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

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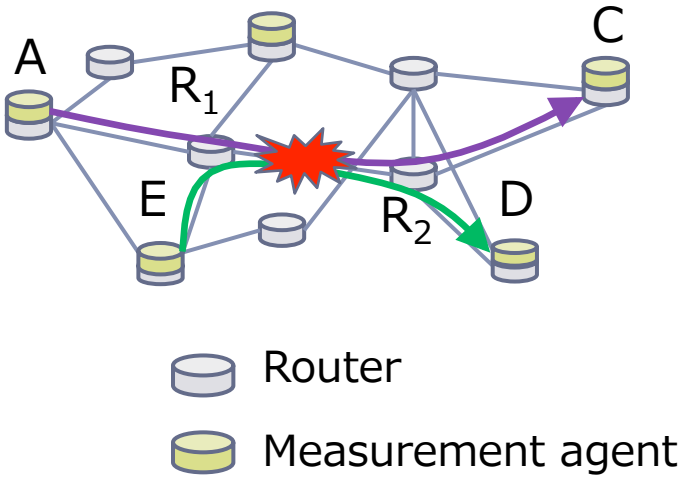
Background
- Measurement of network resource information

- Network resource information
  - Available bandwidth, delay, packet loss rate, link failures, …
  - 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 especially in bandwidth measurement
  - Large link stress



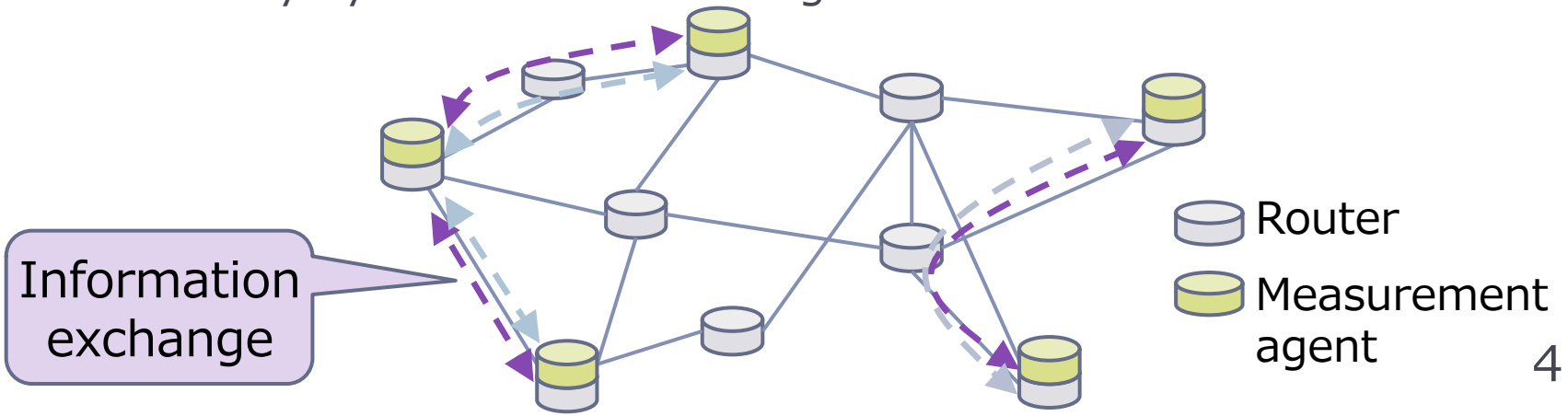
Background
- Existing measurement methods

- Measurement tasks of overlapping paths are scheduled at different timings in centralized manner [1]
  - 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

[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

Objective and approach

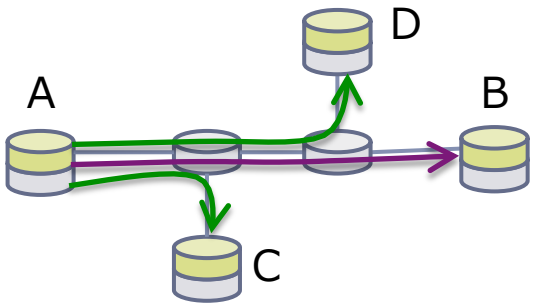
- Objective : Propose distributed measurement method with high measurement accuracy
- Approach : Information exchange between measurement agents
  - Exchange route information to detect overlapping paths to determine measurement frequency and timings
  - Exchange measurement results to improve measurement accuracy and reduce measurement tasks
  - To increase measurement frequency, we give up avoiding measurement conflicts completely, but maintain measurement accuracy by information exchange



