Gradual Reconfiguration of Virtual Network Topologies based on Estimated Traffic Matrices

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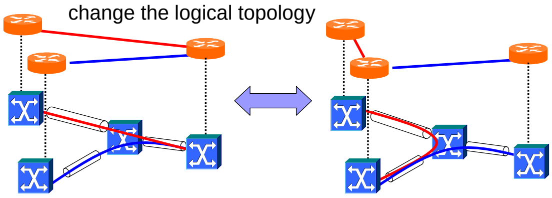
Outline

- Background
  - Multilayer traffic engineering
  - Impact of estimation errors of traffic matrix
- Gradual reconfiguration method based on the estimated traffic matrix
  - Reconfiguration method to limit the number of added/deleted optical paths
  - Estimation method using the additional information of change in routes caused by the VNT reconfiguration
- Evaluation
- Conclusion

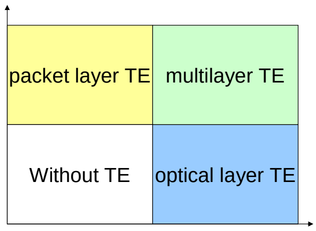
IP / optical multi-layer network

- Packet layer
  - Packet-layer traffic is routed over the VNT
- Optical layer
  - A set of optical paths forms a VNT.
  - By adding or deleting optical paths, we can easily change the logical topology



Traffic engineering (TE) in multilayer network

- Packet layer TE
  - Optimize the routes of packet paths
- Optical layer TE
  - Reconfigure the VNT



- Multi-layer TE
  - Optimize both packet-layer and optical layer
  - Achieve more efficient accommodation of traffic
  - Need traffic matrices as an input

Traffic matrix estimation

- Estimate from the link utilizations

$$X = AT$$

X: link utilization
A: Routing matrix
T: Traffic matrix

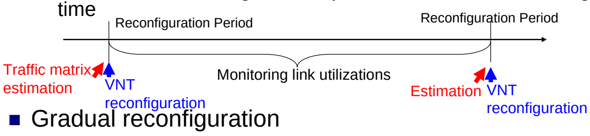
  - **The number of equations is much smaller than the number of entries in traffic matrix**
    - **Number of equations: number of links**
    - **Number of entries: (number of nodes)^2**
- Estimated traffic matrices include estimation errors
- **The estimation errors degrade the performance of traffic engineering**
  - We need a VNT reconfiguration method which is robust to estimation errors

Goal of this work

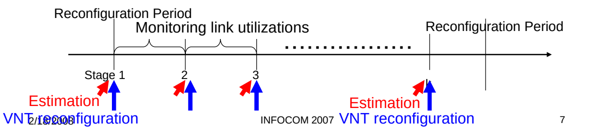
- VNT reconfiguration taking traffic matrix estimation into consideration
  - Limit the impact of estimation errors
    - Gradual reconfiguration
      - Divide the VNT transition sequence into multiple stages
      - Limit the number of addition or deletion of optical paths at a stage
  - Reduce the estimation errors by collaborating with traffic matrix estimation
    - Traffic matrix estimation method using information monitored at multiple stages

Overview of gradual reconfiguration

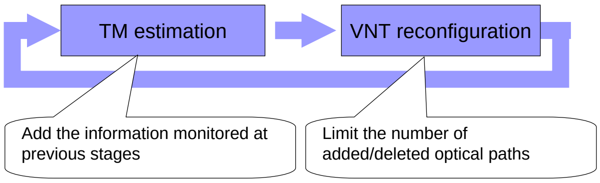
- If we change the current VNT to the optimal VNT at once
  - Estimation errors degrade the performance of TE for a long time



- Gradual reconfiguration
  - We divide the whole VNT transition sequence into multiple stages



Relation between VNT reconfiguration and traffic matrix estimation



- As stages go on
  - Traffic matrix estimation:
    - Use more information
  - VNT reconfiguration:
    - Use more accurate traffic matrix

Algorithm for gradual reconfiguration

- VNT reconfiguration with the limitation of number of optical paths added/deleted at a stage.

  Nr: maximum number of added/deleted optical paths
  - Aim of reconfiguration
    - Make the maximum link utilization less than Th
    - Minimize the constructed optical paths
- Method:
  - Perform following Steps Nr times
    - Calculate the link utilizations by using the estimated traffic matrix
    - If the maximum link utilization is more than Th
      - Add an optical path to reroute the congested path
    - If the maximum link utilization is smaller than Th
      - The optical path is torn down for resource reclamation

Additional equation method

- Add the link utilizations monitored at each stage to the simultaneous equations

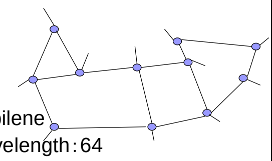
$$\begin{bmatrix} X_0 \\ \vdots \\ X_n \end{bmatrix} = \begin{bmatrix} A_0 \\ \vdots \\ A_n \end{bmatrix} T$$

X_n: Link utilization at stage n

A_n: Routing matrix at stage n

- The number of equations increases as stages go on
- Estimation errors are reduced as stages go on

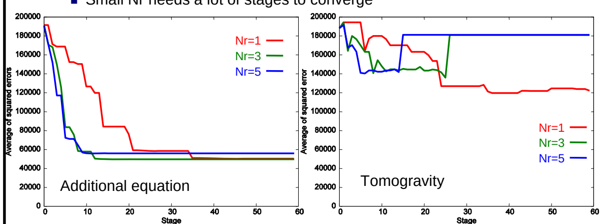
Evaluation



- Simulation Conditions
  - Topology
    - Backbone topology of Abilene
    - Maximum number of wavelength : 64
  - Traffic demand :
    - Generate sudden change to traffic demand monitored at Abilene
    - We assume the traffic matrix is constant after the beginning of reconfiguration
- Metrics
  - Estimation errors of traffic matrix
  - Number of added optical paths

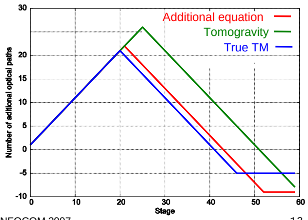
Result (Estimation errors)

- Compare additional equation method with Tomogravity method
  - Additional equation method reduce the estimation errors dramatically
  - About setting Nr, there is a trade-off between convergence time and estimation errors
    - To estimate more accurately, small Nr is better
    - Small Nr needs a lot of stages to converge



Results (Number of optical paths)

- Additional equation methods adds smaller number of optical paths than tomogravity
  - By reducing the estimation errors, we can avoid adding insufficient optical paths



Conclusion and Future works

- Conclusion
  - Gradual VNT reconfiguration method taking the estimation errors into consideration
    - Divide the VNT transition sequence into multiple stages
      - VNT recnfiguration method limiting a number of added/deleted optical paths
      - Additional equation method
- Future works
  - Extend our method so as to estimate in the case of sudden change of traffic