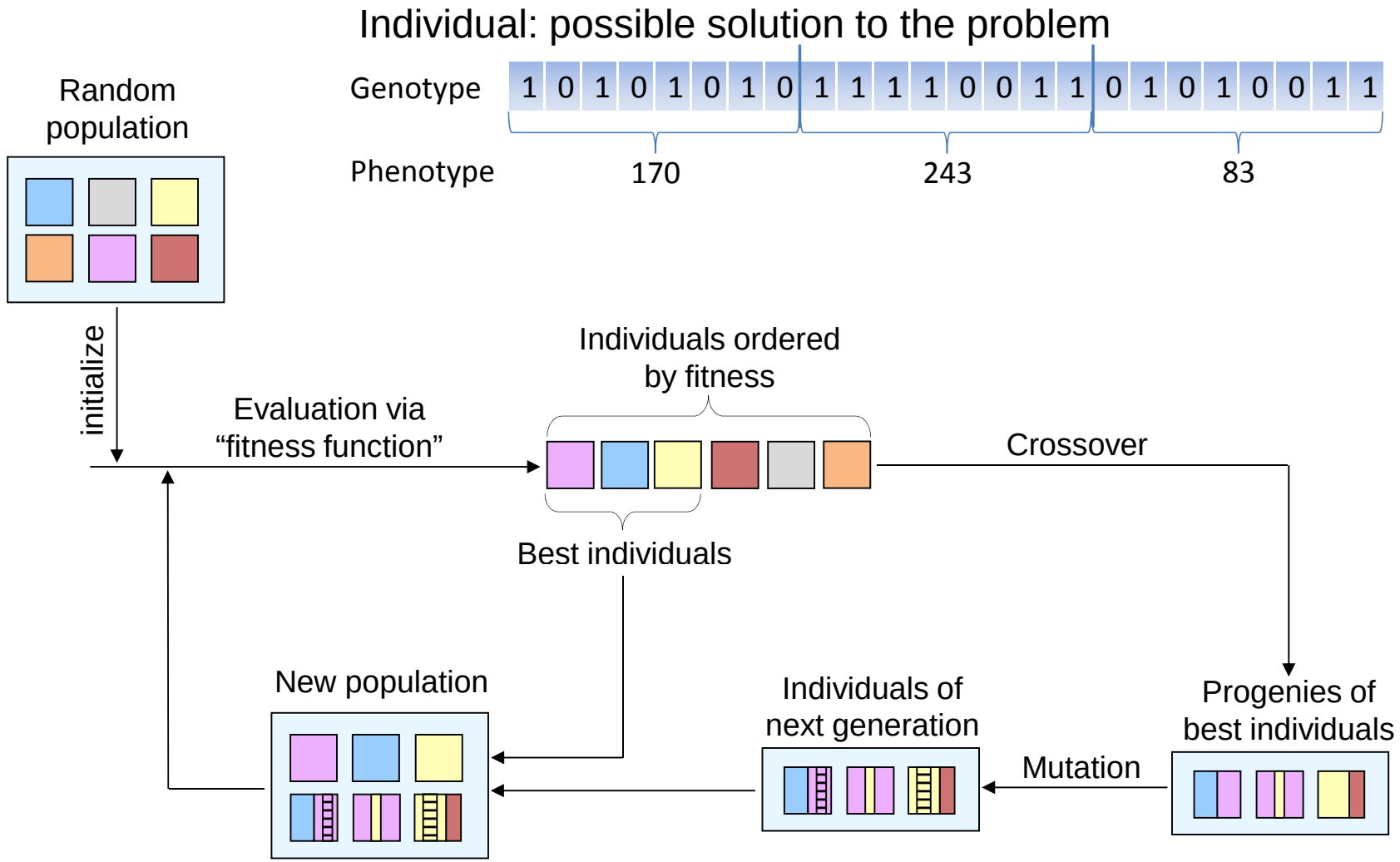


Genetic Algorithms – Main Principles



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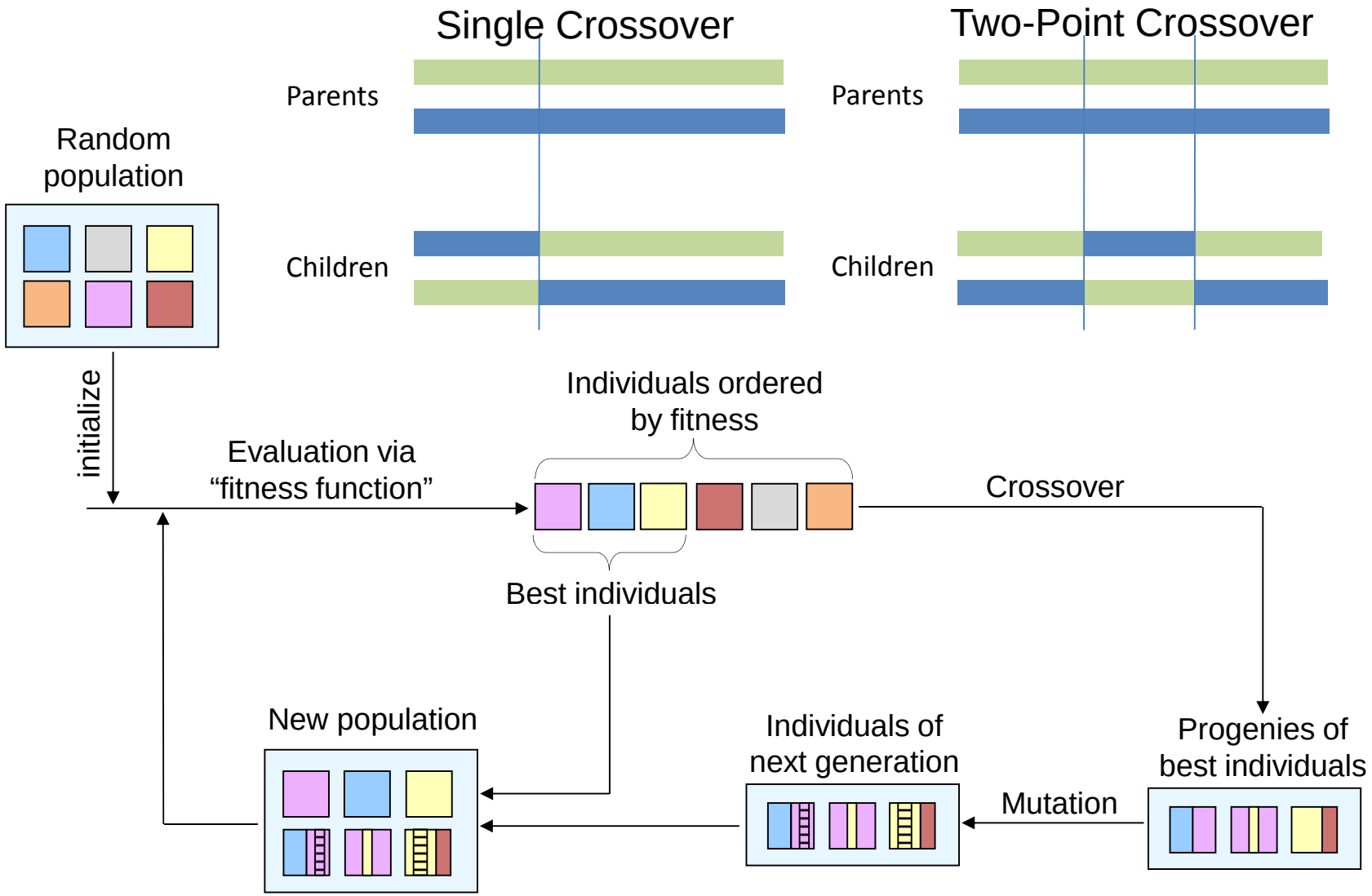
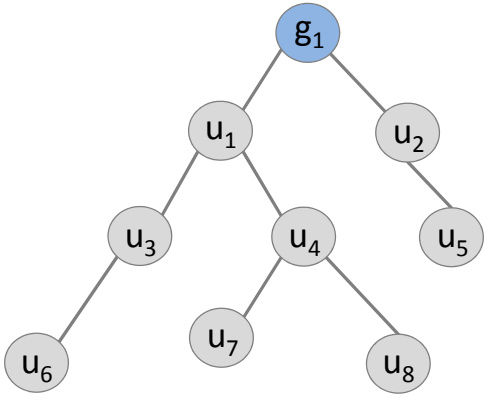


Wireless Mesh Networks: Individual

Possible routing



Corresponding individual

user	u_1	u_2	u_3	u_4	u_5	u_6	u_7	u_8
next hop	g_1	g_1	u_1	u_1	u_2	u_3	u_4	u_4

Wireless Mesh Networks: Individual

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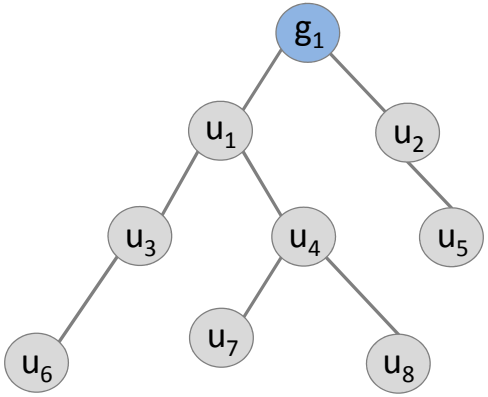

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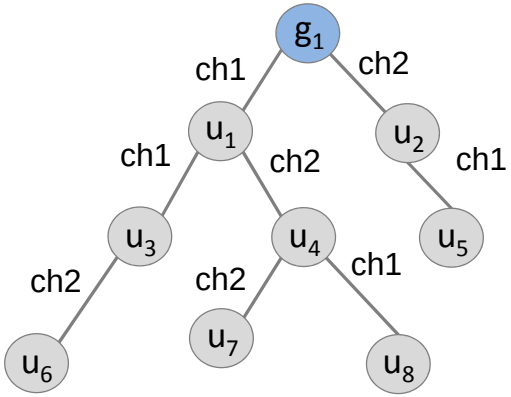
Channel allocation



