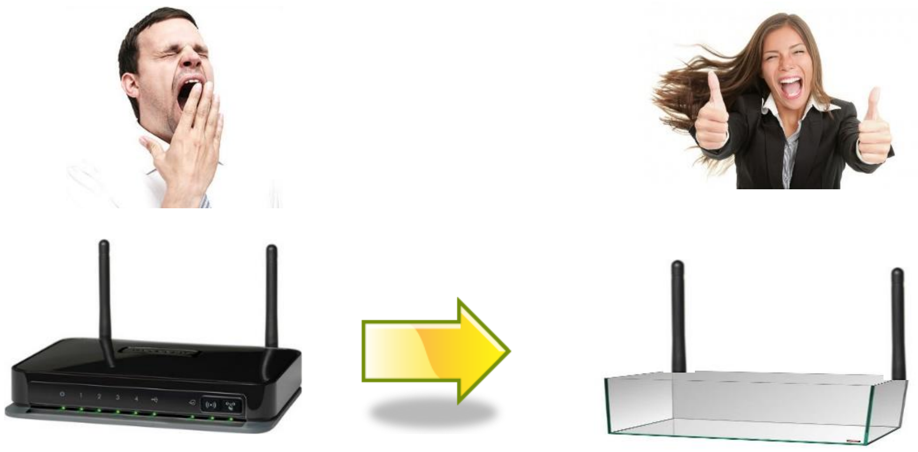
Distributed Consistent Network Updates in SDNs: Local Verification for Global Guarantees

Klaus-T. Foerster, Stefan Schmid

IEEE NCA 2019

Software-Defined Networking



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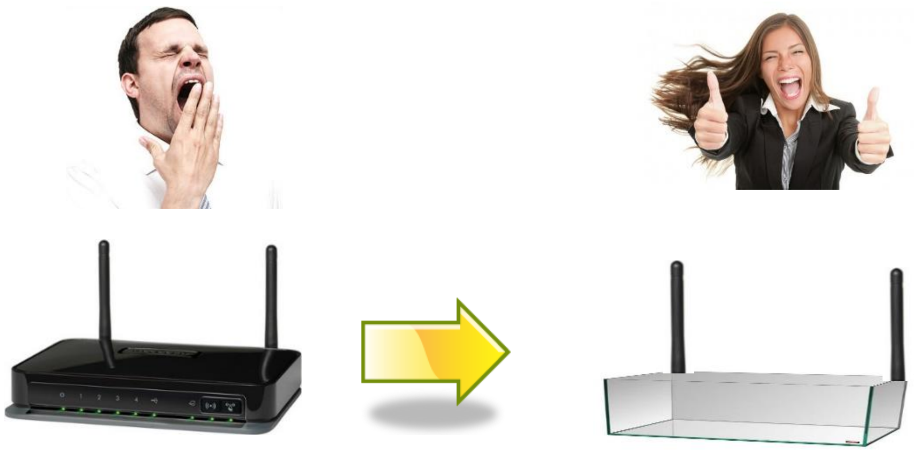
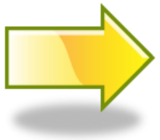


- General Idea: Separate data & control plane in a network

Software-Defined Networking




- General Idea: Separate data & control plane in a network
- Centralized controller updates networks rules for optimization
  - Controller (*control plane*) updates the switches/routers (*data plane*)

Virtual Services ⟷ Controller ⟷ Physical Network

- Logically centralized controller (eg implemented with replication)

Network Updates

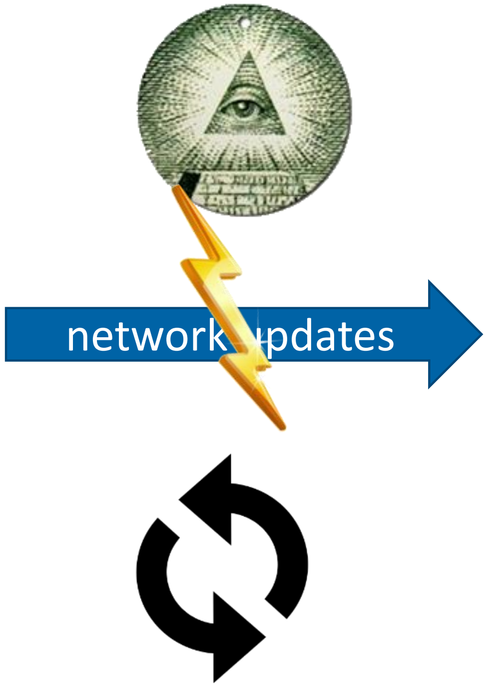
old network rules

network updates

new network rules

Network Updates

old network rules



new network rules

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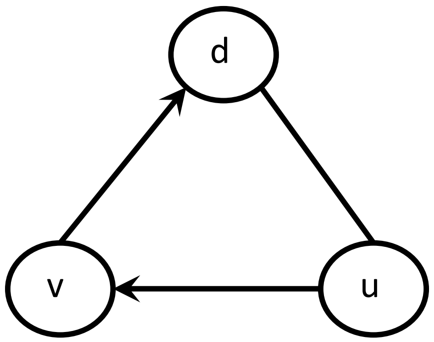
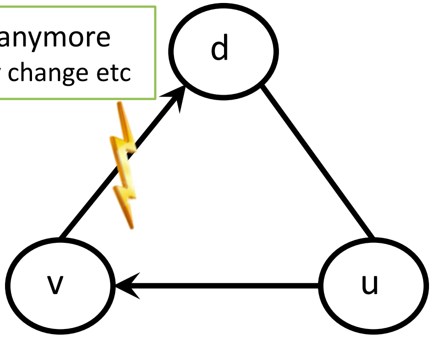
Toy Example



