Accuracy Improvement of CoMPACT Monitor by Using New Probing Method

Kohei Watabe

Graduate School of System Design,
Tokyo Metropolitan University

Sep. 23, 2009

Background (1)

Tokyo Metropolitan University

Kohei Watabe

Change of recent network

- Various applications appear and provide new services including telephony and live video
- The traffic of each flow exhibits various characteristics
- It is necessary to guarantee the reliability to the network used on business

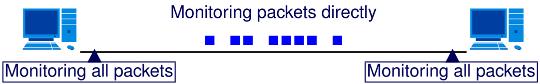
To guarantee the reliability, the measurement technology to produce per-flow QoS information is needed.
(e.g. for each user, application, or organization)

- In this paper, we focus the one-way delay for each flow

Background (2)

- Conventional means of measuring one-way delay can be classified into passive and active measurements

Passive measurement

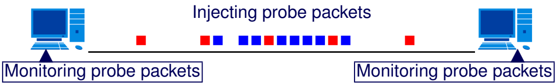


- It monitors the target packets directly by capturing the packets
- It can get accurate one-way delay for each flow
- One-point monitoring to measure volume of traffic can be conducted very easily
- Two-point monitoring to measure one-way delay lacks scalability

Background (3)

- Conventional means of measuring one-way delay can be classified into passive and active measurements

Active measurement



- It monitors one-way delay of probe packets by injecting probe packets
- It is easy for the end user to carry out
- Injection of enormous probe packet debase network performance
- It measures not per-flow one-way delay but one-way delay of probe packet flow

Background (4)

Tokyo Metropolitan University

Kohei Watabe

Traditional methods

- Passive measurement has a scalability problem
- Active measurement can not measure per-flow one-way delay

In large-scale network, we can NOT get per-flow one-way delay by using traditional methods.

The Objective (1)

Tokyo Metropolitan University
Kohei Watabe

We have proposed change-of-measure-based passive/active monitoring (CoMPACT monitor) that achieves scalable measurement of one-way delay distribution for each flow.

+

Study of F.Baccelli

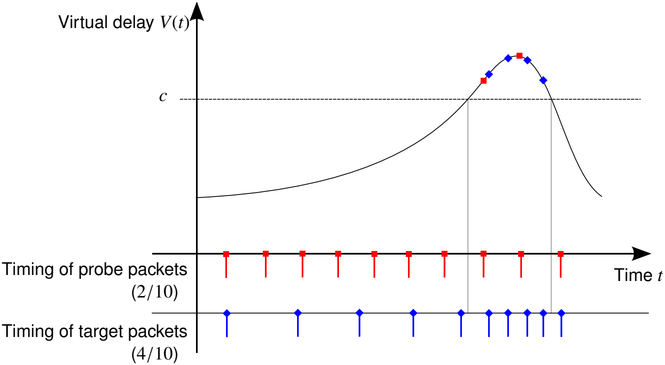
- Study about inter-probe time for active measurement
- Suboptimal probing in terms of accuracy was proposed

||

In our study, we have applied this suboptimal probing to CoMPACT monitor and tried to improve CoMPACT monitor in accuracy.

CoMPACT Monitor (1)

- If arrival timing is different, packet delay is different



- In probe packets, 2 packets of 10 packets arrive in congestion
- In target packets, 4 packets of 10 packets arrive in congestion
- CoMPACT monitor transfers probe packets delay into target packets delay according to density of target packets

CoMPACT Monitor (2)

- Estimator of one-way delay distribution by CoMPACT monitor
- It estimates the probability for target packet delay to exceed c

  m : Number of probe packets
  T_n : Arrival time of nth probe packet
  $V(t)$: Virtual one-way delay
  $a(t)$: Volume of traffic of target flow

$$\underbrace{\frac{1}{m}\sum_{n=1}^{m} 1_{\{V(T_n)>c\}}}_{\substack{\text{Delay of probe packet} \\ \text{(Active)}}} \underbrace{\frac{a(T_n)}{\sum_{l=1}^{m} a(T_l)/m}}_{\substack{\text{Translation} \\ \text{(Passive)}}}$$

- Passive measurement to measure traffic has NOT scalability problem

Suboptimal Probing (1)

- Intervals with an exponential distribution have been widely used as probe packets arrivals
  (Probing method according to PASTA property)
- This is the only appropriate method if we can not ignore the effect of probe packets

---

Assumption

- We can ignore the effect of probe packets

- PASTA-based probing is NOT the only method
- Some other probing method can estimate true value
  (e.g. Intervals with a uniform or Gamma distribution etc.)

Suboptimal Probing (2)

Tokyo Metropolitan University

Kohei Watabe

Assumption

- The autocovariance function of the target process is convex

- Periodic-probing achieves minimum variance of the estimator
- A lower variance is connected with accuracy
- If the autocovariance function is convex strictly, periodic-probing is optimal in accuracy

Tokyo Metropolitan University

Kohei Watabe

Suboptimal Probing (3)

When the cycle of the target process corresponds to the cycle of the probe packet, a phase-lock phenomenon occurs and the estimator may converge on a false value.