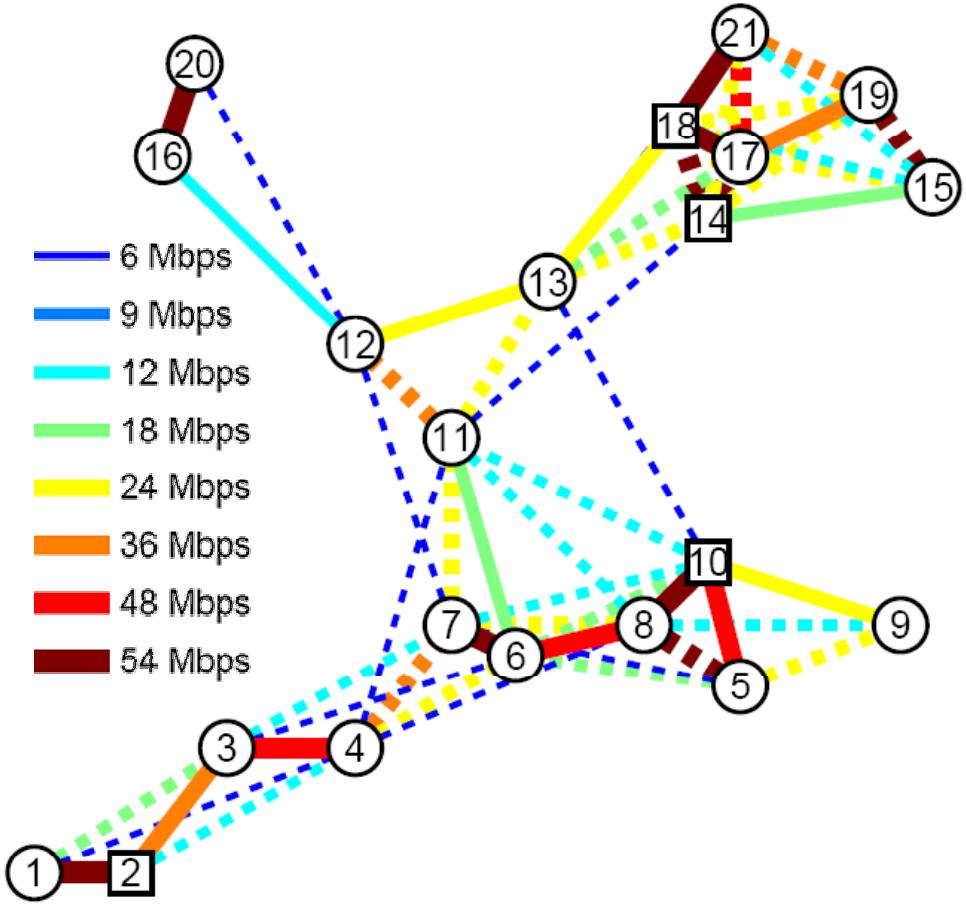
Corresponding individual

user	u_1	u_2	u_3	u_4	u_5	u_6	u_7	u_8
next hop	g_1	g_1	u_1	u_1	u_2	u_3	u_4	u_4
channel	ch_1	ch_2	ch_1	ch_2	ch_1	ch_2	ch_1	ch_1

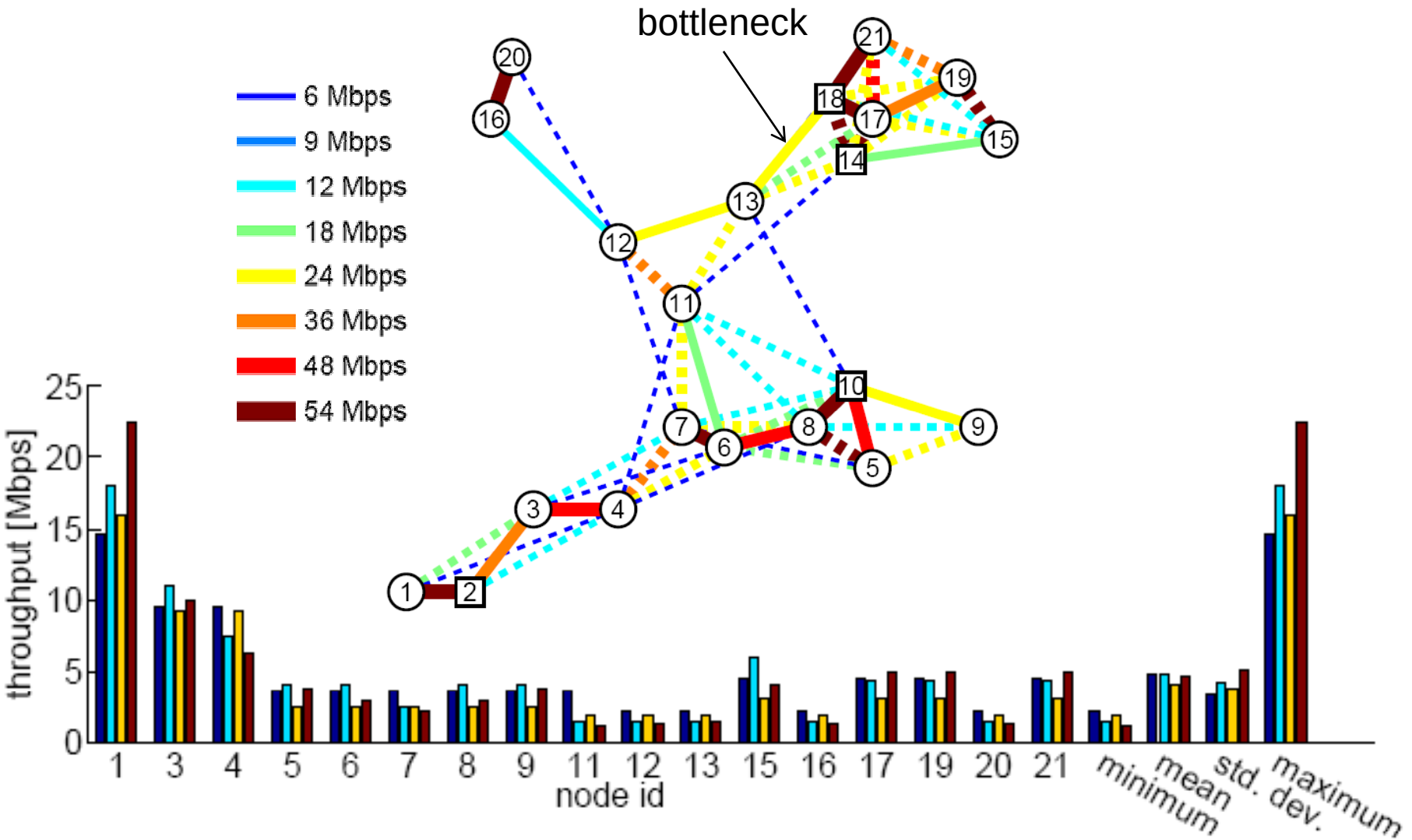
Fitness Function

- Problem:
  - Throughput for saturated traffic from the Internet to the mesh nodes?
  - No **realistic** solution available e.g. for IEEE 802.11 or 802.16
  - Idealistic solution

