On the stability of virtual network topology control for overlay routing services

Yuki Koizumi*, Takashi Miyamura**, Shin'ichi Arakawa*, Eiji Oki**, Kohei Shiomoto** and Masayuki Murata*

* Graduate School of Information Science and Technology, Osaka University, Japan
** NTT Network Service Systems Laboratories, Japan

Outline

- Interaction between Virtual Network Topology control and overlay routing
- To improve the stability and the performance
- Simulation result

Virtual Network Topology Control

- Virtual Network Topology control
  - Constructs an (sub-)optimal VNT for measured traffic demand matrix by configuring lightpaths
  - To balance load or remove bottlenecks in the network
- Overlay routing is performed above the VNT

Overlay Routing

- Overlay routing
  - Constructs a logical topology on the underlying network
  - Performs its routing on that topology
- Advantage of overlay routing
  - Enhances functionality (QoS, resilience,....) without modifying the underlying network (IP network)
  - Is easily deployed
- Disadvantage of overlay routing
  - Overlay routing and existing routing approaches select their routes independently
  - Interaction between these routing approaches

Interaction Between TE and Overlay Routing

- Interaction between MPLS-based TE and overlay routing [Liu05]
  - The performance of TE is degraded
  - The performance of overlay routing is degraded depending on physical topologies
- Confliction between two different routing objectives
  - TE: optimize the performance of the whole network
    - E.g., minimizing maximum link utilization
  - Overlay: optimize the performance of the each overlay node or the overlay network
    - E.g., minimizing end-to-end delay, maximizing end-to-end throughput

Interaction Between VNT control and Overlay Routing

- The routing objective of VNT control is also different from that of overlay routing
  - The same interaction will occur
- The interaction will lead to
  - Degradation of the efficiency of VNT
  - Overlay routing changes the traffic demand matrix
  - The current traffic demand matrix is different from the traffic demand matrix used for constructing the VNT
- No solution to overcome the instability caused by this interaction has been proposed
- Our objective
  - To improve the stability and the performance of VNT control against overlay routing
- Approaches
  - Hysteresis

Interaction Between VNT control and Overlay Routing

Overlay routing constructs a logical topology on the IP network, and the IP network uses the VNT as its infrastructure.

VNT control constructs a VNT on the WDM network, and the traffic demand on the overlay network is computed.

Overlay network changes to the new route (red line), and the delay of the red route is shorter than that of the blue route.

Traffic demand is divided according to overlay routing, and the overlay routing causes the changes in the traffic demand matrix.

VNT control regenerates a VNT to adapt the changes in the traffic demand matrix due to overlay routing.

Overlay network changes the route, and the delay of the red route is shorter than that of the blue route.

The interaction leads to the instability of traffic demand, link utilization, and so on.
Hysteresis

- **Hysteresis is**
  - A property of a system that does not immediately react against changes in the environment
  - Used to increase tolerance against noise
- **Apply hysteresis to VNT control to improve the stability of VNT control**
  - Demand hysteresis
    - Apply hysteresis to traffic demand
    - Absorb heavy fluctuation of the traffic demand due to overlay routing
  - Utilization hysteresis
    - Apply hysteresis to link utilization

Utilization Hysteresis (Result)

- For \( \alpha = 0.2, N = 0.2 \)
  - Increase the ratio of overlay traffic
  - Only the fluctuation due to overlay routing appears
  - Stability is improved, but link utilization is still high
  - Hysteresis threshold \( h \) does not control the utilization in the stable state.

- For \( \alpha = 0.3, N = 0.2 \)
  - Stability is improved
  - Link utilization is still high

Estimate the maximum link utilization on the new VNT, \( u^h \), before using it

- Compare \( u^l \) with the current maximum link utilization, \( u \)
  - Only if the improvement in the link utilization is larger than \( H u \), the new VNT is used
  - Otherwise, the current VNT is kept using

Utilization Hysteresis

- Reduce unnecessary topology changes
  - Improve the stability of the network
  - Change to the new VNT even if improvement is small
  - Keep using the current VNT if improvement is smaller than \( H u \)
  - Change to the new VNT only if improvement is larger than \( H u \)

Two-state Utilization Hysteresis

- To improve both stability and performance
  - Limit the range where utilization hysteresis is applied
  - Avoid VNT control slipping into the stable state when the maximum link utilization is high
- Utilization hysteresis is applied to VNT control only when the current maximum link utilization is lower than \( \theta \)
  - \( \theta = u - (u - u^h)/k \)
  - \( u^l, u^h \): the maximum and minimum value of maximum link utilization
  - \( u^l \), \( u = u^l \), and \( u^h \) are updated at every round of VNT control
  - \( k \): control parameter
- The range where hysteresis is applied
Two-state Utilization Hysteresis (Result)

- $\alpha = 0.3$
- $H = 0.2$
- Hysteresis

Two-state hysteresis ($k = 3$)

It takes long time until VNT control converges to the stable state because hysteresis is applied in only a limited range.

Large $k$ strongly restricts the range. Though the utilization in the stable state is low, the convergence is slow.

Improves both stability and performance

Summary

- Interaction between VNT control and overlay routing
  - Degrade the stability and performance of the network
- To improve stability and performance
  - Apply hysteresis to VNT control
- Utilization hysteresis
  - Improves the stability
  - Does not always improve the performance
- Two-state utilization hysteresis
  - Improves both the stability and the performance
- Future work
  - Achieve fast convergence for two-state utilization hysteresis