Accuracy improvement for spatial compotision-based end-to-end network measurement

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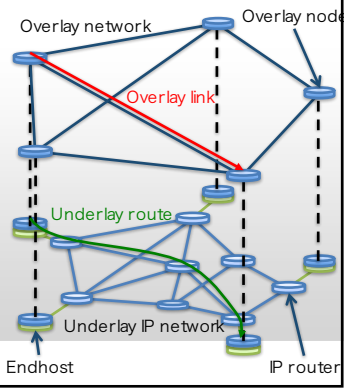
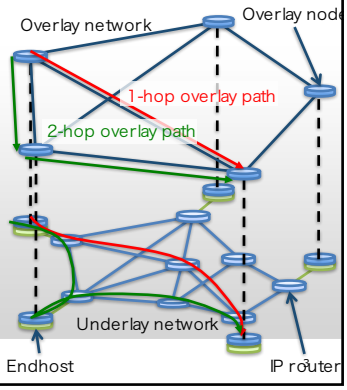
Overlay network

- Application-level logical network build upon the under-layer IP network
- An overlay link corresponds to an IP route in underlay network



Application traffic control on overlay network

- Application-layer traffic routing on the overlay network
  - No need to change IP routing configurations
- Measuring network performance between overlay nodes is important to provide good route to upper-layer applications

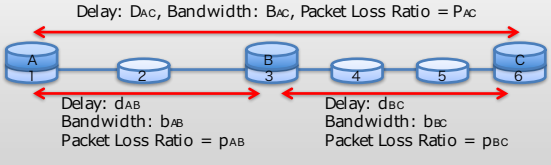


Measuring overlay network paths

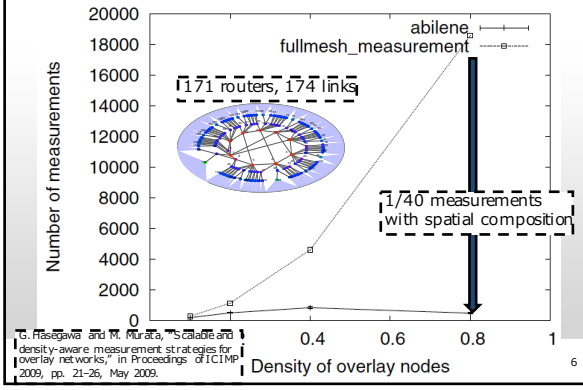
- *N*×*(N-1)* overlay links (paths) can be chosen in overlay network with *N* overlay nodes
  - Overhead for measuring overlay paths quickly increases as the number of overlay nodes increases
  - Multiple overlay paths share the under-layer IP routers and links
    - Measurement overhead on routers/links increases
    - Accuracy of measurements degrades due to measurement overlaps

Spatial composition of measurement results

- When overlay path AC includes overlay node B, we avoid measuring performance of path AC, and estimate it from measurement results of shorter paths AB and AC constructing path AC
  - Delay: $D_{AC}=d_{AB}+d_{BC}$, bandwidth: $B_{AC}=\min(b_{AB}, b_{BC})$
  - Packet loss ratio: $P_{AC}=1-(1-p_{AB})(1-p_{BC})$



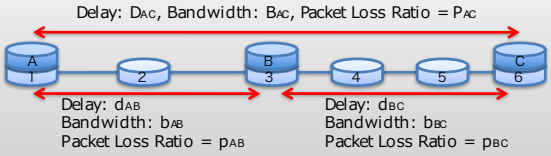
Effect on reducing measurement overhead



G. Hasegawa and M. Murata, "Scalable and density-aware measurement strategies for overlay networks," in Proceedings of ICIMP 2009, pp. 21-26, May 2009.

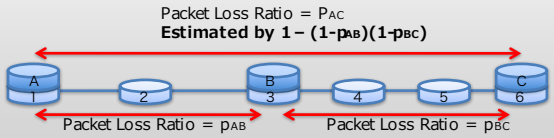
Estimation accuracy of spatial composition

- The accuracy of spatial composition depends on measurement accuracy of shorter paths composing a longer path
- When we predict that the estimation accuracy is bad, we need to directly measure the longer path
  - We should utilize accurate measurement results of shorter paths for maintaining overall measurement accuracy



