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Advanced Network Architecture Research Group
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Adaptive Virtual Network Topology Control in WDM-based Optical Network

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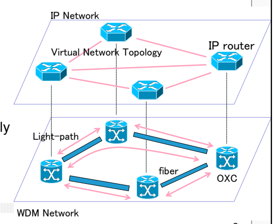
WDM network and VNT control

- WDM (Wavelength Division Multiplexing) network
  - Establish light-paths by wavelength routing
- VNT (Virtual Network Topology)
  - Configured by light-paths
  - Accommodate IP traffic
- VNT control
  - Configure VNT adaptively
    - Avoid overcrowding
    - Accommodate IP traffic efficiently



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Research background and purpose

- The traffic changes unpredictably
  - Increasing traffic volume and influence of many services
  - Need to improve adaptation of VNT control
- Problems of existing VNT control methods
  - Collect traffic demand matrix information
  - High computational complexity
  - Long control duration
- VNT control based on attractor selection
  - We clear the range that our method can be used
  - We evaluate performance of our method by computing
    - How large traffic changes our method can adapt
    - What topologies our method can be used in

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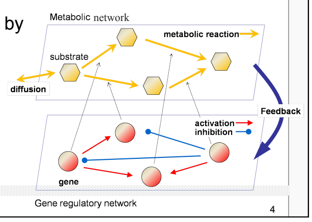
Attractor selection

- Model living organism that adapt to unknown changes [1]
- Function of gene regulatory network and Metabolic network in a cell
  - Genes' working driven by deterministic behavior and Noise
    - Adapt to changes of environment



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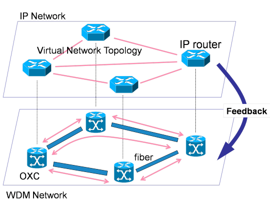
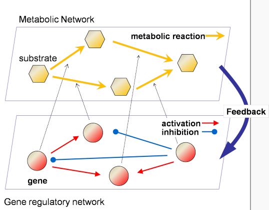
VNT control based on attractor selection





- Apply attractor selection to VNT control
  - Use only maximum link utilization to control VNT as collected information
  - Achieve high adaptability

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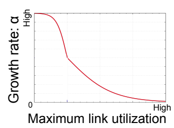
VNT control equation based on attractor selection

Number of light-paths — Noise

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

Growth rate — Deterministic behavior



x_i : number of light-paths in VNT

$f(x_i, \ldots, x_n)$: sigmoid function (having "S" shape function)

α : growth rate determined by maximum link utilization (MLU)
(link utilization: the amount of traffic passing through a light-path)

η : noise (random number follows a normal distribution)

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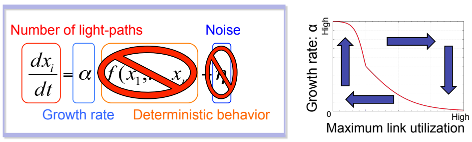
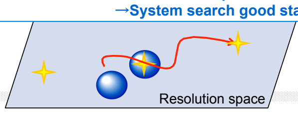
Simple example of VNT control based on attractor



High maximum link utilization → Noise drive system
→**System search good state randomly**



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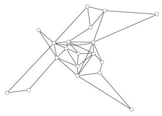
Simulation model

- Physical topology: EON topology (19 nodes 38 bidirectional links)
- Compare with existing heuristic method "Adaptive" which is also developed to achieve adaptability
  - Use estimated traffic demand matrix
  - Control VNT to put link utilization from 0.1 to 0.5
- Traffic demand of each node pair follows a lognormal distribution whose mean is 1 and variance is σ^2
  - Generate new traffic at 500 minutes



EON topology

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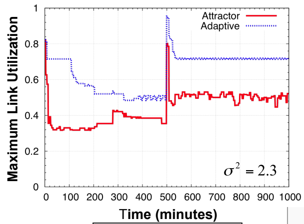
Evaluate metric

- Change σ^2 to evaluate the adaptability
- Conduct the simulation 100 times for each value of σ^2
- Success ratio
  - Set target MLU to 0.5
  - Regard successful when MLU decrease to less than 0.5
- Time until recovery
  - Measure the time from when the traffic change occurs to when VNT control succeeds (exclude the data when failed)



one typical result

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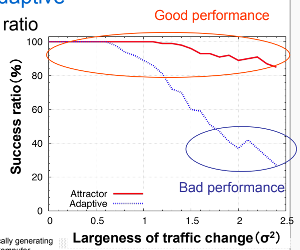
Simulation result – success ratio

- "Attractor" shows higher success ratio in large traffic change than "Adaptive"
  - In "Attractor", success ratio is higher than 80 %
  - In "Adaptive", success ratio is lower than 30 %

σ^2 is nearly 1 for fitting the observed traffic in real ISPs [*].



[*] A. Nucci, A. Sridharan, and N. Taft, "The problem of synthetically generating IP traffic matrices: Initial recommendations," *ACM SIGCOMM Computer Communication Review*, vol. 35, pp. 19–32, July 2005.

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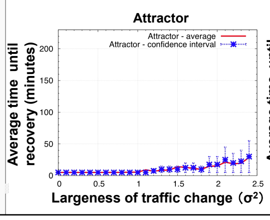
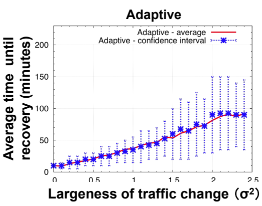
Simulation result –time until recovery

- The time until recovery is much shorter in Attractor
- The confidence interval is narrower in Attractor
  - Estimation errors occur in Adaptive





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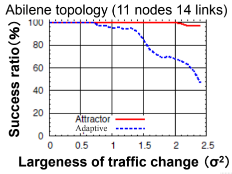
Simulation results in other topologies

- Attractor can adapt to large traffic changes in different topologies
  - The performance doesn't depend on the topology form and the topology scale

Abilene topology (11 nodes 14 links)



Random topology (100 nodes 200 links)

σ^2	Success ratio (%)
2.0	100
2.1	100
2.2	98
2.3	98
2.4	97

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Conclusion and future work

- Conclusion
  - We evaluate adaptability against traffic changes
  - Attractor can adapt to larger changes than the existing heuristic method
  - Attractor achieve about one-tenth of control duration compared with the existing heuristic method
  - We confirm the same tendency in different topologies
- Future work
  - Investigate automatic parameter setting mechanism
    - E.g., according to degree of traffic changes

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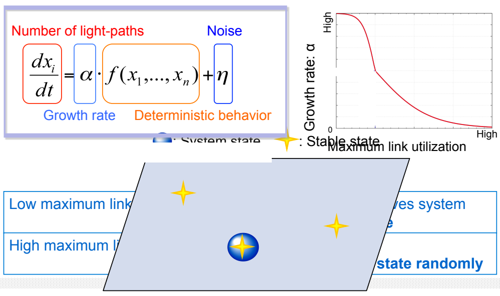
Simple example of Attractor



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Research purpose

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Evaluation metric

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Attractor selection in gene regulatory networks

- Formulate the generic mechanism[1]
- The network is driven by three main factors
  - Deterministic behavior
  - Noise
  - Growth rate (feedback)

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

Gene — Deterministic behavior — Growth rate — Noise

Equation of Attractor selection

- When growth rate of the network is small, the network is driven by noise

[1] C. Furusawa and K. Kaneko, "A generic mechanism for adaptive growth rate regulation," *PLoS Computational Biology*, vol. 4, p. e3, Jan. 2008.

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