Accurate Measurement Technique of Packet Loss Rate in Parallel Flow Monitoring

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Outline

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- Background
- Assumptions and models
- Parallel flow monitoring method for delay
- The proposed loss monitoring method
- Experiments
- Conclusions and future works

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End-to-end Measurements

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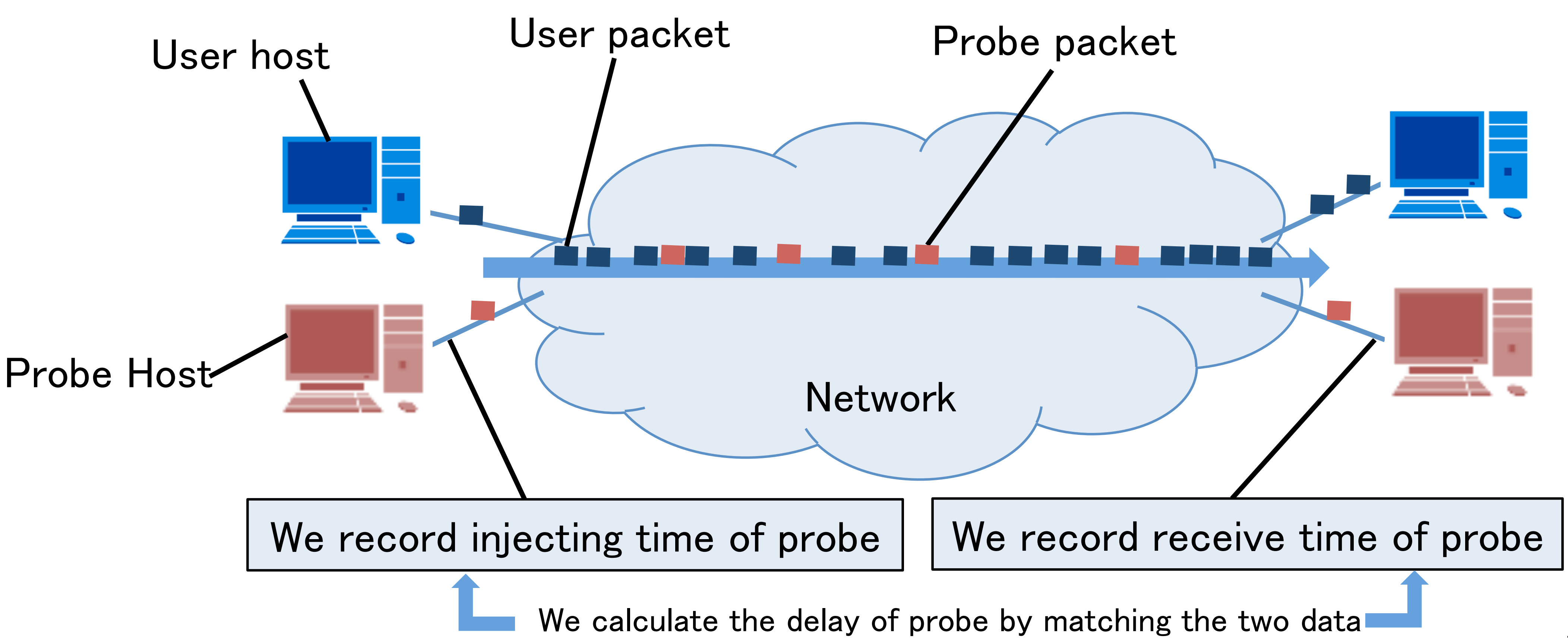
- End-to-end metrics are fundamental for a network evaluation.
- An active measurement is a common method to measure end-to-end metrics.
  - Probe packets are injected into a network for a measurement.
  - It is important to achieve accurate measurement without increasing the number of probe packets.
  - It is difficult to capture rare events (large delay or loss), and they are still hard to measure.



