Network Planning for Stochastic Traffic Demands using a Genetic Algorithm

Dr. Nga Tran
Prof. Dr. Andreas Timm-Giel

Basic network planning problem

<u>Given</u>

- Network information (topologies, link cost, etc.)
- Traffic demands

<u>Determine</u>

- Route for each demand
- Bandwidth allocated for each link

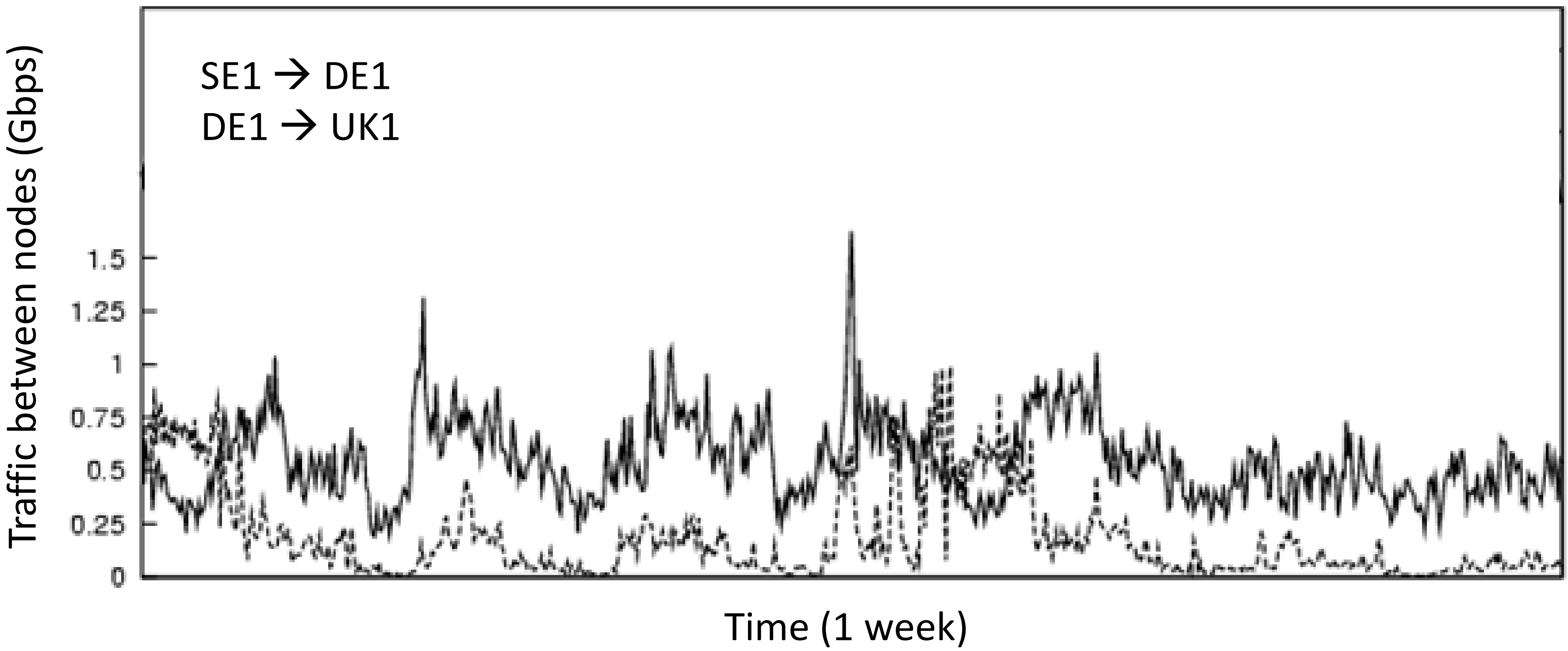
<u>Objective</u>

The total network cost

subject to network constraints is minimized.

Problem

Traffic demands are not deterministic but stochastic.



How to handle the uncertainty?

