Idle Bandwidth Utilization for Multipath Transport Protocols

Michio Honda
Keio University / UCL
July 9, 2010
MSN’10 - Cosener's House, Abingdon

supported by KAKENHI(21-5729)
Goals

- Congestion control for multipath transport protocols
  - Maximum utilization of idle bandwidth on distinct paths
    - e.g., given/limited bandwidth by ISPs
  - Maximum utilization of congested shared link
    - e.g., core of the network congested by other TCP flows
  - TCP-Friendly at the shared congested link
  - E.g.,

```
subflow1 10Mbps
subflow2 30 Mbps
TCP flows
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(40 Mbps aggregate)

(40 Mbps each)
The aggregate throughput of subflows should be equal with TCP at the congested shared link.

We define the weight of TCP is 1.

We maintain the sum of weight of subflows to 1 at the connection.

Each subflow has the weight less than 1.

Subflow with the weight $N$ achieves $N$ times TCP throughput.

We adopt weight$^2$ as an increase parameter of TCP.

Increase the window size by weight$^2$ packets per RTT.
Effective Utilization of Disjoint Links

- We have to adjust the weight of subflows so that disjoint links can cover subflow throughput
  - If both subflows have weight 1/2, each subflow has to achieve 20 Mbps at the shared congested link
    - But idle bandwidth at the subflow1 is less than that of the ideal throughput of subflow1
Effective Utilization of Disjoint Links

- We have to adjust the weight of subflows so that disjoint links can cover subflow throughput
  - If subflows have the weight 1/4 and 3/4, their ideal throughput (10 and 30 Mbps) can be covered by the idle bandwidth
    - Then aggregate throughput should be ideal
Detection of Idle bandwidth Limitation

- If subflows are affected only by the shared congested link, their throughput could be proportional to their weight
- (i.e., the throughput per weight ($T_w$) of subflows should be equal)
- If $T_w$ of one subflow is less than that of the others, that subflow could be affected by idle bandwidth capacity
- Then we reduce the weight of that subflow to equalize $T_w$ to the highest one

$$W_{new} = \frac{T_w^{min}}{T_w^{max}}$$

$W_{new}$: new weight of subflow reducing weight

$T_w^{min}$: throughput per weight of that subflow

$T_w^{max}$: throughput per weight of the subflow that has achieved the highest throughput per weight

- We add the reduction of the weight to another subflow
Control Loop

- So we measure the throughput constantly, and detect subflows constrained by idle bandwidth.
Simulation Setup (1)

- NS-2 simulation
- Ratio of Idle capacity is approx 1:1

10 flows, each of them ideally achieve 3 Mbps
Simulation Result (1)

Linked-increase Algorithm
Approx. 2.8 Mbps

Weight-based Algorithm
Approx. 3.0 Mbps

(Optimal combination of weight is 1:1)
Simulation Setup (2)

- Ratio of Idle capacity is approx 1:2
Simulation Result (2)

Linked-increase Algorithm
Approx. 2.73 Mbps

Weight-based Algorithm
Approx. 3.13 Mbps

(Optimal combination of weight is 2:1)
Simulation Setup (3)

- Ratio of Idle capacity is approx 1:4

10 flows, each of them ideally achieve 3 Mbps
Simulation Result (3)

Linked-increase Algorithm
Approx. 2.67 Mbps

Weight-based Algorithm
Approx. 2.83 Mbps

(Optimal combination of weight is 4:1)
Comparison with Linked Increase Algorithm

**Merit**
- Independency of flows
  - Easy to use with different congestion control variants
    - any weighted variants of existing C.C. algorithm
  - Allow different C.C. algorithms for each subflow
    - Optimal congestion control for each subflow
  - Easy to maintain stability between subflows
  - Better performance at limited idle bandwidth and shared congested link

**Demerit**
- Quickness for optimal convergence
  - We need long measurement (several seconds) for improve weight allocation
- Weakness for very-frequent change of network
Conclusion and Ongoing Work

- Weighted congestion control approach for multipath transport protocols
  - Towards better idle bandwidth utilization
- Ongoing work
  - Parameter optimization
  - Different congestion control variants (e.g., High-speed variants, MuITFRC for MRTP)