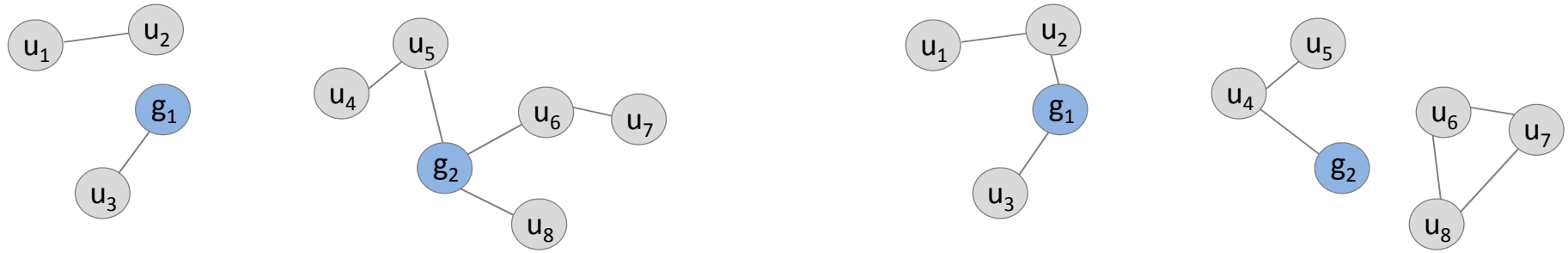
    Max-min fair rate allocation
  - Development of algorithm for
    - effective and nominal load
    - multiple rates
    - multiple gateways
    - multiple channels
  - Fitness Function depends on rate statistics



