Idle Bandwidth Utilization for Multipath Transport Protocols

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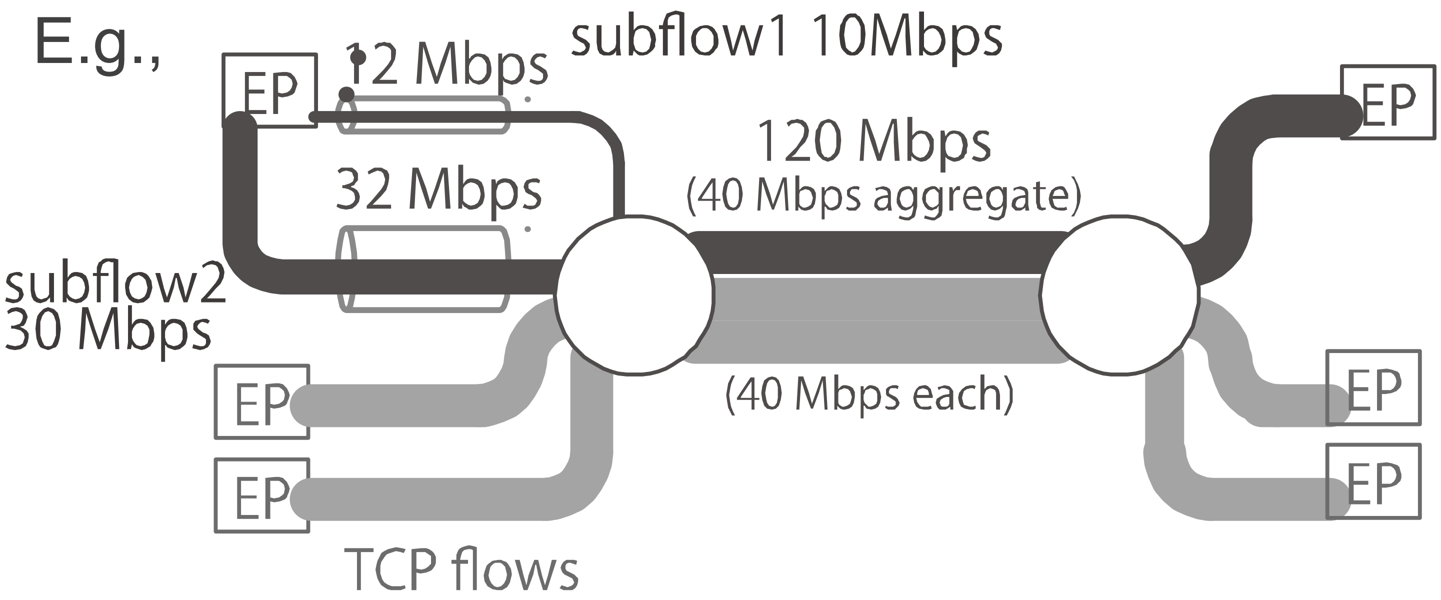
supported by KAKENHI(21-5729)

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.,



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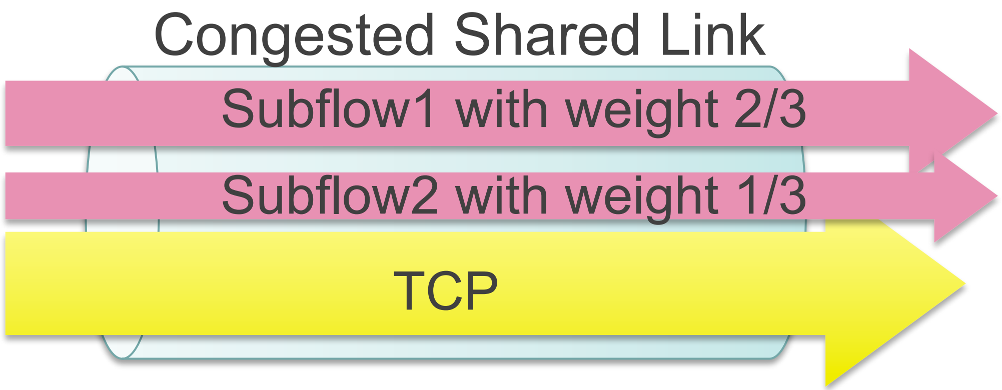
Fair Utilization of Shared Congested Link

