Achieving Efficient and Fast Update for Multiple Flows in SDN

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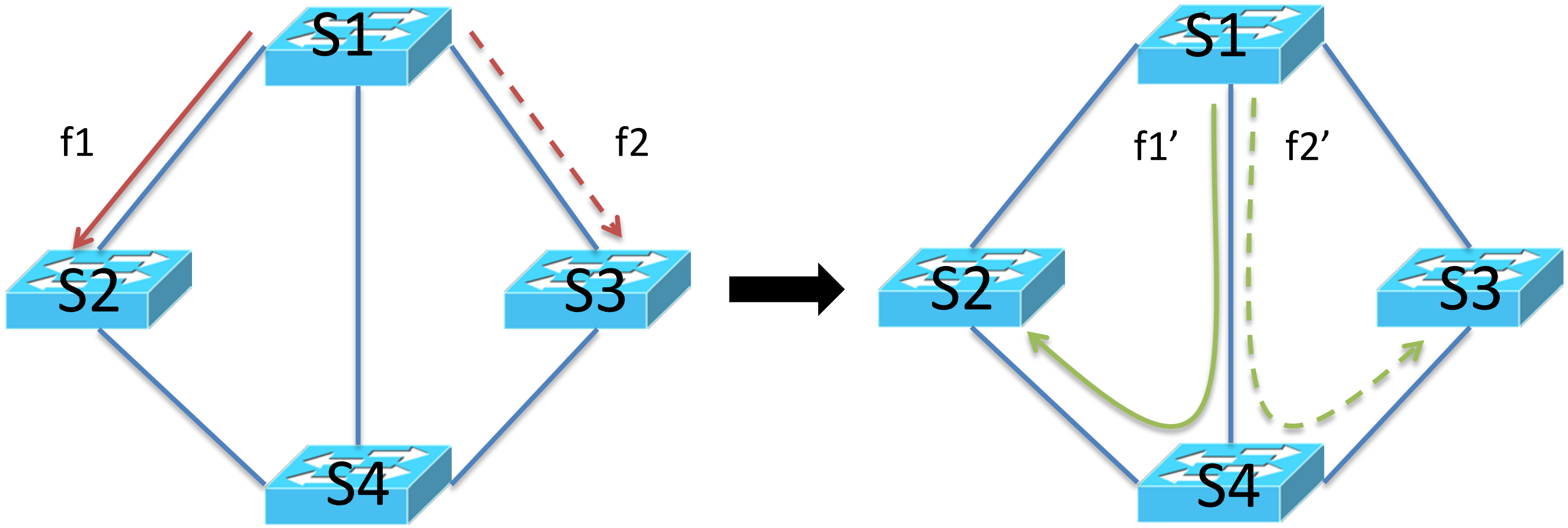
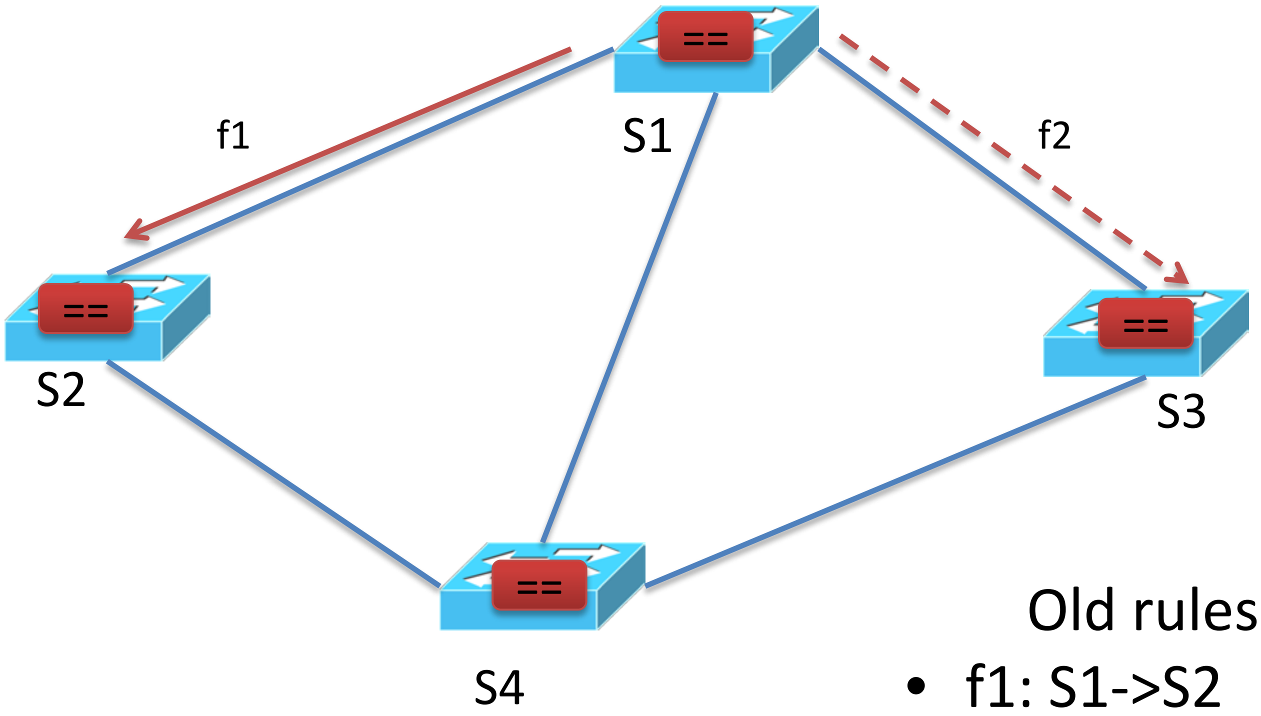
Flow update in SDN