Results for Example Network

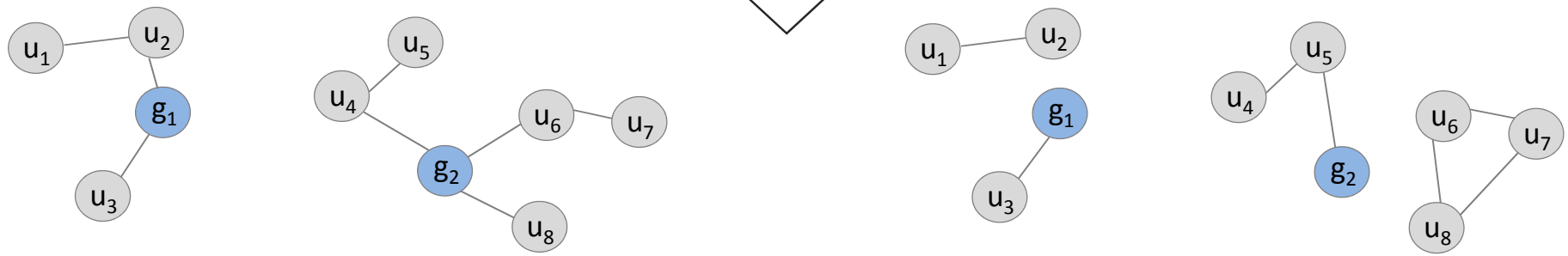


Two-Point Crossover



individual 1

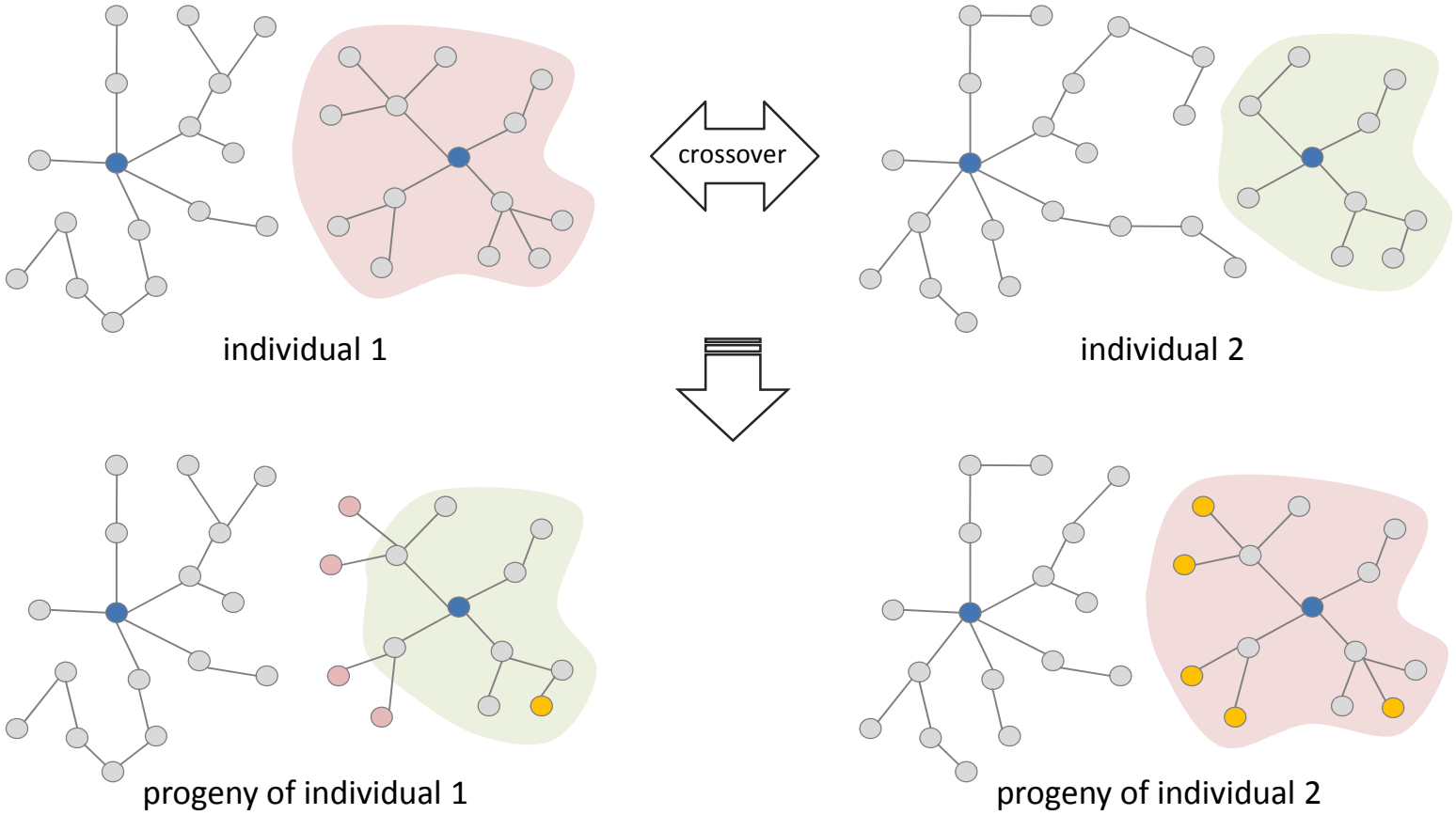
individual 2



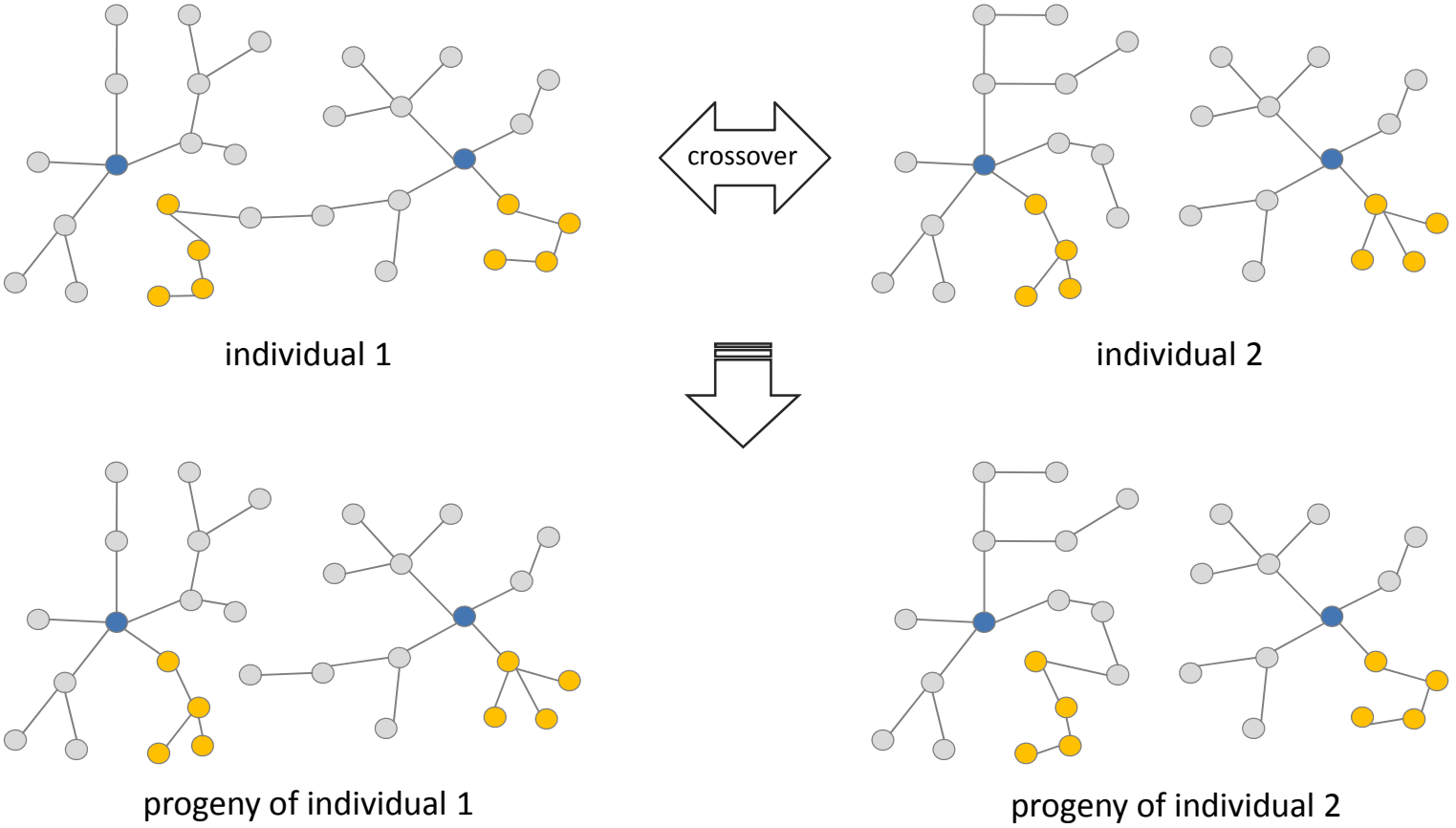
progeny of individual 1

progeny of individual 2