Outline of the proposed method

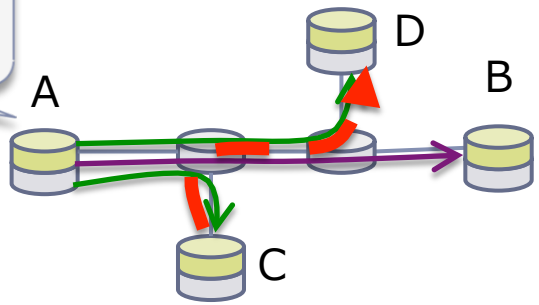
- Detect path overlaps
- Determine measurement frequency and timings
  - Frequency is determined based on the degree of path overlaps
  - Overlapped paths are measured in random timings
- Conduct measurement
  - Latency
  - bandwidth
  - Link failure (under development)
- Exchange measurement results

Detection of overlapping paths



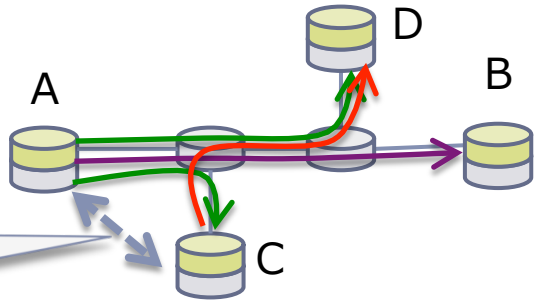
Step 1: Node A checks the router-level paths to node B, C, and D.

Infer that CD is an overlapping path of AB



Step 2: Based on the path information, node A infers that AB and CD overlaps the route

Step 3: Node A exchanges route information with node C to confirm the path overlap



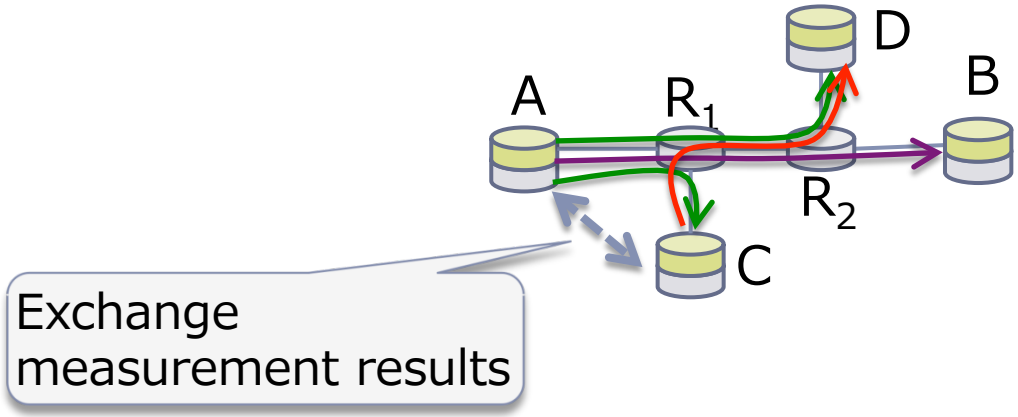
Exchange route information of AB and CD

Step 4: Nodes A and C determine measurement frequency timings of AB and BC to avoid conflict