Toy Example

Link should not be used anymore
eg repair, congestion, policy change etc



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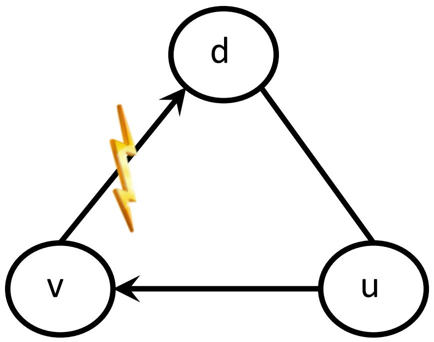

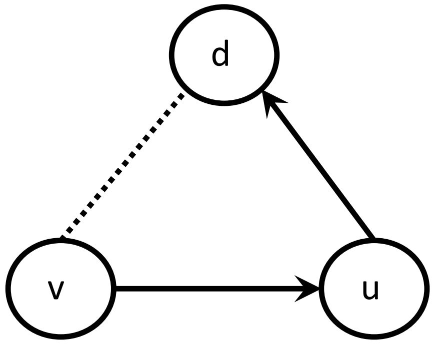

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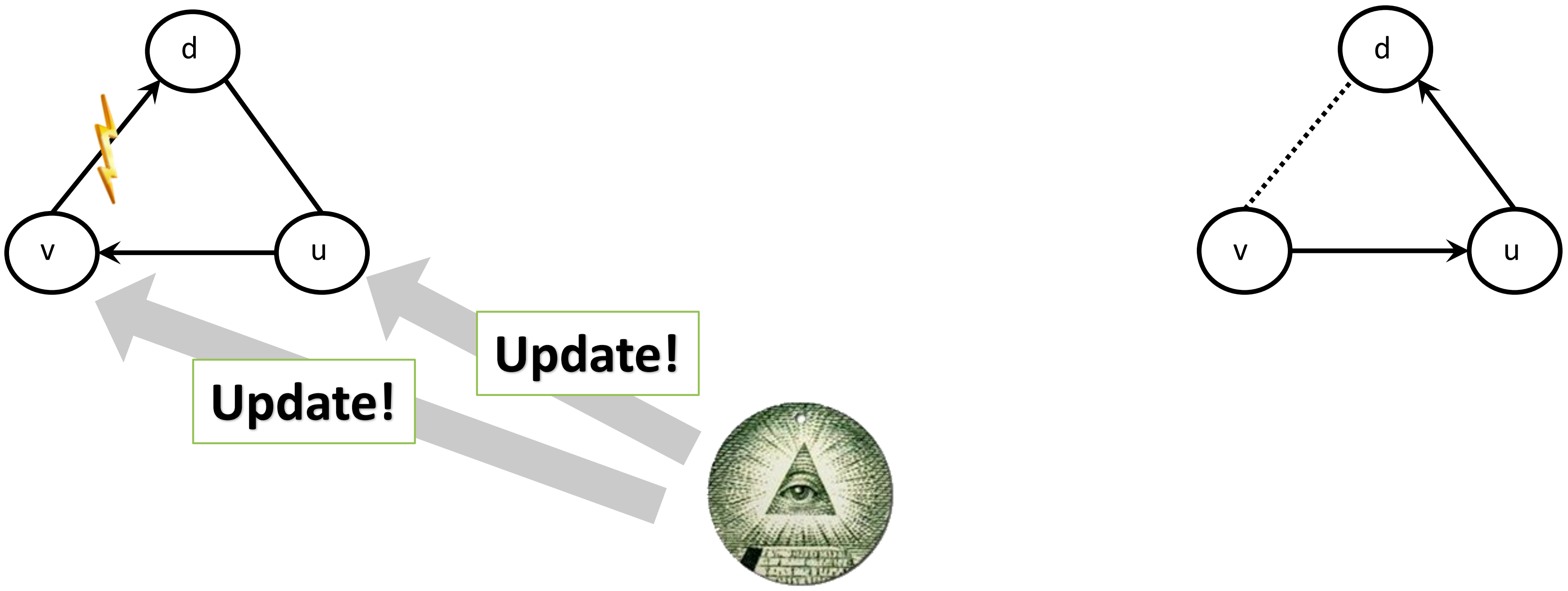

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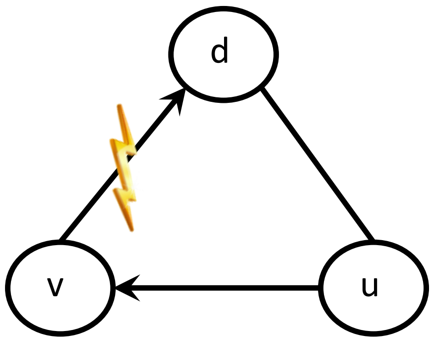
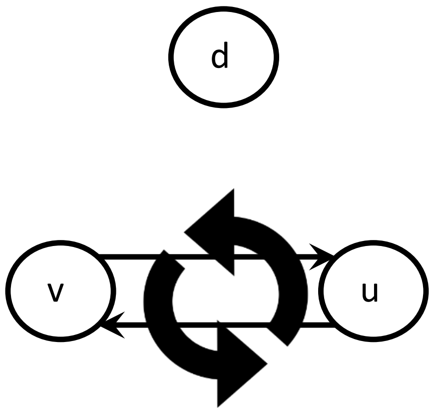
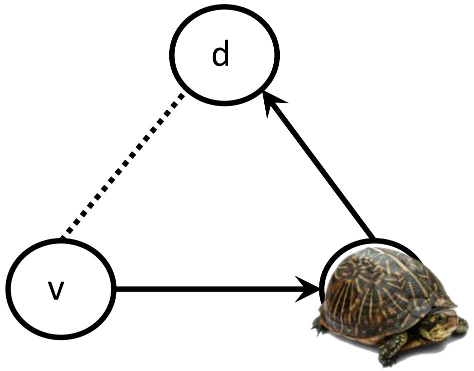
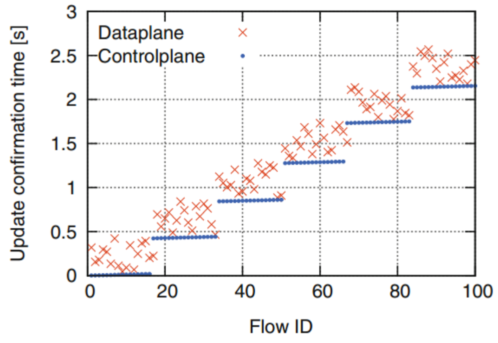