- 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



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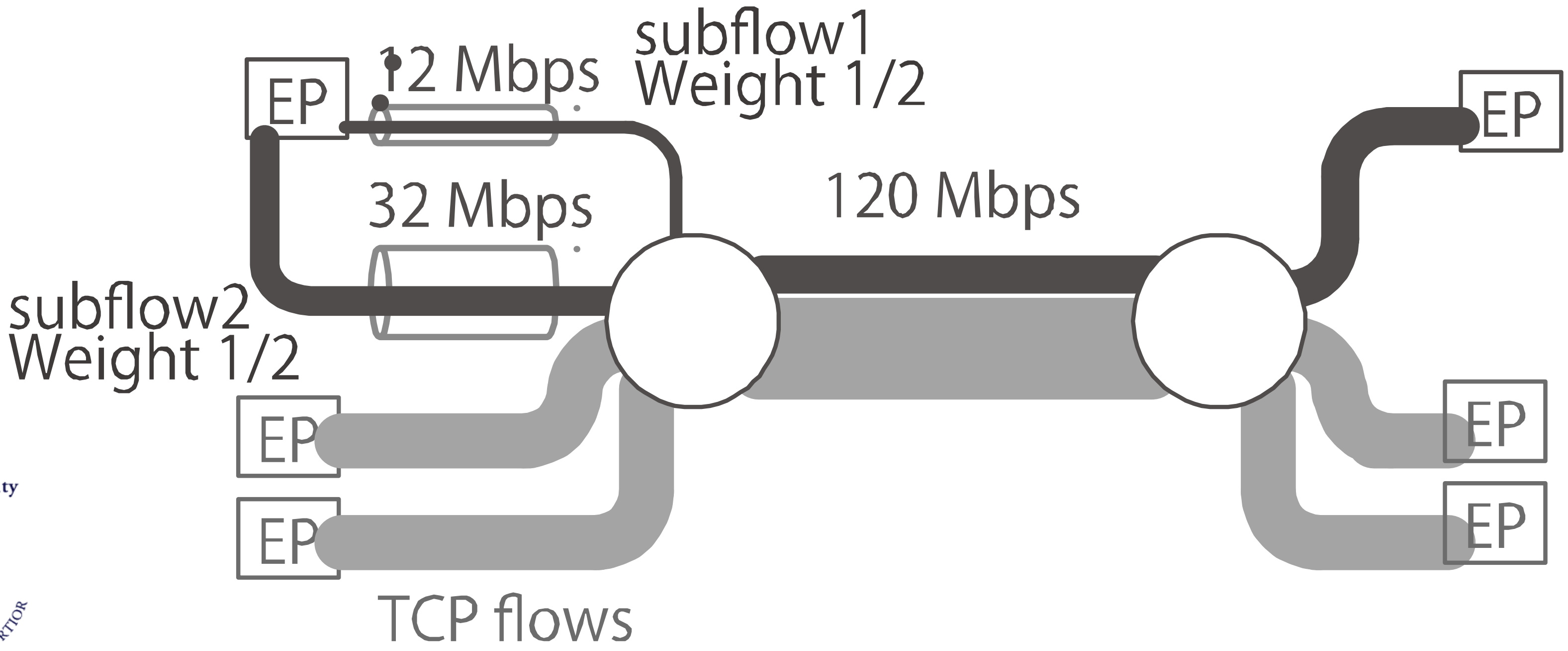
Effective Utilization of Disjoint Links

- 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



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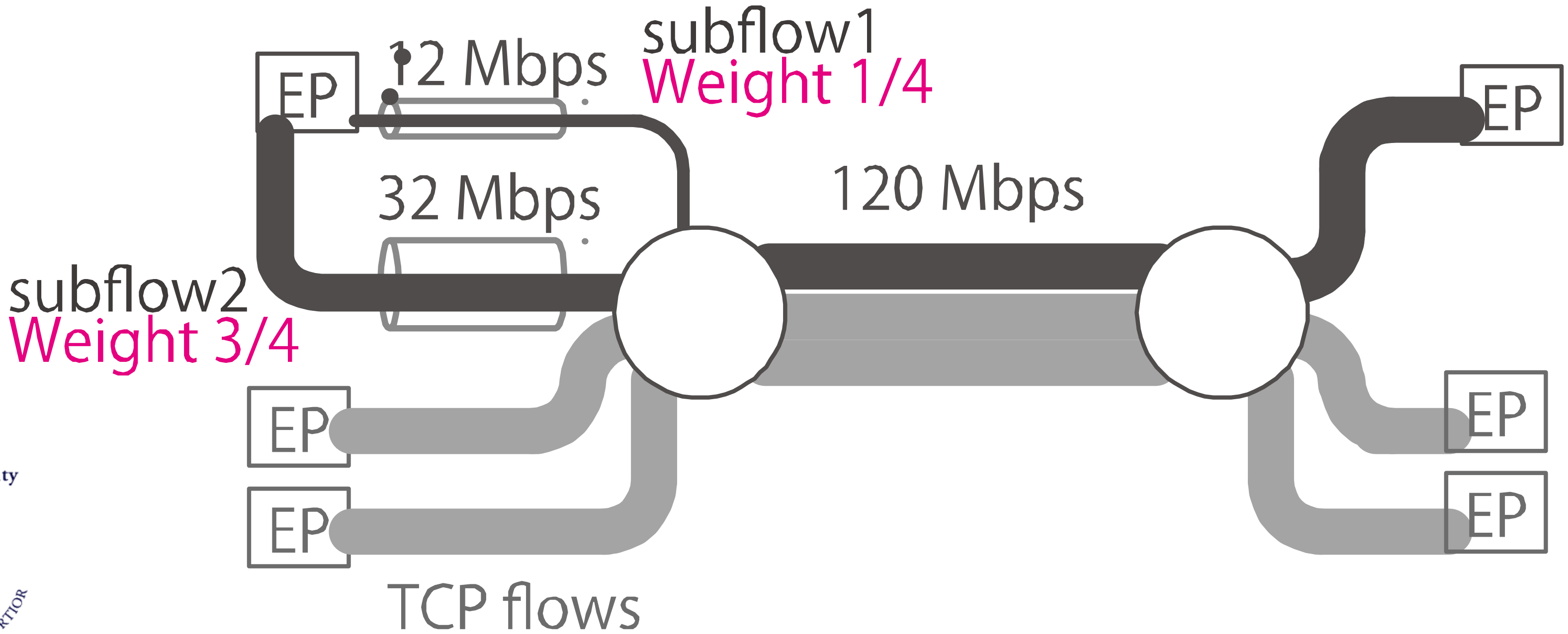
Effective Utilization of Disjoint Links