This method can detect more than 90% of actual overlapping paths

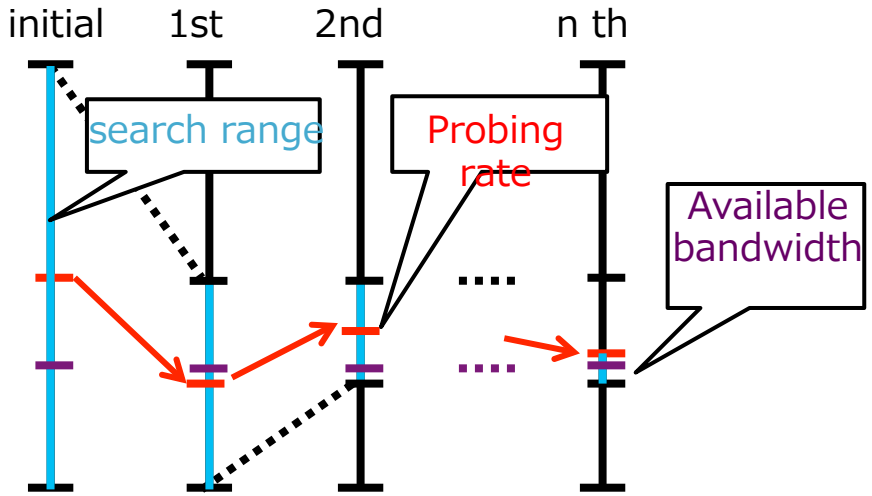
Exchange measurement results

- Exchange measurement results among overlay nodes sharing the overlapping parts
- Use statistical process for exchanged measurement results to improve measurement accuracy
  - Our method can NOT avoid measurement conflict completely, but maintain the measurement accuracy by measurement results exchange and statistical process
  - So, the increasing measurement frequency while decreasing measurement conflicts is important for improving the measurement accuracy



Overhead reduction in bandwidth measurement

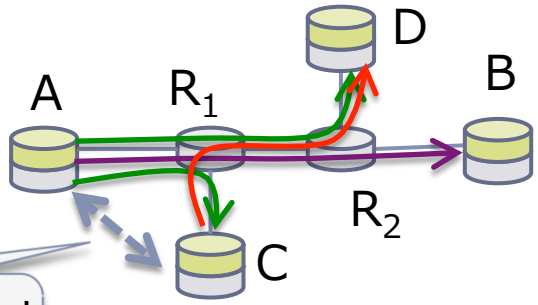
[Bandwidth measurement algorithm : binary search]



Measurement overhead depends on the initial search range

[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



Exchange measurement results of AB and CD

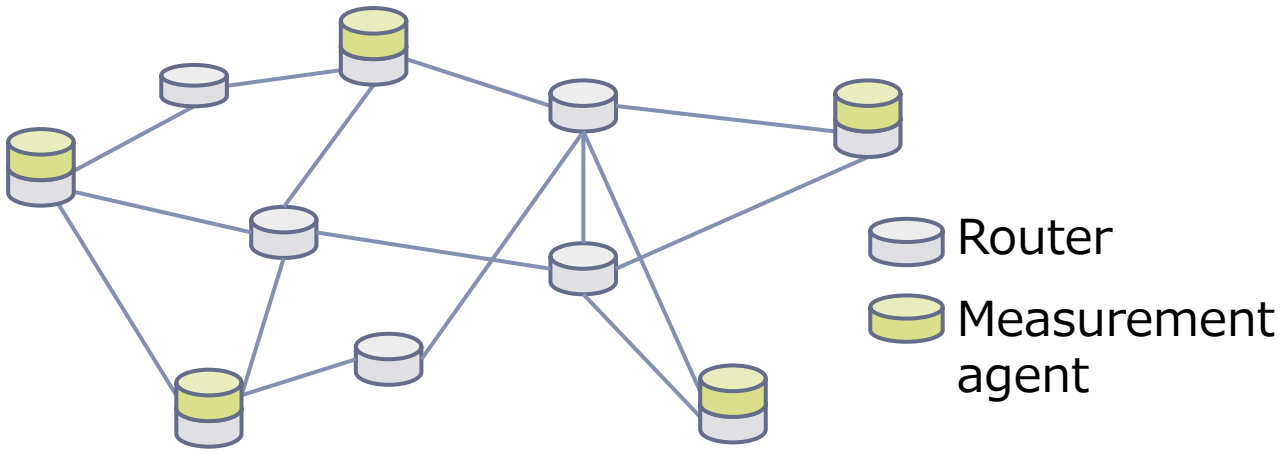
Simulation experiments

- Measurement metrics : latency and available bandwidth
- Compare with existing method [1]
  - Centralized method, no measurement conflict
- Performance metrics
  - Measurement accuracy
    - Relative errors of measurement results
  - System overhead
    - Measurement overhead
    - Information exchange overhead
      - Route information
      - Measurement results

