A distributed measurement method exploiting path overlapping in large scale network systems

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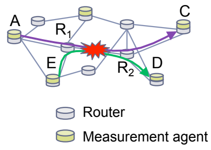
Background
- Measurement of network resource information -

- Network resource information
  - Available bandwidth, delay, packet loss rate, …
  - Essential information for network applications
  - Should be measured frequently to obtain high measurement accuracy
- Overlapping paths
  - Paths that have common IP 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



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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

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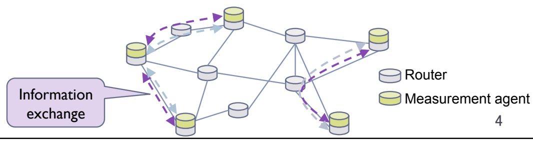
Objective and approach

- Objective : propose a distributed measurement method with high measurement accuracy
- Approach : utilize information exchange between measurement agents
  - Reduce measurement frequency
    - Reduce measurement conflicts
  - Exchange route information to detect overlapping paths
  - Exchange measurement results to improve measurement accuracy and reduce measurement overhead



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Outline of proposed method

1. Method for detecting overlapping paths

2. Method for improving measurement accuracy

3. Method for reducing measurement overhead

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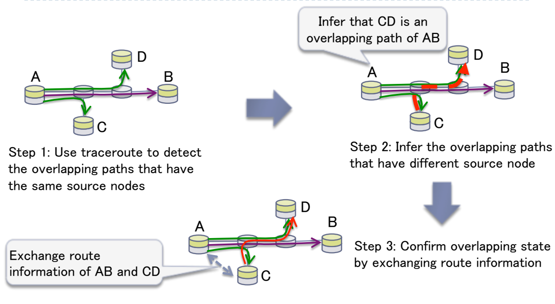
Method for detecting overlapping paths



Detect more than 90% of overlapping paths

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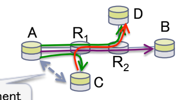
Method for improving measurement accuracy - Metric: latency, loss rate -

- Estimate measurement result of a path from measurement results of included paths

  Latency: $t_{AB} = t_{AR_1} + t_{R_1R_2} + t_{R_2B}$

  Loss rate: $\log(1-l_{AB}) = \log(1-l_{AR_1}) + \log(1-l_{R_1R_2}) + \log(1-l_{R_2B})$

- Exchange measurement results of the overlapping parts
- Use statistical process for exchanged measurement results to improve measurement accuracy



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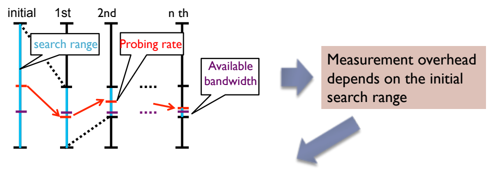
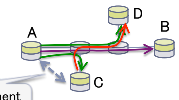
Method for reducing measurement overhead - Metric: available bandwidth -

[Measurement algorithm : binary search]



[Find appropriate initial search range to reduce measurement overhead]

1. Exchange measurement results of overlapping paths
2. Use statistical process for measurements results to calculate initial search range



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Evaluation method

- Measurement metrics : latency, available bandwidth
- 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
  - Network topology
    - AT&T, BA model, Waxman model
    - 523 nodes, 1304 links
  - Measurement agents
    - Measurement agents are chosen randomly among network nodes
    - Density of measurement agent : 0.2

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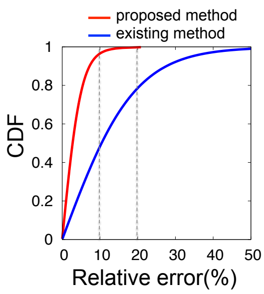
Evaluation result of measurement accuracy - Metric: latency -

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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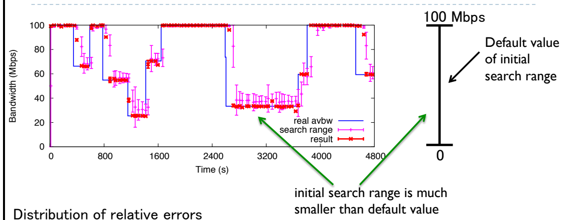
Evaluation result of measurement accuracy - Metric: available bandwidth -



Distribution of relative errors

Method	Relative error			
	≧0.05	≧0.1	≧0.2	≧0.4
Existing method	56.600%	32.184%	9.576%	1.432%
Proposed method	41.999%	18.087%	3.260%	0.194%

Measurement accuracy is far better in proposed method

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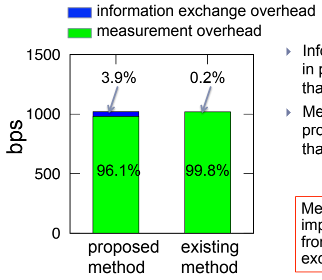
Evaluation result of system overhead
- Metric: latency -

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 measurement method
  - Detect the overlapping of paths by exchanging route information
  - Improve measurement accuracy and reduce measurement overhead by exchanging measurement results
- Simulation evaluation
  - Relative error in proposed method is much smaller than in existing method
  - Measurement accuracy can be improved and measurement overhead can be reduced by shifting overhead from measurement to information exchange

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Thank you !

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