A distributed and conflict-aware measurement method based on local information exchange in overlay networks

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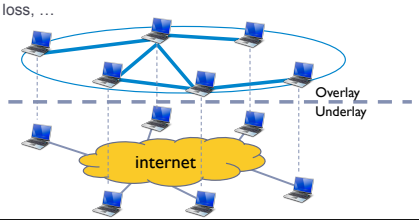
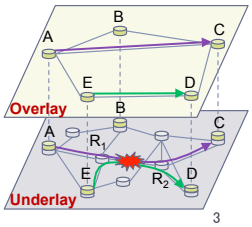
Background
- Overlay networks -

- Application-level network constructed on the IP network
- Applications : P2P systems, CDN, resilient routing, …
- Use network resource information for maintaining and improving performance
  - Network resource information : available bandwidth, delay, packet loss, …



Background
- Measurement of network resource information -

- Should be performed frequently to obtain high measurement accuracy
- Overlapping paths
  - Paths that have common underlay links
    - Path AC : (A,R_1,R_2,C)
    - Path ED : (E,R_1,R_2,D)
- Measurement conflict
  - Occurs when overlapping paths are measured concurrently
  - Causes measurement error, link stress



Background
- Existing measurement methods -

- Require complete topology information of the IP network to detect overlapping paths
  - Time and network traffic for the aggregation of topology information is large
- Measurement tasks of overlapping paths are scheduled at different timings [1]
  - Avoid measurement conflicts completely
  - Low measurement accuracy due to low measurement frequency

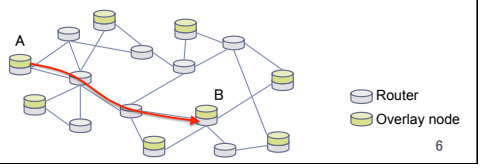
[1] M. Fraiwan and G. Manimaran, "Scheduling algorithms for conducting conflict-free measurements in overlay networks", *Computer Networks*, vol 52, pp. 2819-2830, Oct. 2008

Objectives

- Propose a distributed measurement method with high measurement accuracy
  - Not require complete topology information of the IP network
  - Overlay nodes exchange route information to detect overlapping paths
  - Reduce measurement frequency to reduce measurement conflicts
  - Overlay nodes exchange measurement results to improve measurement accuracy

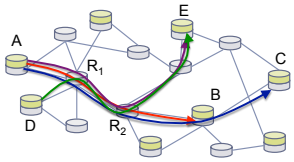
Outline of proposed method

- Measurement method for an arbitrary overlay path AB
  1. Method for detecting overlapping paths of AB
  2. Method for reducing measurement conflicts of AB and its overlapping paths
  3. Method for improving measurement accuracy of AB



1. Method for detecting overlapping paths - Classification of overlapping paths -

- Classify the overlapping paths into three types
  - *Complete overlapping path* : path that includes AB completely
  - *Half overlapping path* : path that shares with AB a route from the source node to a router that is not an overlay node
  - *Partial overlapping path* : path that shares with AB a route that does not include source node



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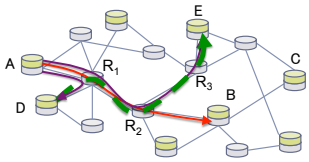
1. Method for detecting overlapping paths - Partial overlapping paths-

1. Find candidates of partial overlapping paths
   - AD overlaps with AB at (A,R_1)
   - AE overlaps with AB at (A,R_1,R_2)

➡ A infers that DE overlaps with AB at (R_1,R_2)

2. Exchange route information with source nodes of candidates



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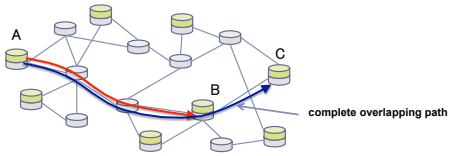
2. Method for reducing measurement conflicts - Complete overlapping paths -

