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A method for updating attractor sets in noise-induced virtual network topology control

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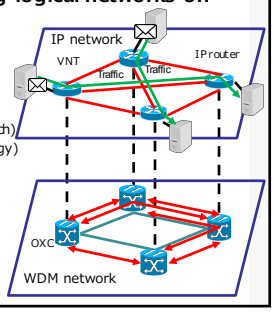
Research Background

- **Many people enjoy various services through the Internet.**
  - e.g., video streaming, cloud services
- **That causes large fluctuations of traffic demands.**
- **A network needs flexibility to accommodate the unstable traffic demands.**

- **Virtual network infrastructures are expected.**
  - Change virtual networks flexibly and accommodate the unstable traffic demands

Virtual Network Infrastructure

- **Virtual Network is provided to clients by dividing physical resources and making logical networks on demand.**
- **e.g., IP over WDM network**
  - WDM network
    - Establish lightpaths between IP routers via Optical Cross Connect (Optical Switch)
    - Construct VNT (Virtual Network Topology) consisting of lightpaths
  - IP network
    - Accommodate IP traffic on VNT
    - **VNT control: Reconstruct VNT adaptively to traffic changes**



Approach to VNT Control

- **Centralized Approach**
  1. Set a management node to control network topology
  2. Collect the information of traffic demands for a long time
  3. Calculate the optimal or sub-optimal VNT using the information
  - Shortcomings
    - The amount of "input" information gets larger as the size of network increases.
      - "input" information : usually, a traffic demand matrix
    - It is difficult to adapt to the fluctuations quickly because it takes a long time to get "input" information.
- **VNT control based on attractor selection**
  - Quickly adapt to traffic changes with a little information about the state of a network instead of traffic demands
  - Application Examples
    - SDI (Software Defined Infrastructure)-based VNT control : Koki Inoue, et al. "Adaptive VNE method based on Yuragi principle for software defined infrastructure" *High Performance Switching and Routing (HPSR), 2016 IEEE 17th International Conference on* IEEE, pp. 188-193 June 2016.
    - WDM (Wavelength Division Multiplexing)-based VNT control : [7] Y. Koizumi, T. Miyamura, S. Arakawa, E. Oki, K. Shiomoto, and M. Murata, "Adaptive virtual network topology control based on attractor selection," Journal of Lightwave Technology, vol. 28, pp. 1720–1731, June 2010.

VNT control based on attractor selection

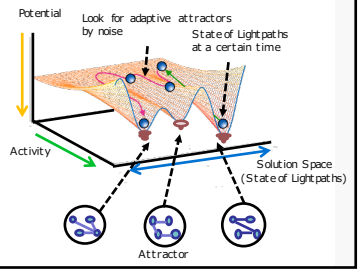
- **Control a state of lightpaths based on attractor selection model**
  - Prepare attractors in advance and create the potential field

Dynamics of our VNT control

$$\frac{dx_i}{dt} = \alpha \cdot f(x) + \eta$$

(Attractor Structure: $f(x)$; activity: α; noise: η)

$x = (x_1, x_2, \ldots, x_n)$: State of lightpaths
x_i : State of the i-th lightpath (l_i)
$x_i \geq 0$: Establish l_i
$x_i < 0$: Tear down l_i
α : Activity (Conditions of IP network)
e.g., Maximum Link Utilization
$f(x)$: Attractor Structure
η : Noise



Dynamics of our VNT control method

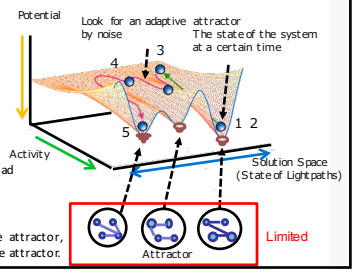
- **Find a solution to accommodate IP traffic by properly using attractor structure and noise based on activity**

Dynamics of our VNT control

$$\frac{dx_i}{dt} = \alpha \cdot f(x) + \eta$$

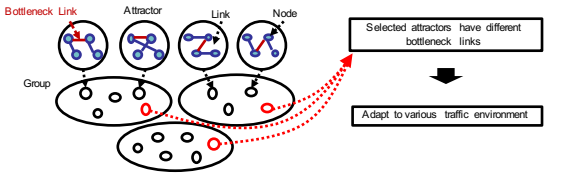
(Attractor Structure: $f(x)$; activity: α; noise: η)

Example
1. Initial state of the system
2. Traffic environment changes
3. The condition of IP network gets bad
   - Activity gets lower
4. Randomly change own state and look for a adaptive attractor
5. When the system finds an adaptive attractor, the state converges to the adaptive attractor.



