Evaluation and improvement of end-to-end bandwidth measurement method for power-saving routers

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Background

- Increasing in energy consumption in computer networks
- Researches related to power-saving of network equipment
  - Low power modes for G-PON, ADSL2, ADSL2+
    - Adjust link speed according to traffic load for power-saving
  - Power-saving router which adjusts the processing performance according to the traffic load
    - The power saving function is triggered in shorter cycles (the order of milliseconds)
    - This behavior may affect network controls and protocols adversely
- The effect on end-to-end network controls and protocols has not been investigated in detail

We focus on interactions between an end-to-end bandwidth measurement method and the power-saving router

K. Zaitsu, K. Yamamoto, and Y. Kuroda, et al. "Hardware implementation of fast forwarding engine using standard memory and dedicated circuit," in Proceedings of 17thIEEE conference on ICECS 2010, pp. 379-382, Dec 2010.

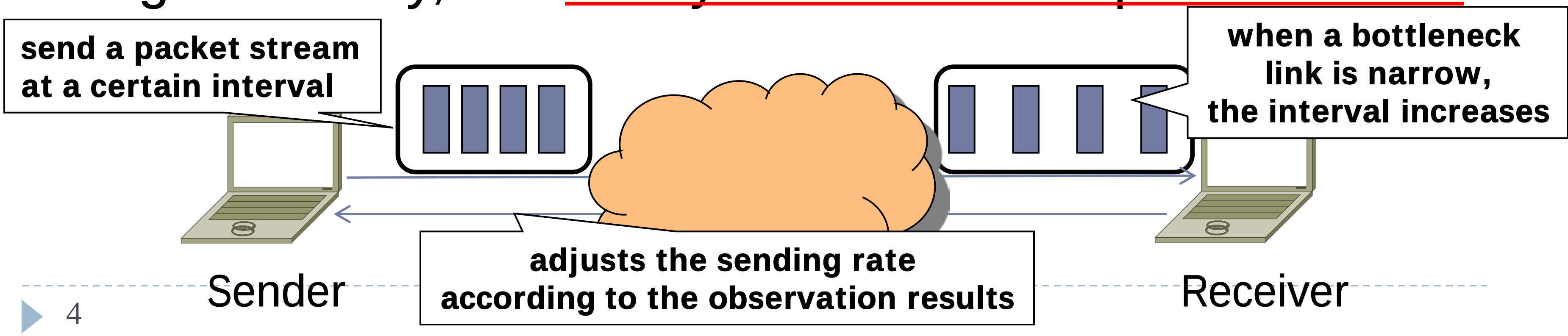
Background and our goal

- Researches on end-to-end available bandwidth measurement method
  - Pathload, ImTCP, Cprobe, Spruce, and others
  - These researches do not take into account the environment where the physical link bandwidth changes by power-saving routers
  - We focus on Pathload
    - Most popular, and highly accurate
- Our goal
  - Investigate the interactions between the bandwidth measurement behavior of Pathload and the behavior of power-saving routers
  - Propose Pathload parameter tuning method
    - Maintain measurement accuracy without affecting the behavior of power-saving routers