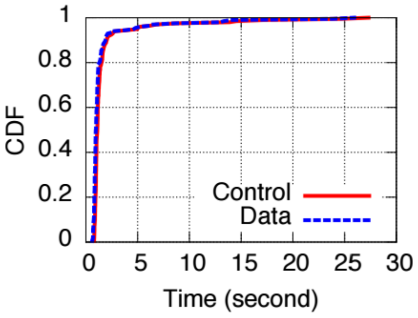




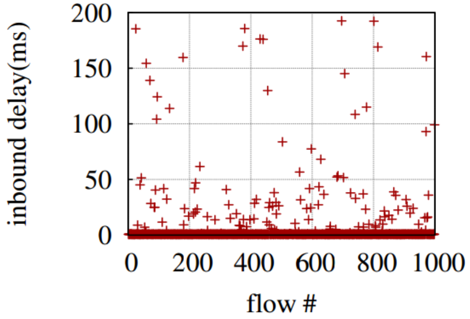
Appears in Practice



“*Data plane **updates may fall behind** the control plane acknowledgments and may be even **reordered**.*”
Kuzniar et al., PAM 2015

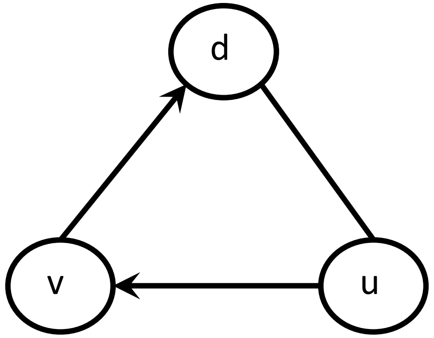


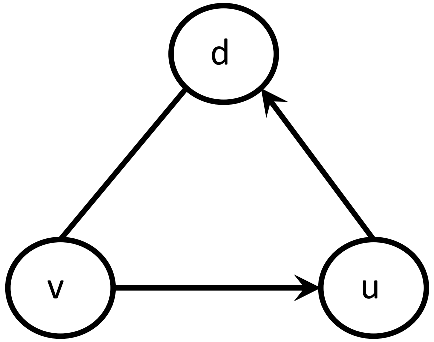
“*some switches can ‘**straggle**,’ taking substantially **more time** than average (e.g., 10-**100x**) to apply an update*”
Jin et al., SIGCOMM 2014



“*…the inbound latency is **quite variable** with a* […] *standard deviation of 31.34ms…*”
He et al., SOSR 2015

Ordering Solution: Go backwards through the new routing tree





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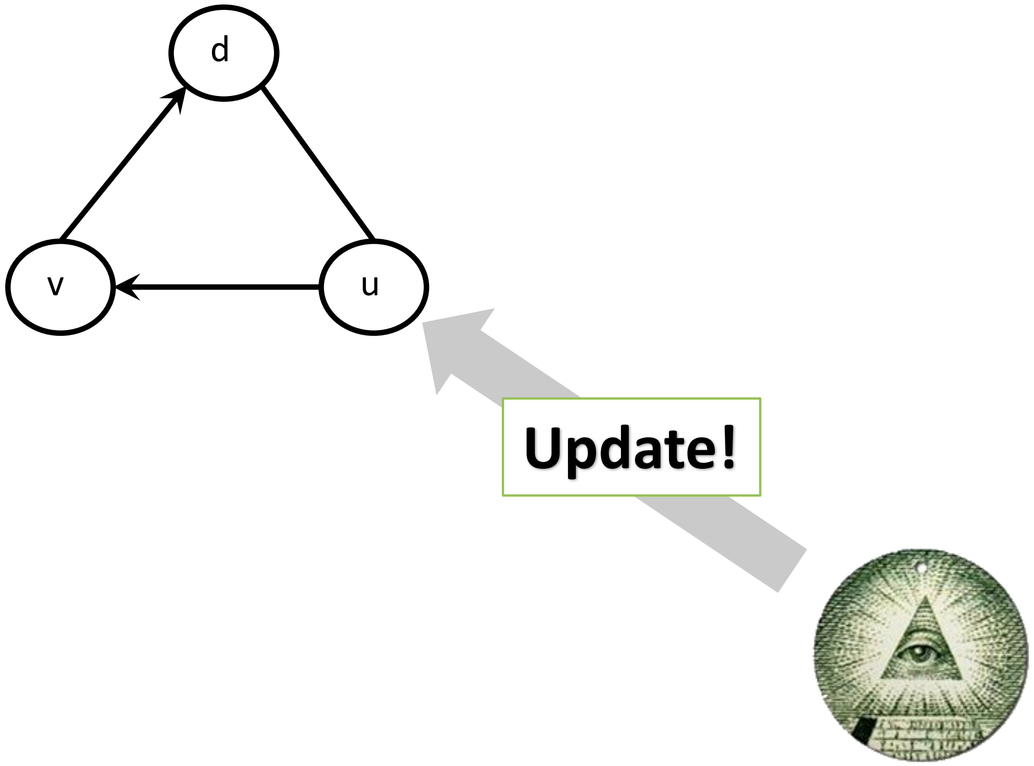