- 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



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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 (*Tw*) of subflows should be equal)
- If *Tw* 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 *Tw* to the highest one

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

Wnew: new weight of subflow reducing weight
Tw^min: throughput per weight of that subflow
Tw^{max}: throughput per weight of the subflow that has achieved the highest throughput per weight

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- We add the reduction of the weight to another subflow

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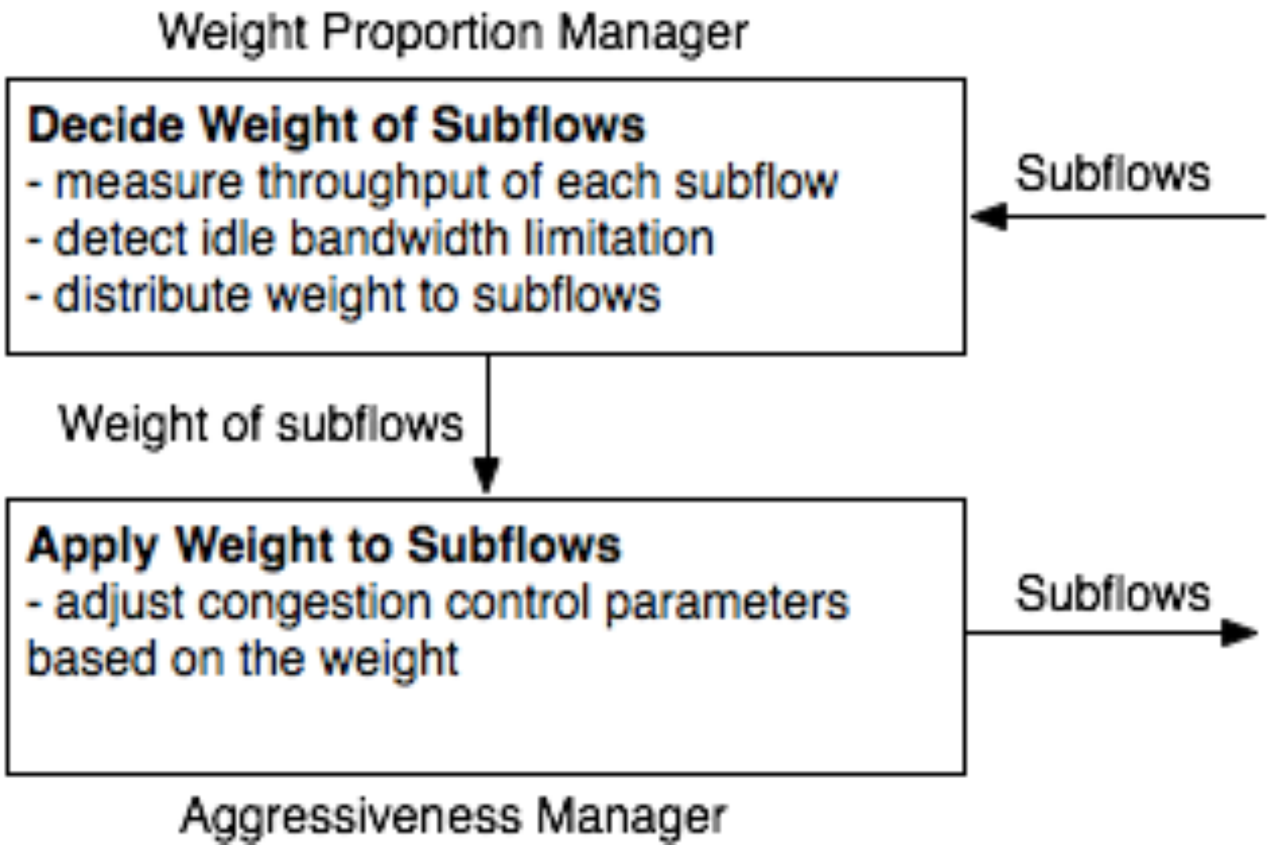
Control Loop

- So we measure the throughput constantly, and detect subflows constrained by idle bandwidth



