Decreasing ISP transit cost in overlay routing based on multiple regression analysis

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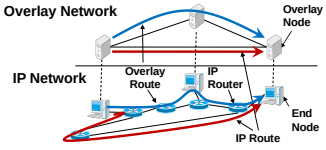
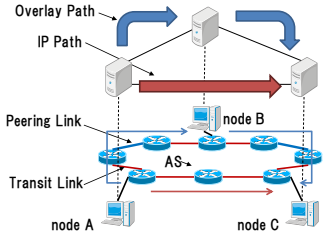
Background



- Overlay Routing
  - A routing mechanism provided by overlay network
  - Improve end-to-end network performance
    - Using application level routing with user-perceived metrics such as end-to-end latency and available bandwidth
    - Performance gain is mainly based on the policy mismatch between IP routing and overlay routing
      - IP routing is based on router hop count, AS hop count and commercial contracts with neighboring ISPs
      - Overlay routing is based on user-perceived metrics

Problem definition: Increasing transit cost

- With overlay routing, there is a possibility of using additional transit links
  - This increases transit cost in the whole network



• Normal IP routing utilize two transit links

• When an overlay routing selects the path via node B, it traverses four transit links

⇩

Transit cost increases

Our goal

Propose a method to decrease ISPs' transit cost in overlay routing

- Estimate the number of transit links with end-to-end network performance values which can be measured easily by overlay nodes
  - Using multiple regression analysis of these values
- Select an overlay-level route with the estimated number of transit links as the metric
  - While decreasing transit costs, the proposed method should maintain the performance improvement provided by overlay routing

Approaches to the goal

- There is no public information of relationships between ASes
  - But the number of transit links may be estimated by performance values which can be measured easily

Investigate the correlation between the number of transit links and these performance values
(router-level hop count, end-to-end latency, available bandwidth)
⇨ Then we select parameters for multiple regression analysis

⇩

To decrease ISPs' transit cost, we limit the number of transit links used by overlay routing using the equation calculated by multiple regression analysis

Dataset (1)

- Assume the overlay network is constructed of PlanetLab nodes, and use the following dataset
  - End-to-end latencies and available bandwidths between nodes
    - *Scalable Sensing Service* (S^3) [1]
      - Measurement results between PlanetLab nodes, which are summarized every four hours, are available
  - IP-level and AS-level paths between nodes
    - Conduct traceroute commands to obtain IP-level paths and convert these results into AS-level paths with AS number and IP address prefix database on *RouteViewsProjcet*

[1] Hewlett-Packard Laboratories, "Scalable Sensing Service," available at http://networking.hpl.hp.com/s-cube/.

Dataset (2)

- Number of transit links on each path between nodes
  - Obtain the relationship information between ASes from CAIDA
    - We can obtain the type of links between ASes such as "transit link" or "peering link" from the relationship information
    - These relationship information is mainly estimated by the degrees of ASes and the constrain of inter-AS topology based on the commercial contracts [2]
  - We consider the number of transit links obtained from this database as "true" number of transit links on the path

[2] University of California, "CAIDA," available at http://www.caida.org/home/.
[3] X. Dimitropoulos, et al., "As relationships: inference and validation," SIGCOMM Comput. Commun. Rev., vol. 37, no. 1, pp. 29-40, 2007.

Routing metrics on overlay routing (1)

- The overlay routing selects a path with these metrics

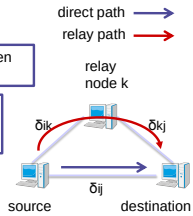
End-to-end latency

$$D^1_{ij} = \delta_{ij}$$
$$D^2_{ikj} = \delta_{ik} + \delta_{kj}$$
$$\hat{D}^2_{ij} = \min_{k \neq i,j} \left(D^2_{ikj}\right)$$
$$I(D^2_{ij}) = D^1_{ij} / \hat{D}^2_{ij}$$

the sum of latencies between each node pair

the smallest latency path among available paths as the best relay path

the improvement ratio which is the ratio of the best relay path to the direct path



Routing metrics on overlay routing (2)

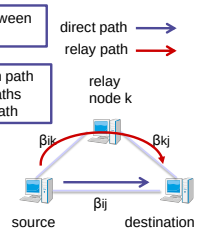
Available bandwidth

$$B^1_{ij} = \beta_{ij}$$
$$B^2_{ikj} = \min(\beta_{ik}, \beta_{kj})$$
$$\hat{B}^2_{ij} = \max_{k \neq i,j} \left(B^2_{ikj}\right)$$
$$I(B^2_{ij}) = \hat{B}^2_{ij} / B^1_{ij}$$

the smallest bandwidth between each node pair

the largest bandwidth path among available paths as the best relay path

the improvement ratio which is the ratio of the best relay path to the direct path