Method for designing attractors [8]

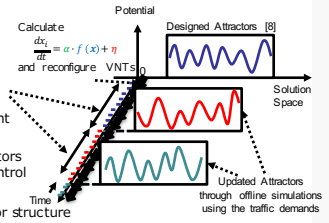
- **Classify attractors that have different bottleneck links into different groups, and pick up an attractor from each group**
  - Use Edge Betweenness Centrality as topological characteristic
    - Edge Betweenness Centrality : The number of shortest paths via the link
  - Bottleneck link has high Edge Betweenness Centrality



[8] T. Chiba, S. Arakawa, Y. Kitani, and M. Murata, "Scalable design method of attractors in noise-induced virtual network topology control," IEEE/OSA Journal of Optical Communications and Networking, vol. 7, pp. 851-863, Sept. 2015.

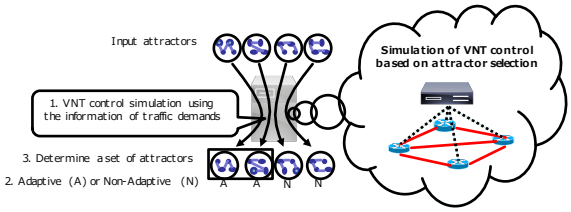
Research Purpose

- **A problem of the existing method**
  - The existing method [8] designs attractors based on topological characteristics, but the time to find a solution may increase depending on the traffic situation.
- **Update to a set of adaptive attractors to the traffic environment, and reduce the time to find a solution**
- **Approach**
  - Attractor update assumes longer period than VNT control
  - Get the traffic demand through long-term observation
  - Create offline traffic environment using the traffic information
  - Decide a set of adaptive attractors by offline simulation of VNT control
  - Update to the adaptive attractor structure



Method for updating a set of attractors

- **Decide a set of attractors for update by simulating VNT control based on attractor selection**
  - We create the same simulation environment as the actual environment.
  - In the simulation environment, we decide adaptive attractors from many attractors prepared in advance.

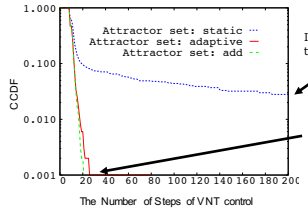


Performance Evaluation

- **Evaluation Index**
  - The number of steps of VNT control to find a solution
    - Solution: a VNT that satisfies 50% or less MLU (Max Link Utilization)
- **Traffic Environment**
  - 1,000 patterns of traffic demand matrices
    - Each component follows log-normal distribution
- **Evaluation Object**
  - ϕ_{static}: A set of attractors prepared by the existing design method
  - $\phi_{adaptive}$: A set of attractors prepared by removing non-adaptive attractors from ϕ_{static}
  - ϕ_{add} : A set of attractors prepared by adding extra adaptive attractors to $\phi_{adaptive}$
- **Adaptive or Non-Adaptive**
  - Adaptive : The success rate of VNT control at 15 steps is more than 50%.
  - Non-Adaptive : Otherwise

Evaluation Results

▼ The number of steps of VNT control by the time to find a solution when 1,000 patterns of traffic demands are given



In about 30 patterns of traffic environment, the system cannot find solutions.

- In all patterns of traffic environment, the system can find solutions by about 20 VNT controls.
- The difference between $\phi_{adaptive}$ and ϕ_{add} is very small.

$\phi_{adaptive}$, removing non-adaptive attractors from the existing attractor set, is the most effective and efficient.

Summary and Future Work

- **Summary**
  - Research background
    - Traffic on the Internet is fluctuating and VN infrastructures are expected.
  - VNT control based on attractor selection
    - Look for a solution to accommodate IP traffic by properly using attractor structure and noise based on activity
  - The problem of the existing design method
    - The existing design method [8] designs attractors based on topological characteristics, but the time to find a solution may increase depending on the traffic situation.
  - Our proposal
    - Update to a set of adaptive attractors to the traffic environment through offline simulation
  - Evaluation results
    - Just by removing non-adaptive attractors, the system can adapt quickly and efficiently to the new traffic environment.
- **Future Work**
  - Take measures if we cannot get the information of traffic demands