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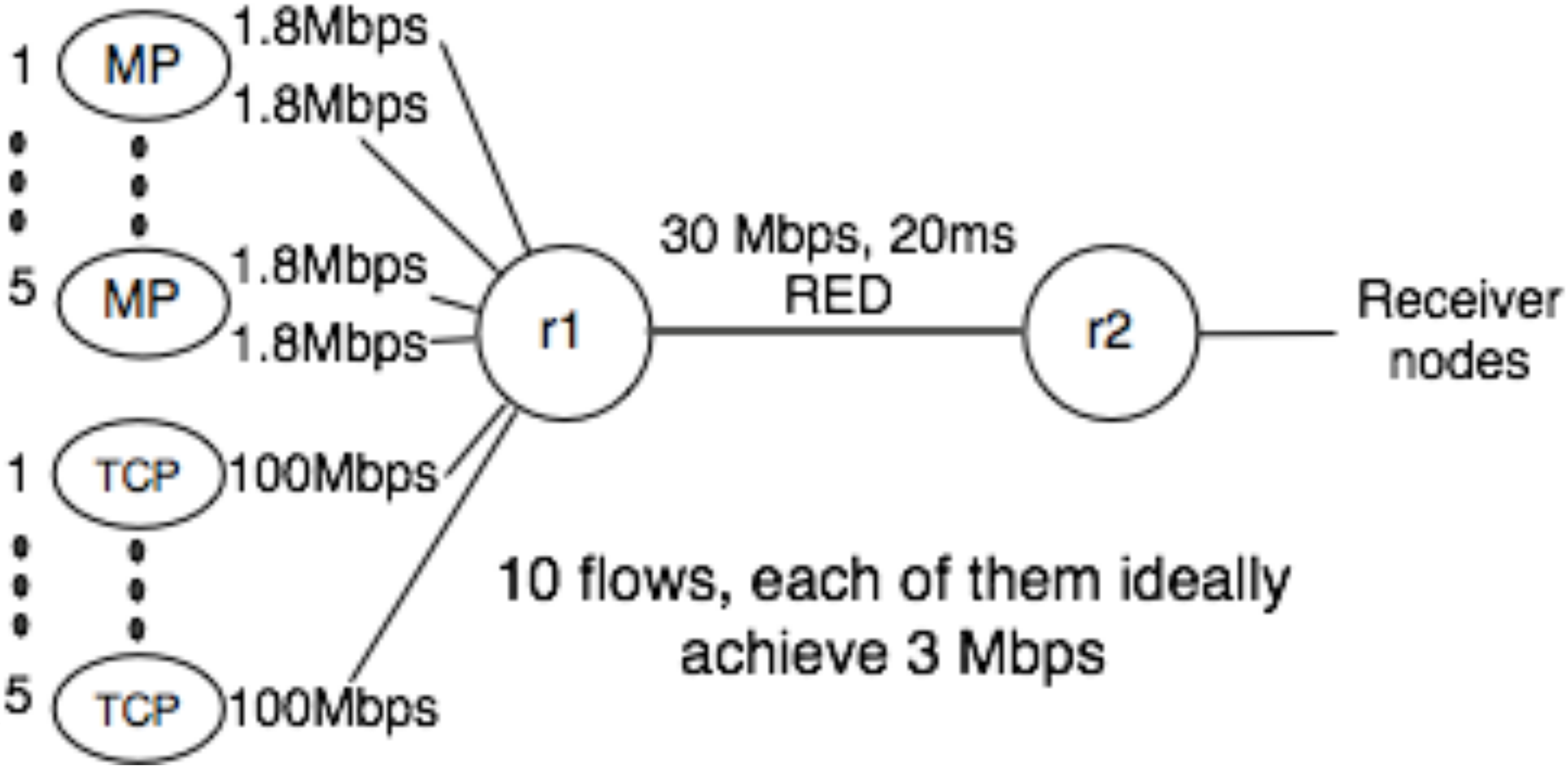
Simulation Setup (1)