- Network maintenance
- Traffic engineering
- Dealing with failure

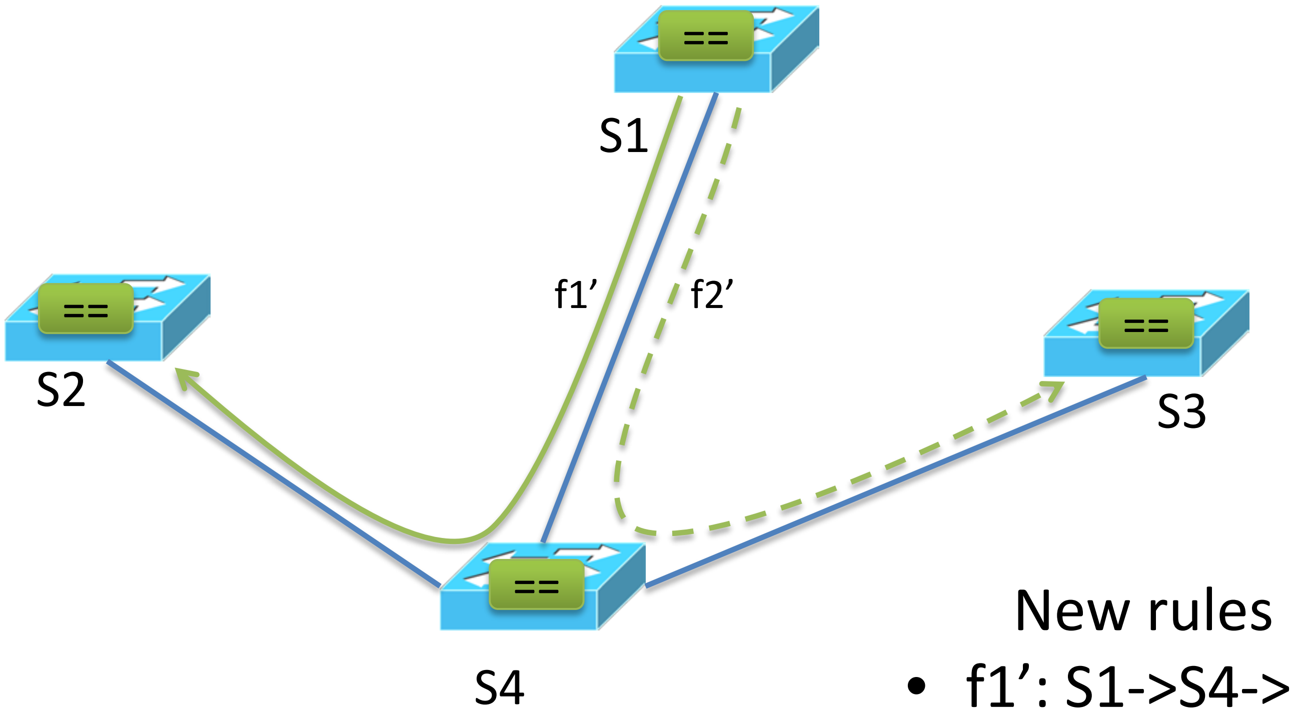
Flow update in SDN



Old rules

- f1: S1->S2
- f2: S1->S3

Flow update in SDN



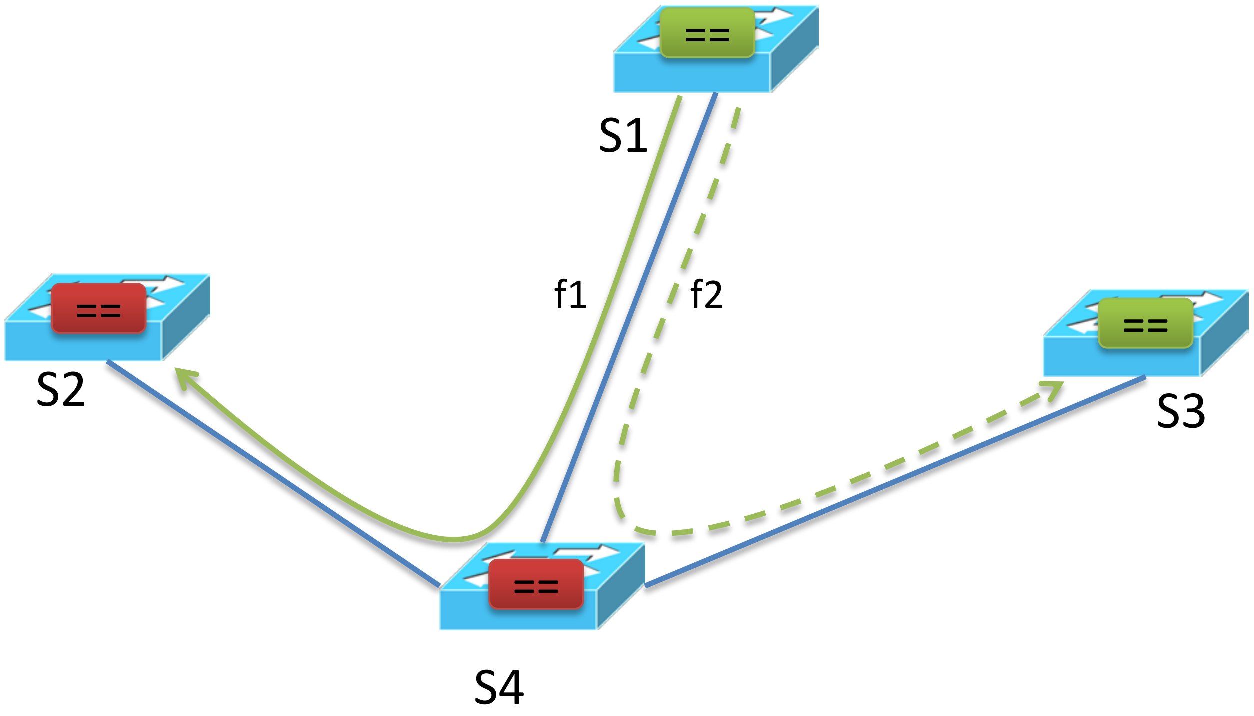
New rules

- f1’: S1->S4->S2
- f2’: S1->S4->S3

Multi-flow update is difficult

- Achieve a flow update which is
  - Consistent
  - Congestion-free
  - Efficient
  - Successful