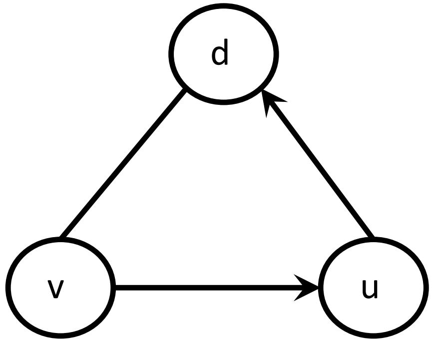

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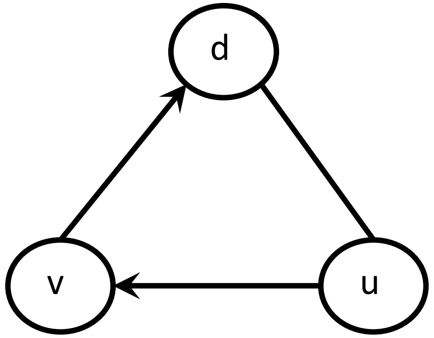

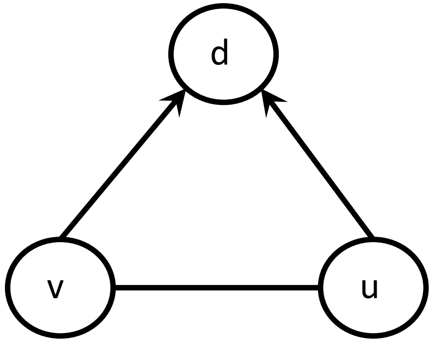

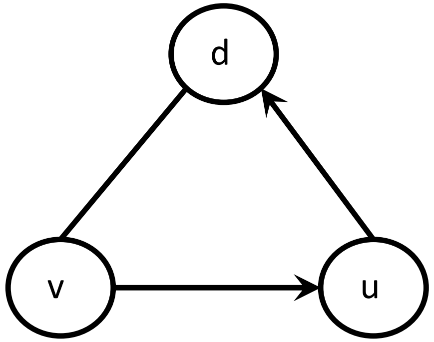

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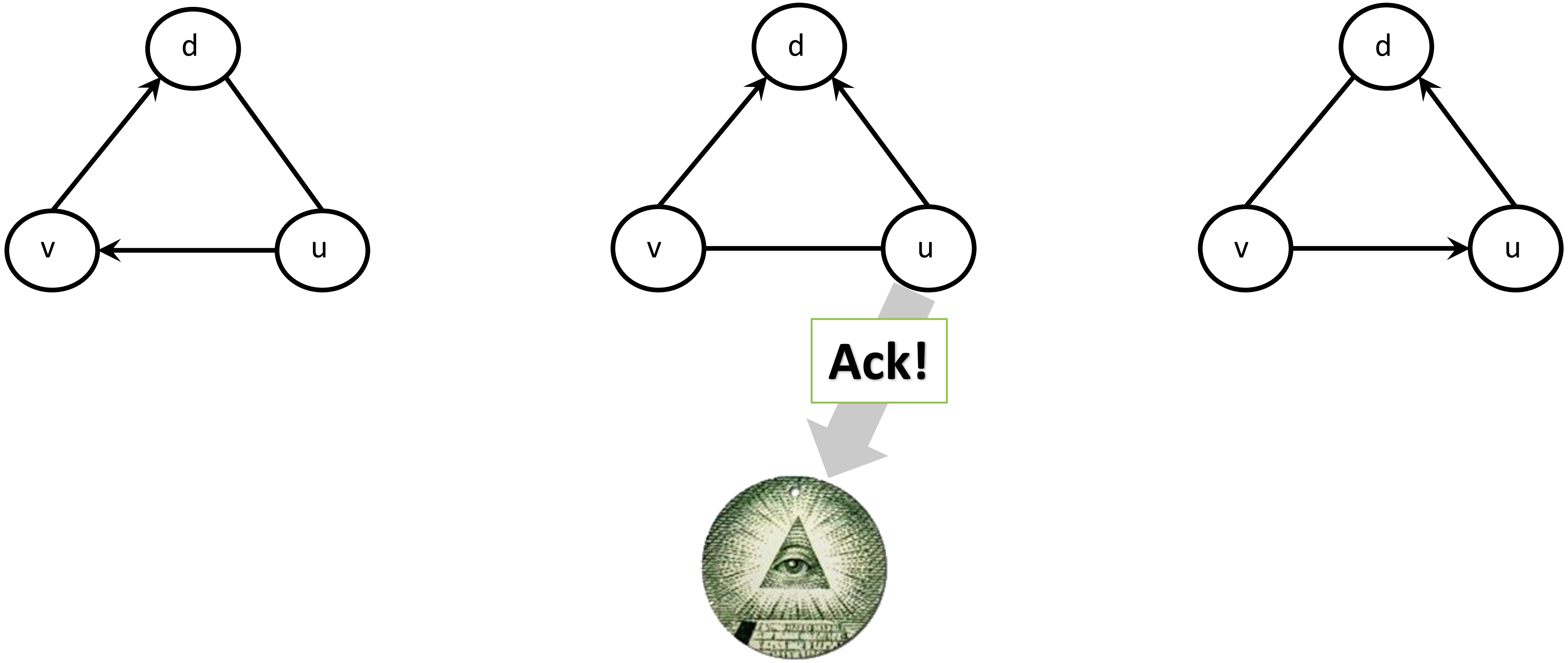