Pathload algorithm

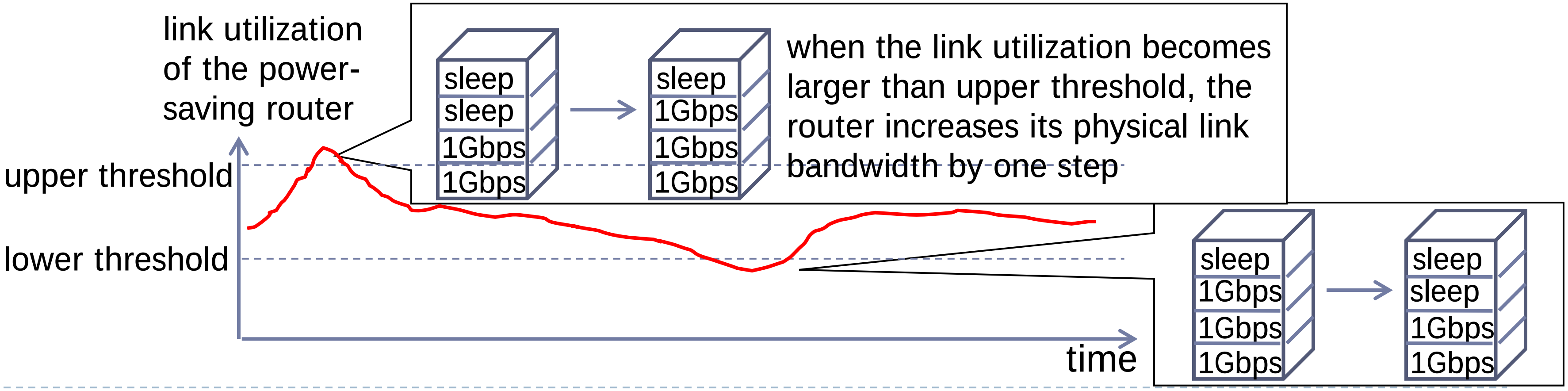
SLoPS: Self-Loading Periodic Streams

- SLoPS measurement principle
  - The sender sends packet streams to the receiver at a certain rate
  - The receiver observes the arrival intervals of the packets
    - The interval increases→the send rate is larger than available bandwidth →decreases send rate of the next stream
    - The interval does not change→the send rate is smaller than available bandwidth →increases send rate of the next stream
  - The sender repeats sending packet stream to the receiver
- High accuracy, but Heavy load in a short period of time



Power-saving router model

- The router has several stepwise power saving configurations
  - Divides into several steps between full power (without power saving) and 0 (sleep mode)
- The router regulates its physical link bandwidth according to the network traffic load
  - Monitors the link utilization at regular intervals
  - Increases or decreases the physical link bandwidth when the average link utilization becomes larger or smaller than threshold



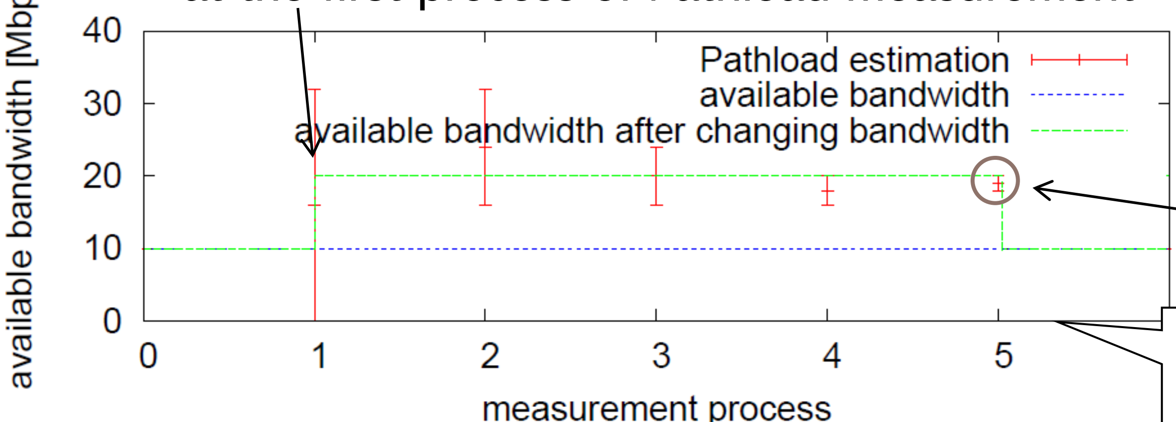
Effects of Pathload's measurement on power-saving routers

- The power-saving router may increase its physical bandwidth to accommodate the measurement load caused by Pathload
  - Packet streams are injected into the network to fill the available bandwidth at the tight link (bottleneck link)
  - The link of the power-saving router is likely to become tight link because they decrease the physical bandwidth in order to reduce power consumption
  - The power-saving router increases the physical bandwidth temporarily because the link utilization approaches 100%

Effects of power-saving router's behavior on Pathload's measurement accuracy

- The power-saving router increases the physical bandwidth due to traffic load by Pathload's measurement
- Pathload measures the available bandwidth based on the increased physical bandwidth
  - In such case, Pathload measurement is not correct

We assume the situation that the power-saving router increases its physical bandwidth due to traffic load by Pathload's measurement at the first process of Pathload measurement