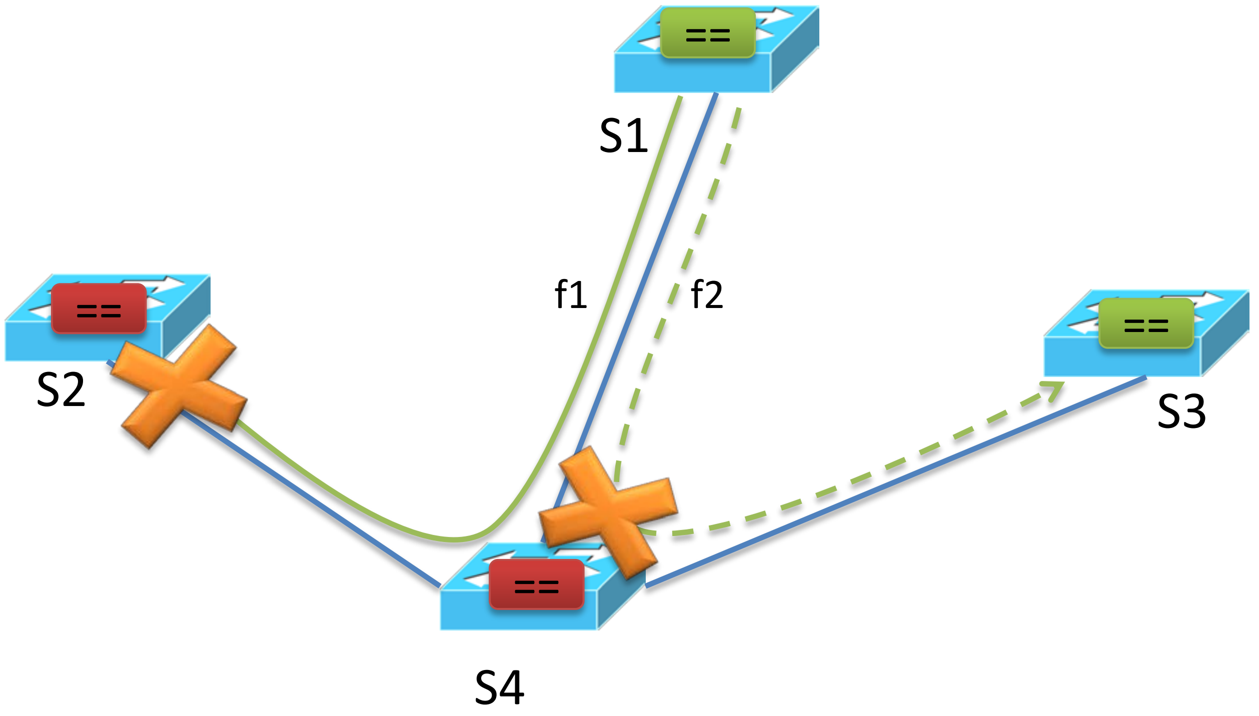
Inconsistent update



S1 and S3 have installed new rules

S2 and S4 have not installed new rules

Inconsistent update

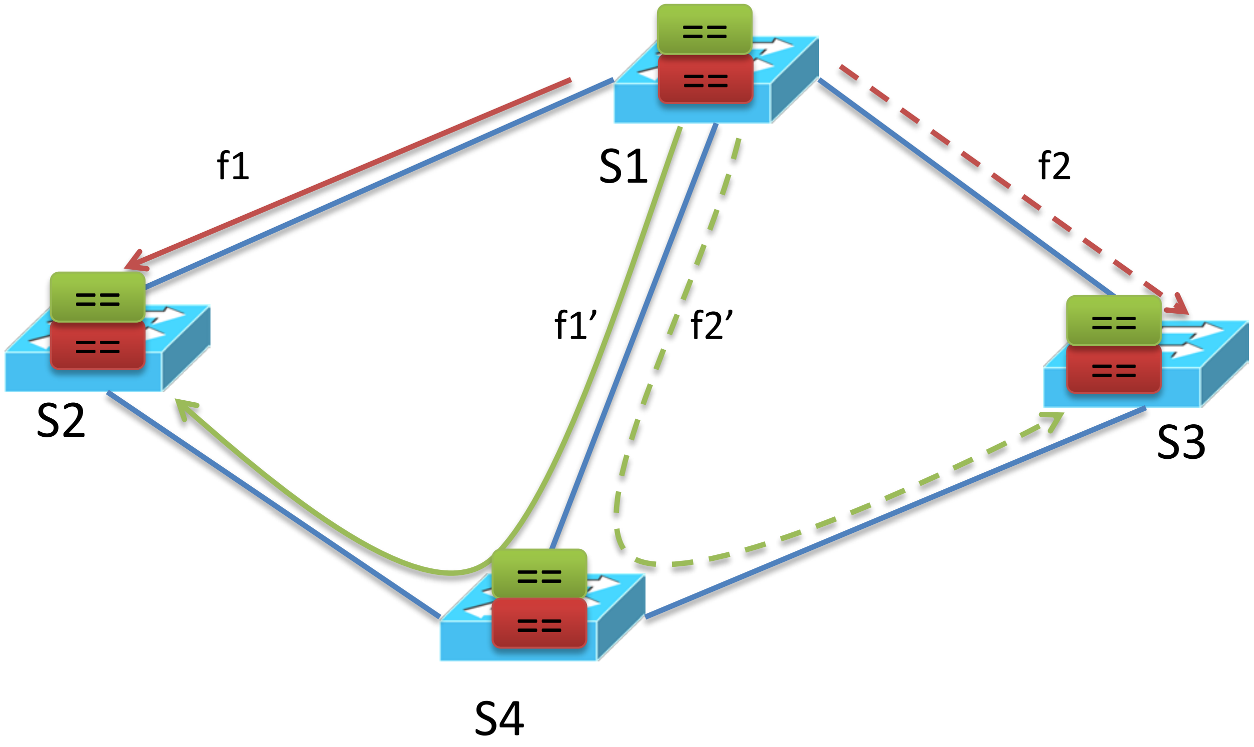


Packet forwarding error

Consistent update

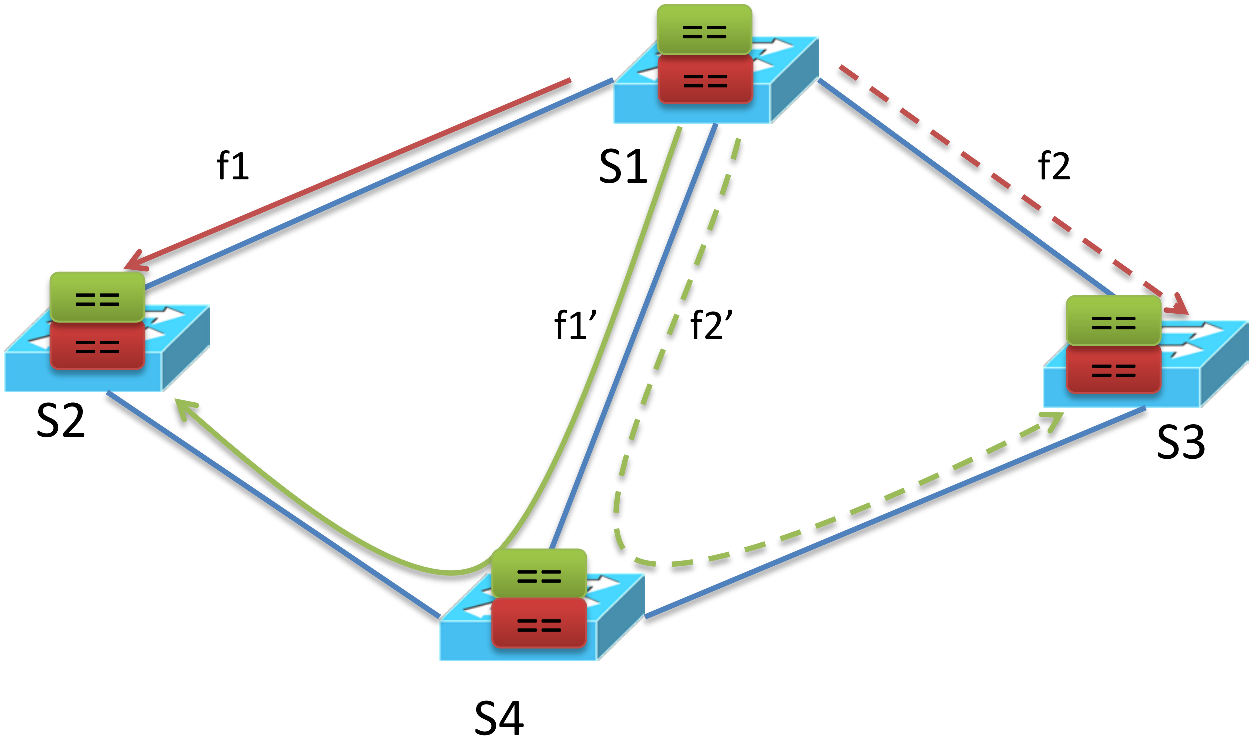
- Per-packet consistent update [Reitblatt’12]
  - A packet is processed by either the new or the old rules, not a mixture of the two.

Solution: 2-phase update [Reitblatt'12]



Keep both the old and the new rules during the update.

Solution: 2-phase update [Reitblatt'12]

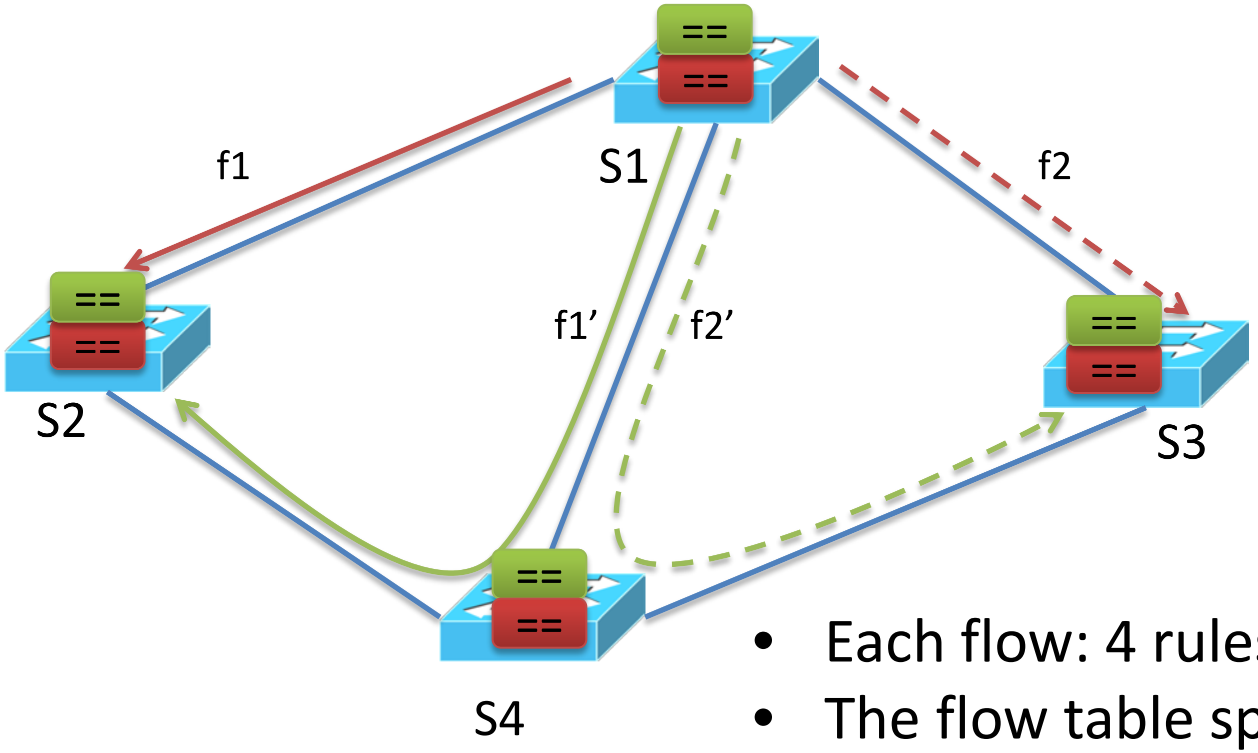


Double flow table space required

The flow table space may not be enough

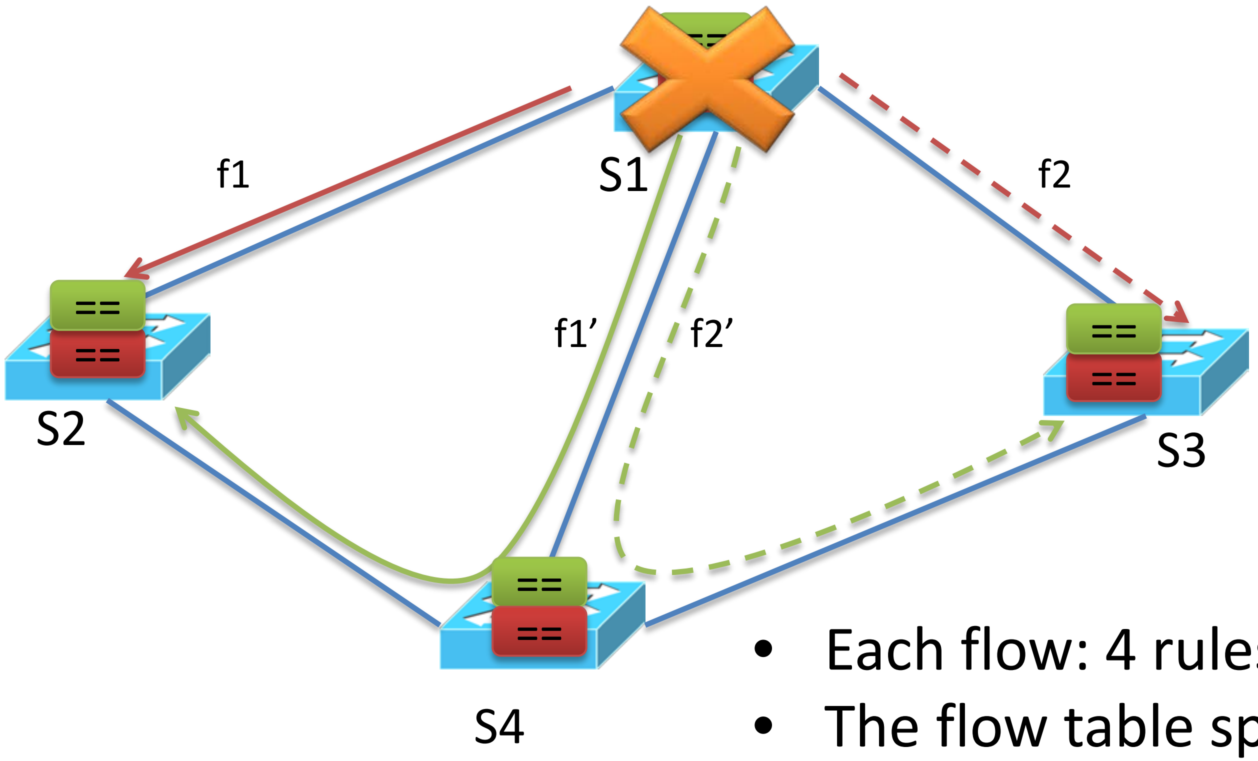
- TCAM is expensive and power hungry. [Hong '13]
  - Today's OpenFlow switch: **1-4K** rules
  - Next generation: **16K** rules
- An example
  - 50 sites
  - 15-shortest path routing
  - **20K** rules are required