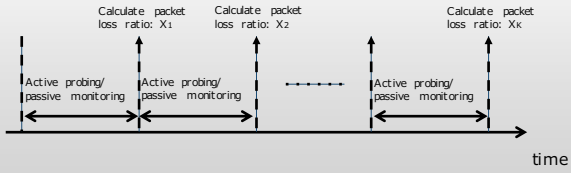
Objectives of this research

- Propose statistical methods to improve the accuracy of spatial composition
  - Based on temporal changes in measurement results
  - Two methods:
    - Remove outliers from measurement results by Smirnov-Grubbs' test
    - Discard whole measurement results based on statistical metrics
- We only focus on packet loss ratio measurements



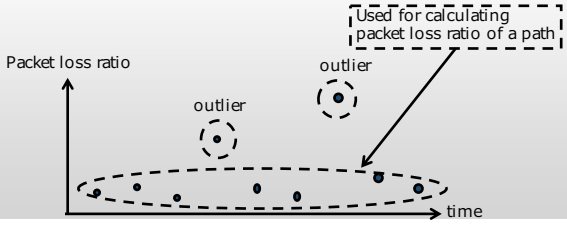
Assumptions and motations

- Packet loss ratios are measured periodically
- $\mathbf{X} = \{X_1, X_2, X_3, \cdots, X_K\}$: measurement results of packet loss ratio of a path
- Packet loss ratio of a path: $P = (X_1+X_2+X_3+ \cdots +X_K)/K$



Applying Smirnov-Grubbs' test

- Remove outliers from measurement results
- Parameter α: significance level
  - Larger α would remove outliers more aggressively

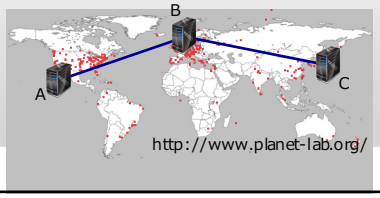


Statistical metrics for assessing reliability of measurement results

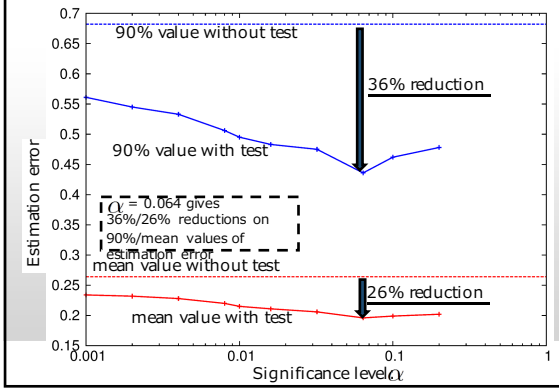
- I_1 = stddev(**X**)/avg(**X**)
- I_2 = max(**X**) – min(**X**)
- I_3 = max(**X**)/avg(**X**)
  - avg(**X**), max(**X**), min(**X**), stddev(**X**): average, maximum, minimum, and standard deviation of $\{X_1, X_2, X_3, \cdots, X_K\}$
- Large values of these metrics for a path mean that the whole measurement results of the path are less reliable
  - Not used for spatial composition
  - Discard all measurement results for the path and conduct new measurement

Performance evaluation settings

- Measurement results on PlanetLab (1,109 servers)
- 3,348 datasets for overlay node combination (A, B, C)
- 2,500 UDP packets used for measuring $X_1, X_2, X_3, \cdots, X_{20}$ (K=20)
  - 50,000 packets in total
- Evaluation metric: Estimation error $E = |\log_{10}P_{AC} - \log_{10}P'_{AC}|$
  - P_{AC}: actual measurement value, P'_{AC}: estimated value



Evaluation results (1): Smirnov-Grubbs' test



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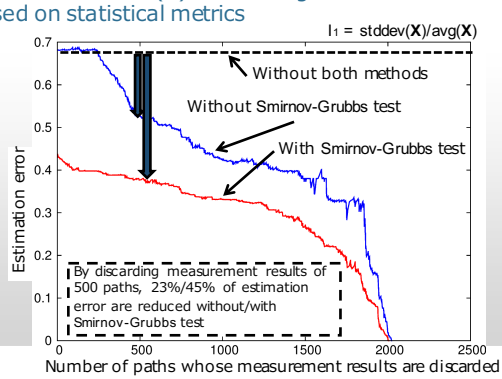
Evaluation results (2): Discarding measurement results based on statistical metrics



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Conclusion

- Improving estimation accuracy of packet loss measurement on overlay networks with spatial composition
  - Remove outliers from measurement results by Smirnov-Grubbs' test
  - Discard whole measurement results based on statistical metrics
- Up to 45% reduction in estimation error by combining two methods
- Future work
  - Evaluations with other measurement datasets
  - Application to other path performance metrics
    - Delay, bandwidth, TCP throughput, …

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