"Free-riding" Traffic Problem in Routing Overlay Networks

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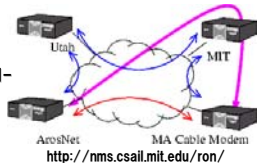
Overlay networks

- Various network services provided by overlay networks (service overlay networks)
  - CDN, Grid, Application-Level Multicast (ALM), VPN, Anonymous file sharing, …
- Requirements for underlay IP networks
  - Delay, jitter, bandwidth, packet loss rate, TCP throughput, …
  - Overlay applications perform measurements to maintain their service quality
    - Streaming services with delay and delay-jitter measurements
    - Server selection and parallelizing TCP sessions based on throughput results of previous transmissions
    - Locating contents cache/mirror based on delay and bandwidth characteristics

Overlay routing

- Overlay routing: upper-layer traffic routing to enhance user-perceived end-to-end network performance
  - Concentrates only on traffic routing
  - Does not assume specific upper-layer applications
- Example:
  Resilient Overlay Network (RON)
  - Full-mesh measurement of end-to-end network performance
  - Select overlay-level traffic routing path based on the measurement results



http://nms.csail.mit.edu/ron/

[4] D. G. Andersen, H. Balakrishnan, M. F. Kaashoek, and R. Morris, "Resilient overlay networks," in *Proceedings of 18th ACM Symposium on Operating Systems Principles*, Oct. 2001.

Effect of overlay routing

- Reduction of end-to-end delay
  - 40% node-pairs in U.S. network [*]
  - 20% node-pairs in JAPAN network [6]
  - Especially effective to reduce maximum delay
- Recovery from network failures
  - BGP requires recovery time proportional to hop counts
    - It may takes minutes to hours for routing table convergence
  - RON can detect and recover from network failures in seconds, independent on hop counts

[*] Akihiro Nakao, 'Network Embedded Test-beds for New Generation Network Research,' Overlay Network Symposium, December 2006.
[6] M. Uchida, S. Kamei and R. Kawahara, 'Performance Evaluation of QoS-aware Routing in Overlay Network,' in Proceedings of ICOIN 2006, January 2006.

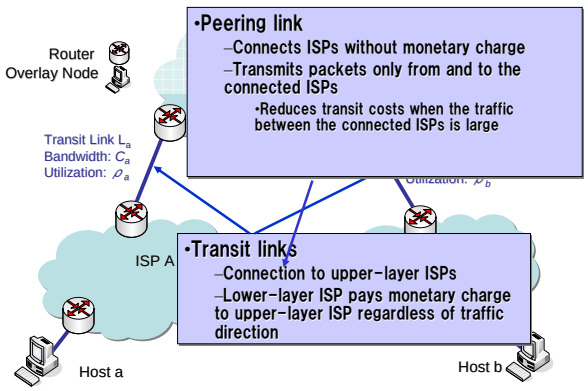
Policy mismatch between overlay routing and IP routing

- Overlay routing
  - Configured to improve user-perceived end-to-end network performance
- IP routing
  - Does not consider user-perceived performance directly
  - Most of BGP routing decisions are based on monetary and political relationships between ISPs
- This difference may generate the traffic which ignores ISPs' monetary cost structure
  - Free-riding traffic

Objectives of this work

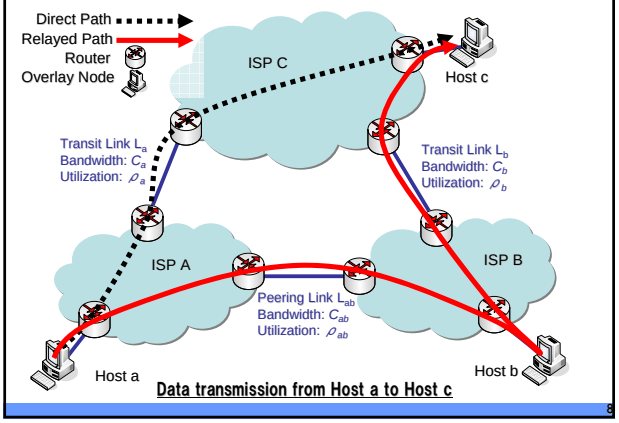
- Focus on free-riding traffic problem caused by overlay routing networks
  - Simple problem definition
  - Formulation of the amount of free-riding traffic
- Numerical examples using PlanetLab measurement data
  - Effectiveness of overlay routing
  - Estimation of the amount of free-riding traffic

Network model



7

Network model



Data transmission from Host a to Host c

8

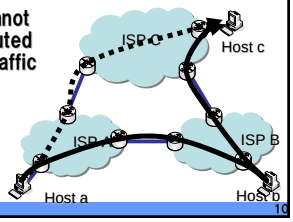
Who pays monetary costs for the data transmission?