One-step update



- Each flow: 4 rules
- The flow table space: 15 rules
- 16 rules are needed at most

One-step update



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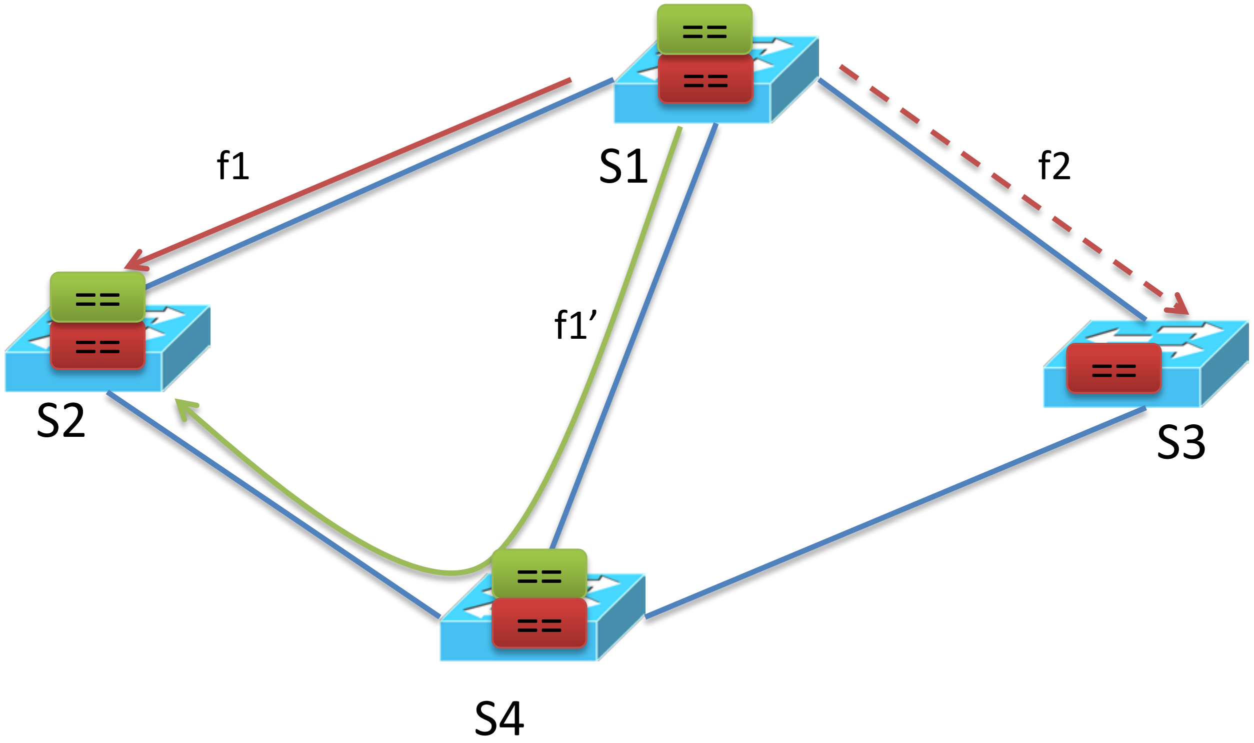
- 16 rules are needed at most

The method doesn't work!

Separate the update into steps



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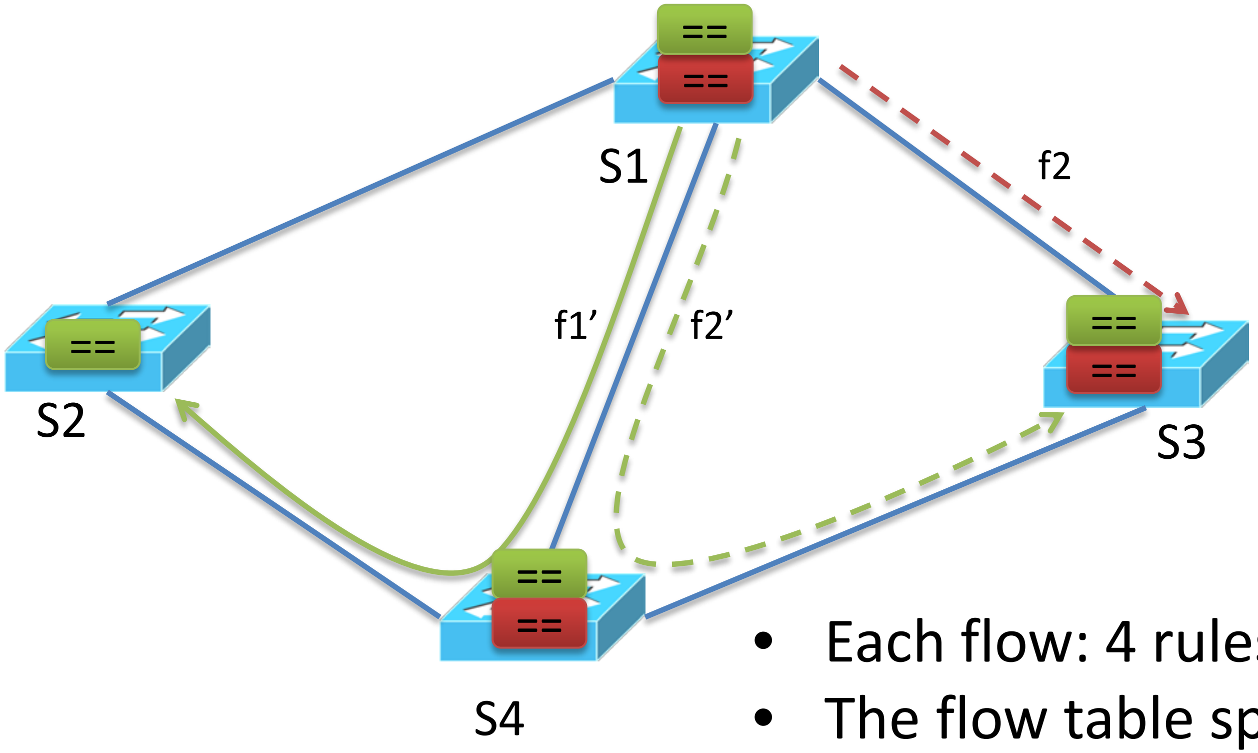


- Each flow: 4 rules
- The flow table space: 15 rules
- 12 rules are needed at most

The method works!

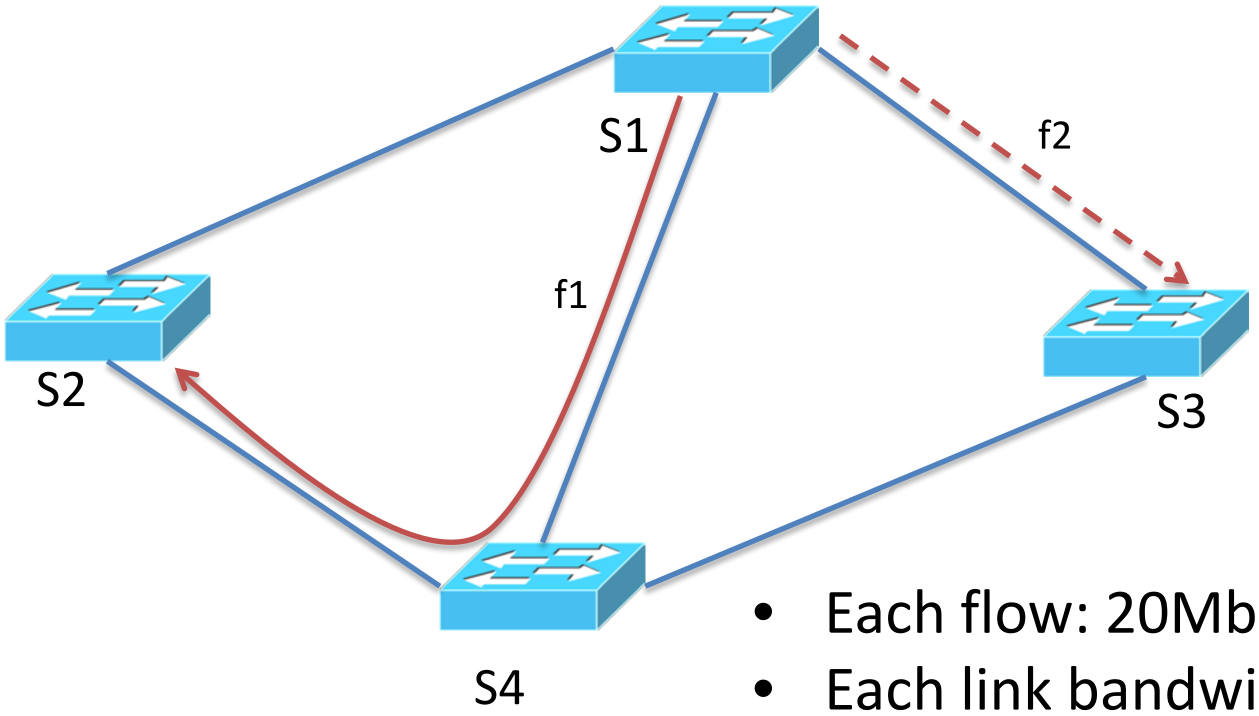
Separate the update into steps

- Tradeoff between flow table space & update time
  - To reduce flow table space overhead, more steps are required.
  - To complete the update in the shortest time, we should update as many flows as possible in one step.