- Periodic-probing is not actually optimal
- There is the tradeoff between PASTA-based probing and periodic-probing

Suboptimal Probing (4)

- To solve the tradeoff, intervals with the parameterized Gamma distribution is proposed
- When $\beta = 1$, it corresponds to exponential distribution
- When $\beta \to \infty$, it converges on determinate value

Property of this Gamma-probing

This Gamma-probing links PASTA-based probing with periodic-probing continuously.

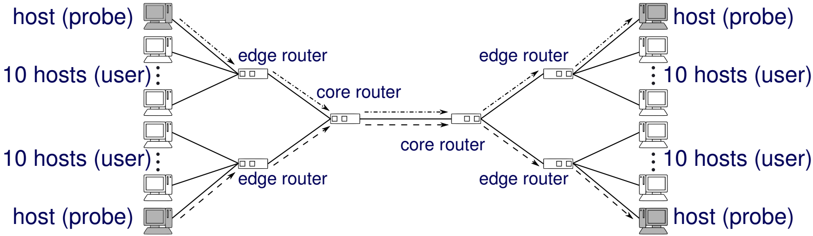
$$\boxed{\text{Exponential}} \quad \mathbf{1} \longleftarrow \boldsymbol{\beta} \longrightarrow \boldsymbol{\infty} \quad \boxed{\text{Periodic}}$$

Variance decrease → ← Phase-lock occurs →

- Variance decreases with increase of β
- Phase-lock occurs when β is so large value
- We can get a suboptimal probing if we tune appropriate β

Simulation Model (1)

- We investigated the effectiveness of Gamma-probing for CoMPACT monitor through simulations
- Each source end host transfers packets by UDP/TCP to the corresponding destination end host



Simulation Model (2)

Tokyo Metropolitan University

Kohei Watabe

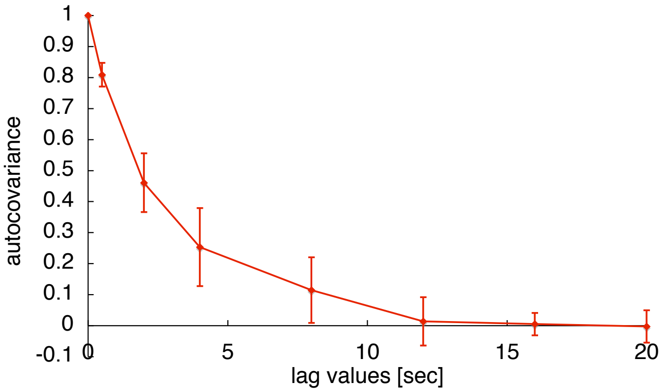
- User flows are given as ON/OFF processes and categorized into the 4 types
- Probe packet trains are categorized into the 5 types listed in the following table

Distribution of probe intervals	Parameter of Gamma distribution	Mean probe intervals
Exponential	$(\beta = 1)$	0.5 s
Gamma	$\beta = 5$	0.5 s
Gamma	$\beta = 25$	0.5 s
Gamma	$\beta = 125$	0.5 s
Periodic	$(\beta \to \infty)$	0.5 s

- Parameters of Exponential and Periodic are parameters of the Gamma distribution corresponding to each probing

UDP Simulation (1)

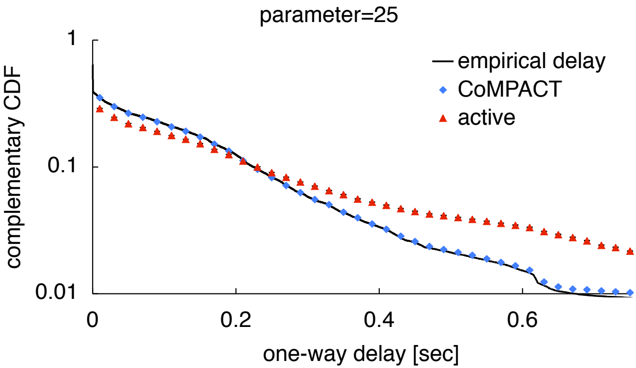
- We checked the convexity of target process
  (We must assume the convexity to apply the gamma-probing)



- We can confirm the convex trend

UDP Simulation (2)

- We confirmed that we can estimate the empirical delay by CoMPACT monitor with Gamma-probing
- Parameter β of Gamma-probing is 25



- We have plotted for other parameters and gotten similar results

UDP Simulation (3)

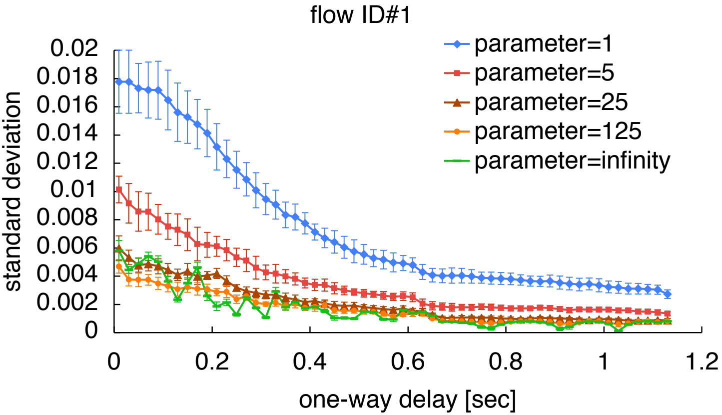
Tokyo Metropolitan University
Kohei Watabe