Parallel Monitoring of Probe Flows

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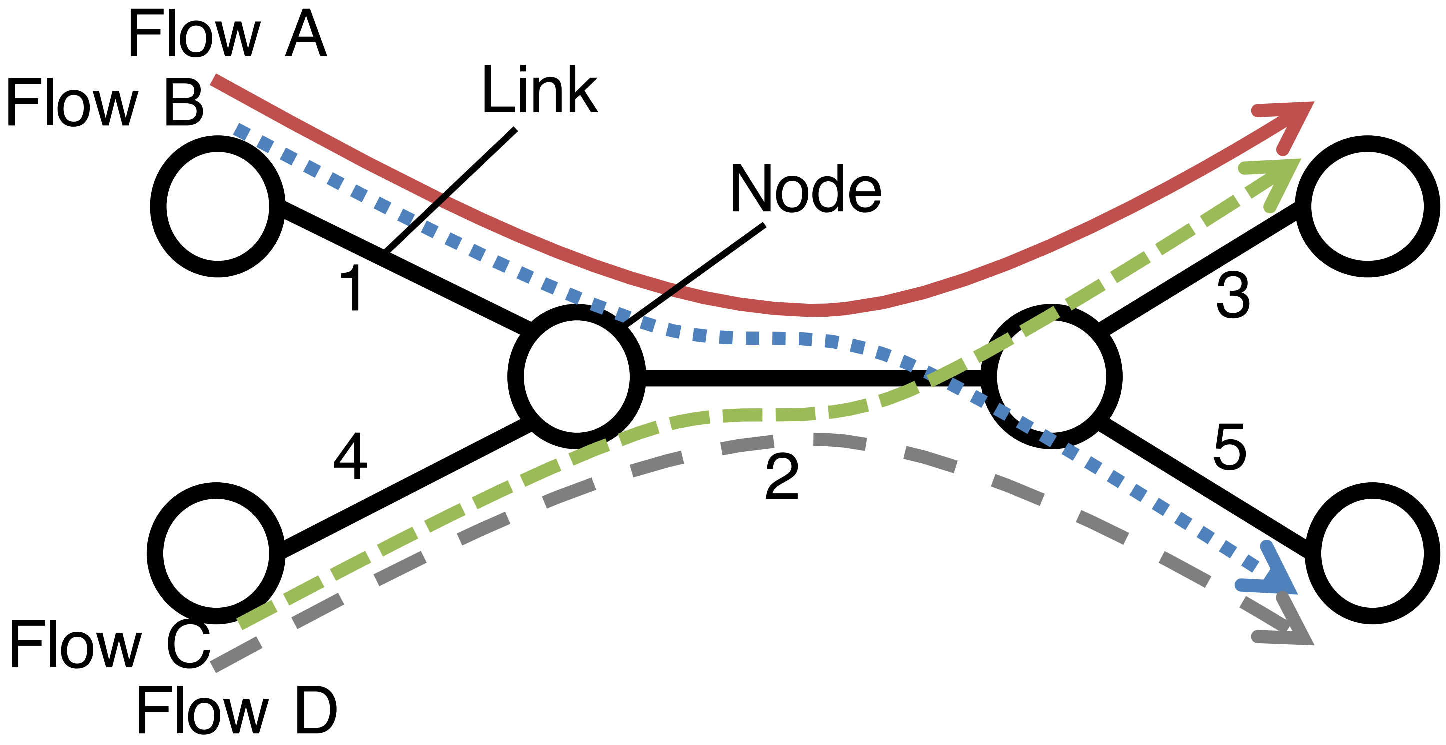
- For most measurement applications, multiple paths are monitored in parallel to measure end-to-end metrics.
  - e.g., SLA monitoring by Internet Service Providers.
- Most of prior works utilize only one probe flow for a measurement of one path in a parallel path monitoring.
- The information concerning a flow can be utilized supplementary for improving a measurement of another flow.



Objectives

- We have proposed a parallel flow monitoring method for delay [5].
  - The method achieves accurate measurement by utilizing the observation results of flows sharing the source/destination.
- In this paper, we propose a parallel flow monitoring method for packet loss rate.

Contributions

1. We extend the delay measurement method to a loss measurement.
2. We improve its accuracy by utilizing information of all flows including flows with different source and destination.
3. We evaluate the effectiveness of the proposed method though simulations.

[5] K. Watabe, S. Hirakawa, and K. Nakagawa, "Accurate Delay Measurement for Parallel Monitoring of Probe Flows," in *Proceedings of 2017 13th International Conference on Network and Service Management (CNSM 2017)*, Tokyo, Japan, 2017.

