Osaka University NTT

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

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Outline

- Interaction between Virtual Network Topology control and overlay routing
  - Conflict two different routing objectives
  - Degrade stability and performance of the network
- To improve the stability and the performance
  - Introduce "hysteresis" to VNT control
- Simulation result
  - Hysteresis improves the stability
  - Two-state hysteresis improves both the stability and the performance

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

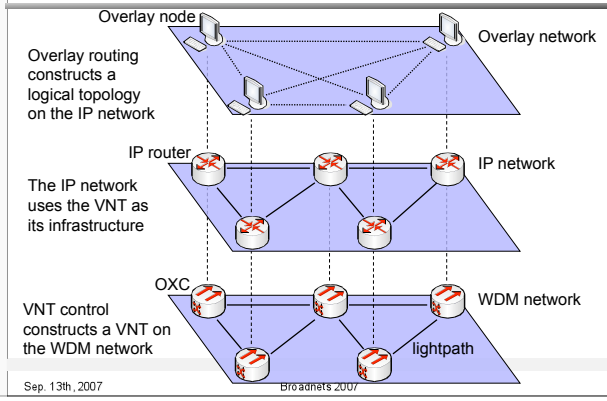
- Interaction between MPLS-based TE and overlay routing [Liu05]
  - The performance of TE is degraded
  - The performance of overlay routing is degraded depending on physical topologies
- Confliction between two different routing objectives
  - TE: optimize the performance of the whole network
    - 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

[Liu05] Y. Liu, H. Zhang, W. Gong, and D. Towsley, "On the interaction between overlay routing and underlay routing," in *Proceedings of IEEE INFOCOM*, pp. 2543–2553, Mar. 2005.

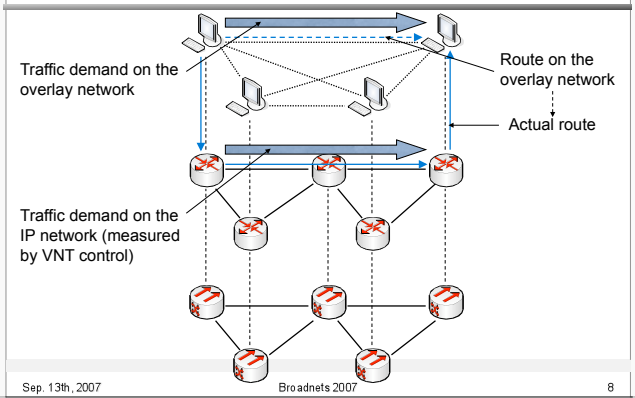
Interaction Between VNT control and Overlay Routing

- 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



Interaction Between VNT control and Overlay Routing



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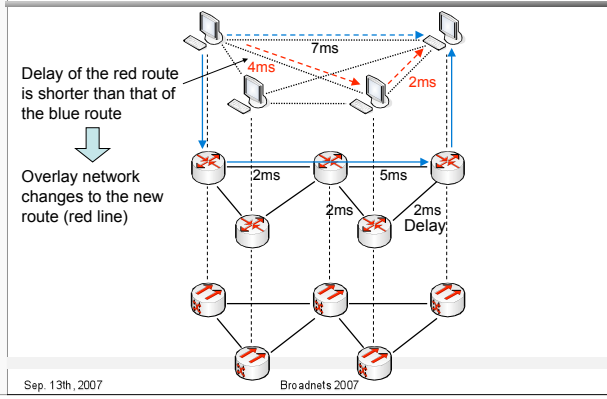

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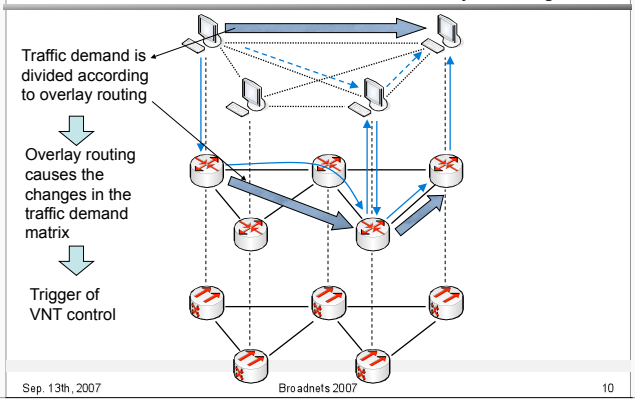

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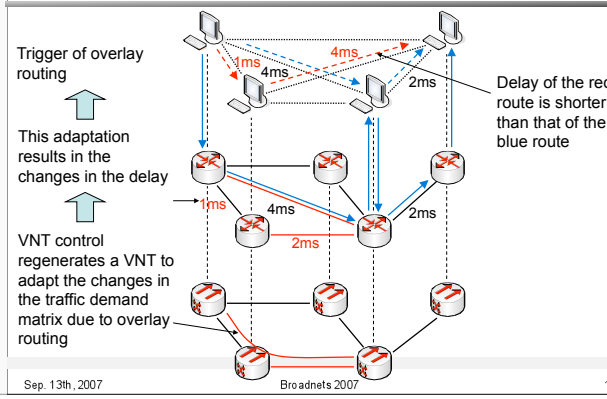

