How to Establish Loop-Free Multipath Routes in Named Data Networking?

NDNcomm 2017

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The University of Arizona

Routing and Forwarding in IP Networks

No Loop Detection on Forwarding Plane

- Very high cost (packets loop through same routers until TTL runs out)

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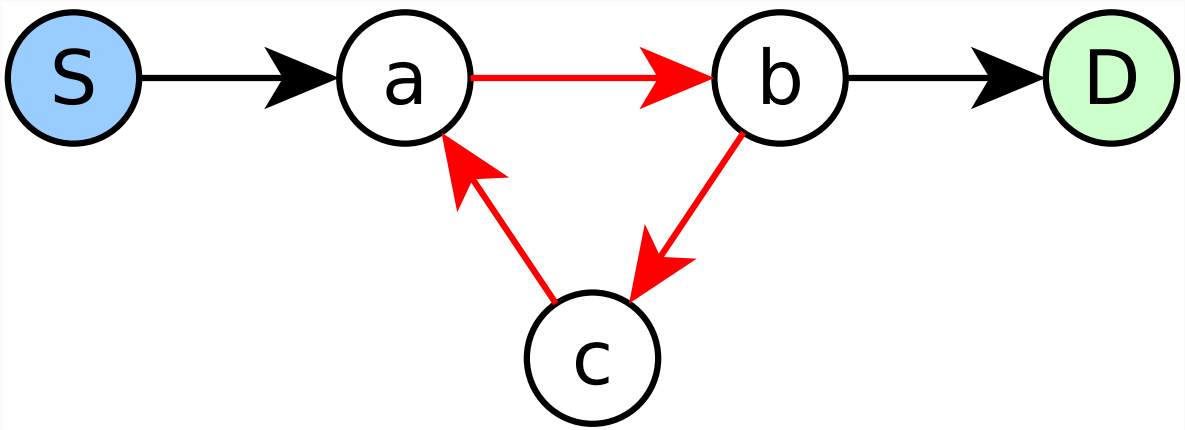

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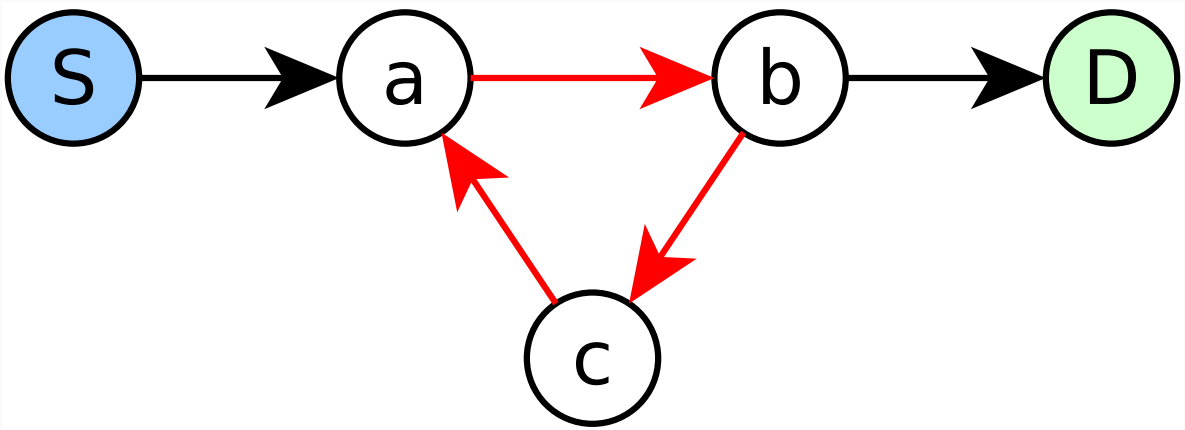

NDN: Detect & handle loops via **nonce!**

Traffic Splitting

Great benefits of using multiple paths **at the same time!**

- Load Balancing
- Gradual shifting of traffic during congestion [1, 2]
- Exploiting differences in cost and performance of paths (WiFi vs. LTE) [3]