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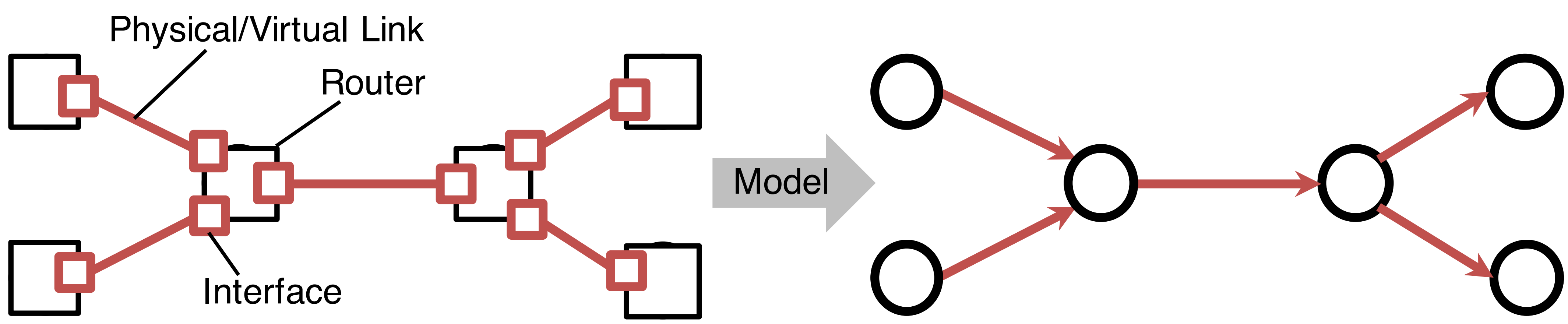
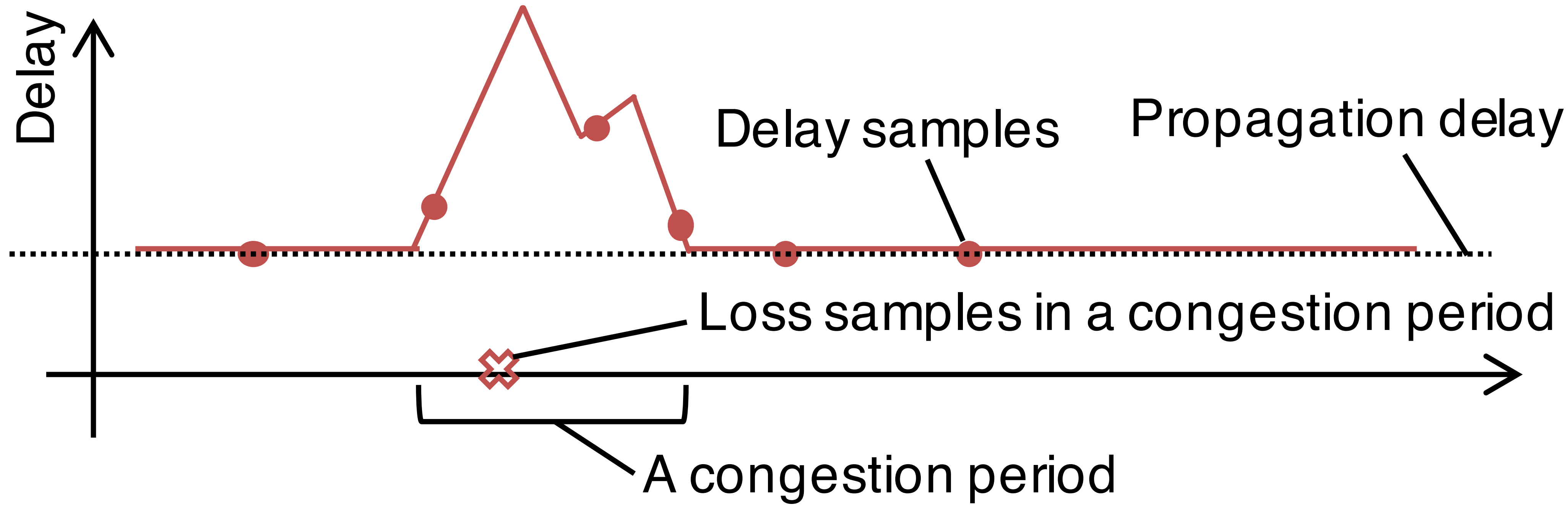
Network Model

- A network considered within the scope of this work is represented by a directed graph.



- To measure packet delay and loss rate on paths, probe packets are periodically injected for all or a part of paths.
- A delay/loss sample can be obtained by a probe packet.
- Though the metric we want to measure is loss rate in wired packet networks, we utilize delay information to improve an accuracy of loss rate measurement.

Sparsity Assumption of Congestion Periods



- An end-to-end delay is consisted of propagation delay and queueing delay.
  - Propagation delay can be regarded as a constant.
- Most of loss events are caused by buffer overflows in interfaces placed on links with congestions.
- We assume that links with large queueing delay, i.e. links with many packet loss events, are sparse among all links in a network.

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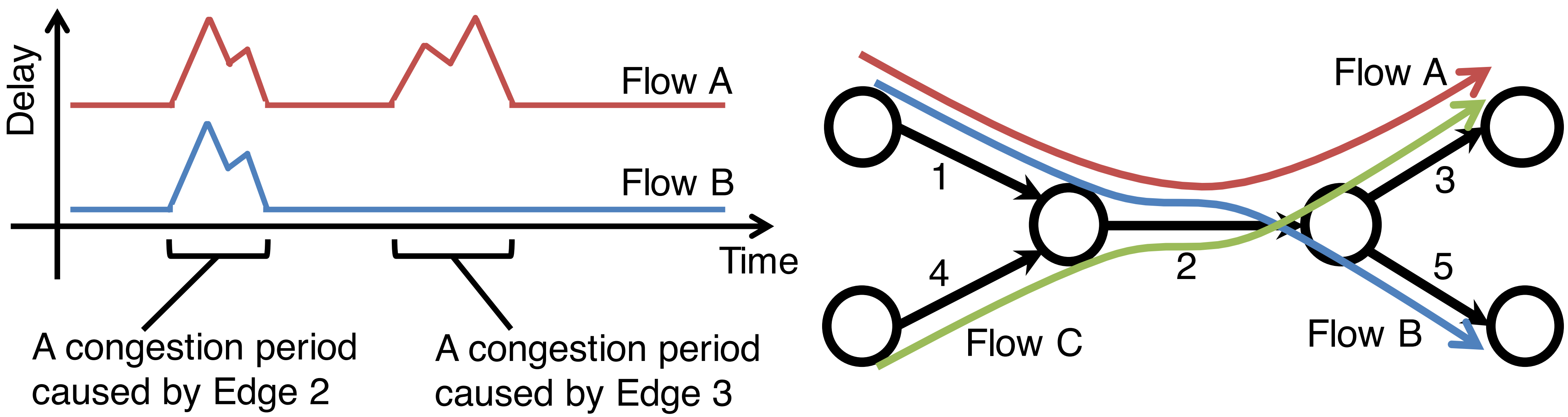
Overlap of Virtual Delay Processes

- Queueing delay processes within a congestion period that have common links frequently overlap.