[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

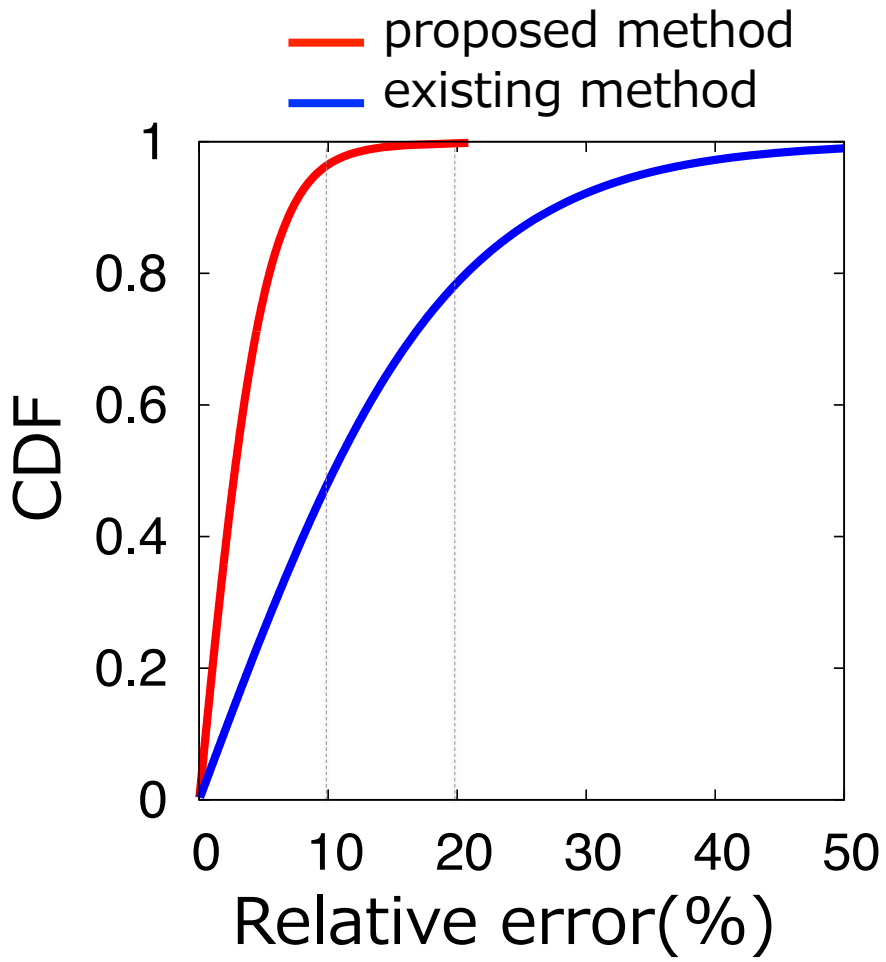
Simulation settings

- Network models
  - Network topology
    - AT&T router-level network (523 nodes and 1304 links)
  - Measurement agents are chosen randomly among network nodes
    - Density of measurement agent : 0.2
- Measurement errors by conflict
  - Determined by queueing theory