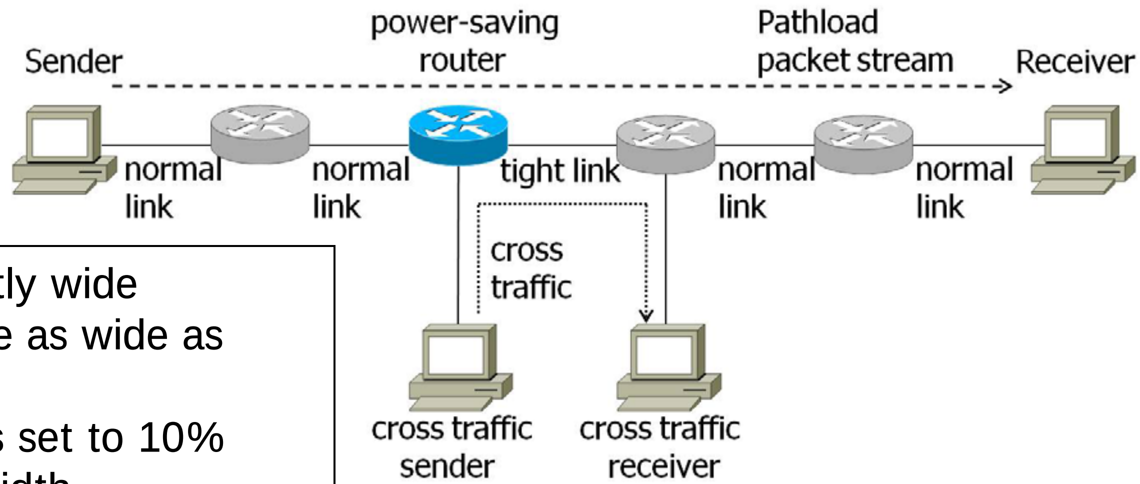


Measuring the available bandwidth based on the increased bandwidth (20 Mbps)

Pathload's measurement process based on SLoPS principle

Simulation settings

- Network topology



・normal links provide sufficiently wide physical link bandwidth (twice as wide as the tight link bandwidth)
・The load of the cross traffic is set to 10% of tight link maximum bandwidth

- Settings of the power-saving router and Pathload

parameters of the power-saving router

Parameter	Value
Maximum value of physical link bandwidth	2000 Mbps, 1000 Mbps, 100 Mbps
Number of steps for regulating physical bandwidth	10
Upper threshold of link utilization for increasing physical bandwidth	0.8
Lower threshold of link utilization for decreasing physical bandwidth	0.3
Averaging weight	0.3
Length of the interval for monitoring link utilization	5 ms

parameters of Pathload

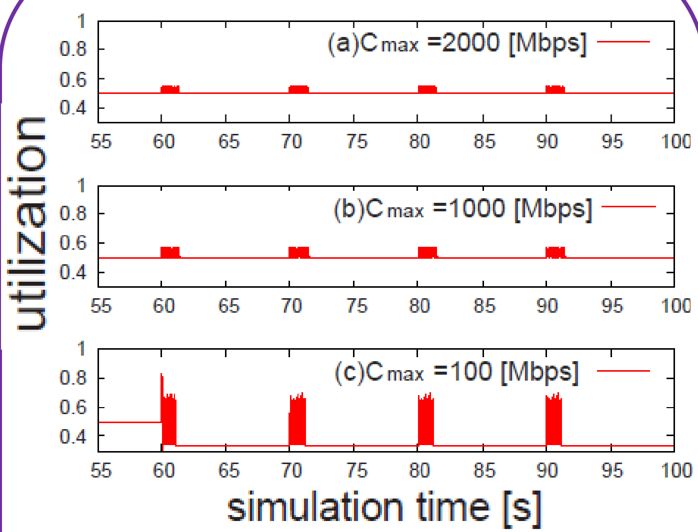
Parameter	Value
Probing packet size	1500 bytes
Number of packets included in a packet stream	25
Number of streams for determining the trend	3
Estimate resolution	1 Mbps

With changing this parameter, we show evaluation of
・the impact of traffic generated by Pathload
・the measurement accuracy of Pathload in the presence of a power-saving router