Cell Crossover

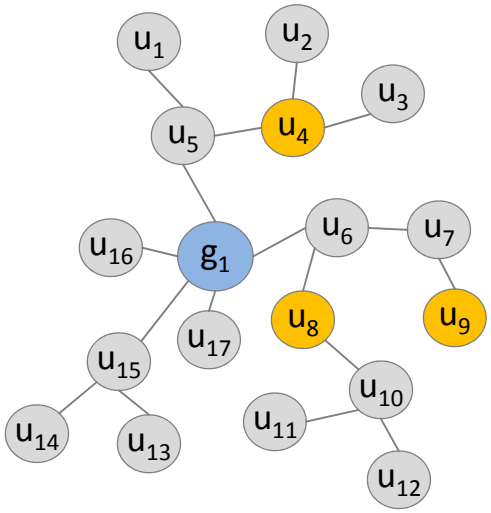


Subtree Crossover

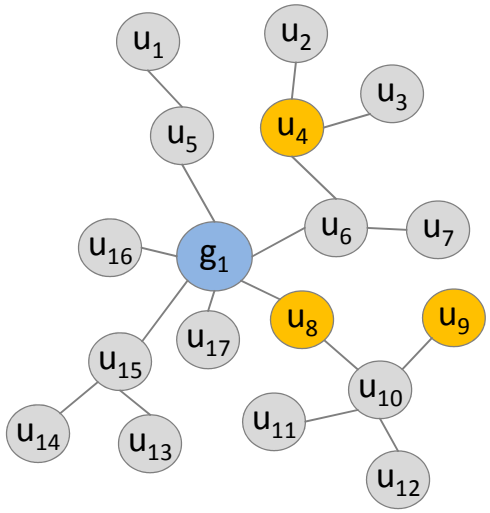


Mutation

- Changes within a single individual
- Number of mutations per individual can be controlled
- Disconnected parts are not allowed