Planning Approaches

- Mean-rate based
- Pro: low cost
- Con: high amount of traffic is discarded

- Peak-rate based
- Pro: able to handle a large traffic demand variation
- Con: very expensive

Statistical network planning

- Objective: minimize the cost
- Constraint: accept a violation probability for the link load (Grade of Service – GoS)

Mathematical model (1)

- Parameters:
  - Traffic demand distribution of a nodepair (sd) :t^{sd}

    (Traffic demands are statisticaly independent.)
  - Cost of a bandwidth unit on the link *ij*: c_{ij}
  - GoS agreement: ε

- Variables:
  - Routing (binary) decision variable: f_{ij}^{sd}
  - Bandwidth assignment variable: b_{ij}

Mathematical model (2)

- Objective: minimize the total cost

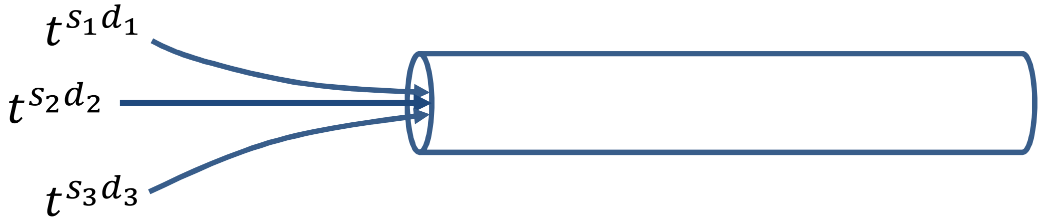
$$min \sum_{ij} c_{ij} \cdot b_{ij}$$

- Multi-commodity flow constraint

$$\sum_{j} f_{ij}^{sd} - \sum_{j} f_{ji}^{sd} = \begin{cases} 1 & i = s \\ -1 & i = d \\ 0 & i \neq s, d \end{cases} \qquad \forall i$$

Mathematical model (3)

- Capacity constraint



Aggregated traffic distribution:

$$t = t^{s_1 d_1} \otimes t^{s_2 d_2} \otimes t^{s_3 d_3}$$

Probability that the aggregated traffic is lower than the capacity *b* of a link is: $\int_0^b t(x)dx$

Mathematical model (4)

- Capacity constraint

$$\int_0^{b_{ij}} \left(f_{ij}^{s_1 d_1} \cdot t^{s_1 d_1} \otimes f_{ij}^{s_2 d_2} \cdot t^{s_2 d_2} \otimes \ldots \otimes f_{ij}^{s_n d_n} \cdot t^{s_n d_n} \right)(x)dx \geq 1 - \varepsilon$$

$$\forall i, j$$

$$\longrightarrow \prod_{\{s,d;f_{ij}^{sd}=1\}} \int_0^{b_{ij}} f_{ij}^{sd} \cdot t^{sd}(x)dx \geq 1 - \varepsilon$$