Evaluation results (1)
- Accuracy in latency measurement

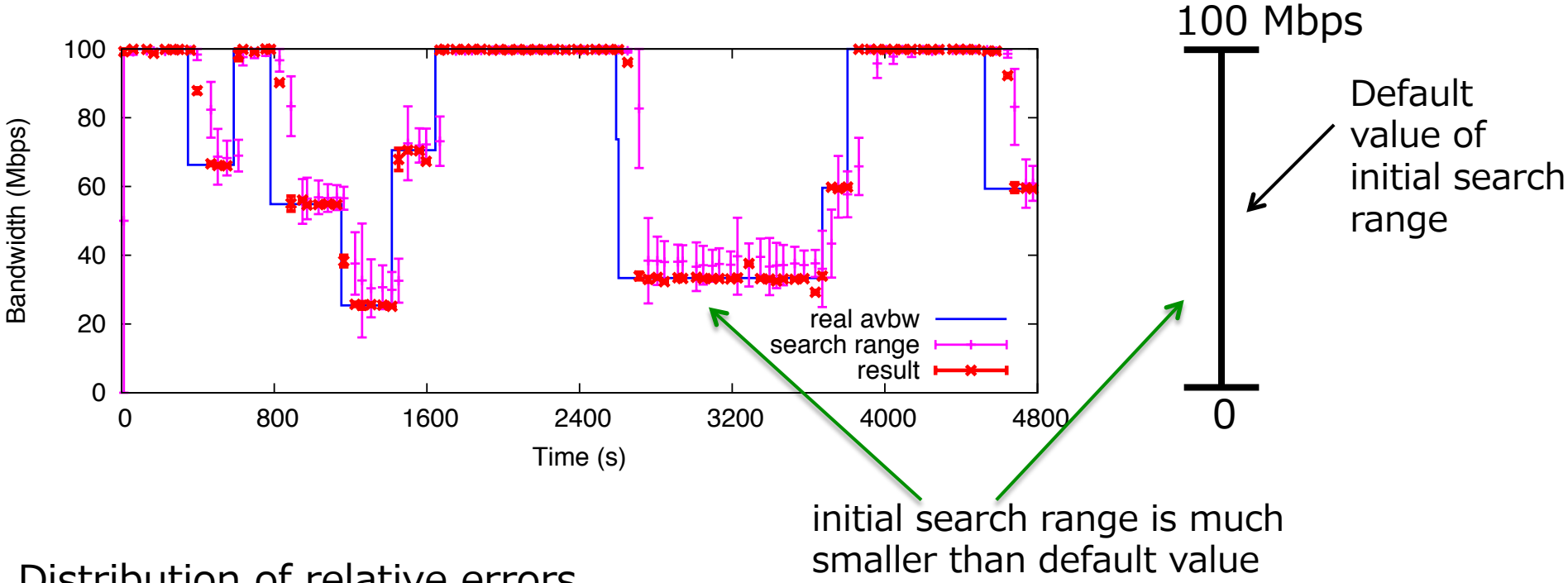
AT&T topology



- 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

Evaluation results (2)
- Accuracy in bandwidth measurement



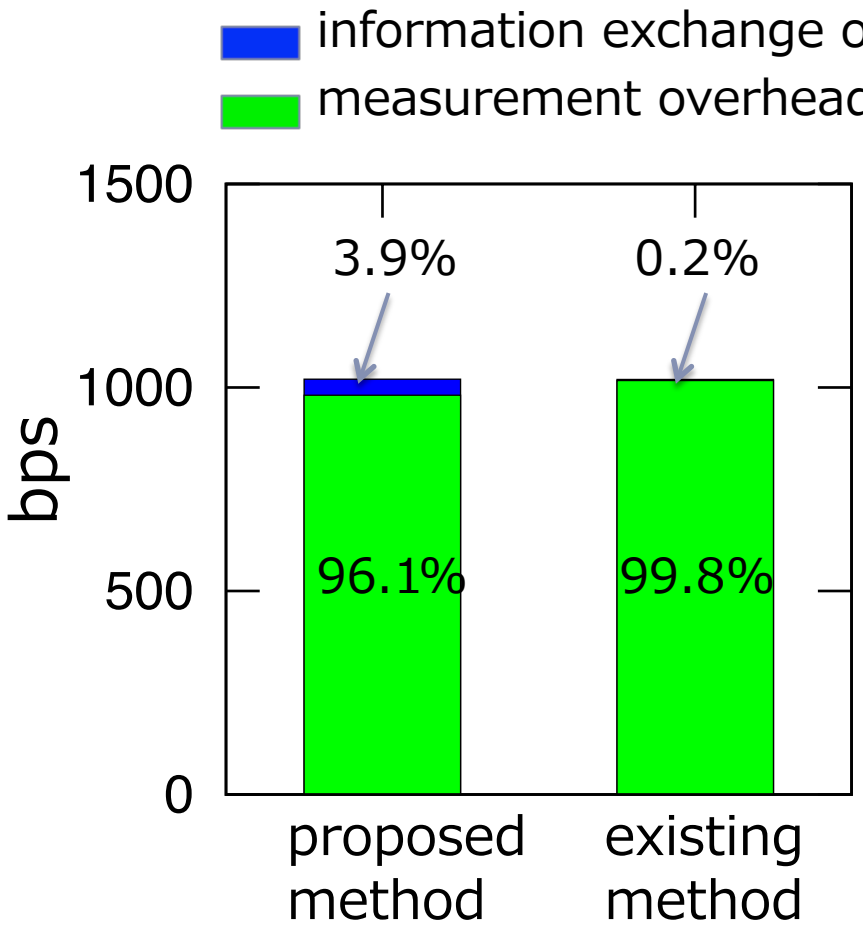
Distribution of relative errors

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

Evaluation results (2)
- System overhead in latency measurement

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 slightly shifting overhead from measurement to information exchange

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
- Evaluation by simulation experiments
  - Relative error in proposed method is much smaller than the existing method
- Measurement accuracy can be improved and by slightly shifting overhead from measurement to information exchange

Thank you !