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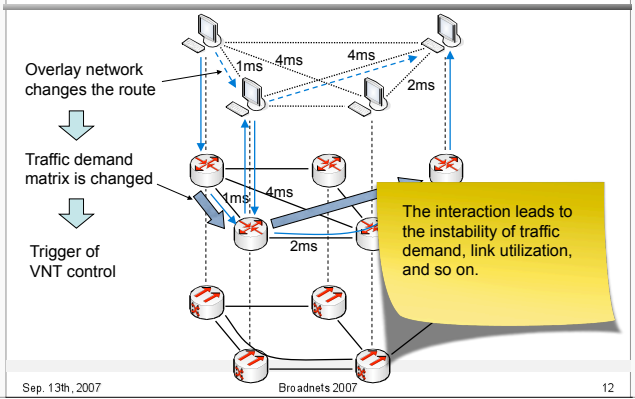
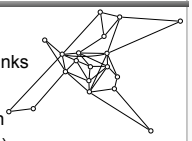
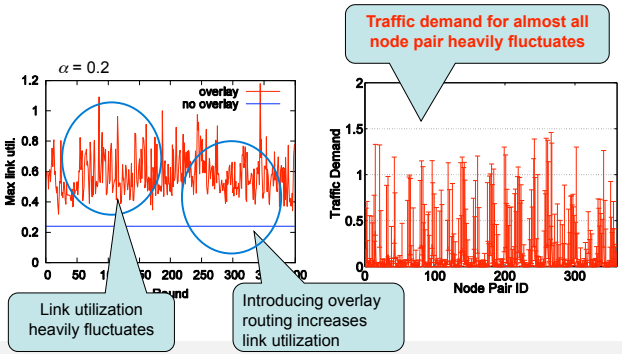


Simulation Model



- Physical topology
  - European Optical Network: 19 nodes and 39 links
- Network model
  - VNT control: minimize maximum link utilization
  - IP routing: minimum hop routing (static routing)
  - Overlay routing: Select routes that has the maximum available bandwidth
- Initial traffic demand matrix
  - Generate randomly
  - Overlay traffic demand: a proportion (α) of the total traffic demand
- Performance metric
  - Maximum link utilization

Instability of Link Utilization

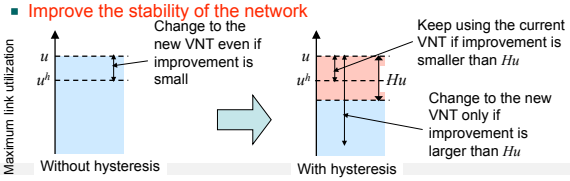


Hysteresis

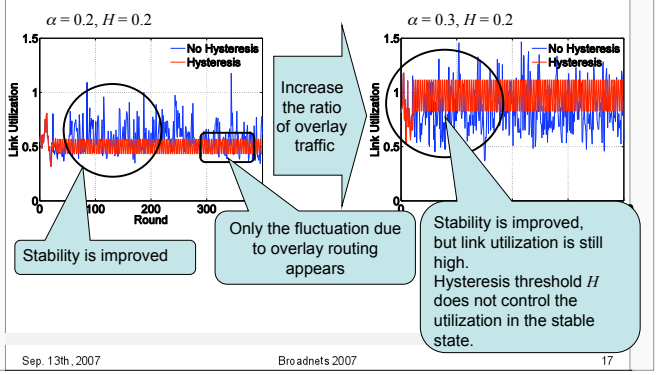
- Hysteresis is
  - A property of a system that does not immediately react against changes in the environment
  - Used to increase tolerance against noise
- Apply hysteresis to VNT control to improve the stability of VNT control
  - Demand hysteresis
    - Apply hysteresis to traffic demand
    - Absorb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

Utilization Hysteresis

- Estimate the maximum link utilization on the new VNT, u^h, before using it
- Compare u^h 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
- Reduce unnecessary topology changes
  - Improve the stability of the network

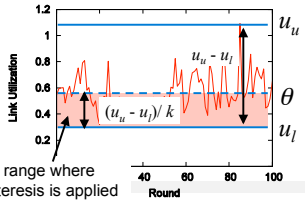


Utilization Hysteresis (Result)

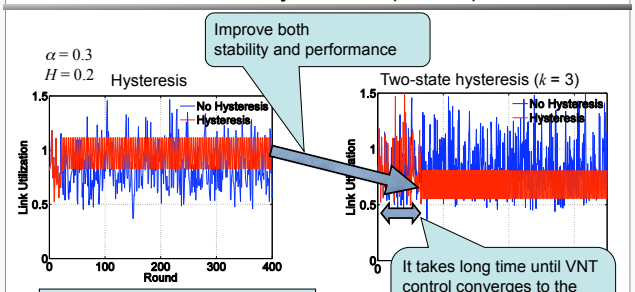


Two-state Utilization Hysteresis

- 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 θ
  - $\theta = u_l + (u_u - u_l)/k$
    - u_u, u_l: the maximum and minimum value of maximum link utilization
    - u_u and u_l are updated at every round of VNT control
    - k: control parameter



Two-state Utilization Hysteresis (Result)



Improve both stability and performance

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

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

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