$$P\{\text{link (i,j) is overloaded}\} \leq \varepsilon$$

$$b_{ij} = ?$$

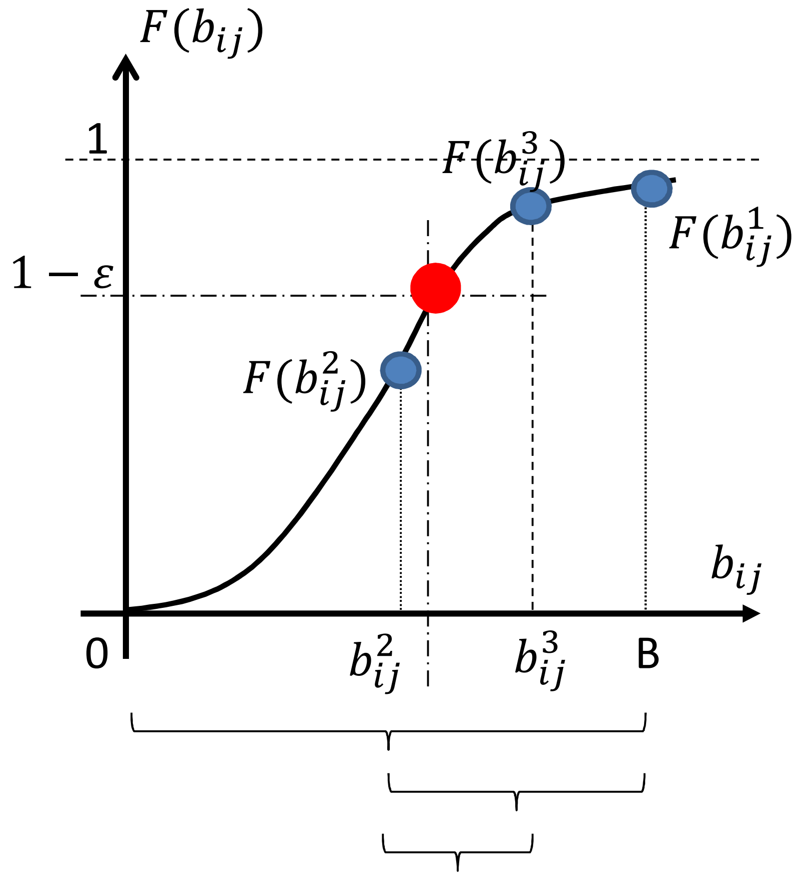
Calculate the link bandwidth b_{ij}

$$F\left(b_{ij}\right) = \prod_{\{s,d;f_{ij}^{sd}=1\}} \int_0^{b_{ij}} f_{ij}^{sd} \cdot t^{sd}(x)dx \geq 1-\varepsilon$$