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



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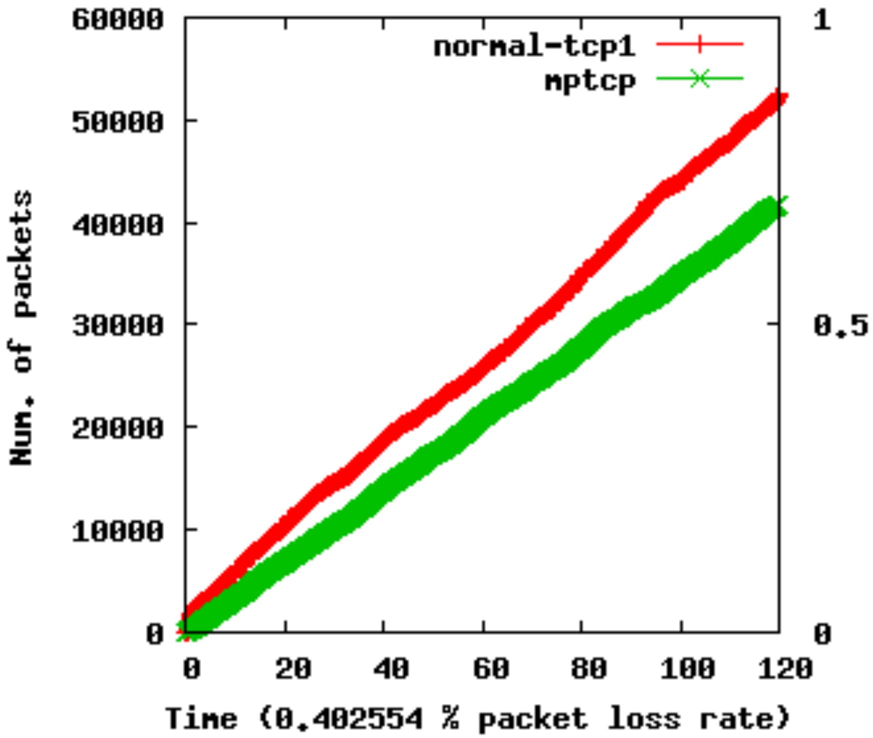
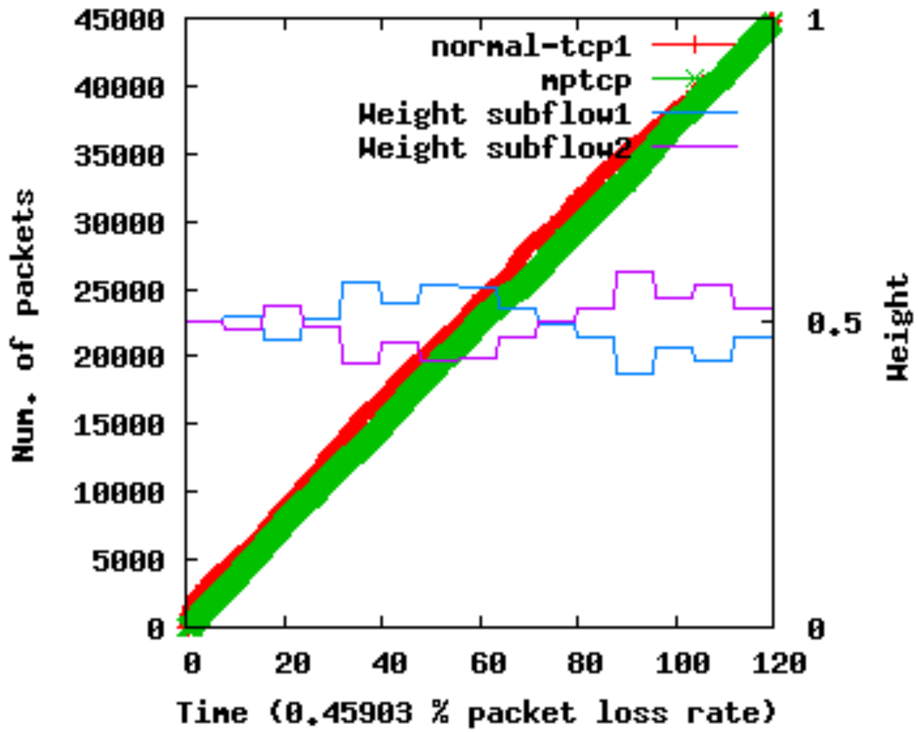
Simulation Result (1)

Linked-increase Algorithm
Approx. 2.8 Mbps



Weight-based Algorithm
Approx. 3.0 Mbps



(Optimal combination of weight is 1:1)