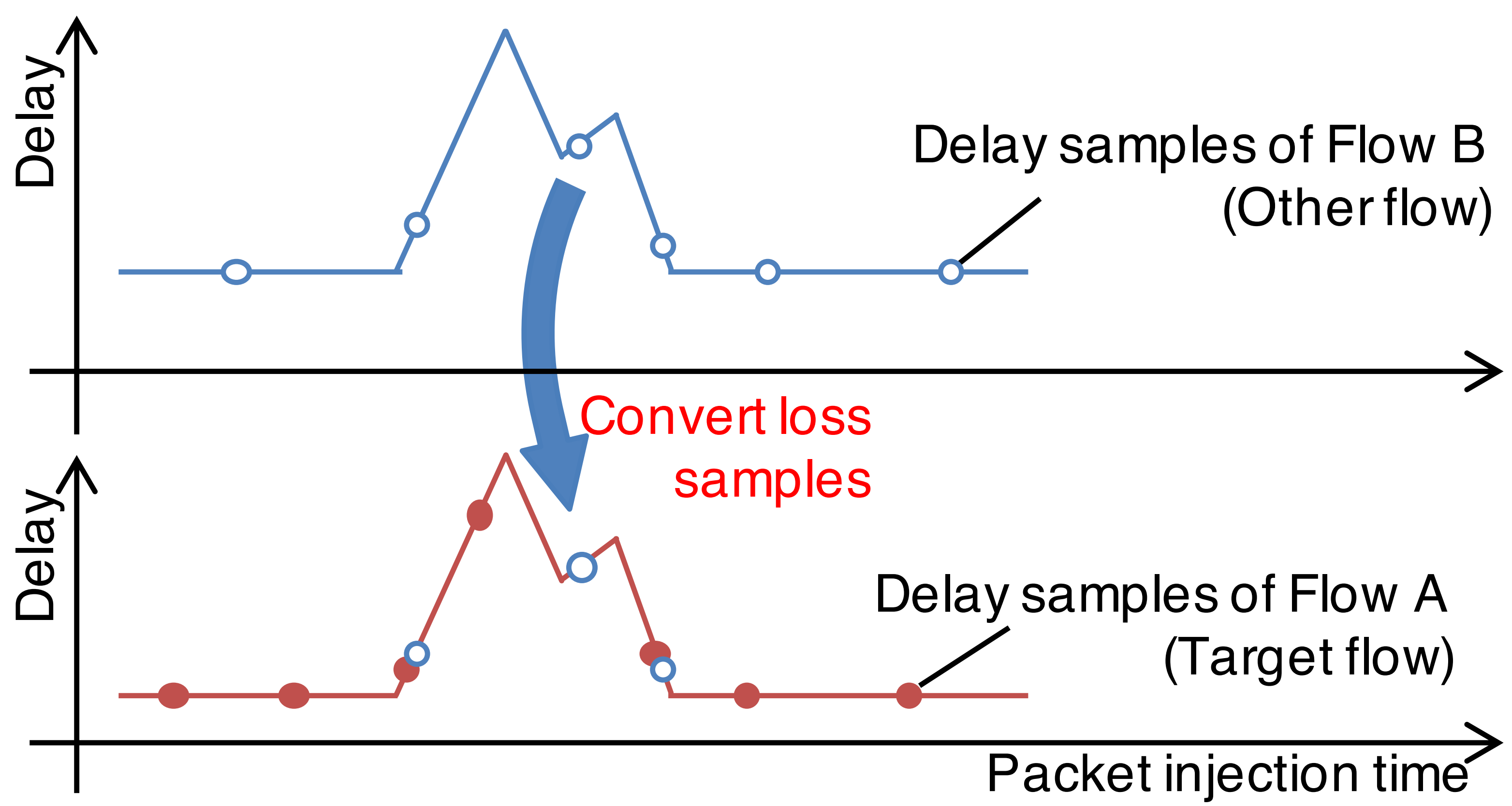
$\hat{\chi}_{\mathrm{A}}(t)$: A virtual delay which is the queueing delay experienced by a virtual packet injected into the path of Flow A at time t.



- If $\hat{\chi}_{\mathrm{A}}(t)$ and $\hat{\chi}_{\mathrm{B}}(t)$ in a congestion period tightly overlap, information of the period can be utilized each other.
- To utilize this information, we should discriminate whether processes overlap.
- The determination should be based on samples.

Conversion Process

- We consider that virtual delay processes overlap if the two flows satisfy the following conditions:
  1. The two flows have the same source/destination;
  2. The interval between the packet injection/receive times of the first and last samples in a congestion period is smaller than δ;
- Samples within the overlap period are converted each other.



- To remove inappropriate samples, we utilize a clustering technique in machine learning.