- $F\left(b_{ij}\right)$ is the CDF of the traffic distribution on the link

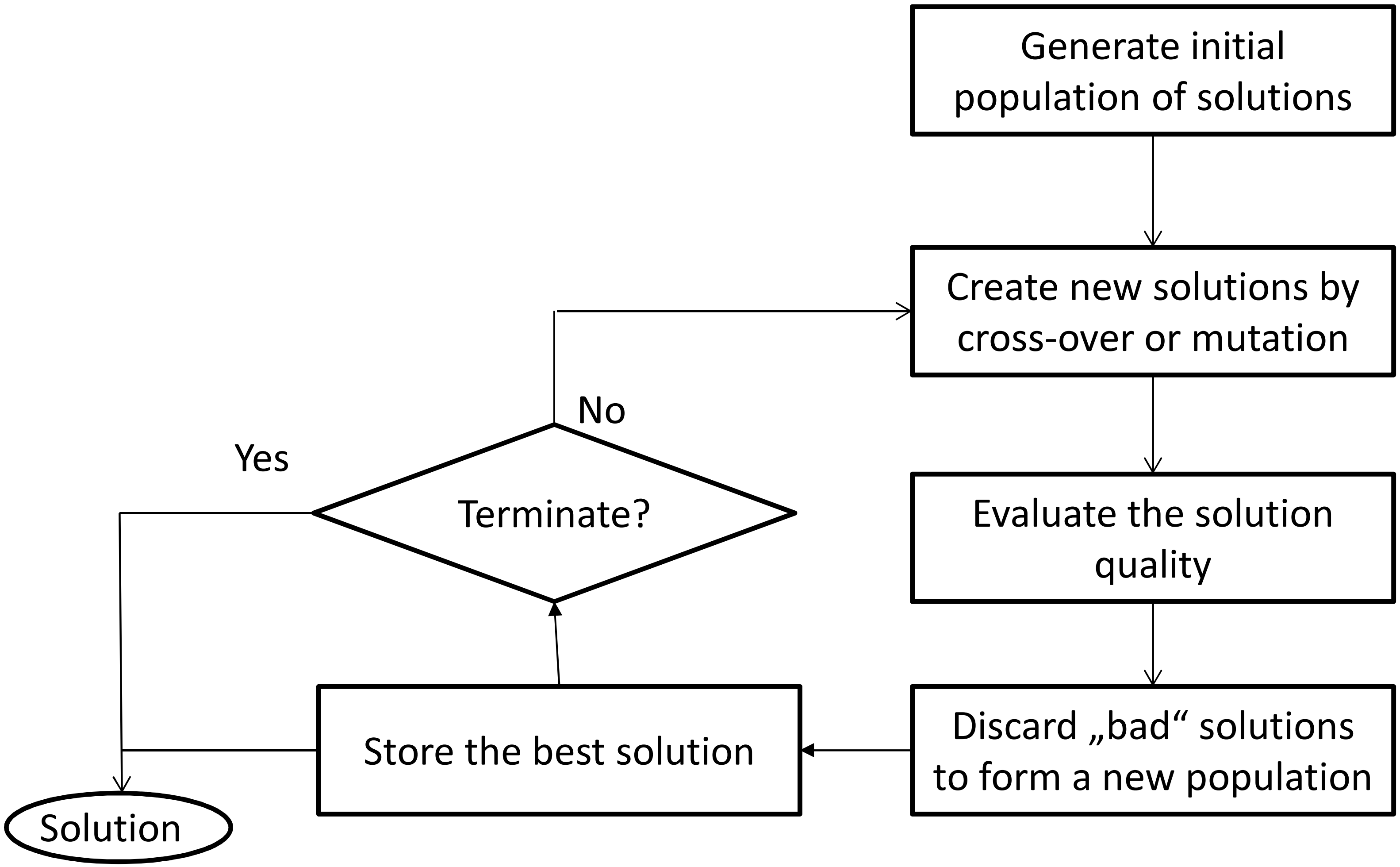
  → a monotone function

- bisection method can be used to find b_{ij}



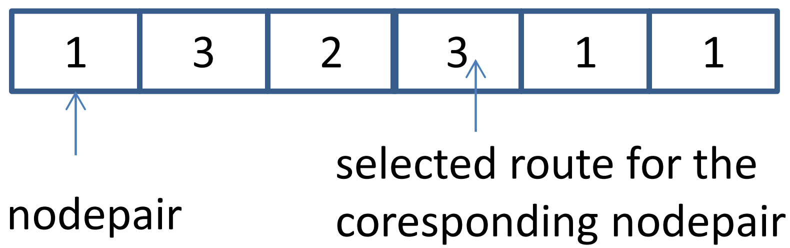
Solution interval

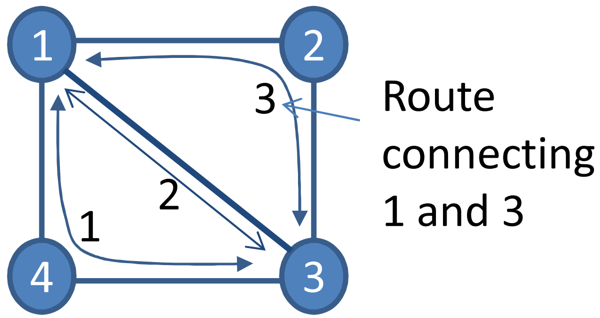
Genetic algorithm (1)



Genetic algorithm (2)

- A set of routes for each nodepair is pre-selected.
- A solution is encoded in a chromosome





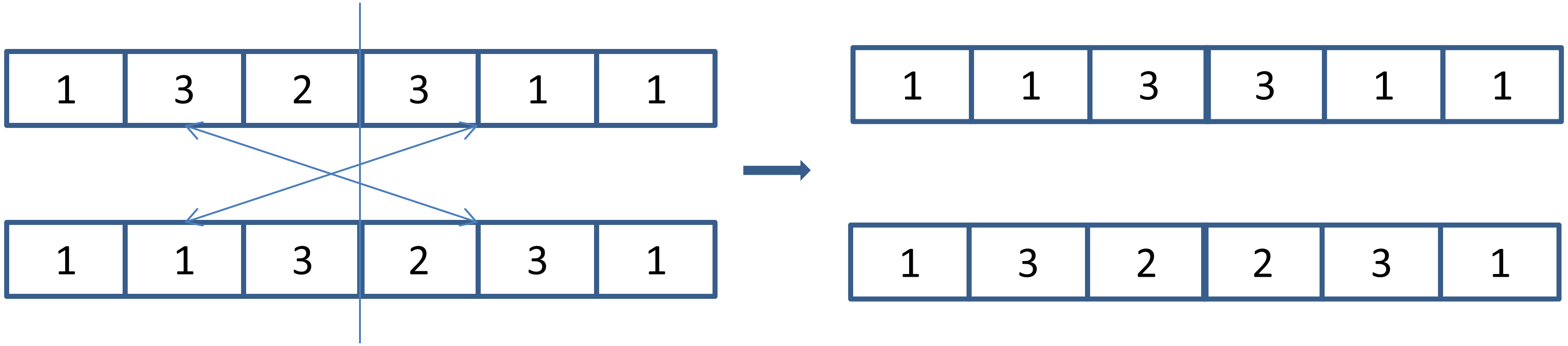
→ a chromosome represents a routing solution for the problem.