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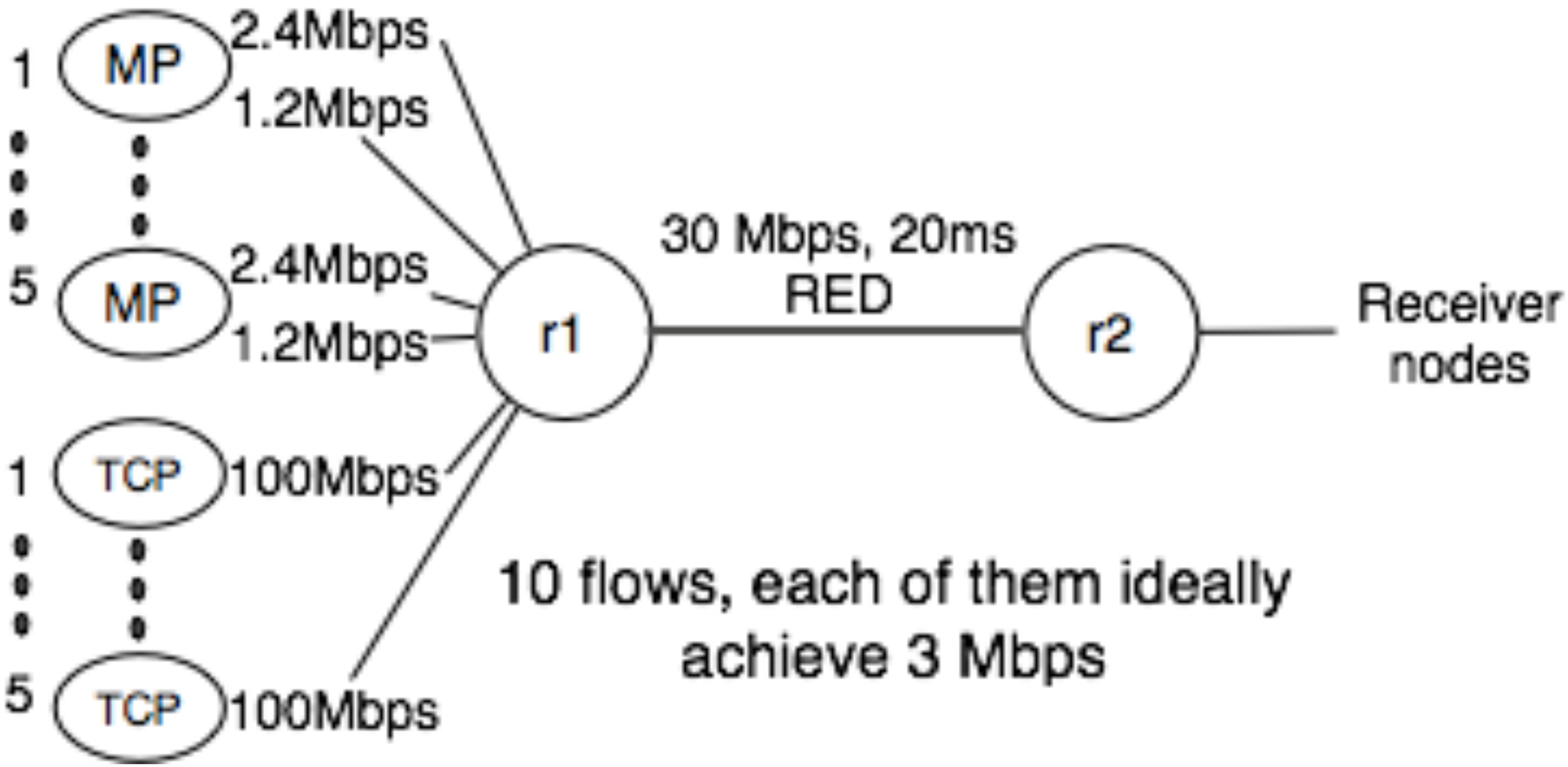
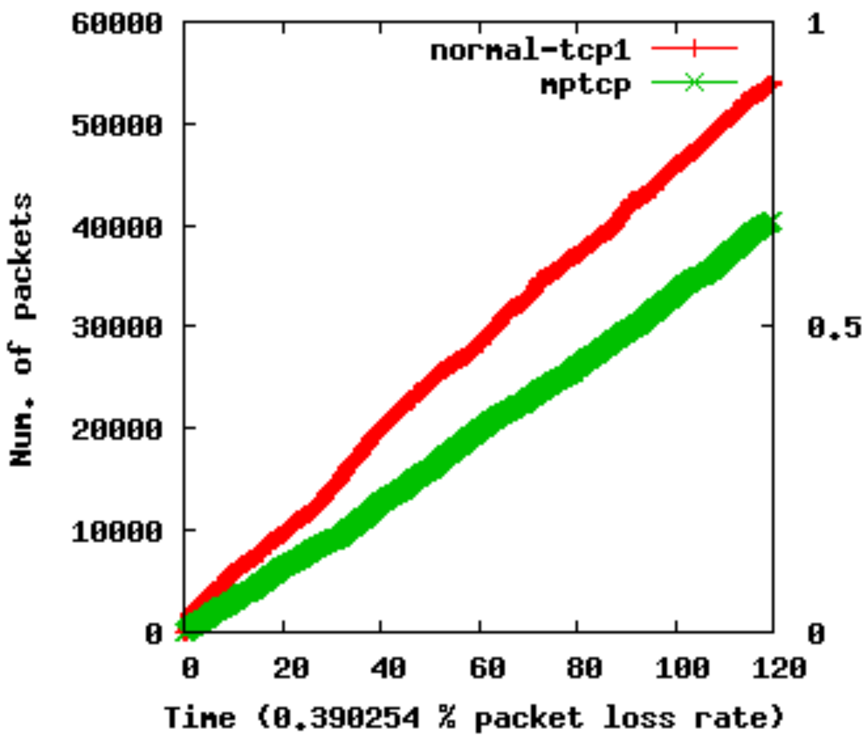
Simulation Setup (2)