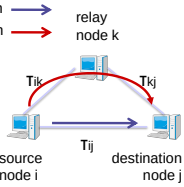


The limitation of the transit links

- The proposed method limits the number of transit links

$$T^1_{ij} = \tau_{ij}$$
$$T^2_{ikj} = \tau_{ik} + \tau_{kj}$$
$$T_{ikj} \leq T_{ij} + \alpha$$
$$\alpha = 0, 1, \ldots, n$$

the sum of the number of transit links between each node pair



This equation means the limitation of the number of transit links, where α is the upper limit of the increase in the number of transit links comparing with that of direct path (T_{ij})

Correlation between the true number of transit links and other metrics

- Calculate the correlation coefficients between the true number of transit links and each network

Utilize router-level hop count and end-to-end latency as the parameters for multiple regression analysis, from the viewpoints of calculation complexity and accuracy of regression analysis

Correlation coefficients

Router-level hop count	0.420
End-to-end latency	0.300
Available bandwidth	-0.027

Multiple regression analysis

- Calculate the regression equation with multiple regression analysis
  - The estimated number of transit links in PlaneLab environment (11/12/2008) is described below

$$T_{ij}^{e} = 0.1419h_{ij} + 0.002482\delta_{ij} + 1.136$$

Router-level hop count between each node pair

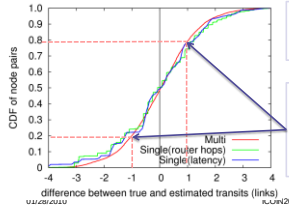
End-to-end latency (ms) between each node pair

Estimation accuracy

- Estimation accuracy of the regression equation with the value

$$d_{ij} = T_{ij}^{t} - T_{ij}^{e}$$

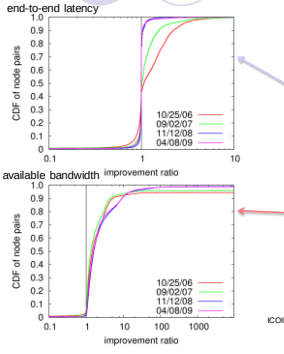
the true number of transit links between node i and j



The multiple regression equation has high accuracy comparing with other single regressions

The regression equation can estimate where estimation error is lager than 1 with 80% of node pairs, and smaller than -1 with 80% of node pairs

Results: Year-by-year changes in overlay routing efficiency

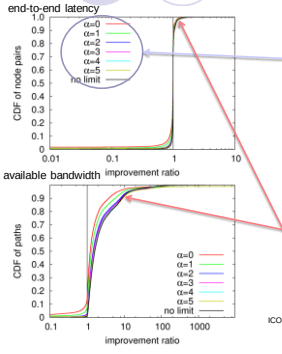


The improvement degree on 10/25/06 is largest, and it decreases year-by-year.

One possible reason is the decrease in the degree of "distorted" routing configurations due to commercial inter-ISP relationships

There are large improvements on all years

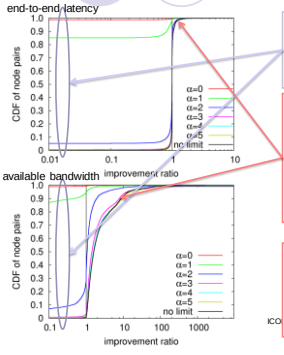
Results: Efficiency of the overlay routing with the limitation of the true number of transit links



Parameter α is represents the limitation of the number of transit links equal to or less than direct path's plus α

There are little improvements with end-to-end latency as the metric, however, on the whole including the case of available bandwidth, it has the same improvement degree when parameter α is equal to or larger than three

Results: Efficiency of the overlay routing with the limitation of the estimated number of transit links



When α is equal to or less than two there are some node pairs they can not find any path which can satisfy the constrain of transit links

When α is equal to or larger than three, the overlay routing can get the same improvement degree as that without the limitation, and this means the same improvement degree as that with the true number of transit links

Our method can achieve the same improvement degree as that with the true number of transit links, without the information of the true number of transit links

Conclusion & future works

- Conclusion
  - Propose the method decreasing ISPs' transit cost in overlay routing
    - Using the multiple regression analysis with the network performance values which can be measured easily, we limit the number of transit links on the path selected by overlay routing
  - Give the numerical evaluation results on PlanetLab environment
    - While our method can limit the increase of the number of transit links equal to or larger than three, achieving the same improvement degree as that without the limitation
- Future works
  - Improve the accuracy of the regression equation considering outlier values
  - Consider different mechanism such as P4P to decrease ISPs' cost