

# Measuring Available Bandwidth of Multiple Parts on an End-to-end Network Path

Kazumasa Koitani, Go Hasegawa, and Masayuki Murata  
Osaka University, Japan

## Background

- Measuring available bandwidth on an end-to-end network path enables to
  - Detect network congestion
  - Adapt transmission rate
- But existing methods cannot
  - Identify bottleneck part
  - Know available bandwidth of all parts of the path

If we know available bandwidth of multiple parts of the path,

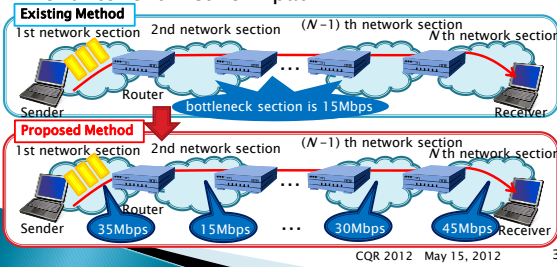
- The sender configure the data rate of wireless network to lower bit rate with smaller bit error rate

Sender High bit error rate Bottleneck location Receiver

CQR 2012 May 15, 2012 2

## Objective

- Propose a simultaneous measurement method of available bandwidth of multiple parts on an end-to-end network path



## Basic principle of measuring available bandwidth

- Measuring available bandwidth on an end-to-end network path
  - (i)  $x \leq A$   
Intervals of the packets remain unchanged
  - (ii)  $x > A$   
Intervals of the packets become large

Repeating these operations enables the estimation of available bandwidth on an end-to-end network path

CQR 2012 May 15, 2012 4

## Approach to simultaneous measurements

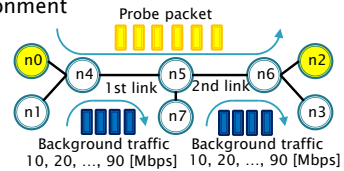
- Measure available bandwidth of multiple parts by using the basic principle
  - Available bandwidth of each part of the path may not be measured because of background traffic at sender-side network
  - To measure, injecting rates of all probe packets should be smaller and larger than available bandwidth



We first validate the possibility of simultaneous measurements by simulation experiments

## Validation of possibility of simultaneous measurements (1)

- Validate the possibility of simultaneous measurement by using ns-2
- Environment



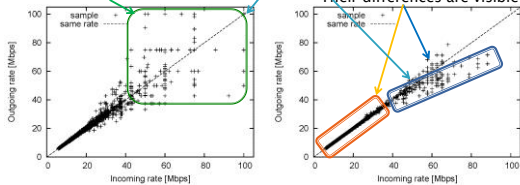
- Physical bandwidth: 100 [Mbps] (all links)
- Observe incoming rate of successive  $K_0$  probe packets at node n5 and outgoing rate at node n6

### Validation of possibility of simultaneous measurements (2)

**Results**

- Injecting rates of probe packets become smaller and larger than available bandwidth
- Incoming and outgoing rates are smoothed
- Their differences are visible

Can not observe the stable relationship between incoming and outgoing rates



Background traffic: (1st link, 2nd link) =  $(50, 40)$  [Mbps]

Parameter  $K_0$  affects the measurement accuracy

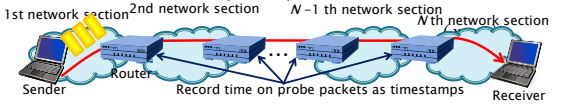
### Proposed method (1)

**Assumption**

- Intermediate routers record time on probe packets as timestamps

**Estimation process**

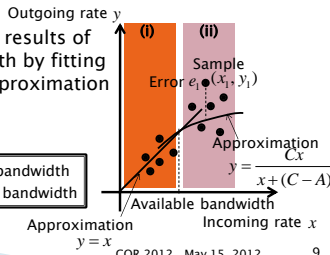
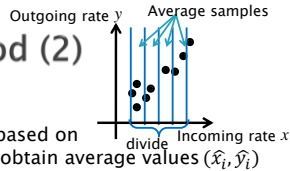
- The sender sends probe packets at various rates
- Calculate the incoming and outgoing rates  $(x_i, y_i)$  from timestamps at intermediate routers



### Proposed method (2)

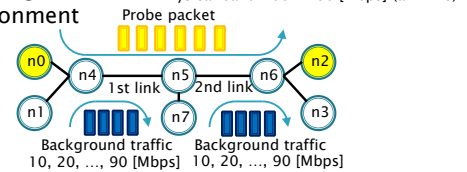
**Estimation process**

- Divide these samples based on their incoming rate to obtain average values  $(\bar{x}_i, \bar{y}_i)$
- Obtain estimation results of available bandwidth by fitting samples to the approximation model



### Performance evaluation (1)

- Evaluate performance of the proposed method by using ns-2
- Environment

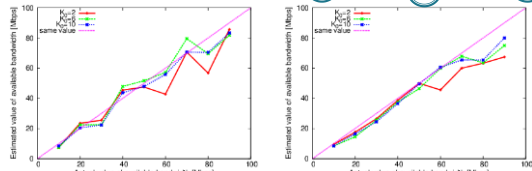
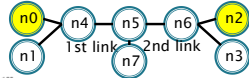


- Estimate available bandwidth of 2nd link using incoming rate of successive  $K_0$  probe packets at node n5 and outgoing rate at node n6

### Performance evaluation (2)

(In the case that available bandwidth of 1st link is large)

**Estimation results**



1st link background traffic: 10 [Mbps] 1st link background traffic: 30 [Mbps]

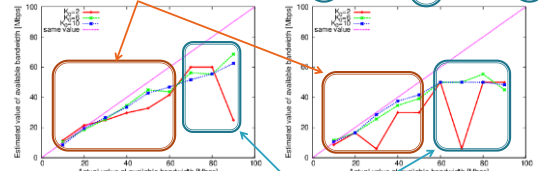
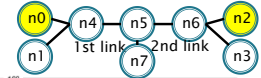
Regardless of available bandwidth of 1st link and  $K_0$ , available bandwidth is measured accurately

### Performance evaluation (3)

(In the case that available bandwidth of 1st link is small)

**Estimation results**

The available bandwidth is almost measured accurately




1st link background traffic: 70 [Mbps] 1st link background traffic: 90 [Mbps]

The measurement accuracy remains reasonable although incoming rates can not be large


## Conclusion and future Work

- ▶ Conclusion
  - Propose simultaneous measurement method of available bandwidth of each part of an end-to-end network path
  - Validate the performance of the proposed method by simulation experiments
- ▶ Future work
  - Propose the number of probe packets considering the measurement overhead and accuracy



CQR 2012 May 15, 2012 13

## Question ?



CQR 2012 May 15, 2012 14