- Ratio of Idle capacity is approx 1:2

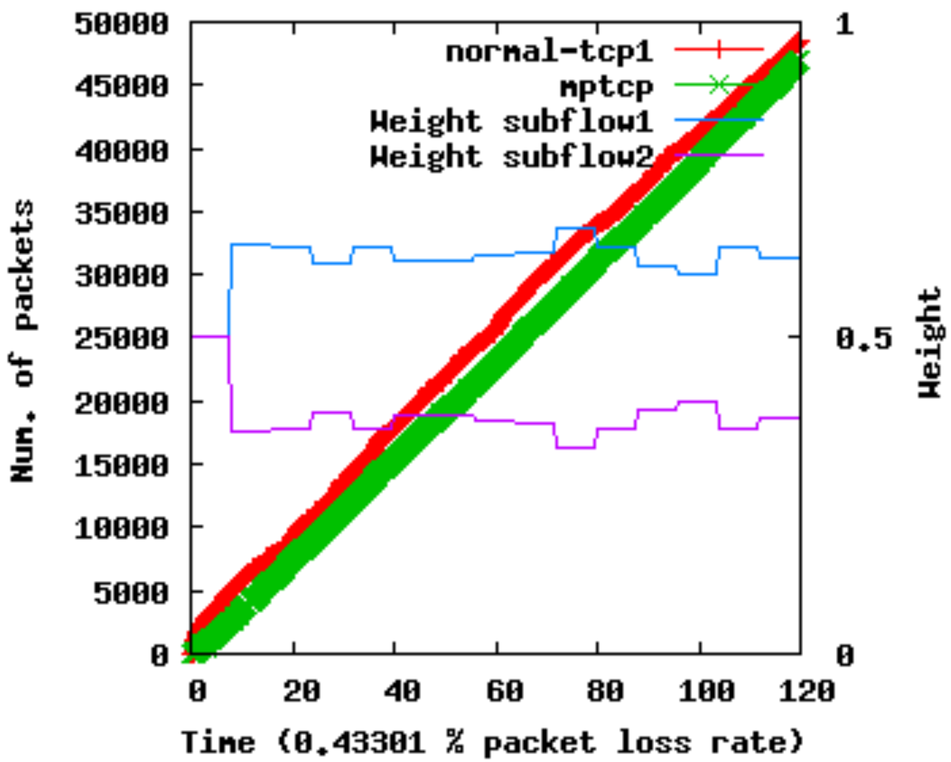


Simulation Result (2)

Linked-increase Algorithm
Approx. 2.73 Mbps



Weight-based Algorithm
Approx. 3.13 Mbps



(Optimal combination of weight is 2:1)

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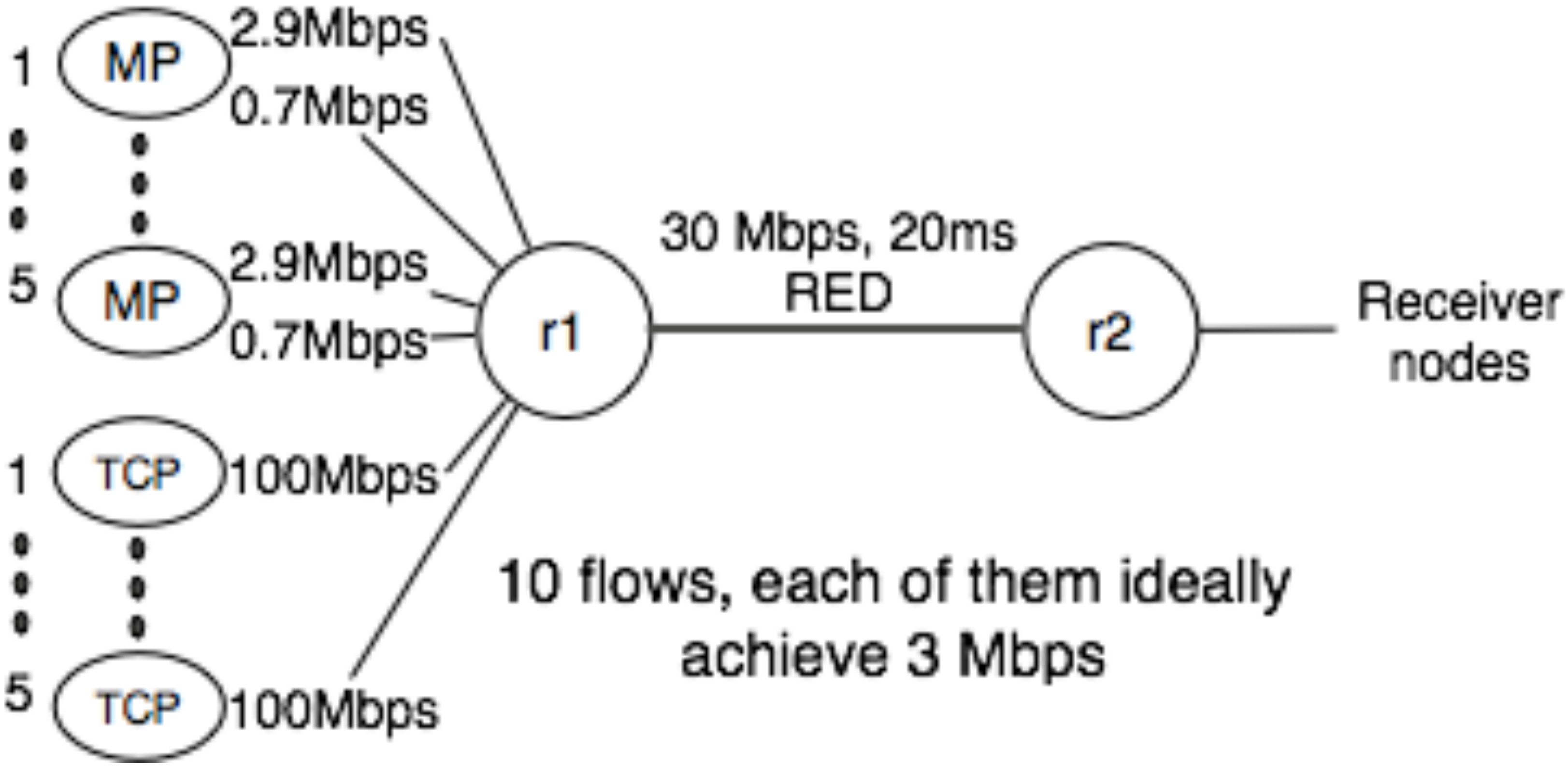
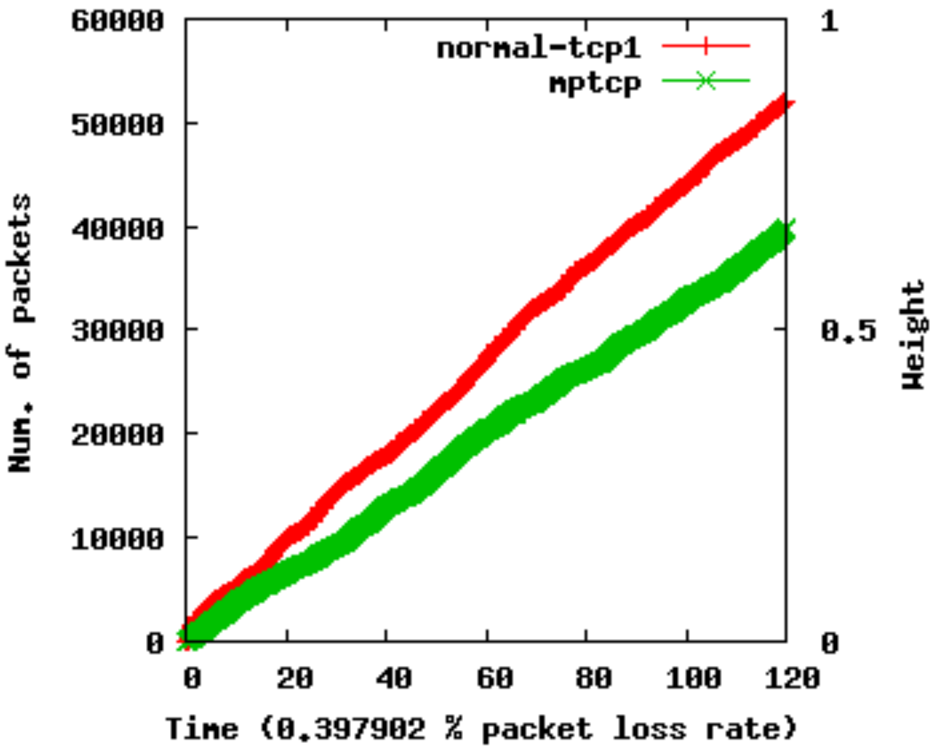
Simulation Setup (3)