How to complete the update using the least number of steps?

Congestion-free update

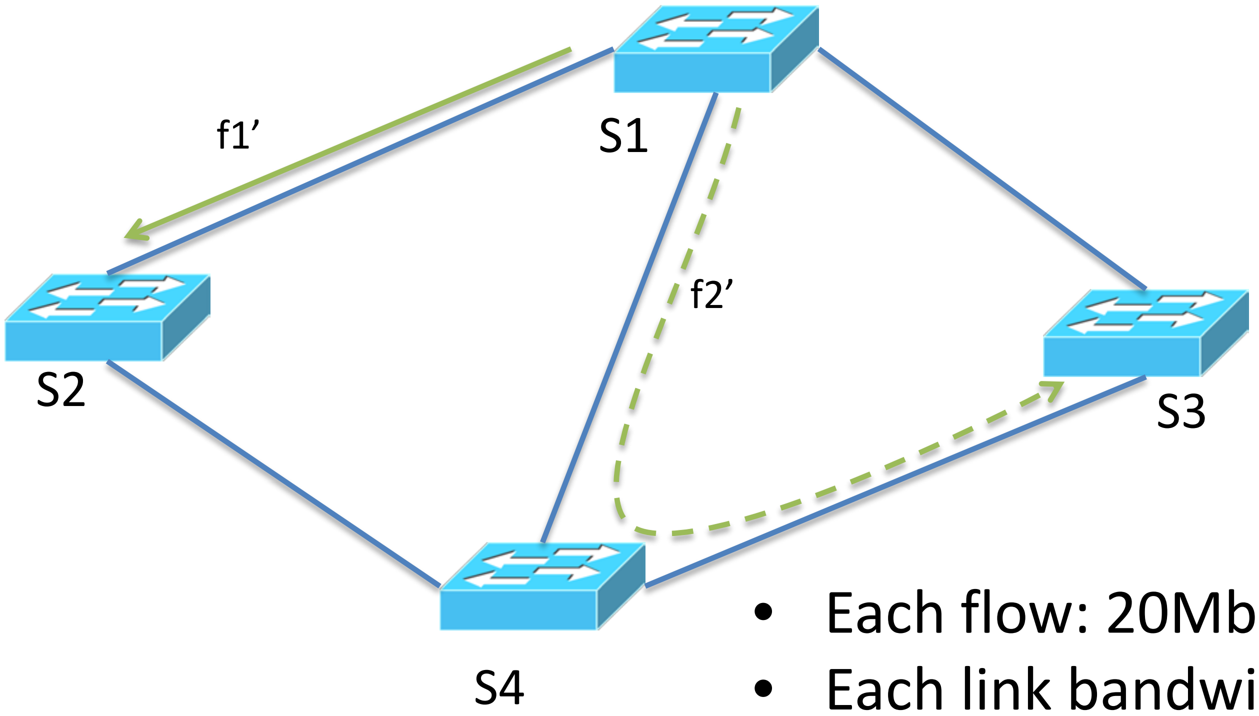
Initial network state



- Each flow: 20Mbps
- Each link bandwidth: 30Mbps

Congestion-free update

Final network state



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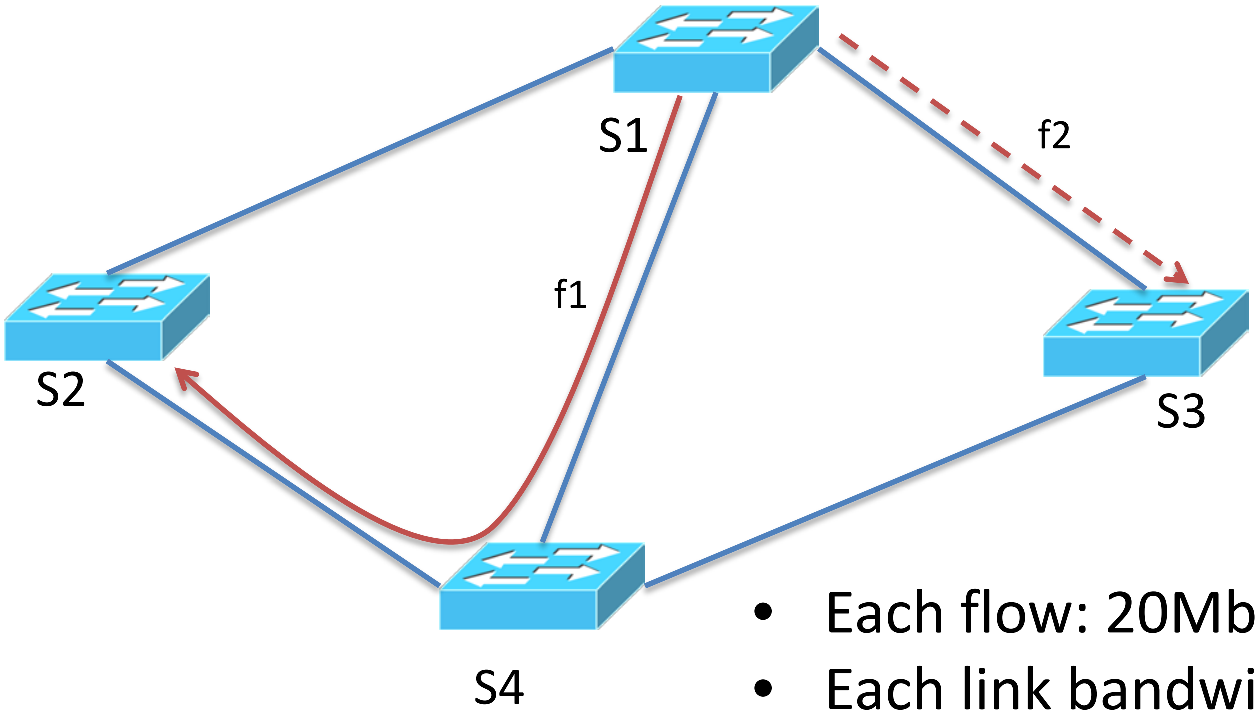
Flow update may lead to congestion

Update sequence: f2->f1



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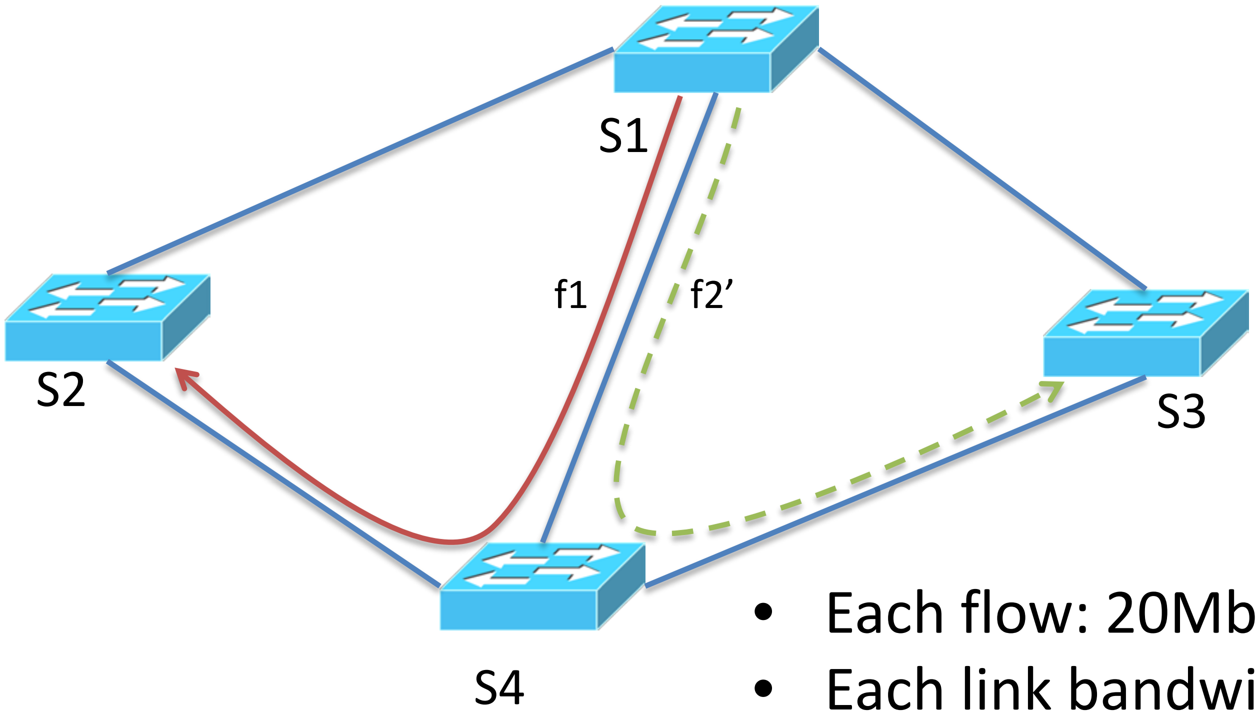