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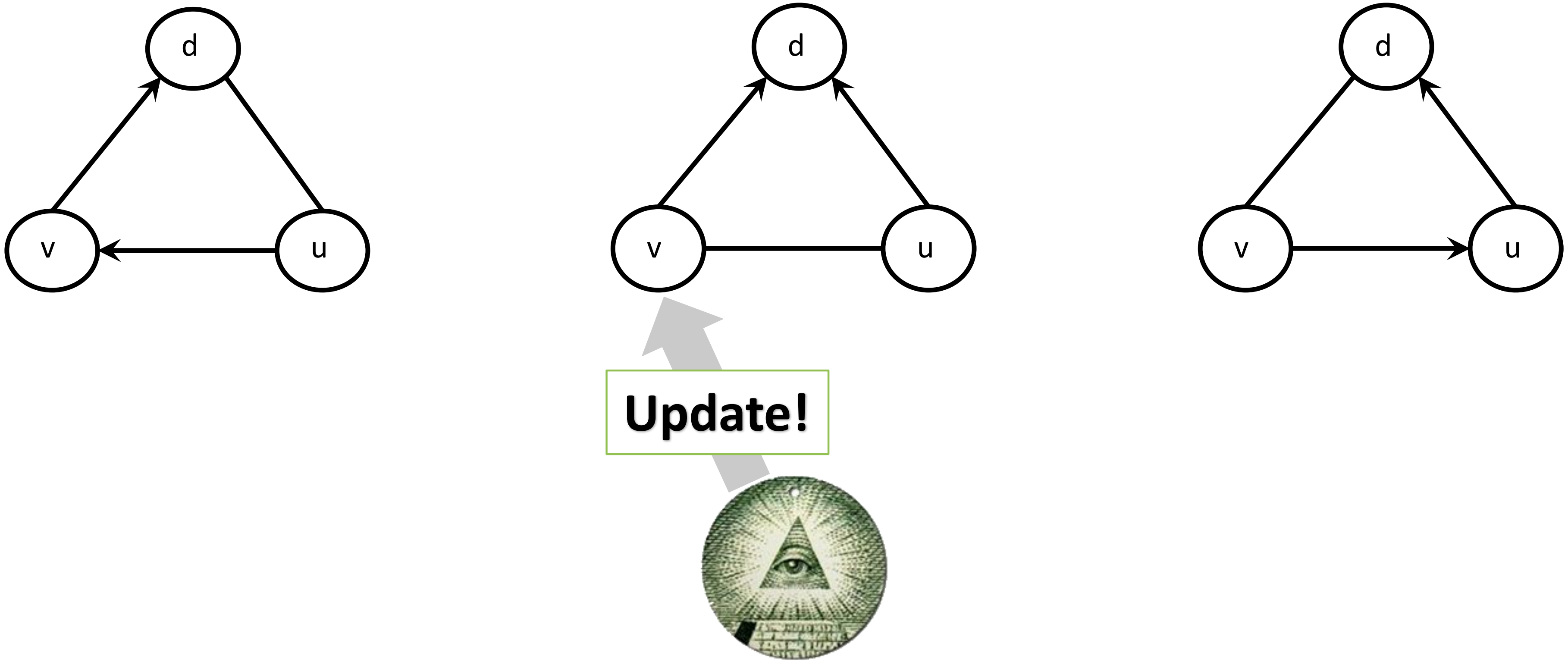

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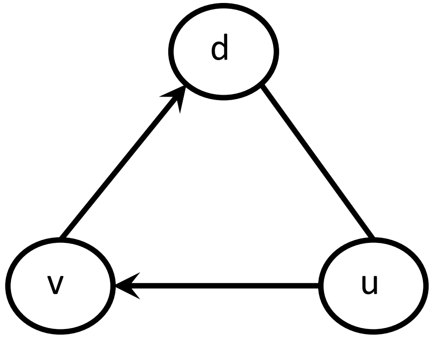
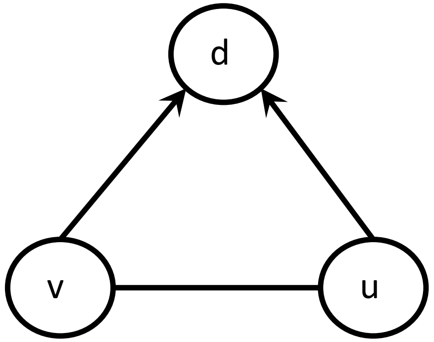
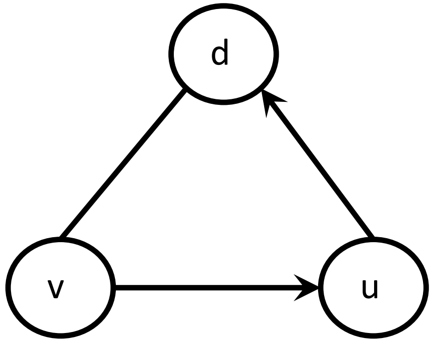


Round **0** *(old)*



Round **1**



Round **2** *(new)*

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- So far: every round:
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This paper: #1) General application to loop freedom and 2) routing path deployment via 2-phase commit

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- Problem: Loops are a “global“ property
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    - Slow and might require a locking mechanism ☹

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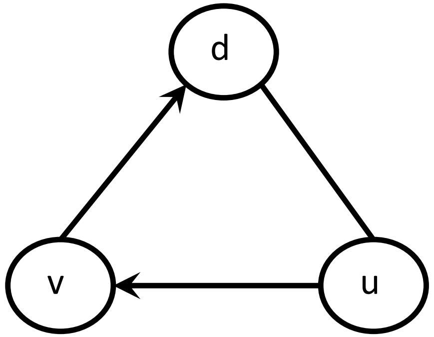
- Intuition on next slide