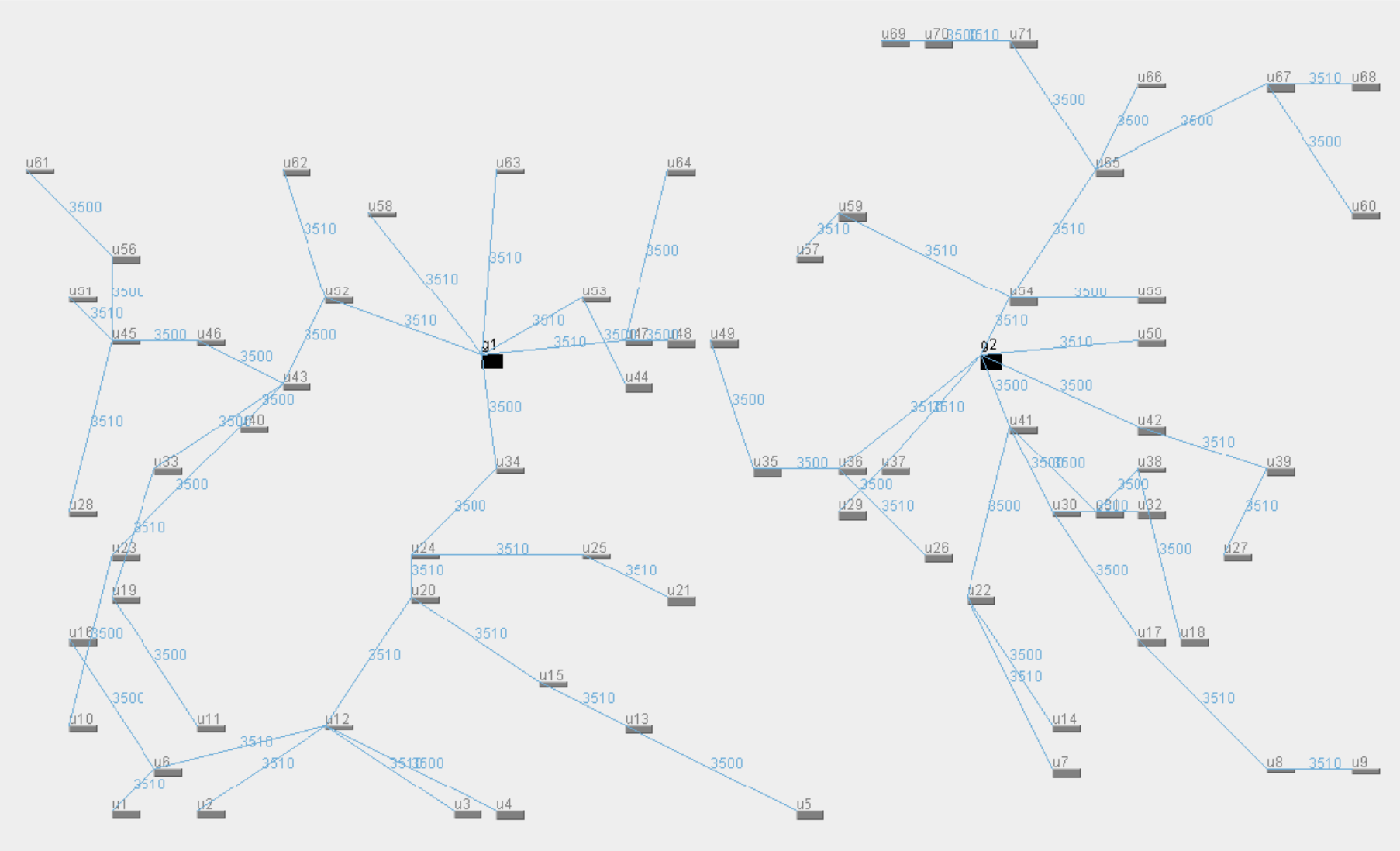


individual



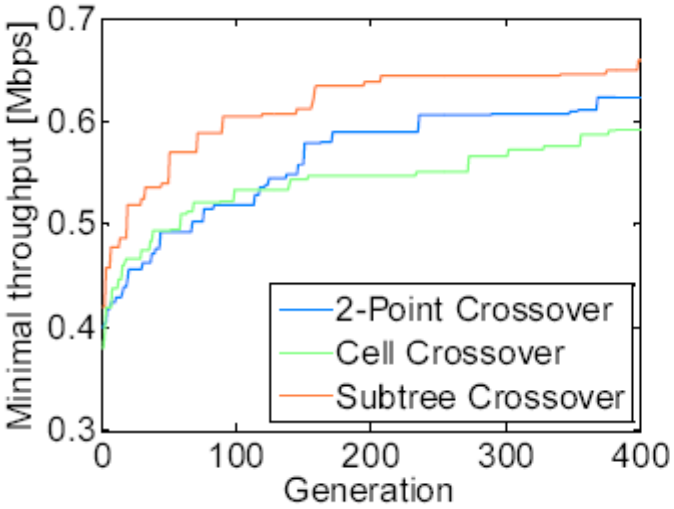
mutated individual

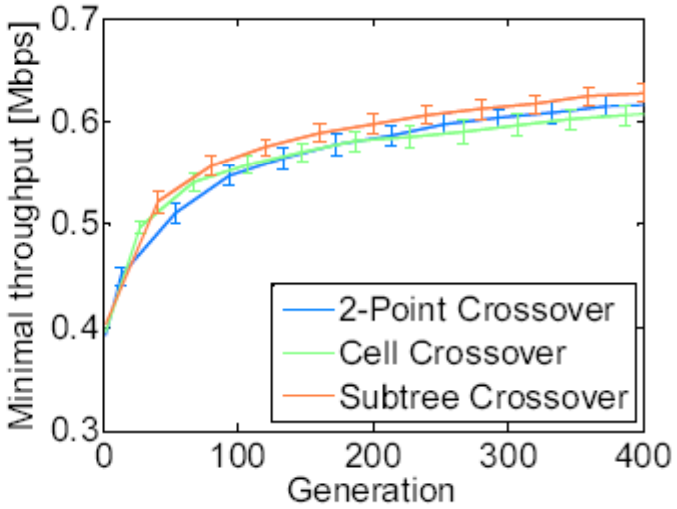
Result of Example Network 1



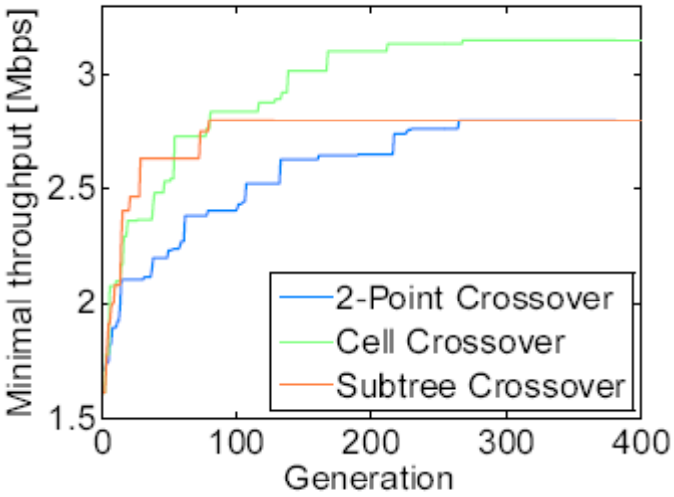
Impact of Crossover

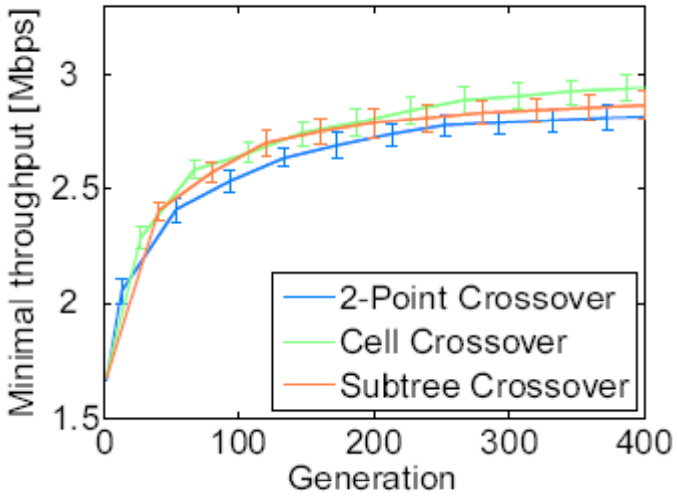
Network 1
2 gateways
71 nodes



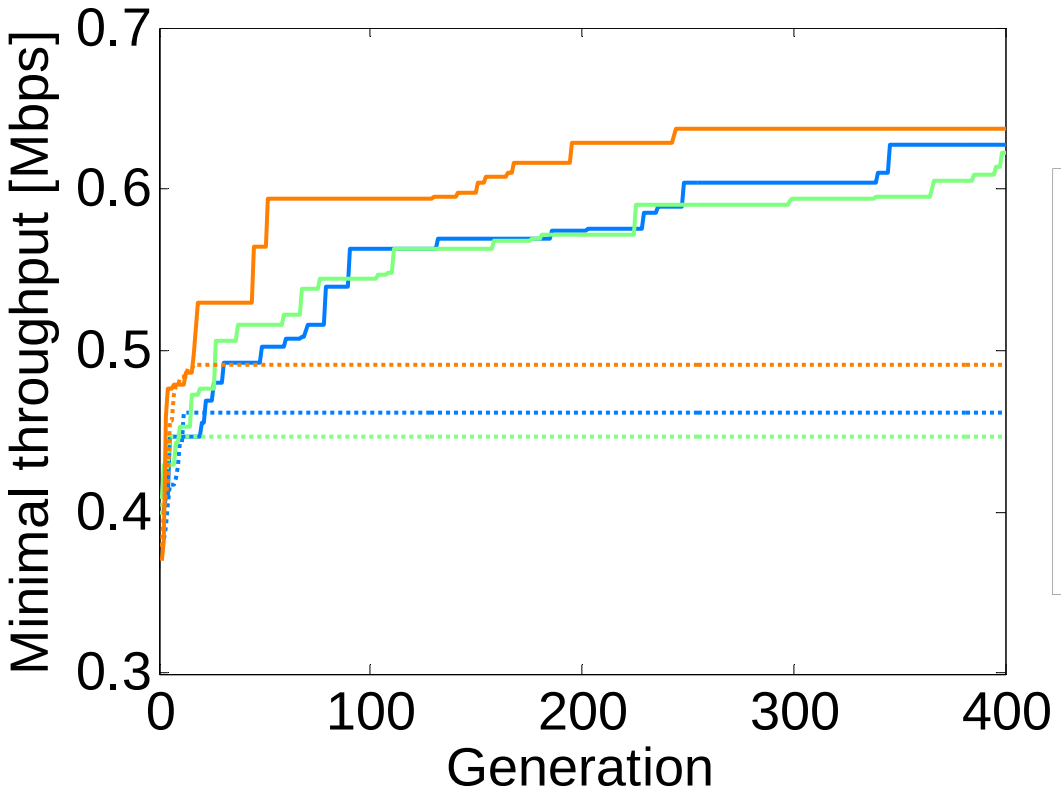


Network 2
6 gateways
38 nodes





Impact of Mutation

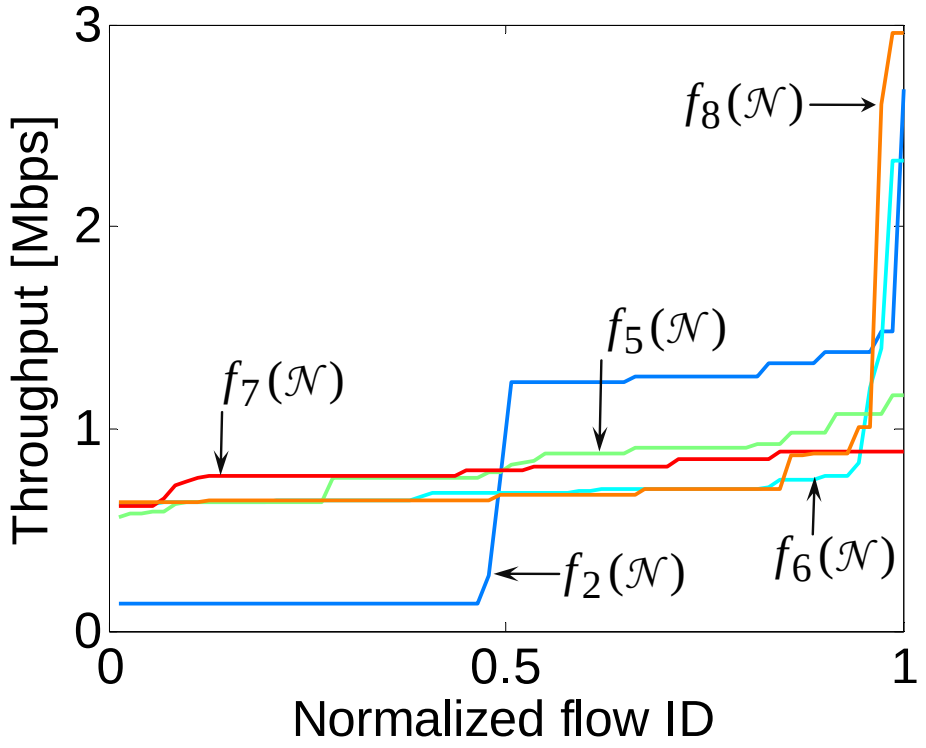


Network 1
2 gateways
71 nodes

- Subtree CO, mutation ON
- Subtree CO, mutation OFF
- 2-Point CO, mutation ON
- 2-Point CO, mutation OFF
- Cell CO, mutation ON
- Cell CO, mutation OFF

Impact of Different Fitness Functions

$$
\begin{aligned}
f_1(\mathcal{N}) &= min(\mathcal{R}_\mathcal{N}) \\
f_2(\mathcal{N}) &= median(\mathcal{R}_\mathcal{N}) \\