- Using direct path between Host a and Host c
  - Host a in ISP A transmits the data using ISP A's transit link
  - Cost of conveying the traffic is charged to ISP A
  - ISP A can collect the cost from Host a
- Using relayed path via Host b
  - Host a in ISP A transmits data using the peering link between ISP A and B, and ISP B's transit link
  - Cost of conveying the traffic is charged only to ISP B
  - ISP B can not collect the cost from Host a because Host a has no relationship to ISP B
- Free-riding traffic problem

9

Possible solutions

- Can ISP B collect the cost from Host b, since Host b relays the traffic?
  - Difficult, because in many cases Host b is not aware of the relayed data
- Can ISP B collect the cost from ISP A, since the relayed traffic is generated from ISP A's host?
  - Difficult, because we cannot separate the overlay-routed traffic from the normal traffic between ISP A and B
    - src: Host a, dst: Host b



10

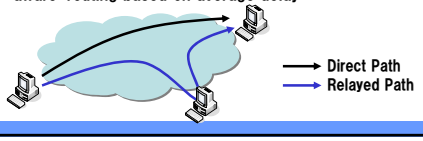
Analysis

- The analysis results of the amount of overlay-routed traffic on relayed path
- Two types of overlay routing metrics
  - Bandwidth-aware: routing based on available bandwidth
  - Delay-aware: routing based on average delay

11

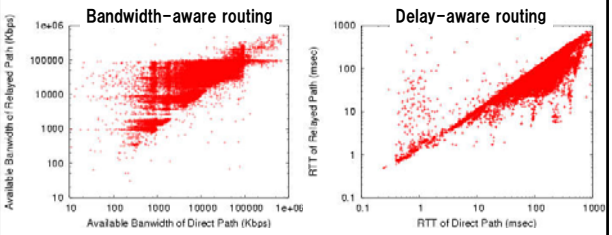
Numerical examples

- Scalable Sensing Service project in PlanetLab
  - http://networking.hpl.hp.com/s-cube/
  - Full-mesh measurement data of delay, loss, and bandwidth between 700 PlanetLab nodes are available
- For each node pair, we compare:
  - Delay and available bandwidth of direct path and relayed path
  - For relayed path, we plot the best case from all possible candidates
- Overlay routing metric:
  - Bandwidth-aware: routing based on available bandwidth
  - Delay-aware: routing based on average delay



12

Effectiveness of overlay routing



- In 96.2% node pair for bandwidth, and 96.3% node pair for delay, we can find the relayed path which has better performance than the direct path
- Bandwidth-aware routing has larger advantage than delay-aware routing
  - Effect of IP routing which is configured based on hop-counts

13

Amount of relayed traffic

	Ratio of available bandwidth	Path with larger available bandwidth
Best relayed path	72.8%	96.2%
Good relayed path	58.5%	96.2%
All relayed path	49.2%	22.6%

- Significant amount of overlay traffic is conveyed by relayed paths
- All relayed paths are not free-riding path, which depends on the type (transit/peering) of inter-ISP links
  - When at least one transit link is used, the path may covey the free-riding traffic
  - When all links are peering links, the path is not free-riding path, but the additional cost for conveying such traffic cannot be ignored

14

Conclusions

- Free-riding traffic problem caused by overlay routing
  - Problem definition and formulation
  - Has large impact on ISP's monetary cost structure
- Future work
  - Deeper investigation with PlanetLab data
    - Considering the effect of link type between ISPs
  - Methods how to detect free-riding traffic
  - ISP's monetary structure to overcome the increase of overlay-routed traffic

15