Accurate Measurement Technique of Packet Loss Rate in Parallel Flow Monitoring

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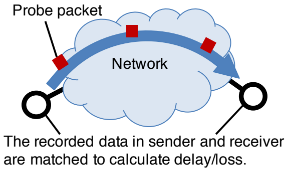
Background and Objectives

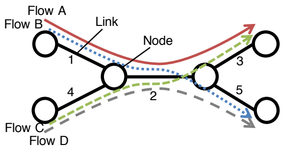
End-to-end Measurements

- End-to-end metrics are fundamental for a network evaluation.
- An active measurement is a common method to measure end-to-end metrics.
- It is important to achieve accurate measurement without increasing the number of probe packets.



Parallel Monitoring of Probe Flows

- For most measurement applications, multiple paths are monitored in parallel to measure end-to-end metrics.
- 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.

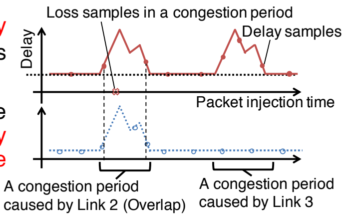


Objectives

- 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 for packet loss rate.
  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.

Assumptions and Models

- 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.
- 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.



Parallel Flow Monitoring Method for Delay

Overlap of Virtual Delay Processes

- Queueing delay processes within a congestion period that have common links frequently overlap.
- If $\hat{x}_A(t)$ and $\hat{x}_B(t)$ 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.

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

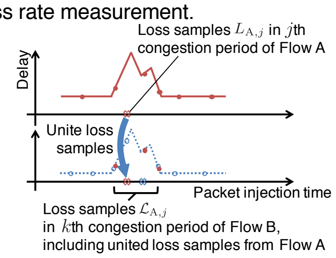
Conversion Process

- 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/last samples in a congestion period is smaller than δ;
- To remove inappropriate samples, we utilize a clustering technique in machine learning.

The Proposed Loss Monitoring Method

Extension for Loss Rate Measurements

- We extend the method [5] to a loss rate measurement.
  1. Samples $L_{A,j}$ are recorded for all congestion periods.
  2. Delay samples are converted each other with method [5].
  3. Samples $L_{A,j}$ are united to $\mathcal{L}_{B,k} = L_{A,j} \cup L_{B,k}$ when delay samples are converted.



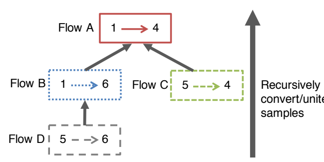
- The samples by our method is not uniformly distributed.
- To provide an unbiased estimator of loss rate on each path, samples should be weighted.
- The loss rate on the path of Flow A is estimated by,

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

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 convert 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.

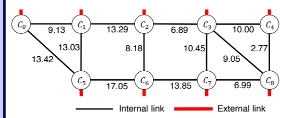
Recursive Conversion

- 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.



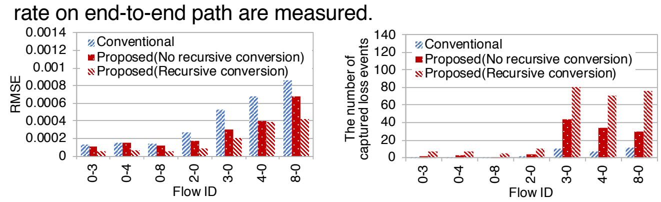
Experiments

- We perform NS-3 simulations to confirm that loss samples of parallel flows are appropriately united between each other.
- Poisson, Exponential ON/OFF, and Probe traffic stream between all pairs of 9 nodes in a network (i.e., 72 flows stream for each type).



Probe packet intervals δ: 0.2 s
The threshold x_{th} to define congestion: 0.01 s
The tuning parameter r in clustering process: 0.1
Simulation time T: 1005 s (Data are used from 5 s to 1005 s)
Queue size q: 1024 packets Link capacity C: 15.552 Mbps

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



- The proposed method provides 31.3% (No recursive) and 57.5% (Recursive) reduction of RMSE on average.
- The number of captured loss events extremely increases.

Conclusions and Future Works

- We proposed a loss measurement method that fully utilizes flows, including flows with different source and destination in this paper.
- We plan to develop highly accurate delay/loss tomography using the parallel monitoring technique.

References

[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.