- Calculate the required bandwidth for each „chromosome“ to guarantee GoS

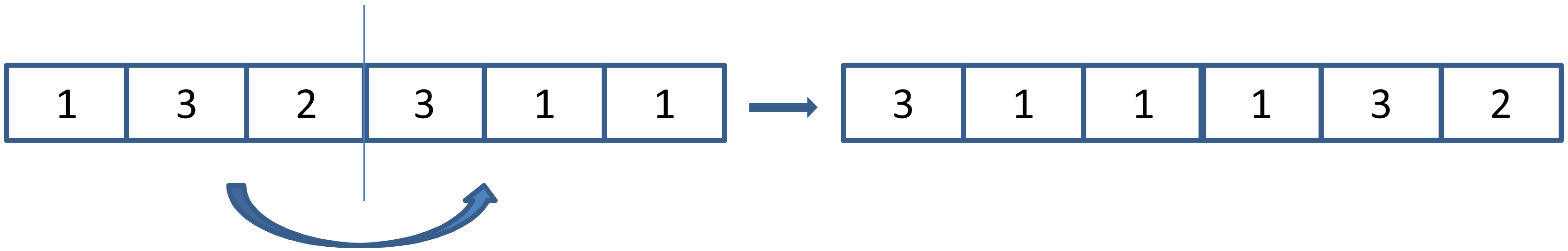
  → calculate the cost of each „chromosome“

Genetic algorithm (3)