Simulation results

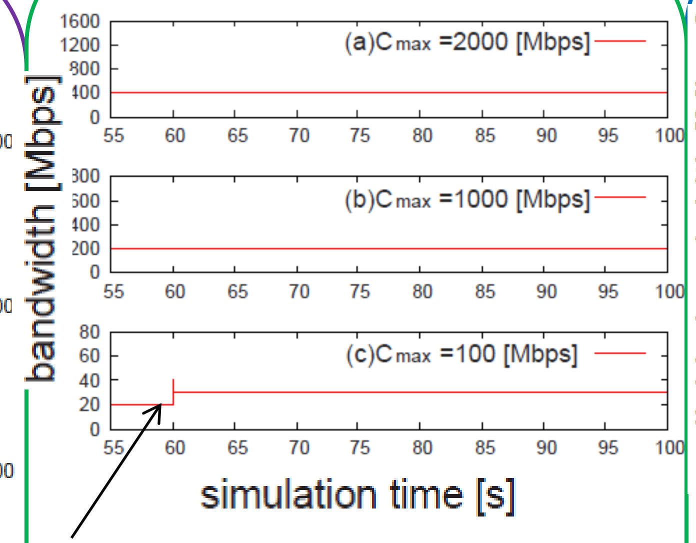
- Effects of changing the maximum bandwidth of the tight link

link utilization



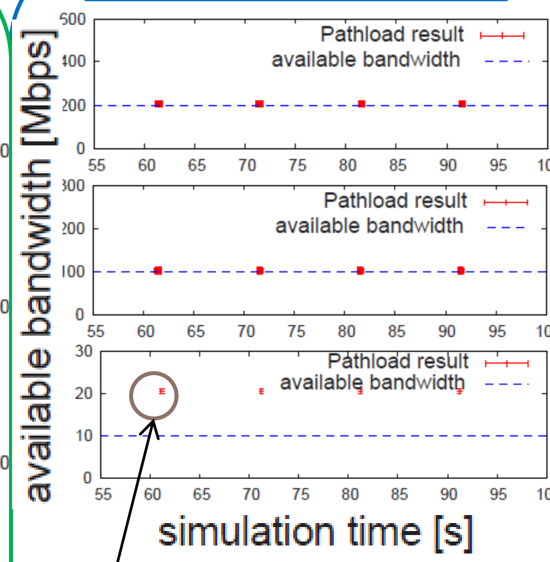
The change in link utilization becomes large when maximum bandwidth becomes small

physical bandwidth of power-saving router



The power-saving router increases its bandwidth when maximum bandwidth is 100 Mbps

measurement results of Pathload



The results obtained with Pathload are far from the true available bandwidth

- The power-saving router increased its physical bandwidth due to the measurement load
  - Especially when maximum bandwidth is small
- The behavior of the power-saving router degrades the measurement accuracy

Parameter tuning of Pathload

packet stream length of Pathload

monitoring interval by power-saving router

→ In such cases the measurement traffic generated by Pathload strongly influences the behavior of power-saving routers

We obtained Eq. (1) through simple mathematical analysis.
Eq. (1) means the condition for not affecting a power-saving router in such case.

$$U(t_{j-1}) = w\sum_{k=0}^{j-1}(1-w)^{j-1-k}\frac{R(f)}{C(t)} + \frac{R^C}{C(t)} \leq \lambda_u \qquad (1)$$

- $U(t_{j-1})$: the average link utilization
- $w\sum_{k=0}^{j-1}(1-w)^{j-1-k}\frac{R(f)}{C(t)}$: link utilization contributed by Pathload's measurement
- $\frac{R^C}{C(t)}$: contributed by cross traffic
- λ_u: Upper threshold of link utilization for increasing physical bandwidth

We verified the validity of Eq. (1) through comparison with the simulation results in previous slide

By configuring the number of packets in each packet stream to satisfy Eq. (1), we can prevent Pathload from affecting the behavior of power-saving routers

Conclusion and future works

- Conclusion
  - Investigated the interactions between the bandwidth measurement behavior by Pathload and the behavior of power-saving routers
    - Accurate measurement results are difficult to be obtained, particularly when the physical bandwidth of the tight link is narrow
  - Obtained the parameter tuning method of Pathload
- Future works
  - Enhance the algorithm of Pathload to accommodate power-saving routers
    - Automatic parameter tuning
    - Evaluate the performance of enhanced Pathload