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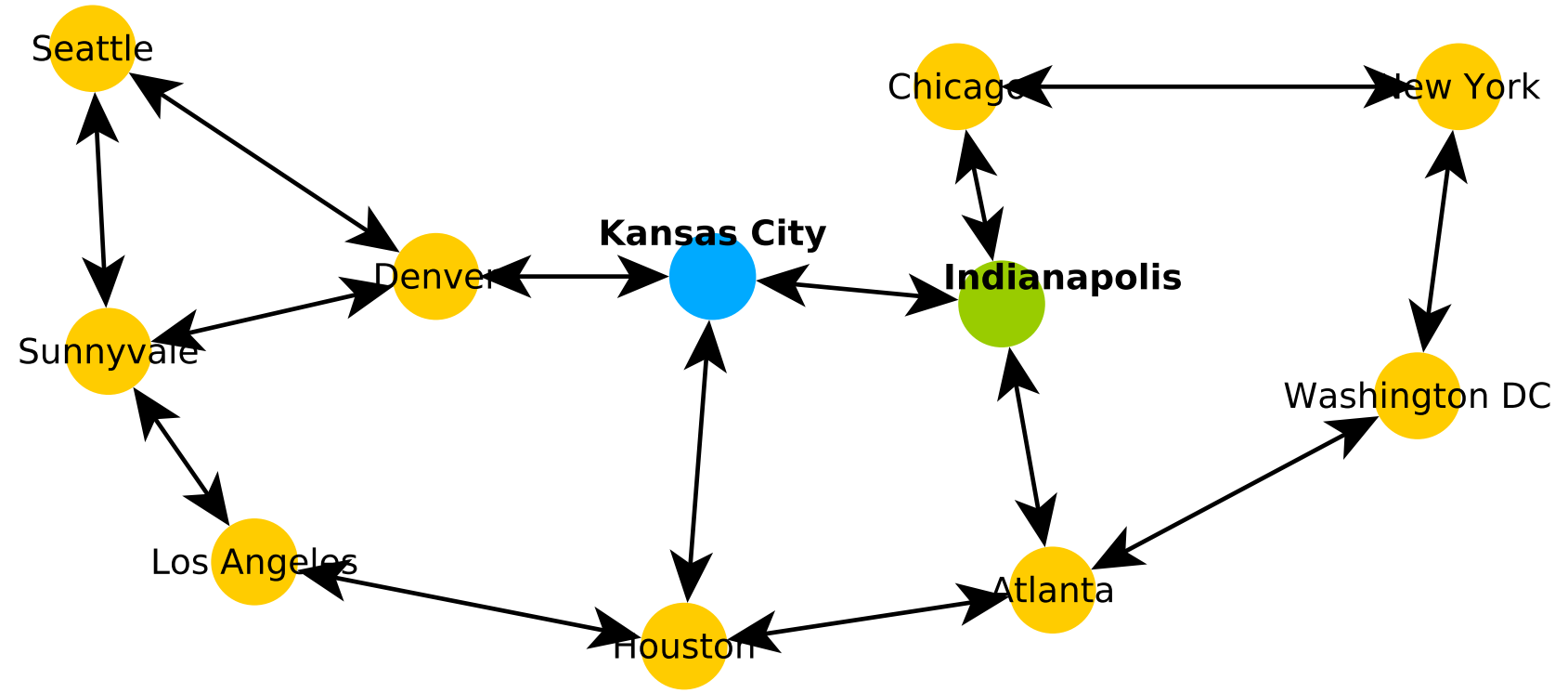