Proof Labeling – Without Network Updates



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  - Distance to root d
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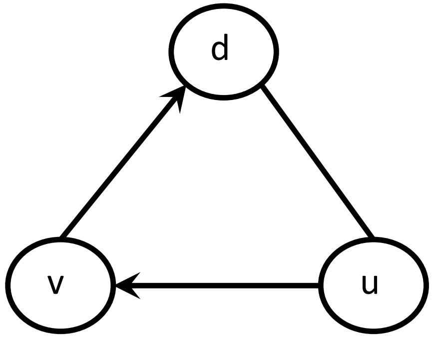

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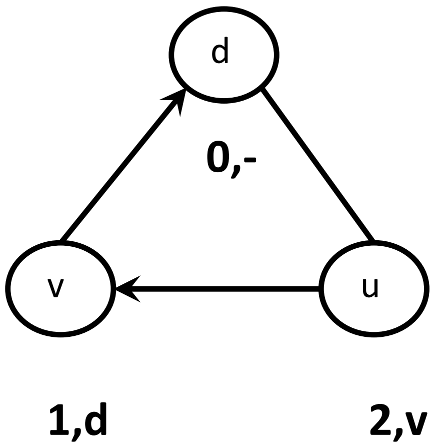

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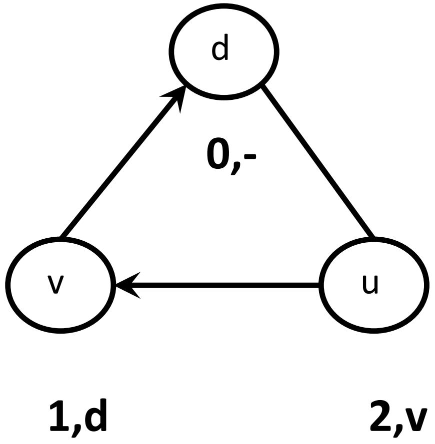

**We assume node Ids cannot be faked and d doesn't need a parent*

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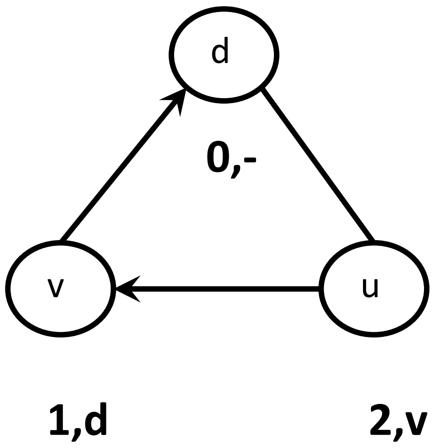

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- **All nodes will output YES**

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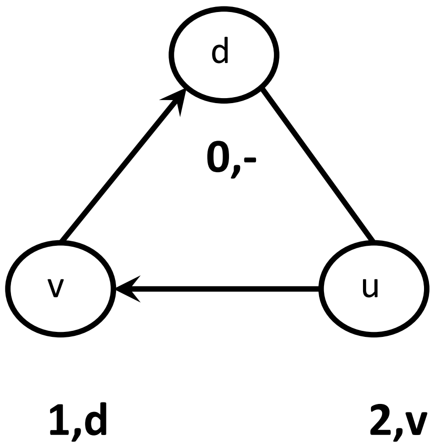

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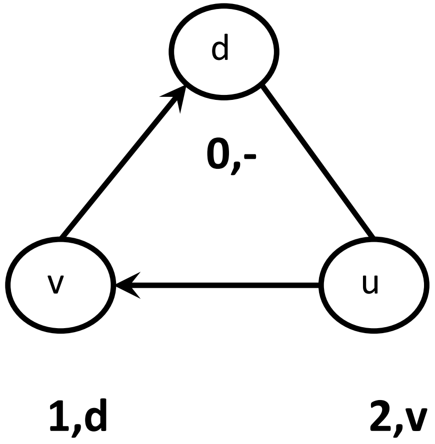

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- Note:
  - Requires O(log |V|) bits (optimal,Korman et al. 2005)
  - Already explored in SDN context by Schmid/Suomela, 2013

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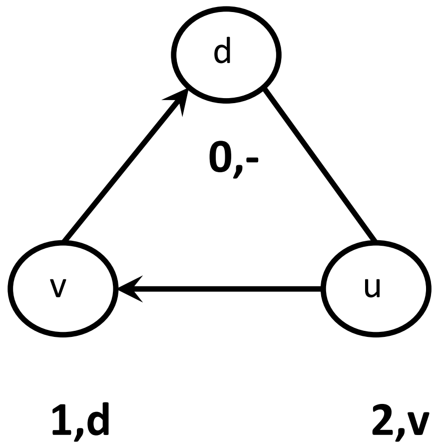

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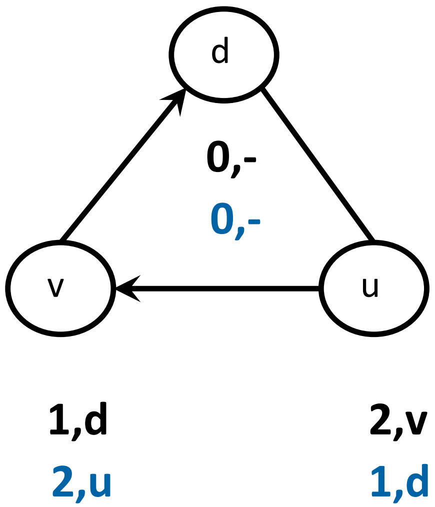

