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Advanced Network Architecture Research Group
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Adaptability of Virtual Network Topology Control based on Attractor Selection

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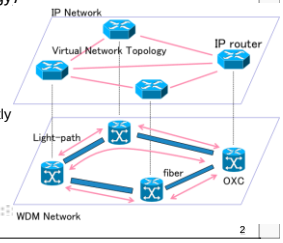
IP-over-WDM network and VNT control

- IP-over-WDM network
  - WDM（Wavelength Division Multiplexing）network
    - Establishing light-paths by wavelength routing
  - VNT (Virtual Network Topology)
    - Configured by light-paths
    - Accommodate IP traffic
- VNT control
  - Configure VNT adaptively
    - Accommodate IP traffic efficiently
    - Use network resource efficiently



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Attractor selection

Change of traffic demand in network become bigger
→Research VNT control based on attractor selection

- Outline of attractor selection
  - Model behavior where living organism adapt to unknown changes
  - Three motivations for defining System movement
    - Noise, Deterministic behavior, Growth rate

System movement Deterministic behavior

$$\frac{dx_i}{dt} = \alpha \cdot f(x_1,\ldots,x_n) + \eta_i$$

Growth rate Noise

Equation of Attractor selection

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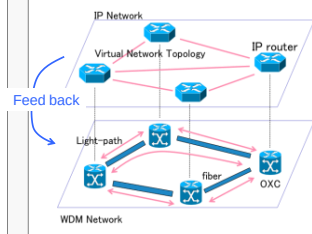
VNT control based on attractor selection



System movement Deterministic behavior

$$\frac{dx_i}{dt} = \alpha \cdot f(x_1,\ldots,x_n) + \eta_i$$

Growth rate Noise

x : variable to decide number of light-path
α: growth rate determined by maximum link utilization
η : noise

Control influences of noise and deterministic behavior by growth rate
→ achieve high adaptability

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Main equation of attractor selection

$$\frac{dx_{ij}}{dt} = \alpha \cdot \left(f\left(\sum_{p_{kl}} W(p_{ij}, p_{kl}) \cdot x_{p_{kl}} - \theta_{p_{ij}} \right) - x_{p_{ij}} \right) + \eta$$

x_{ij} : variable to decide the number of light-path between node pair p_{ij}

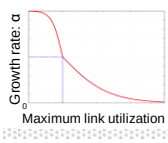
$f(\theta) = \frac{1}{1+e^{-\theta}}$: sigmoid function

$W(p_{ij}, p_{kl})$: regulatory matrix determined by relation of light-path between node pairs

α : growth rate determined by maximum link utilization

⇩

Low maximum link utilization
→influence of regulatory matrix become bigger
High maximum link utilization
→influence of noise become bigger



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Policy of Evaluation

In the past evaluation, simulation conditions were limited and did not evaluate adaptability

→Evaluation adaptability of VNT control based on attractor selection

・Consider about scale of traffic demand change and size of physical topology

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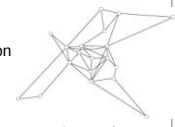
Evaluation models（1/2）

- Simulate by computing
  - Change traffic demand and the variance
  - Measure the change of maximum link utilization
  - Physical topology: EON topology (19 nodes 38 bidirectional links)
  - Compare with “Adaptive” which aims achieving adaptability
    - Use estimated traffic demand matrix
    - Control VNT to put maximum link utilization from 0.1 to 0.5
  - Both methods reconfigure VNT per 5 minutes



EON topology

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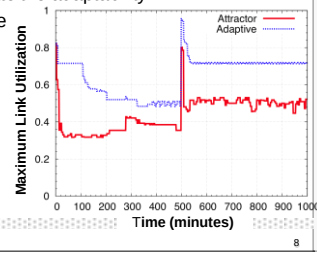
Evaluation models（2/2）

- The traffic demand of P_{ij} follows a lognormal distribution which mean and variance is 1 and σ^2
  - Change σ^2 to evaluate the adaptability
  - Change traffic at time 500
- Conducting the simulation100 times for each value of σ^2



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Rules of evaluation

- Regard that the VNT control is successful when the maximum link utilization is decreased to less than 0.5
- Evaluate the success rate and the time until recovery
  - The adaptability is better as the success rate is higher and the time is shorter

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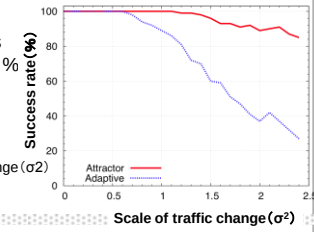
Simulation result – Success rate

- Attractor show high success rate in big traffic change than Adaptive
  - In Attractor, success rate is higher than 80 %
  - In Adaptive, success rate is lower than 30 %

Vertical axis: Success rate
Horizontal axis: Scale of traffic change（σ2）
Red：Attractor
Blue：Adaptive



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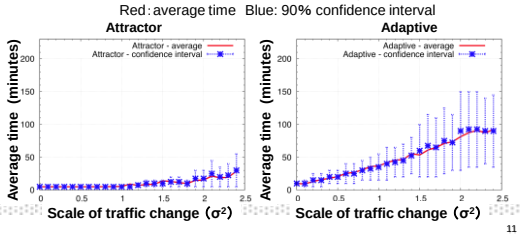
Simulation result – Average time until recovery

- The time until recovery is very shorter than existing method

Vertical axis：average time until recover
Horizontal axis：scale of traffic change（σ²）
Red：average time Blue: 90% confidence interval



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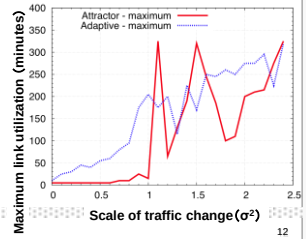
Simulation result – Maximum control duration

- Maximum control duration is big in Attractor when σ^2 is 1.1 and 1.5
  - The noise does not work well in some cases

Vertical axis：
Maximum control duration
Horizontal axis：
Scale of traffic change
Red：Attractor
Blue：Adaptive



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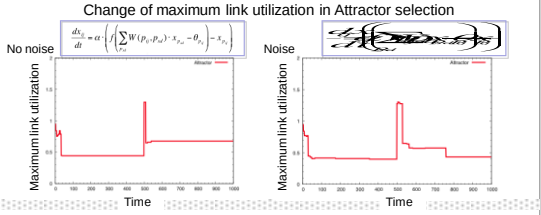
Effect of Noise

- Deterministic behavior has minimum rules
  - Control might find local solution
- Go out from local solution by Noise

Change of maximum link utilization in Attractor selection



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Conclusion and Future work

- Conclusion
  - Evaluation Adaptability when traffic demand change by simulation
  - Our method can adapt more big change than existing heuristic method
  - Achieve about one-tenth of control duration compared with existing heuristic method
  - Observe same tendency in different scale topology
  - In some cases, control duration become long for noise
- Future work
  - Decrease control duration
    - Rethink growth rate function and deterministic behavior