f_3(\mathcal{N}) &= mean(\mathcal{R}_\mathcal{N}) \\
f_4(\mathcal{N}) &= min(\mathcal{R}_\mathcal{N}) + \frac{median(\mathcal{R}_\mathcal{N})}{8} \\
f_5(\mathcal{N}) &= mean(\mathcal{R}_\mathcal{N}) - var(\mathcal{R}_\mathcal{N}) \\
f_6(\mathcal{N}) &= min(\mathcal{R}_\mathcal{N}) + \frac{median(\mathcal{R}_\mathcal{N})}{8} + \frac{mean(\mathcal{R}_\mathcal{N})}{|\mathcal{L}|} \\
f_7(\mathcal{N}) &= \sum_{i=0}^{|\tilde{T}|-1} (\left|\tilde{T}\right| - i) \cdot \tilde{T}(i) \\
f_8(\mathcal{N}) &= \sum_{i=0}^{|\tilde{T}|-1} k^{|\tilde{T}|-i} \cdot \tilde{T}(i)
\end{aligned}
$$



idea: stronger weight for smaller throughputs

Conclusion

- Target: Mesh Network Planning
- Subtarget: Optimal/Good Routing and Channel Allocation
- Genetic algorithms
  - need to be adapted to the problem
  - crossover variants: subtree crossover best/most robust
  - different fitness functions
- A lot of work to do
  - performance evaluation of mesh networks
  - planning of “self-organized” mesh networks

Next Steps

1. Comparison with other heuristics
2. Improve evaluation of mesh networks with static resource assignment
   - closer to actual technology
   - heterogeneous traffic scenarios, stochastic traffic
3. Proceed towards network planning
   - selection of node locations and gateway node
   - adapt genes, mutation, crossover, fitness function

   Direction 1:
   - extend routing and channel assignment problem

   Direction 2:
   - develop more abstract fitness function for “self-organized” mesh networks
   - network configuration/gene does not determine routing and channel allocation but only node and gateway location