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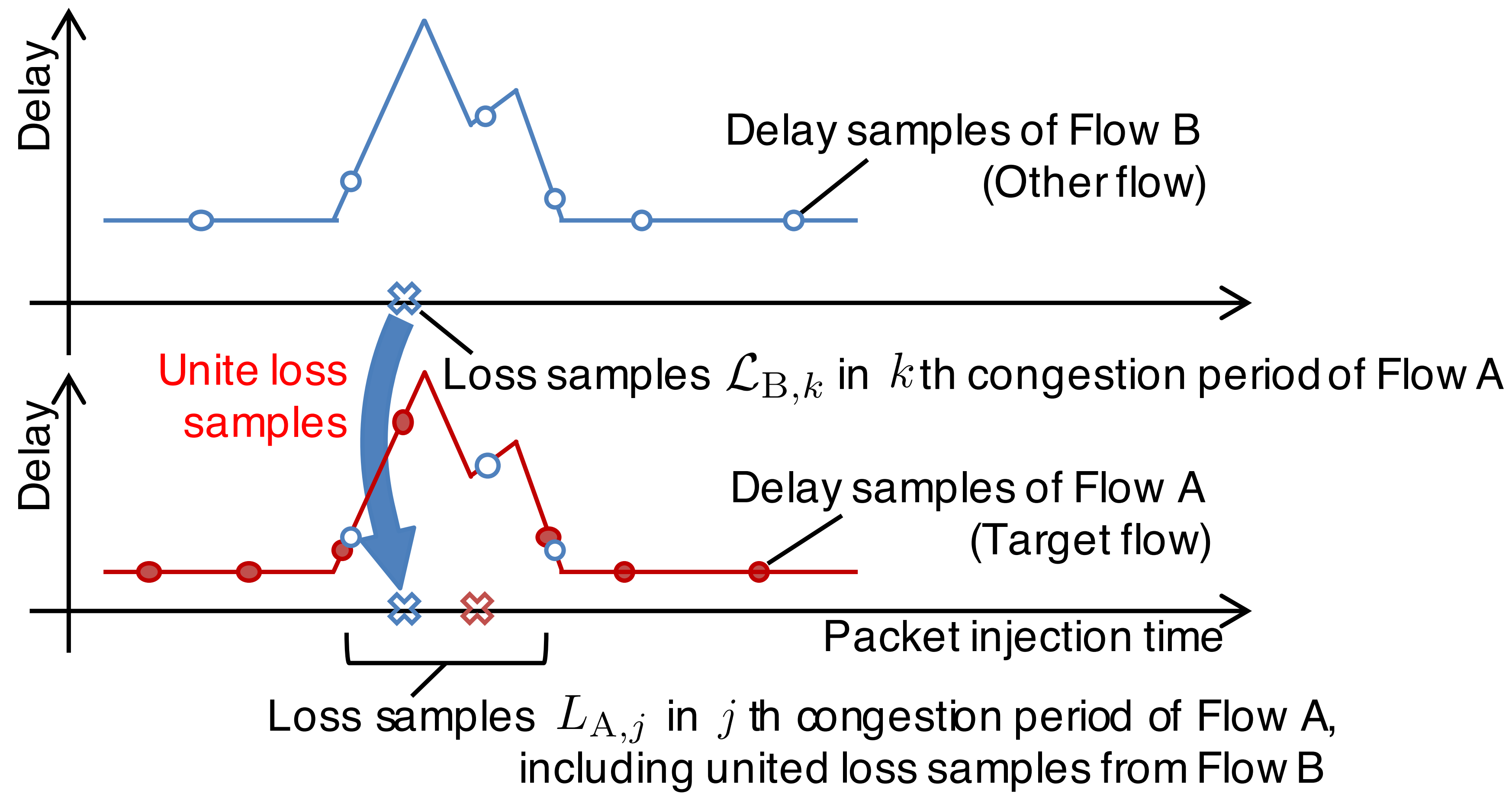
Extension for Loss Rate Measurements

- We extend the method [5] to a loss rate measurement. xxx

$L_{A,j}$: The set of loss samples in jth congestion period of Flow A.



1. Loss samples $L_{A,j}$ are recorded for all congestion periods.
2. Delay samples are converted each other with method [5].
3. Loss samples $L_{A,j}$ are united to $\mathcal{L}_{B,k} = L_{A,j} \cup L_{B,k}$ when delay samples are converted.

Extension for Loss Rate Measurements (2)

- The samples by our method are not uniformly distributed.
- To provide an unbiased estimator of loss rate on each path, samples should be weighted.
- The loss rate on the path of Flow A is estimated by the following estimator with weight w_s of a sample s,

$$\sum_j \sum_{s \in \mathcal{L}_{A,j}} \frac{w_s}{|X_A| + |L_A|}, \quad \text{where} \quad w_s = \frac{|X_{A,j} \cup L_{A,j}|}{|\mathcal{X}_{A,j} \cup \mathcal{L}_{A,j}|} \quad \text{for } s \in \mathcal{L}_{A,j}$$

X_A : The set of all delay samples of flow A.

L_A : The set of all loss samples of flow A.

$X_{A,j}$: The set of original delay samples in jth congestion period of Flow A.

$\mathcal{X}_{A,j}$: The set of delay samples in jth congestion period of Flow A, including converted samples.

$L_{A,j}$: The set of original loss samples in jth congestion period of Flow A.

$\mathcal{L}_{A,j}$: The set of loss samples in jth congestion period of Flow A, including united samples.