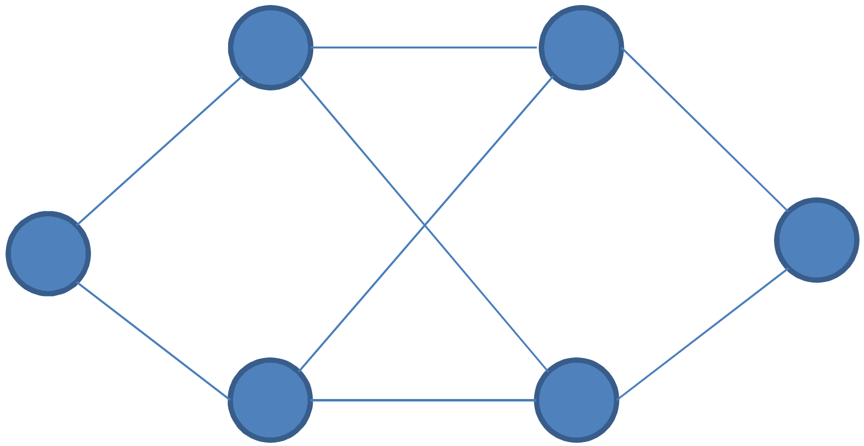
- Cross-over



- Mutation



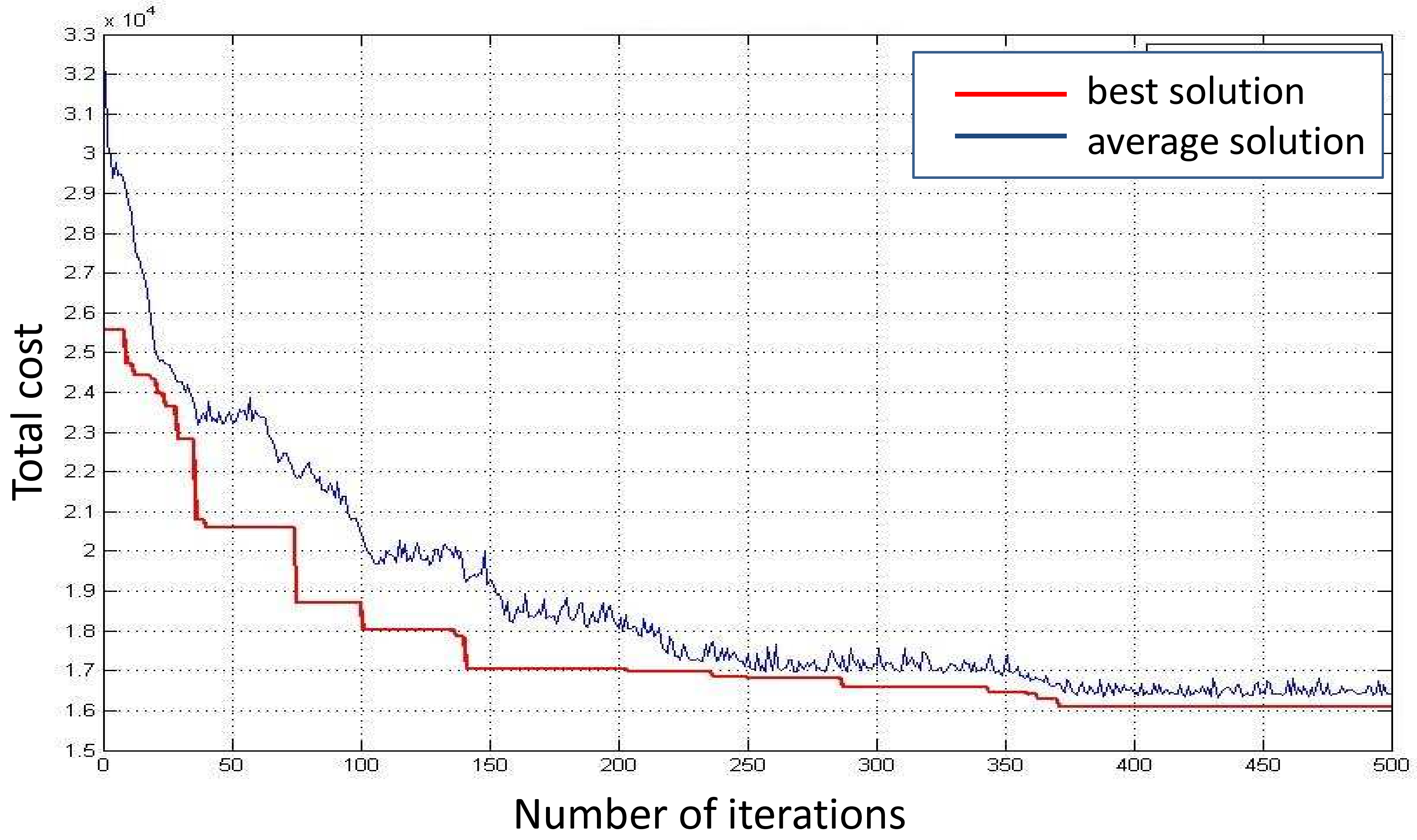
Performance Evaluation



- Traffic demands are taken from GEANT project*
- Link cost = 1 per Mbps
- GoS agreement: ε = 5%