- Complete overlapping path is not measured directly
  - The measurement result is estimated based on the measurement results of included overlay paths [2]
  - Example : delay of AC = delay of AB + delay of BC



➡ Measurement conflicts do not occur

[2] G. Hasegawa and M. Murata, "Scalable and density-aware measurement strategies for overlay networks", *in Proceedings of ICIMP 2009*, vol 52, pp.21–26, May 2009

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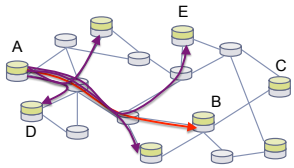
2. Method for reducing measurement conflicts - Half overlapping paths -

- A measures AB and half overlapping paths AD, AE, … sequentially



➡ Measurement conflicts are avoided completely

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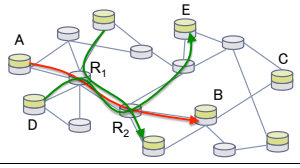
2. Method for reducing measurement conflicts - Partial overlapping paths -

1. Adjust measurement frequency of AB

$$f_{AB} \leftarrow \min(f_{AB}, \frac{1}{K+1})$$

f_{AB} : measurement frequency of AB
K : number of partial overlapping paths of AB

2. Take the measurement timings of AB randomly



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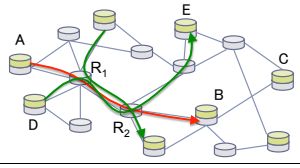
3. Method for improving measurement accuracy

- *Assumption* : measurement metric is latency

$$t_{AB} = t_{AR_1} + t_{R_1R_2} + t_{R_2B}$$
$$t_{DE} = t_{DR_1} + t_{R_1R_2} + t_{R_2E}$$

t_{AB} : latency of AB

- Proposed method
  - A and D exchange measurement results of the overlapping part R_1R_2



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Evaluation method

- Measurement metric : latency
- Compare with existing method [1]
- Comparing metrics
  - Measurement accuracy
    - Relative errors of measurement results
  - System overhead
    - Measurement overhead
    - Information exchange overhead
      - Route information exchange overhead
      - Measurement results exchange overhead

[1] M. Fraiwan and G. Manimaran, "Scheduling algorithms for conducting conflict-free measurements in overlay networks", *Computer Networks*, vol 52, pp. 2819-2830, Oct. 2008

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Evaluation settings

- Network models
  - Underlay topology
    - AT&T, BA model, Waxman model
    - 523 nodes, 1304 links
  - Overlay topology
    - Overlay nodes are chosen randomly
    - Density of overlay node : 0.2

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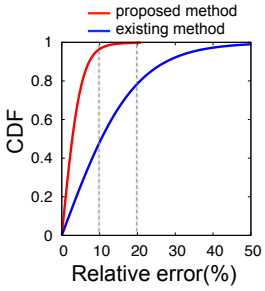
Evaluation result
- Measurement accuracy -

AT&T topology



- Proposed method
  - Most of the paths have relative error less than 10%
  - Maximum of relative error is about 20%
- Existing method
  - About 45% of the paths have relative error less than 10%
  - Maximum of relative error is about 50%

Measurement accuracy is much improved in our method

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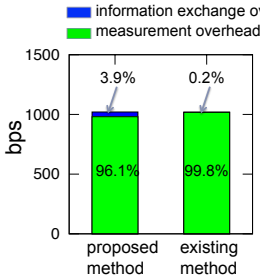
Evaluation result
- System overhead -

AT&T topology



- Information exchange overhead in proposed method is larger than existing method
- Measurement overhead in proposed method is smaller than existing method

Measurement accuracy can be improved by shifting overhead from measurement to information exchange

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Conclusions

- Proposed a distributed overlay network measurement method
  - Detect the overlapping of paths
  - Reduce measurement conflicts
  - Improve measurement accuracy by exchanging measurement results
- Simulation evaluation
  - Relative error is halved compared to existing method
  - Measurement accuracy can be improved by shifting overhead from measurement to information exchange

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Thank you !

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