Proof Labeling – *With* Network Updates

- Prover sends out **new labels**
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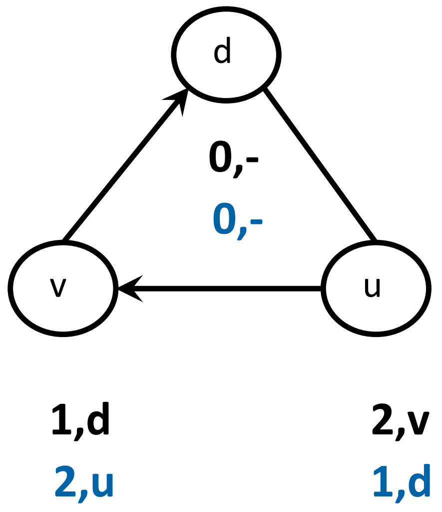

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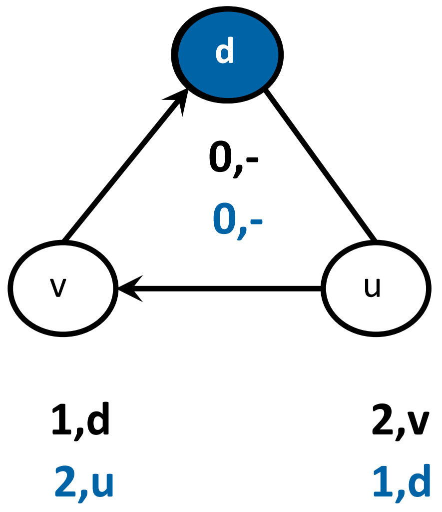

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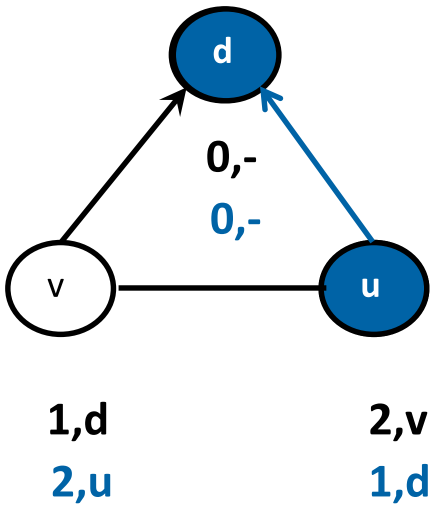

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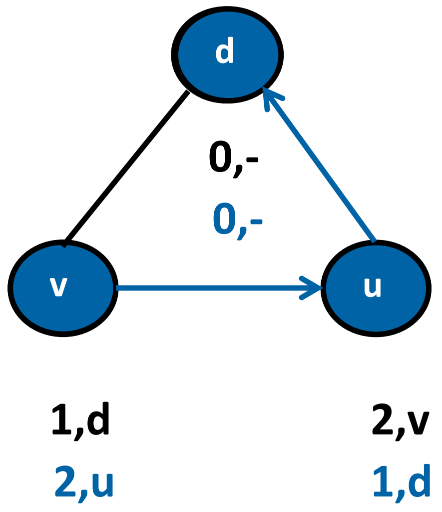

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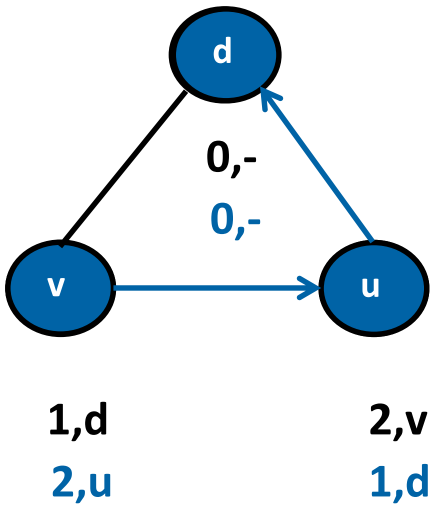

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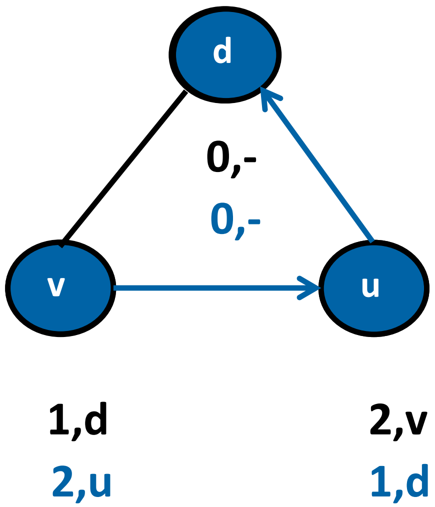

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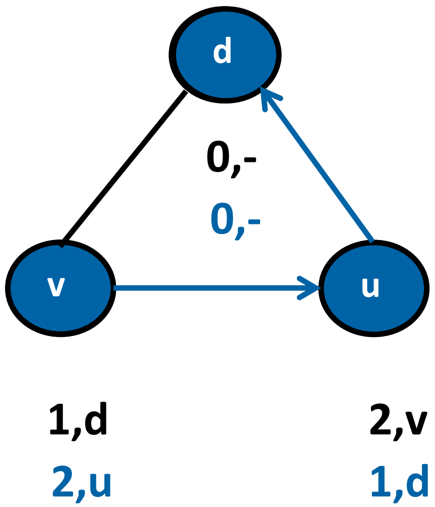

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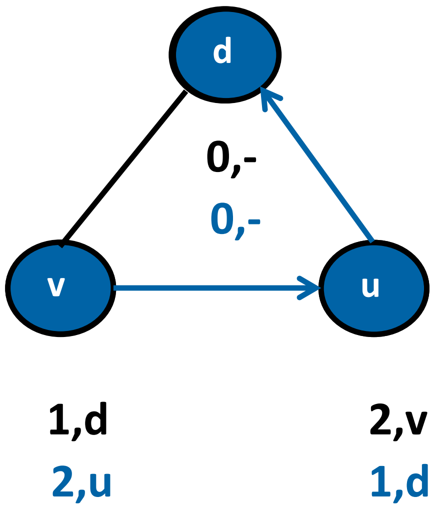