(*) http://www.geant.net/

Performance of the genetic algorithm



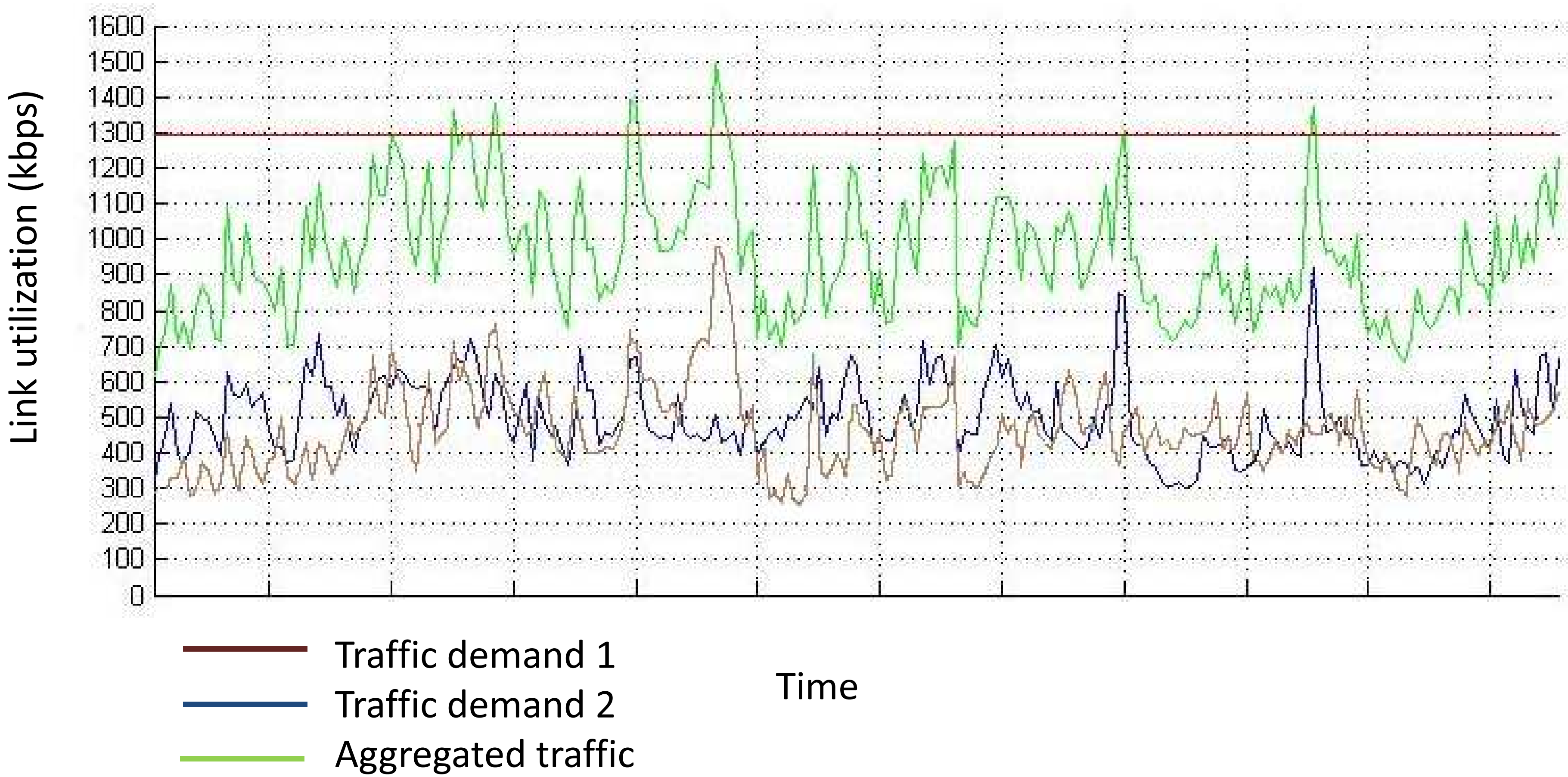
Results

	Mean rate	Peak rate	Stastical
Normalized cost	0.42	1	0.53
Link overload probability	18% - 25%	0%	5% (ε)