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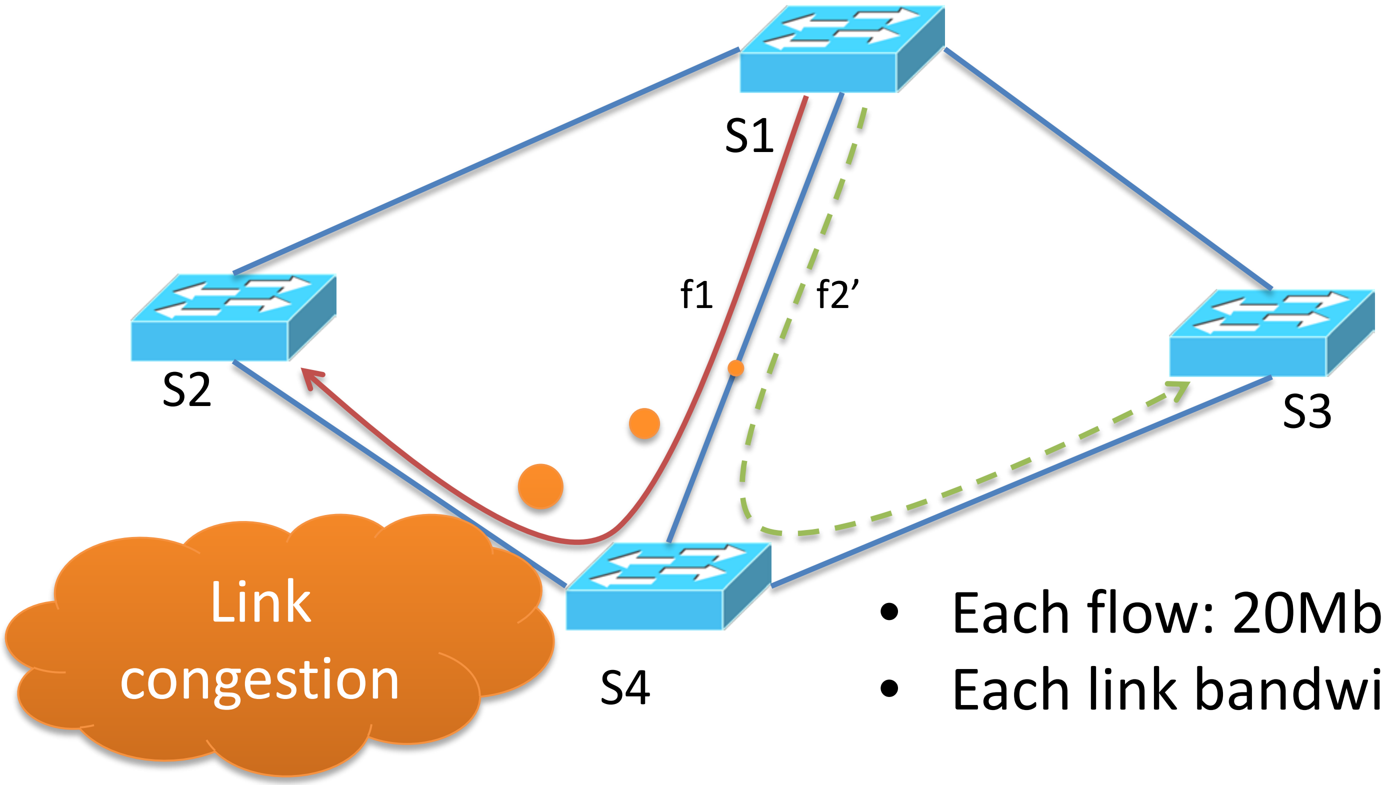

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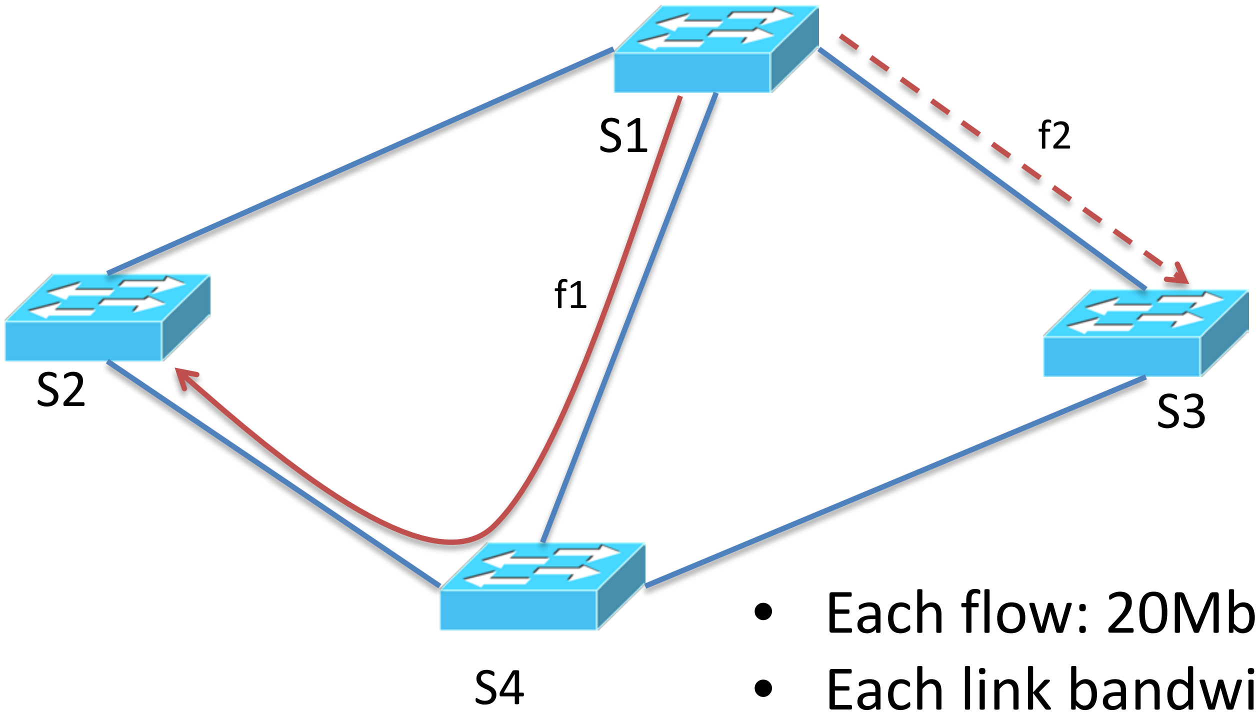
Congestion-free update

Update sequence: f1->f2



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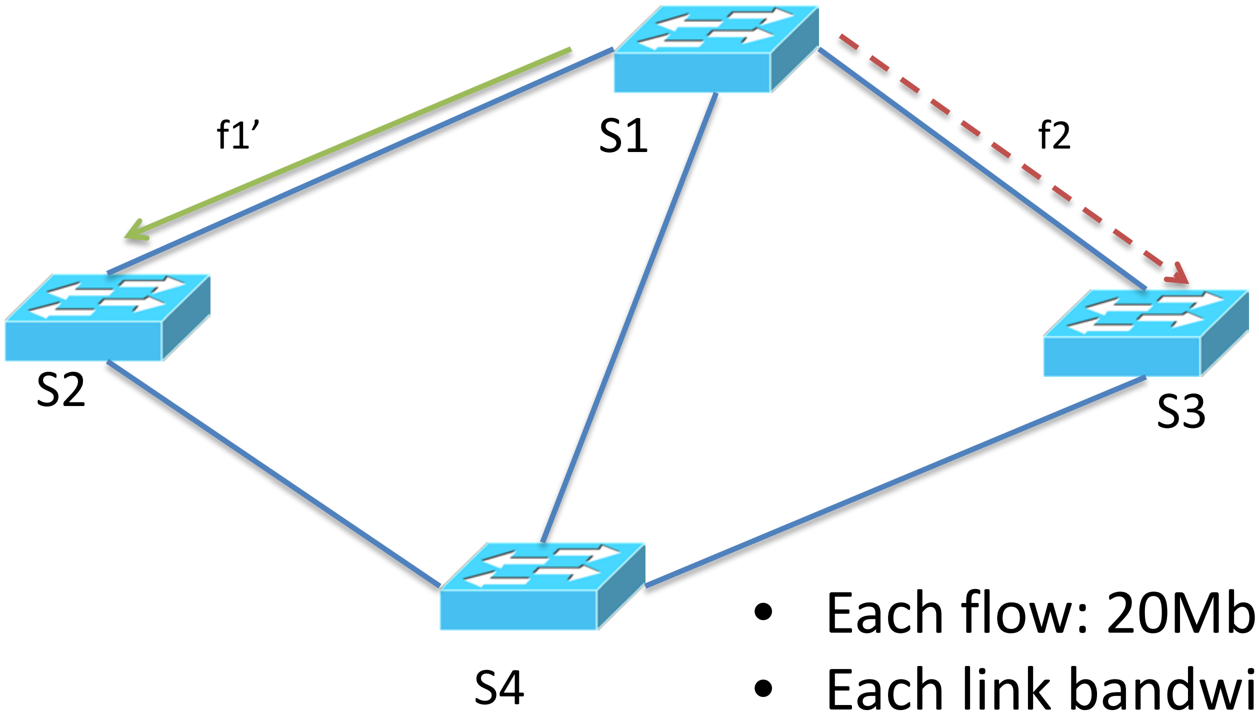