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  - **New labels** can be sent before **old labels** are finished

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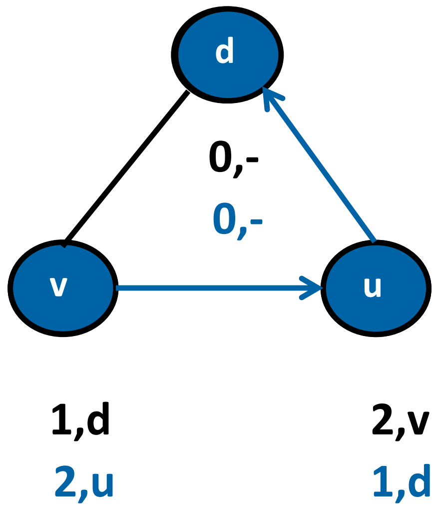

- Advantages:
  - Controller only sends labels once
  - Captures asynchrony, nodes refuse incorrect updates
  - **New labels** can be sent before **old labels** are finished
    - Look at tree #, only update to higher tree #

Can Standard Proof Labeling Methods Always be Directly Applied?

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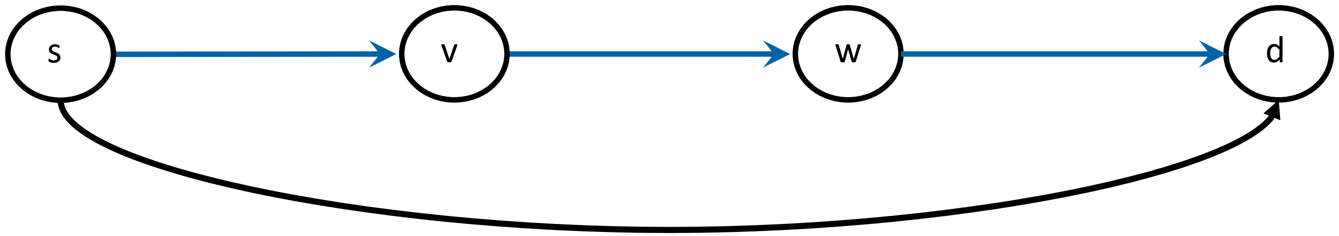

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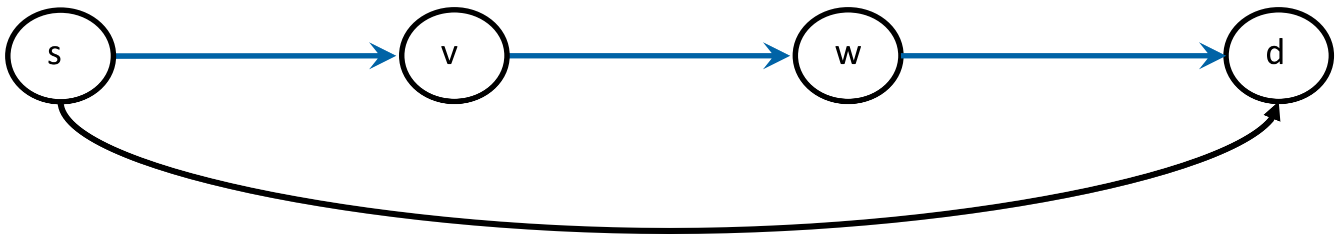

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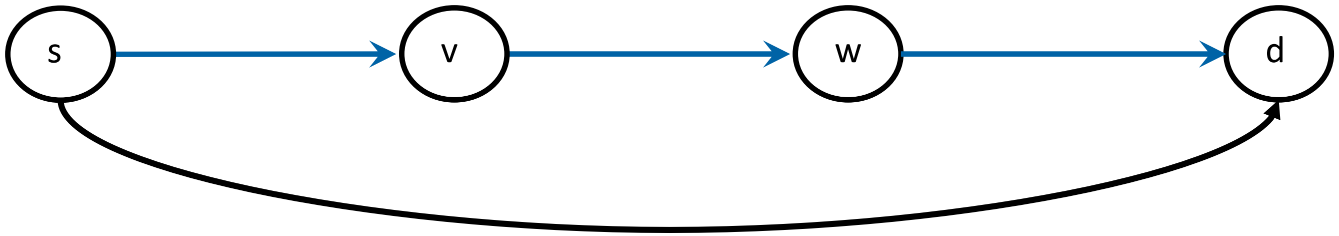
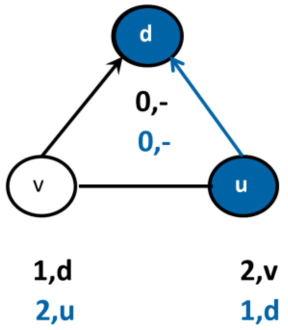


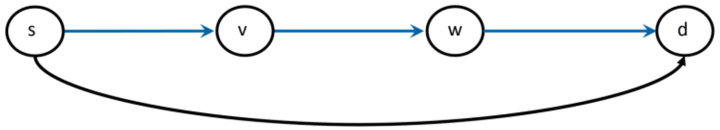
- Problem: v and w can never update!
  - v needs w to update before and vice versa ☹
  - Can be fixed with distance-labeling again ☺

Summary

- We investigated verifiable distributed consistent network updates

- With applications to:
  - Loop-free routing trees (destination based)
  - Path deployment (flow based)





- Next challenge: Deploy proof labeling concepts in P4/OpenFlow hardware and/or Mininet

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