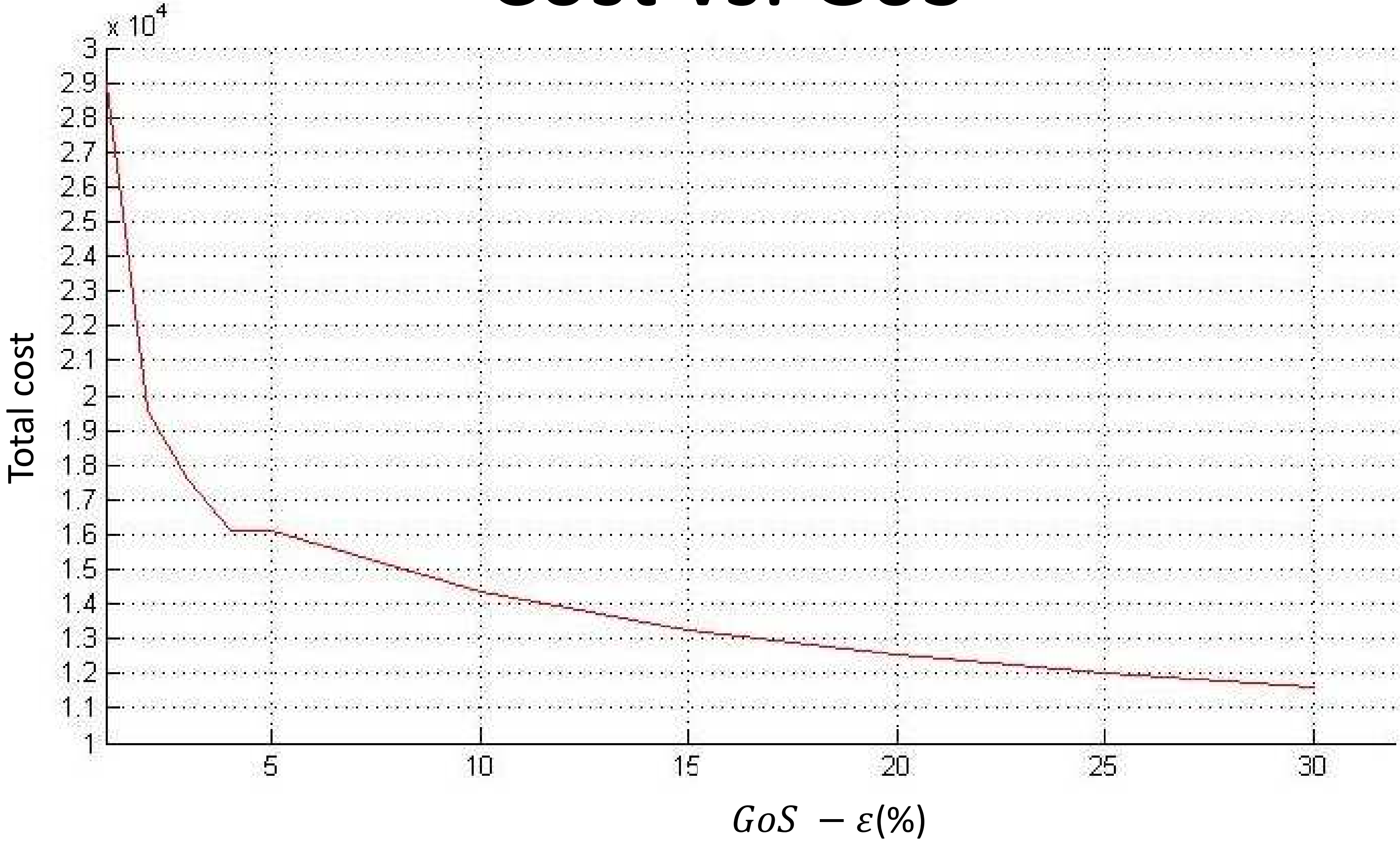
- Peak rate planning: too expensive
- Mean rate planning: high link overload probability

→ Statistical planning is a good compromise

Link utilization



Cost vs. GoS



x 10^4
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
5
10
15
20
25
30
Total cost
$GoS\ -\varepsilon(\%)$

Conclusion

- Proposal of a solution for network planning problem with stochastical traffic demands using a genetic algorithm.
- Limitation: guarantee the overload probabilty for each link only
- Future work: guarantee the GoS for each end-to-end flow