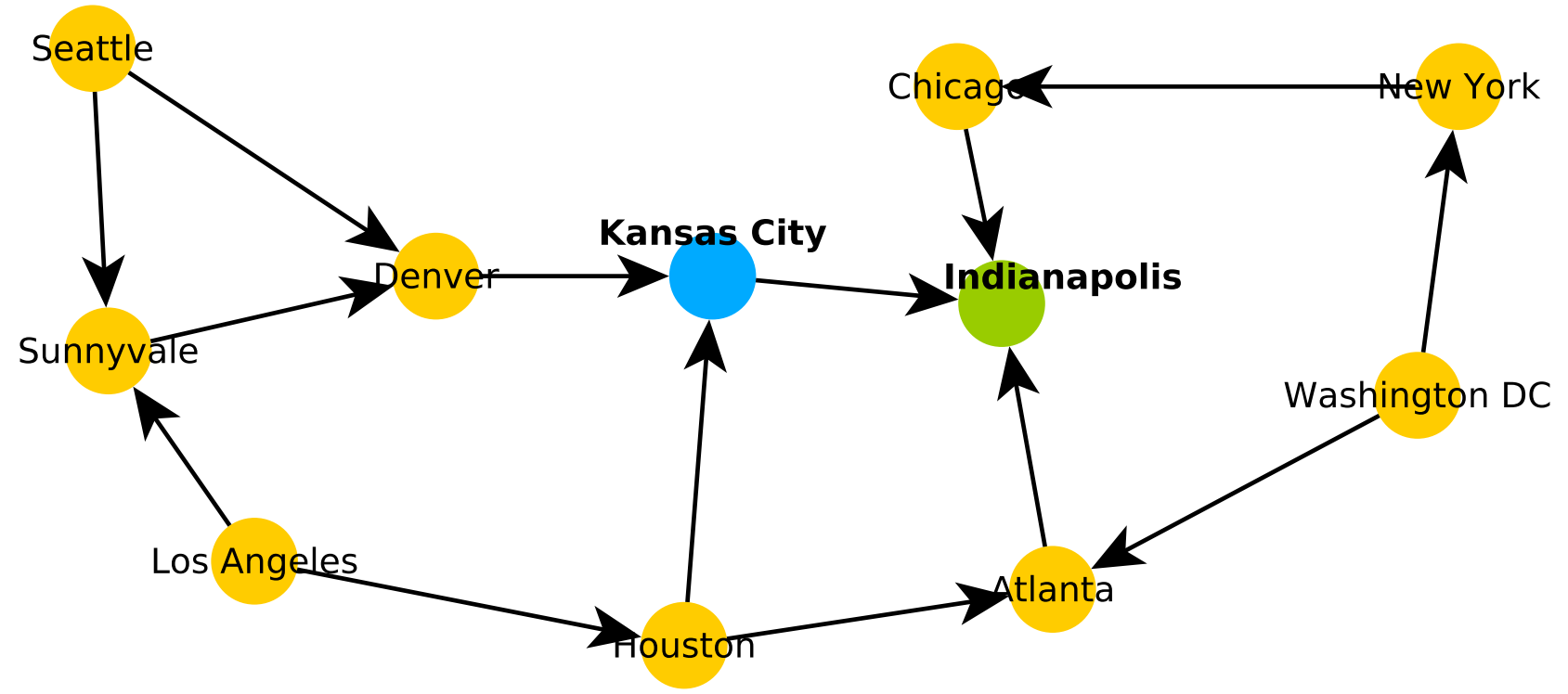
Traffic Splitting requires **Loop-Freeness** and **Path Choice**