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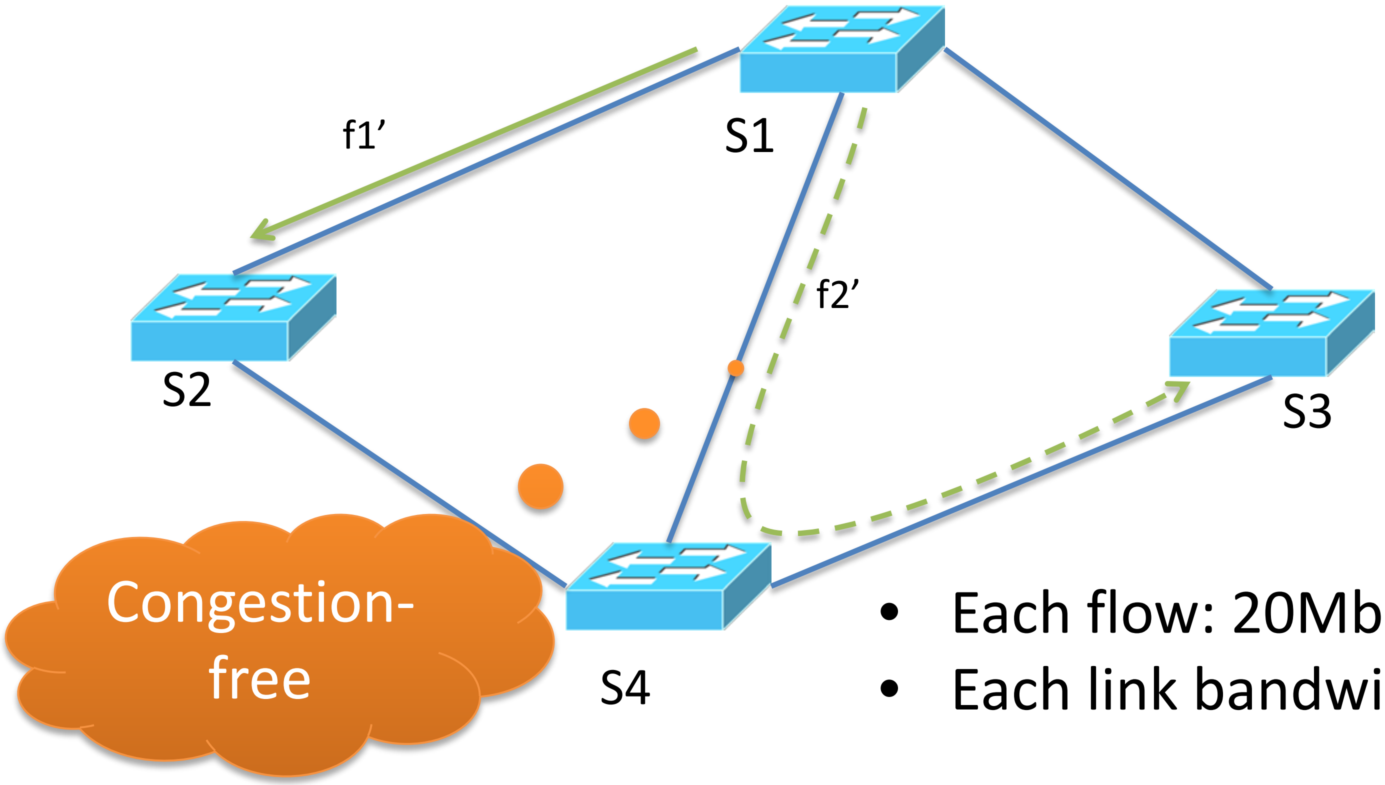

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Problem statement

How to schedule the update of multiple flows?

- Considering link bandwidth
- Under the constraint of flow table space
- Using the least steps

Scheduling the multi-flow update

- Given the initial and final network states, compute which flows to update in each step.
- Formulate it as a Mixed Integer Problem
  - **Minimize** the number of steps
  - Constraints
    - $link\ utilization \ \le link\ bandwidth,$
      $\forall\ link, \forall\ time$
    - $flow\ table\ usage \ \le flow\ table\ space,$
      $\forall\ switch, \forall\ time$

Problem formulation

$$\min \quad \sum_{k=1}^{K} I_k$$

$$s.t. \begin{cases} f_i(e) \leq \theta c(e), \forall i \in \{1, \cdots, K\}, \forall e \in E; \\ n_i(u) \leq q(u), \forall i \in \{1, \cdots, K\}, \forall u \in U; \\ 0 \leq x_{ij} \leq 1, \forall i, j \in \{1, \cdots, K\}; \\ \sum_{i=1}^{K} x_{ij} = 1, \forall j \in \{1, \cdots, K\}; \\ I_k \geq \sum_{j=1}^{K} \frac{1}{K} x_{kj}, \forall k \in \{1, \cdots, K\}; \\ I_k \geq I_{k+1}, \forall k \in \{1, \cdots, K-1\}. \end{cases}$$

I_k	whether the update is still in progress in step k
x_{ij}	the part of flow j updated in step i
$c(e)$	link capacity
q(u)	flow table space
θ	max allowed link utilization

Our heuristic solution

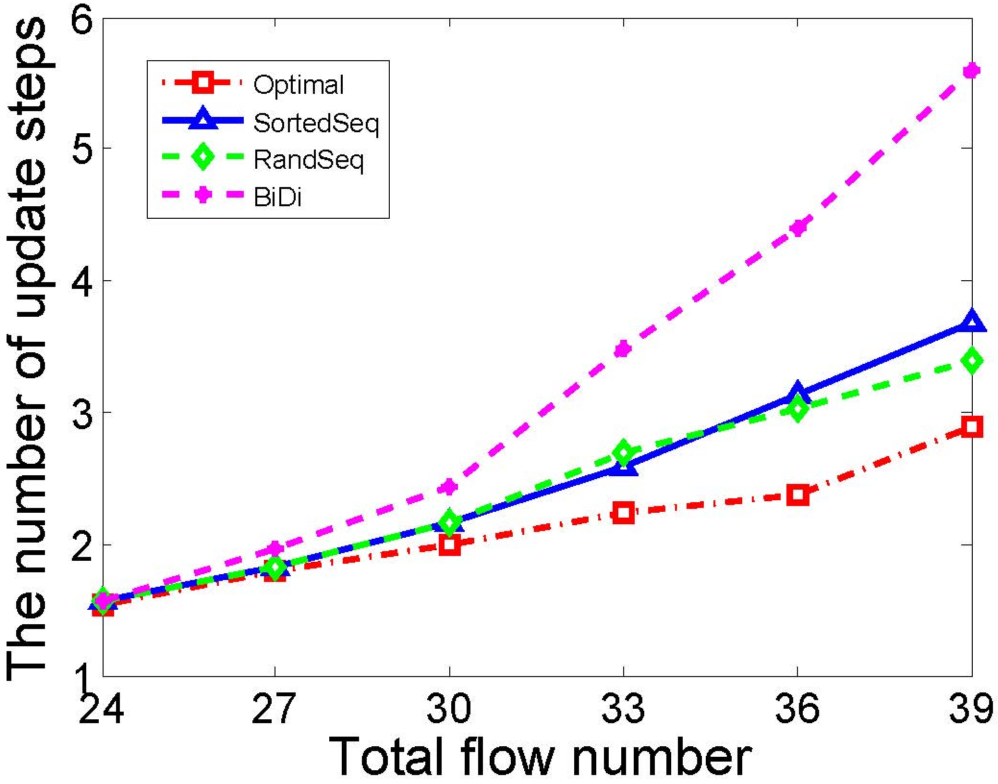
- SortedSeq (Update the flows in a sorted sequence.)
  - Update the **key flows** first
    - The flows that utilize more flow table space
    - Or the available flow table resource is scarce on the new path
  - Update as many flows as possible in each step
    - As long as the link and switch constraints are not violated

