Monitoring available bandwidth in overlay networks using local information exchange

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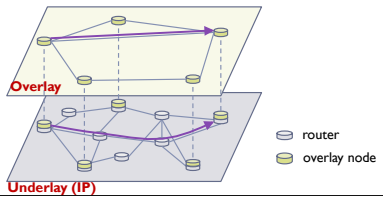
Background
- Overlay networks -

- Many overlay network-based services have been deployed
  - e.g., P2P systems, CDN, resilient routing, …
- Information of end-to-end available bandwidth is important
  - To use the resource of bandwidth effectively
  - To improve the quality of the network service by appropriately choosing communication paths



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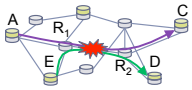
Background
- Measurement of available bandwidth -

- End-to-end available bandwidth is obtained by measurements conducted by the overlay nodes
- Challenges in measurements of end-to-end available bandwidth
  - Require high measurement frequency to obtain high measurement accuracy
  - Concurrent measurements of overlapping paths cause conflict, which degrades measurement accuracy



Overlapping paths :
(A,R_1,R_2,C)
(E,R_1,R_2,D)

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Background
- Existing measurement methods -

- Measurement tasks of overlapping paths are scheduled at different timings in centralized manner [8]
  - Avoid measurement conflicts completely
    - Require complete topology information of the IP network to detect overlapping paths
    - Time and network traffic for the aggregation of topology information is large
  - Low measurement accuracy due to low measurement frequency

[8] 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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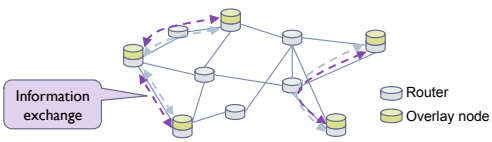
Objective and approach

- Objective : propose a distributed measurement method with high measurement accuracy
- Contrast approach with existing method [8]
  - Maintain high measurement frequency
  - Give up avoiding conflicts completely, but try to reduce them
    - Using information exchange between overlay nodes



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Outline of the proposed method

1. Detect path overlaps
   - Use route information exchanged between overlay nodes

   More details in the paper …
2. Determine measurement frequency and timings
   - Based on the degree of path overlaps
   - Random measurement timings for overlapping paths

   More details in the paper …
3. Conduct measurements
   - Use information exchanged between overlay nodes to configure parameters of each measurement

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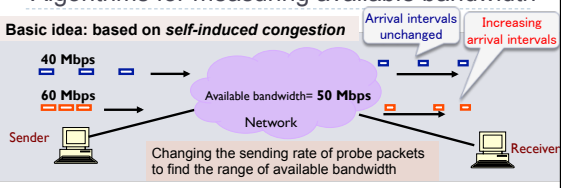
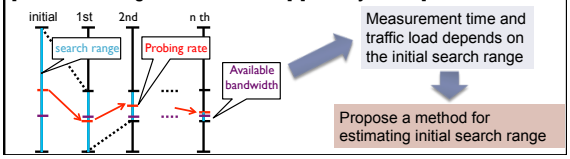
Algorithms for measuring available bandwidth

Basic idea: based on *self-induced congestion*



[Measurement algorithm of Pathload [3]: binary search]



Observations

1. Available bandwidth varies gradually

   ⇩

   Recent measurement results can be used to estimate the initial search range

2. If the bottleneck links of two overlapping paths belong to the overlapping segment, then the measurement results of two path are the same

   ⇩

   Recent measurement results of overlapping paths can be used to estimate the initial search range

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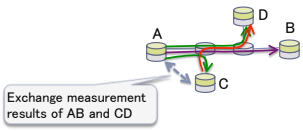
Proposed method for estimating initial search range

1. Save the recent measurement results
2. Exchange recent measurement results of overlapping paths
   - Also exchange the probability that bottleneck links belong to the overlapping segment
3. Use statistical processing for the exchanged data to calculate the initial search range



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Evaluation method

- Confirm the improvement at each measurement
  - Compare the initial search range estimated by proposed method with the default value of Pathload [3]
- Compare with existing method [8]
  - Metrics
    - Measurement frequency
      - Number of measurements per hour
    - Measurement conflict
      - Percentage of measurements that experience conflicts
    - Measurement accuracy
      - Relative errors of measurement results

[8] 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
  - Overlay nodes are chosen randomly among network nodes
    - Density of overlay nodes : 0.2
- Link capacity: 100Mbps
- Create cross-traffic randomly so that the end-to-end available bandwidth varies from 0 to 100Mbps
- Measurement errors by conflicts
  - Determined by queuing theory and statistics theory

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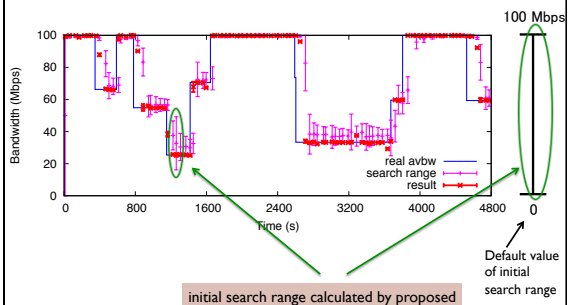
Improvement at each measurement - Reduction of initial search range -



initial search range calculated by proposed method is much smaller than default value

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Evaluation results of measurement frequency and measurement conflicts

Measurement frequency :
Number of measurements per hour

Topology	AT&T	BA	Waxman
Existing method	0.913	1.394	3.242
Proposed method	3.014	4.977	7.155

Measurement frequency is larger in proposed method

Measurement conflict :
Percentage of measurements that experience conflicts

Topology	AT&T	BA	Waxman
Existing method	0.0%	0.0%	0.0%
Proposed method	12.4%	9.5%	11.4%

About 10% of measurements in proposed method experience conflicts

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Evaluation result of measurement accuracy - Distribution of relative errors -

AT&T topology

Method	Relative error			
	≧0.05	≧0.1	≧0.2	≧0.4
Existing method	56.770%	32.757%	10.070%	1.486%
Proposed method	41.956%	18.330%	3.450%	0.207%

BA topology

Method	Relative error			
	≧0.05	≧0.1	≧0.2	≧0.4
Existing method	51.635%	30.074%	9.837%	1.221%
Proposed method	35.472%	14.161%	2.546%	0.105%

Waxman topology

Method	Relative error			
	≧0.05	≧0.1	≧0.2	≧0.4
Existing method	34.279%	16.032%	3.703%	0.192%
Proposed method	26.986%	9.516%	1.403%	0.025%

Measurement accuracy is far better in proposed method

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Conclusions

- Proposed a distributed method for measuring available bandwidth in overlay networks
  - Improve measurement accuracy and reduce measurement traffic by using information exchange between overlay nodes
- Simulation evaluation
  - Relative error in proposed method is much smaller than in 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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