Recursive Conversion

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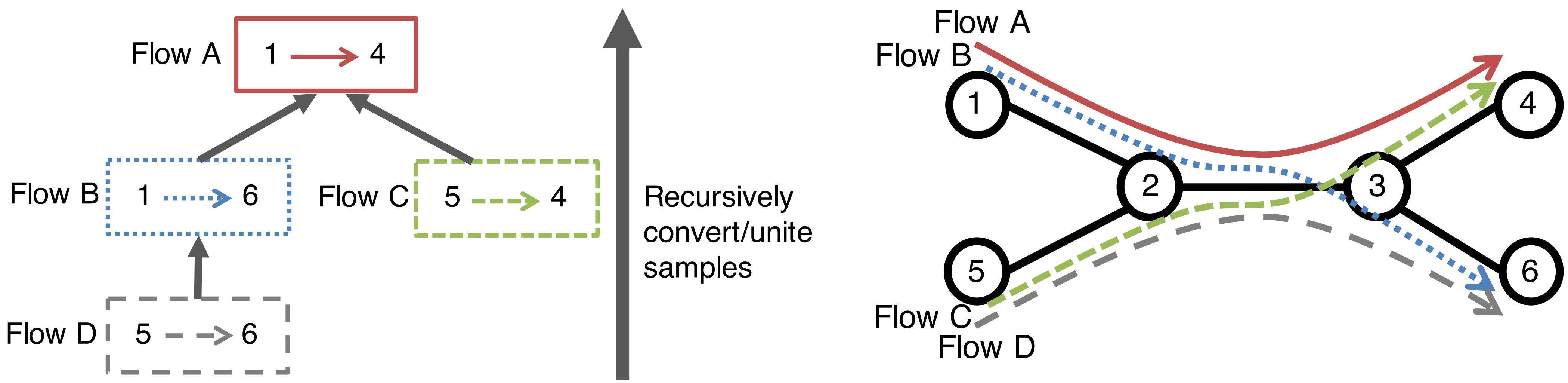
- The method in [5] only utilize information of flows that has the same source/destination with a target probe flows.
- By recursively converting samples obtained from each probe flow, the proposed method utilizes information of all probe flows.



- Trees that represent dependency of conversions are generated for each congestion period.
- The proposed method recursively converts/unites samples from the leaves to the root of the tree.

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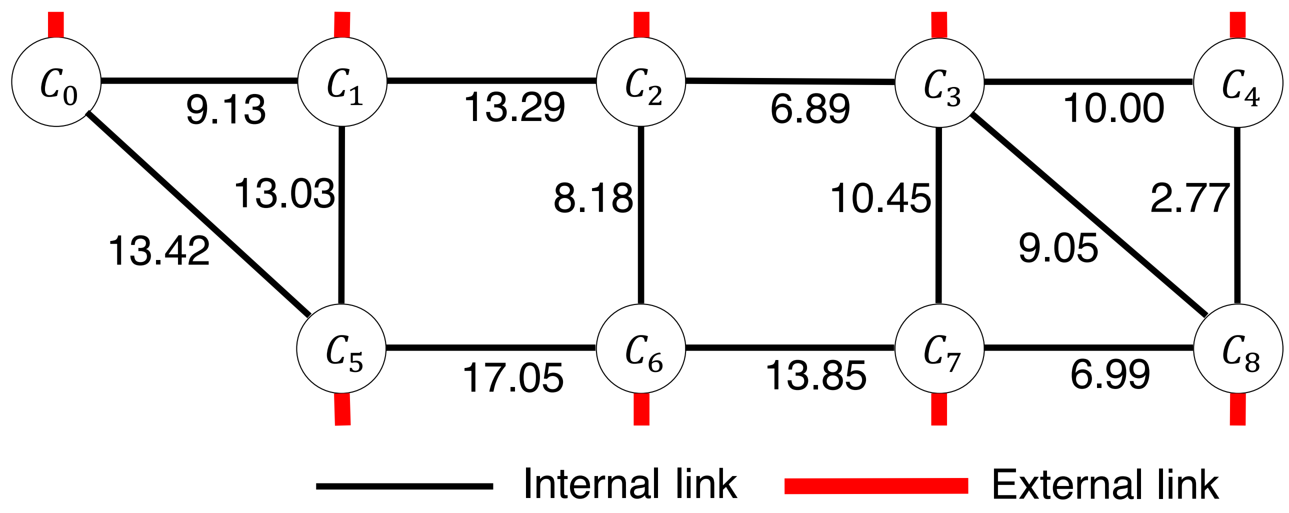
Simulation Settings

- We perform NS-3 simulations to confirm that loss samples of parallel flows are appropriately united between each other.



Link capacity: 15.552 Mbps
Queue size: 1024 packets
Queueing policy: Drop-tail

- 3 types of traffic stream between all pairs of 9 nodes in a network (i.e., 72 flows stream for each type).

Stationary	Packet size	600 [Byte]
	Traffic pattern	Poisson arrivals
	Traffic intensity	388.8 [Kbps] (4% of a link capacity)
Burst	Packet size	500 [Byte]
	Traffic pattern	On/off process with periodic arrivals
	Traffic intensity	8,000 [Kbps] in burst periods
	Burst period	Exponential distribution with mean 1.0 [s]
	Idle period	Exponential distribution with mean 100.0 [s]
Probe	Packet size	74 [Byte]
	Traffic pattern	Periodic arrivals

Simulation Settings (2)

- The parameters common to the privious method [5] are as follows:

  $\delta = 0.2$: Probe packet intervals.