- We were able to confirm that the CoMPACT monitor with Gamma-probing gives good estimates
- We cannot judge the superiority or inferiority of any parameter
- To judge the superiority or inferiority, we should investigate variance of estimator

Tokyo Metropolitan University
Kohei Watabe

UDP Simulation (4)

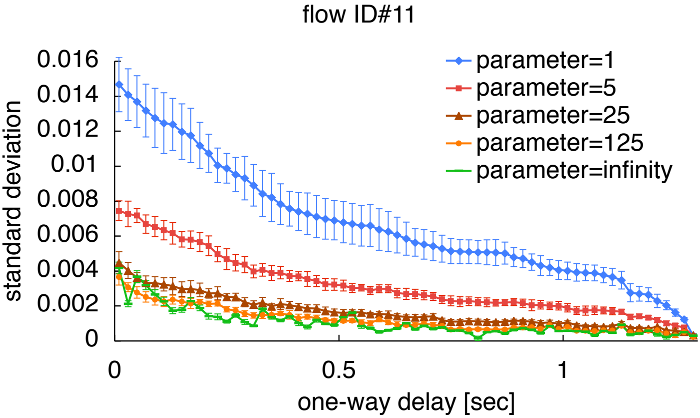
- We show the standard deviation of estimator
- A case of flow #1



UDP Simulation (5)

Tokyo Metropolitan University
Kohei Watabe

- We show the standard deviation of estimator
- A case of flow #11



Results and Discussion (1)

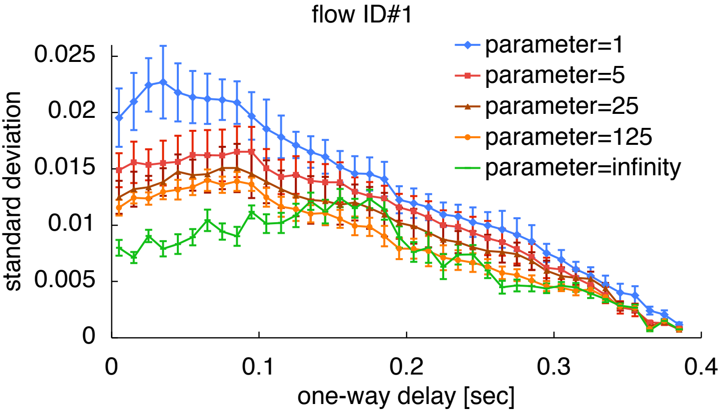
Tokyo Metropolitan University

Kohei Watabe

- The standard deviation clearly decreases as β increases from $\beta = 1$ to $\beta = 125$
- The standard deviation of periodic-probing is larger than that for $\beta = 125$
- This reversal may be a sign of incorrectness due to the phase-lock phenomenon
- If we tune appropriate parameter β, we can get more accurate estimation than traditional PASTA-based probing

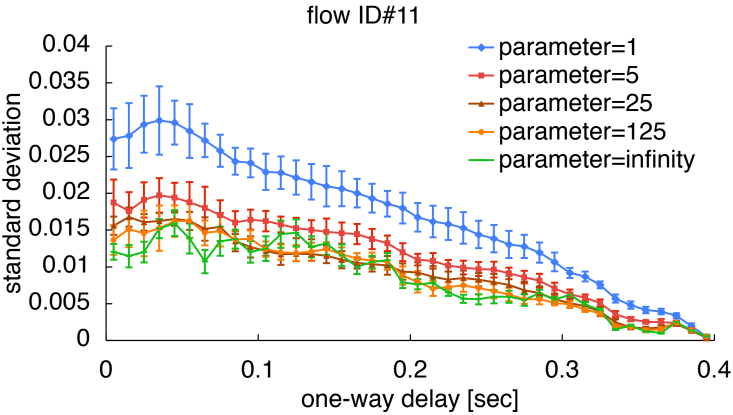
TCP Simulation (1)

- We also simulated the network for the case of TCP flows
- A case of flow #1



TCP Simulation (2)

- We also simulated the network for the case of TCP flows
- A case of flow #11



Results and Discussion (1)

Tokyo Metropolitan University

Kohei Watabe

- The standard deviation has the decreasing tendency as β increases
- A condition of this simulation is that user traffic is very unstable
- So the confidence intervals overlap each other
- We should set long measurement period for unstable flow
- However, we can confirm effect of accuracy improvement

Conclusion

It was confirmed that Gamma-probing is effective when the complementary CDF of one-way delay was estimated by CoMPACT monitor.

- Long measurement period is required for seriously variable traffic

Residual issues

- We should present the method to determine appropriate parameter β
- Application should be verified about not only one-way delay but also packet loss

Tokyo Metropolitan University

Kohei Watabe

Thank you very much for your kind attention