Evaluation

- Google’s inter-datacenter WAN
- Routing policy
  - Shortest path
  - The source and destination of each flow are selected randomly.
  - The traffic rate follows uniform distribution.
- Comparison algorithms
  - Optimal algorithm
  - RandSeq, BiDi

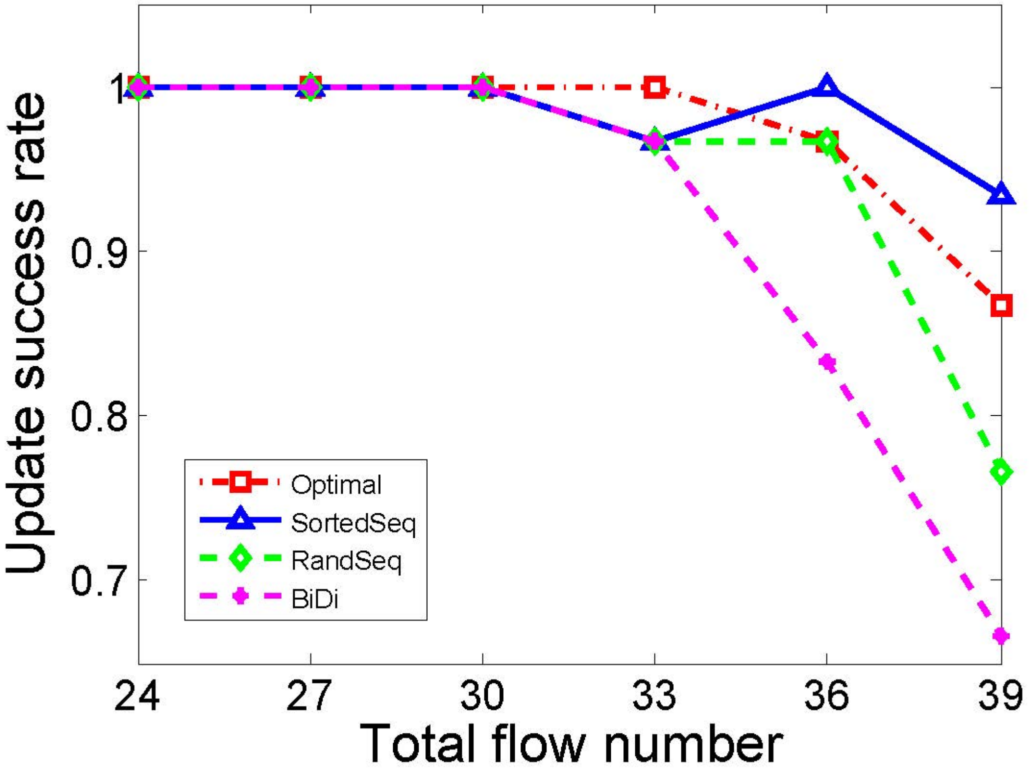
SortedSeq has near-optimal performance

- Impact of flow number



SortedSeq achieves high success rate

- Impact of flow number



SortedSeq has near-optimal performance

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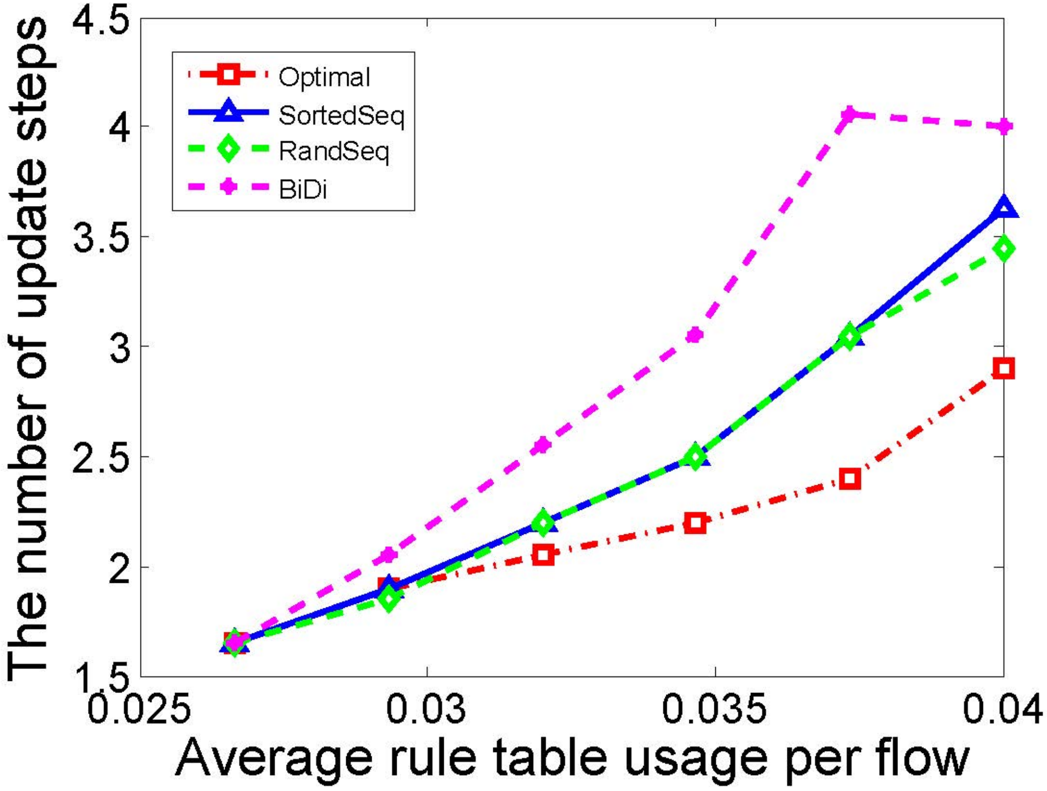

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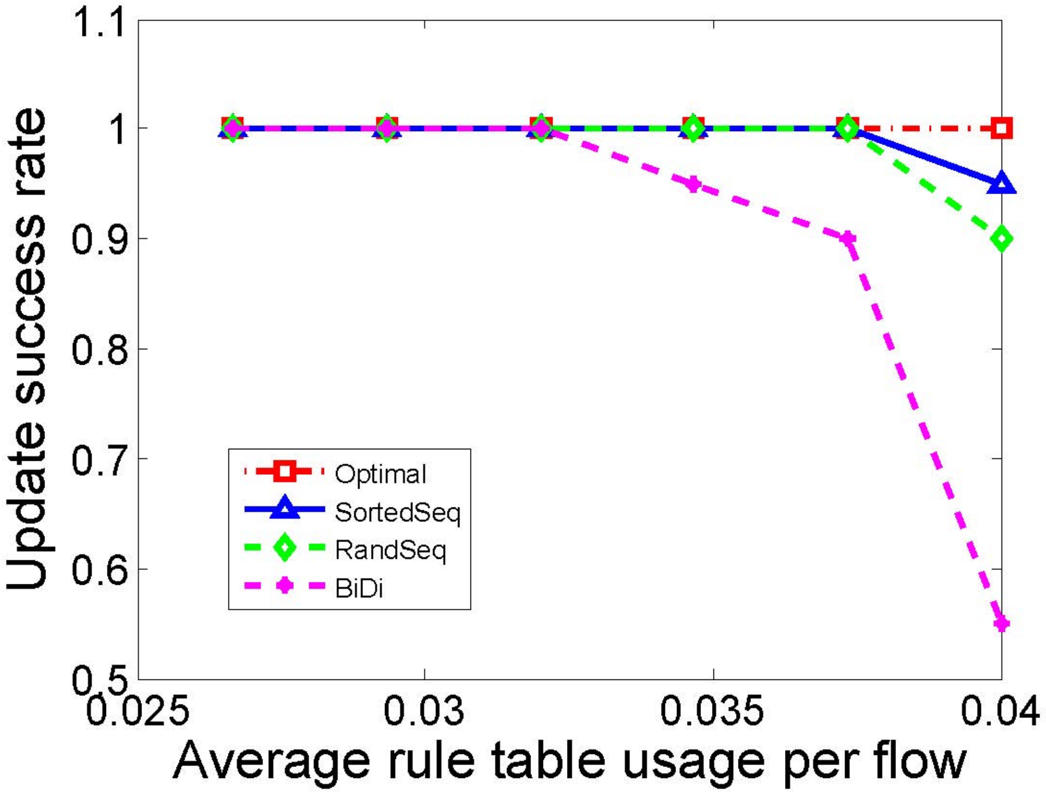

Summary

- Link bandwidth and flow table space constraints should be considered in multi-flow update.
- Our algorithm
  - Finds the solution with near-optimal steps
  - Completes the update efficiently and successfully

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Future work

- Carry out experiments on practical platforms.
- Apply it into the multi-path scenario
- Analyze the tradeoff between link utilization and flow table overhead.

Thanks!

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