- Ratio of Idle capacity is approx 1:4

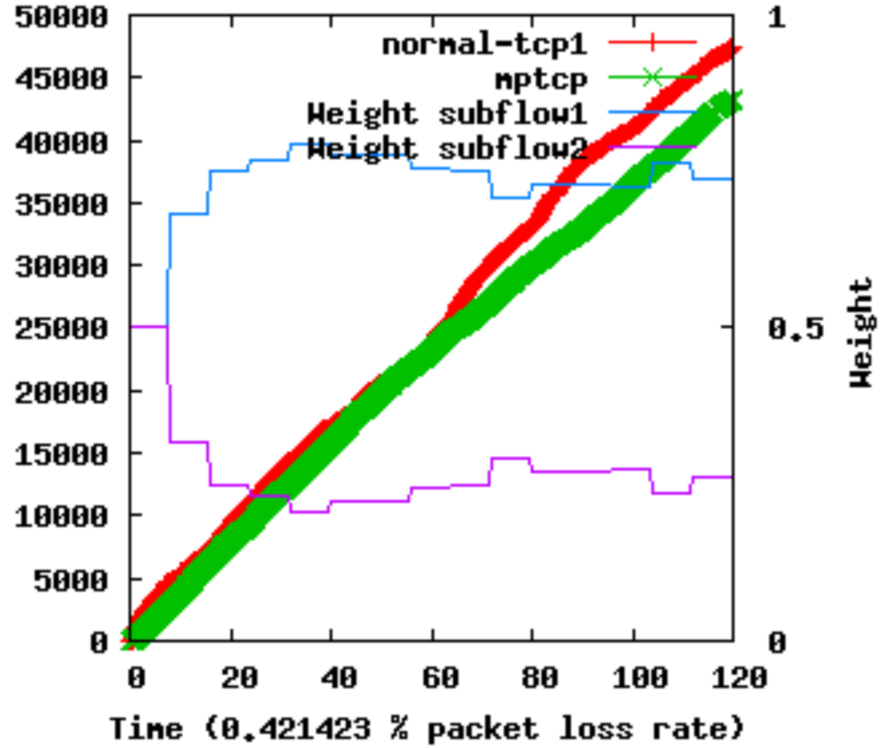


Simulation Result (3)

Linked-increase Algorithm
Approx. 2.67 Mbps



Weight-based Algorithm
Approx. 2.83 Mbps



(Optimal combination of weight is 4:1)

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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, MulTFRC for MRTP)

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