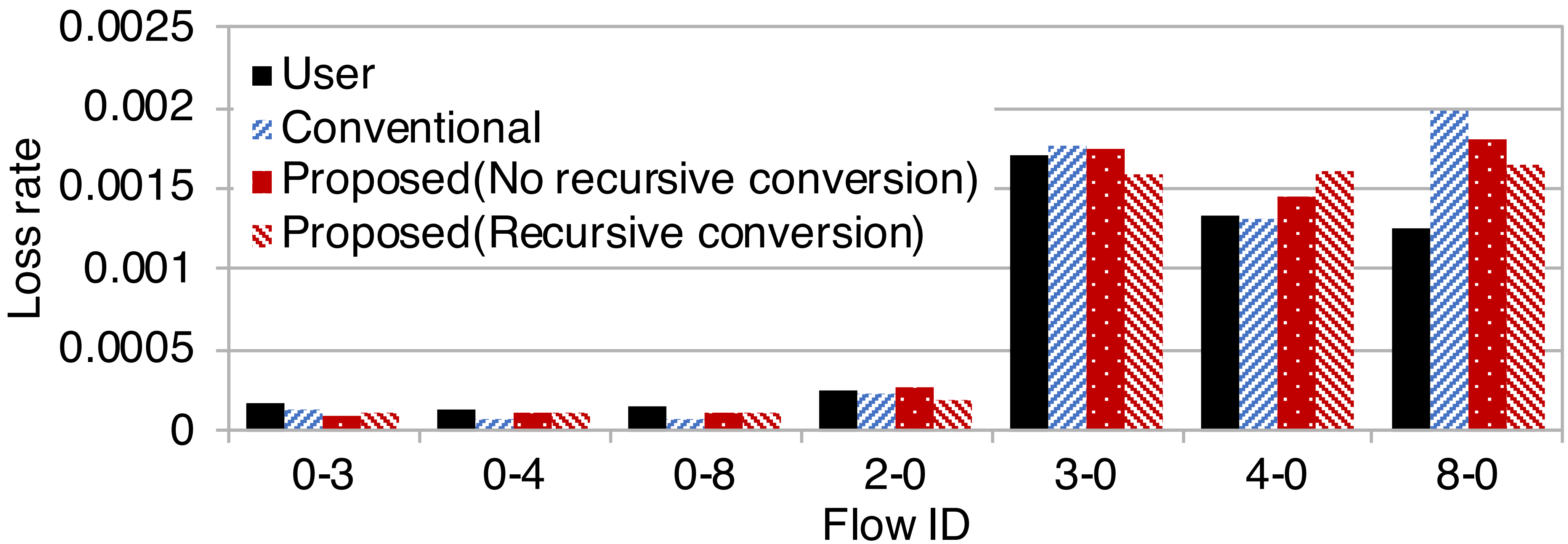
  $x_{\mathrm{th}} = 0.01$: The threshold to define start/end time of congestion periods.

  $r = 0.1$: The tuning parameter in clustering process.

- The simulation time is 1005 [s] and we only use the data from 5 [s] to 1005 [s].
- The simulation is repeated 10 times by changing the phase of the probe packet injection time.

Average Loss Rate

- The avarage of user loss rate and estimators are calculated.
- The conventional estimator is simply calculated as the ratio of the number of loss samples to the total number of samples.



- The maximum loss rate experienced by stationary user flows was about 1.7×10^{-3}.
- Relatively small loss rate was about 1.2×10^{-4}.
- We can confirm that all methods can estimate loss rate without bias.

Root Mean Squared Errors (RMSE)

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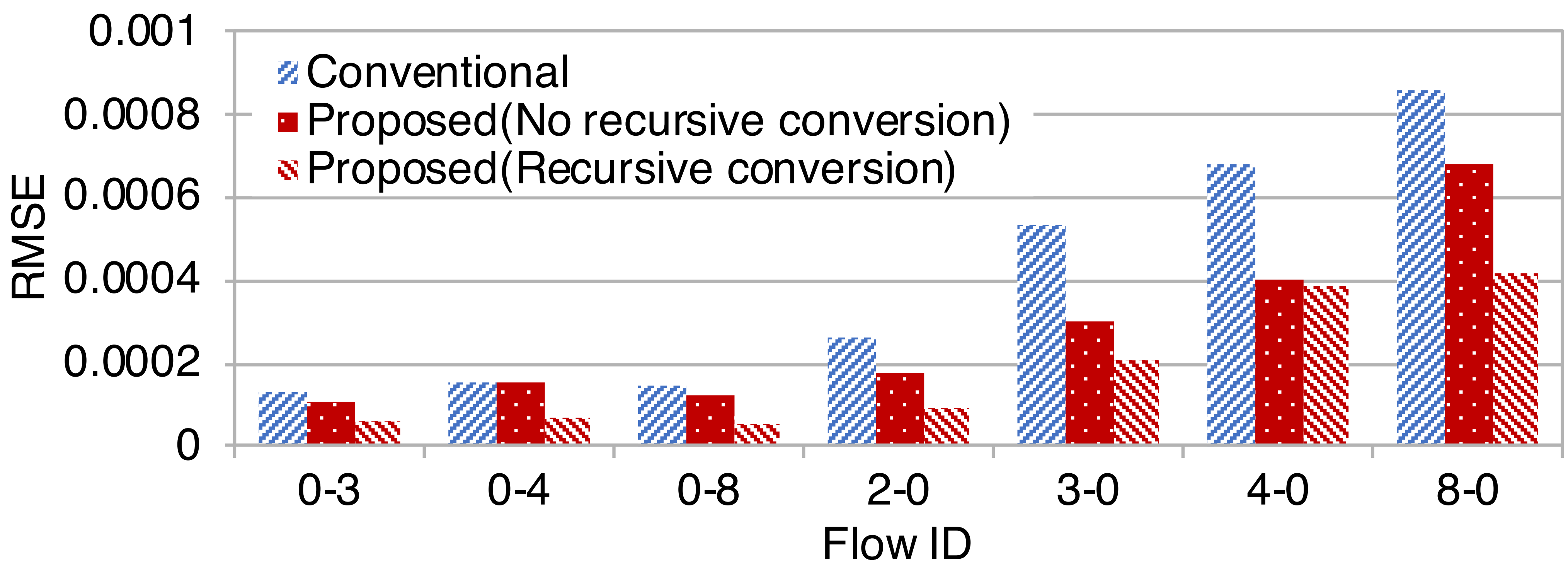
- We also evaluate Root Mean Squared Errors (RMSE) when the loss rate on end-to-end path are measured.



