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Achieving Plasticity in WDM networks: Application of Biological Evolutionary Model to Network Design

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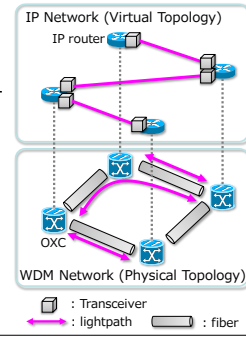
VNT (Virtual Network Topology) control

- **VNT control reconfigures VNT in accordance with traffic changes**
  - by establishing or tearing-down lightpaths
  - to lower link utilization



VNT (Virtual Network Topology) control

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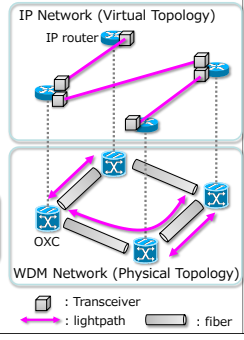
A lightpath needs a transceiver on both source and destination IP-router.



Research Background

Problem: Traffic growth and drastic fluctuation caused by the appearances of new web services

- **VNT control against traffic fluctuation**
  - Some VNT control methods have showed good performance, such as keeping link utilization lower
    - VNT control method based on attractor selection[4] shows high adaptability to unexpected traffic demand changes

[4] Y. Koizumi, T. Miyamura, S. Arakawa, E. Oki, K. Shiomoto, and M. Murata, "Adaptive virtual network topology control based on attractor selection," *IEEE/OSA Journal of Lightwave Technology*, vol. 28, no. 11, pp. 1720–1731, Jun. 2010.

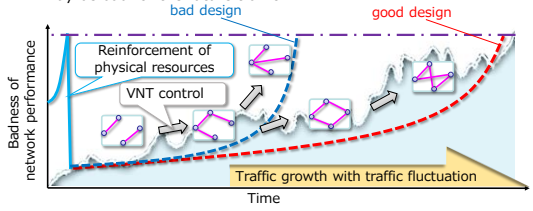
- **Shortage of resources caused by traffic growth**
  - The VNT control may fail to obtain a good VNT

⇒ Reinforcement of physical resources is needed

Network Design against Traffic Growth

Purpose: Add physical resources, e.g., transceivers in order to improve the adaptability of VNT control

- A good network design (, or reinforcement of physical resources) can accommodate future unknown traffic demands
- Optimization toward the present traffic may be bad for the future traffic

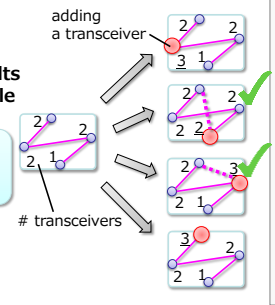


An Effect of Adding Transceivers

- **We consider a method of adding transceivers**
  - Selection of IP-routers where transceivers should be added
- **Adding a transceiver results in a new lightpath available**

⇩

Key: the transceivers distribution has effect on available VNTs



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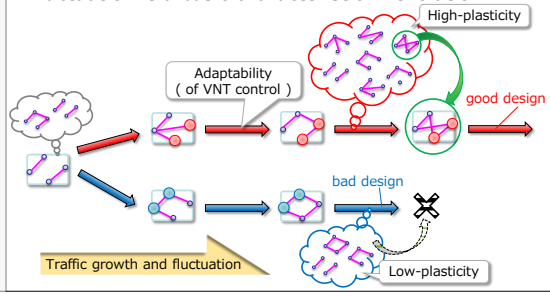
Approach: Achieving a Biological *Plasticity*

- **A plasticity, i.e., a changeability to environmental fluctuation is a basic characteristic in evolution**



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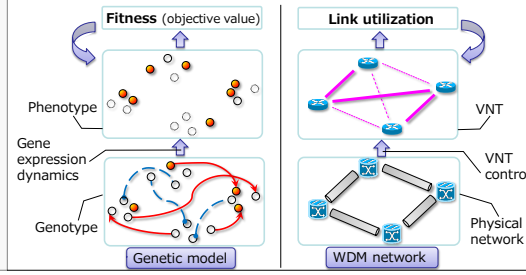
Applying a Genetic Evolutionary Model

Apply the biological model which explains *plasticity*

- Evaluate the plasticity by computational simulation in case some transceivers were added to some nodes