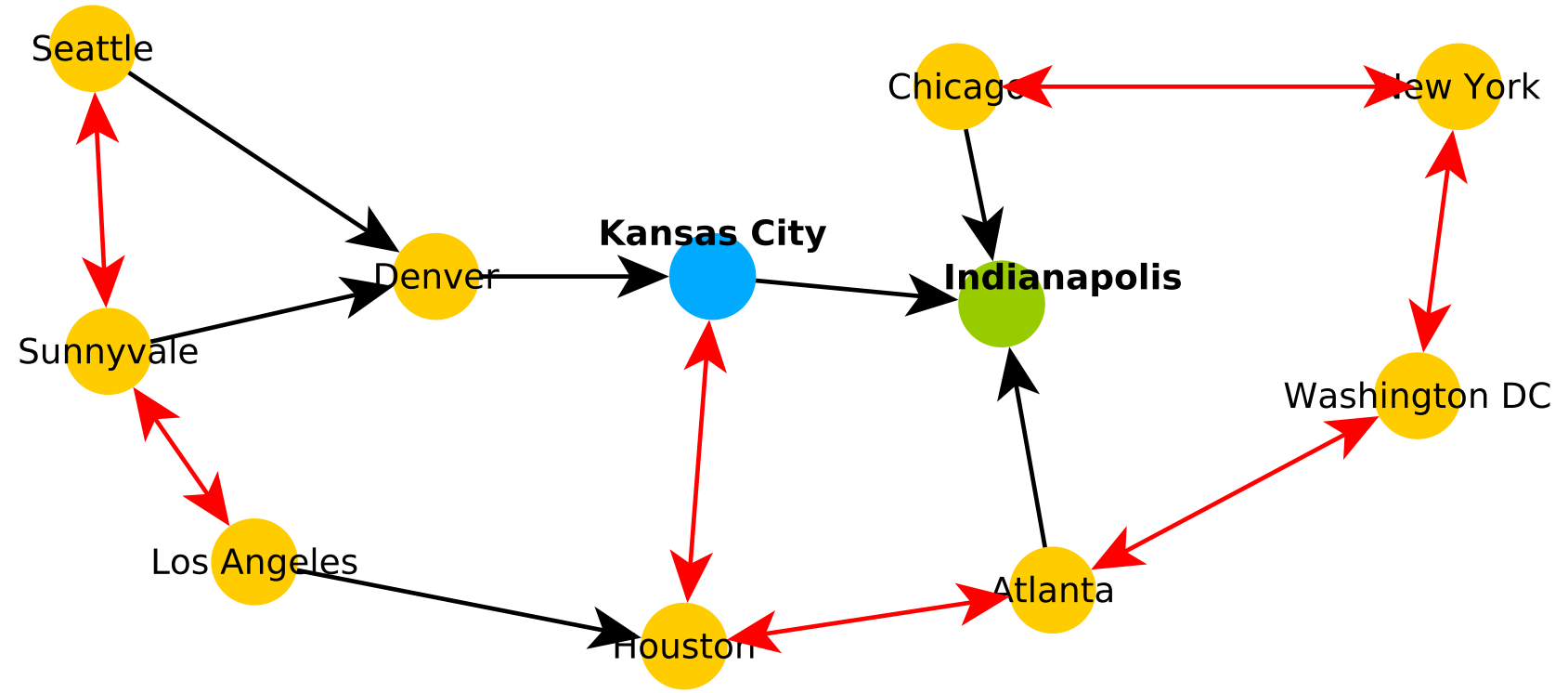
NLSR: High Path Choice, but many Loops



Loop-Free Routing: Limited Path Choice



Incoming Interface-Exclusion: Higher Path Choice



How To Achieve That?

Via Routing? **Too complex!**

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2. Now: $\Rightarrow$ Directed graph **without cycles longer than one hop!**

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Solution:

1. **Almost Loop-free Routing** (ALR)
2. On-demand **Loop Removal** at forwarding layer

Almost Loop-Free Routing

Give each nexthop in FIB a Type: { `Downward`, `Upward`, `Disabled` }.

1. Fill FIB with Downward Nexthops
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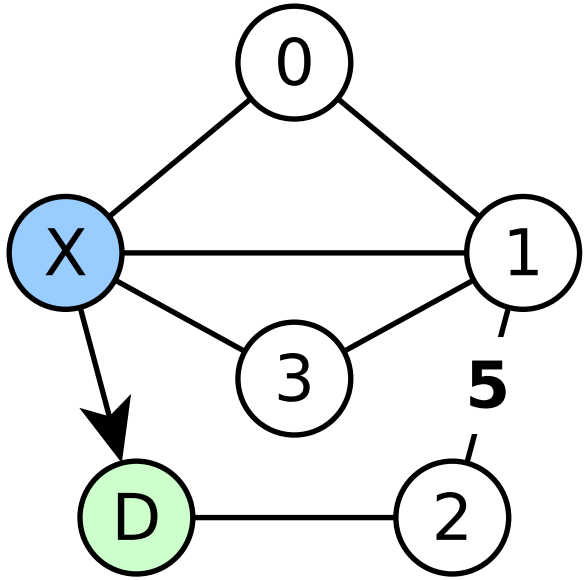
⇒ Much more nodes with **at least 2 nexthops**, and low looping chance.