- The proposed method without recursive conversion provides 31.3% reduction of RMSE on average.
- The proposed method with recursive conversion achieves 57.5% reduction.

Number of Loss Samples

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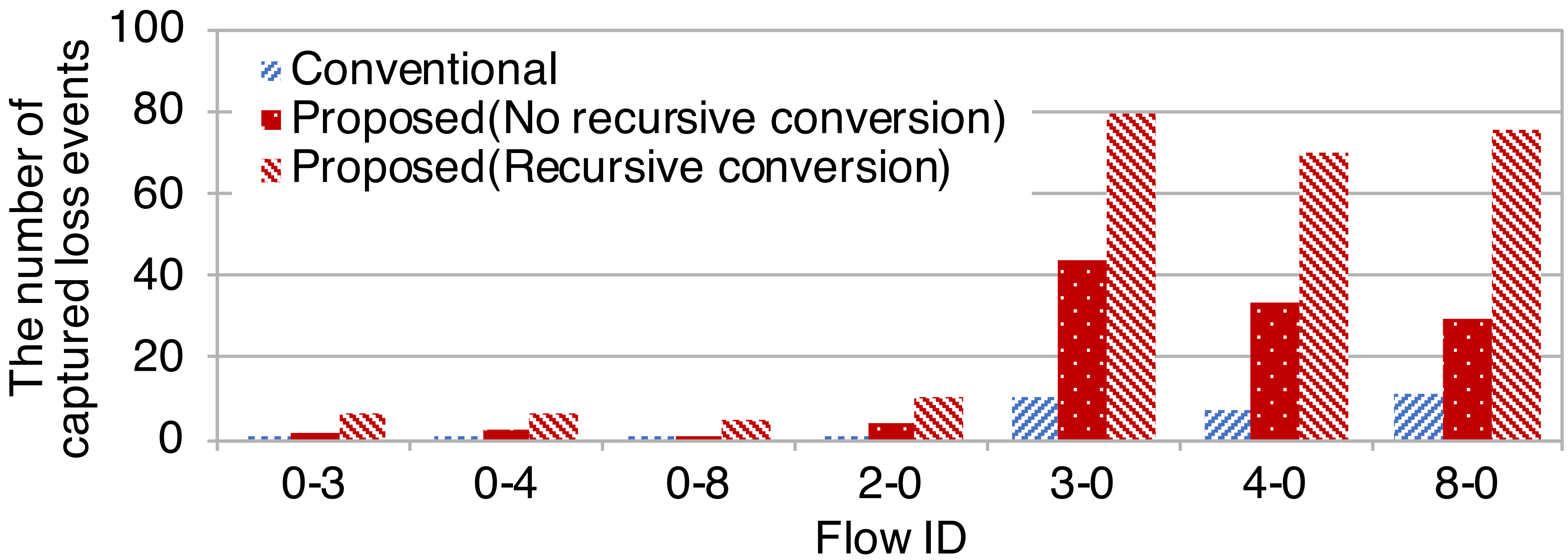
- The number of captured loss events extreamely increases.



- It is impossible for the conventional method to estimate the loss rate less than 2.0×10^{-4} since the number of the probe packets par flow is 5000 in the simulation.
- However, the proposed method overcomes this fundamental limitation in accuracy.

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Conlusions and Future Works

We proposed a loss measurement method that fully utilizes flows, including flows with different source and destination in this paper.

- Through simulations on ns-3 simulator, we confirmed that the proposed method can reduce estimation errors by 57.5% on average.

Future Works

- As future research, we plan to develop highly accurate delay/loss tomography using the parallel monitoring technique.
- We also have a plan to implement the proposed method for a real network, and evaluate the effectiveness of the method.

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Thank you for your kind attention.