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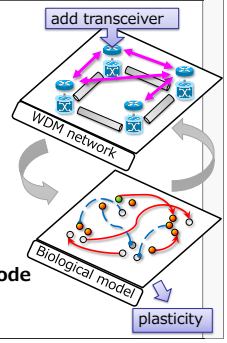
Proposed Method of Adding Transceivers

[Step.1]:
Select a node to add a transceiver

[1.1]: Temporarily add a transceiver to one node
[1.2]: Evaluate the plasticity by using the biological model
- Repeat [1.1-1.2] for another node -
[1.3]: Select the node which shows the highest value of plasticity

Temporarily add a transceiver and evaluate the plasticity

[Step.2]:
Add a transceiver to the selected node
- If there remains another transceiver, go back to Step.1
- Otherwise, finish



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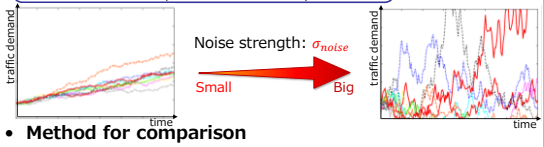
Evaluation

[3] D.Banerjee and B.Mukherjee, "Wavelength-routed optical networks: Linear formulation, resource budgeting tradeoffs, and a reconfiguration study," *IEEE/ACM Transactions on Networking*, vol. 8, no. 5, pp. 598–607, Oct. 2000.

- **Simulation environment**
  - Physical topology:
    - Initially, each nodes has `2 + its degree' transceivers
  - Traffic demand model:

$T^{i,j}_{exp}(t) = m + T^{i,j}_{act}(t-1)$ ..... Increase linearly

$T^{i,j}_{act}(t) = T^{i,j}_{exp}(t) + N\left(0, \left(\sigma_{noise} \times T^{i,j}_{exp}(t)\right)^2\right)$ .... Noise



- **Method for comparison**
  - An ad-hoc design based on a heuristic method[3]

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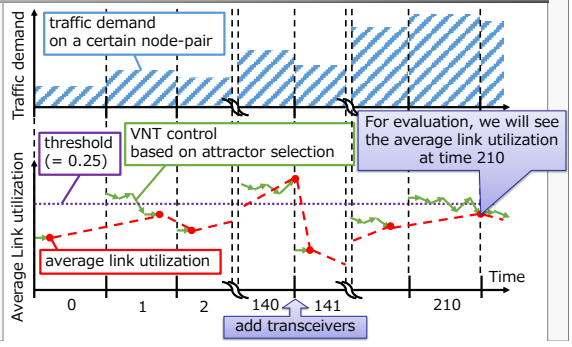
Simulation Result and Evaluation Scenario



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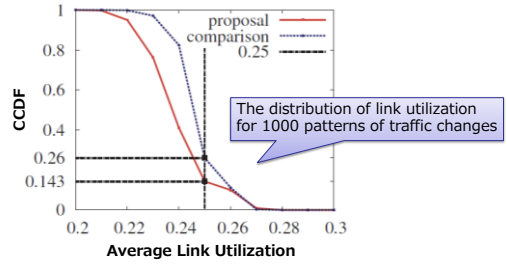
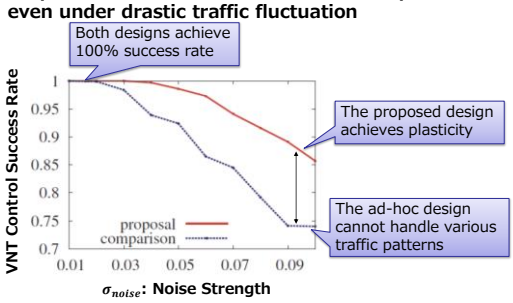
Performance against Traffic Changes

- **Proposal method accommodates about 15% more traffic patterns**



Performance against Noise Strength

- **Proposal method with VNT control is adaptable even under drastic traffic fluctuation**



Conclusion and Future Work

- **Proposal**
  - We proposed a design method of WDM network, which determines a set of IP-routers where transceivers should be added
  - The proposed method is inspired from biological evolution so that the network can obtain plasticity
- **Computer simulation**
  - Simulation showed the proposed method makes VNT control more adaptive against unexpected traffic fluctuations
- **Future work**
  - Evaluation on other physical topologies
  - Extension of the method so that it should add other resources
    - not only transceivers of a node but also links between nodes