Forwarding loop: **Uphill Nexthop Removal** (UNR)

Example of Loop-Freeness Heuristic



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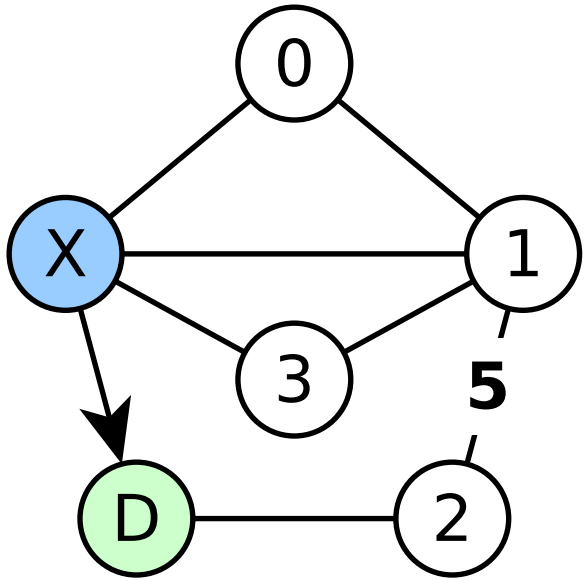

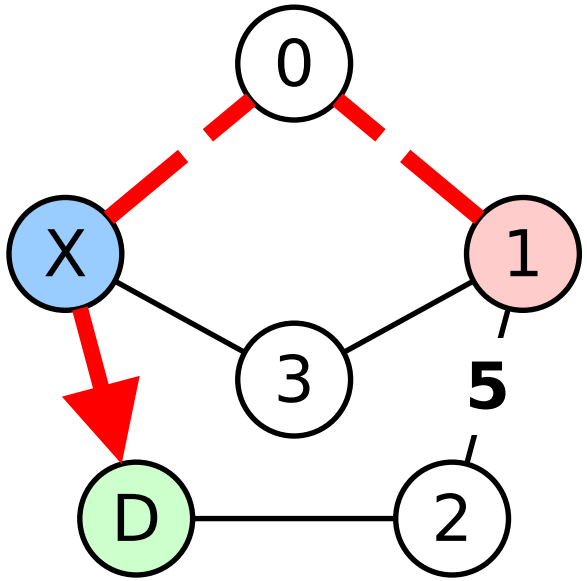

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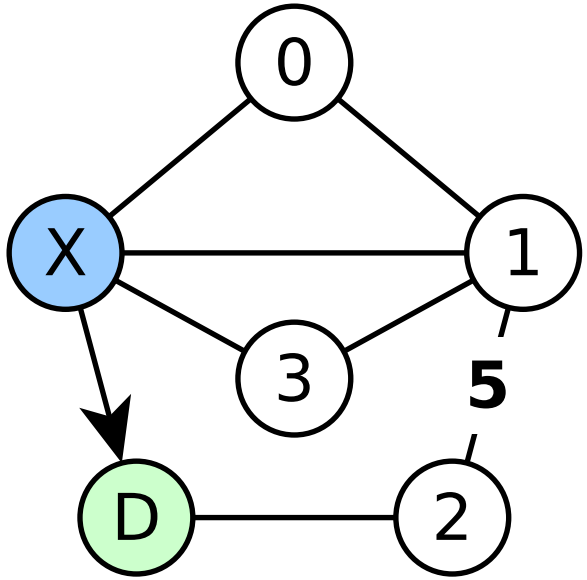

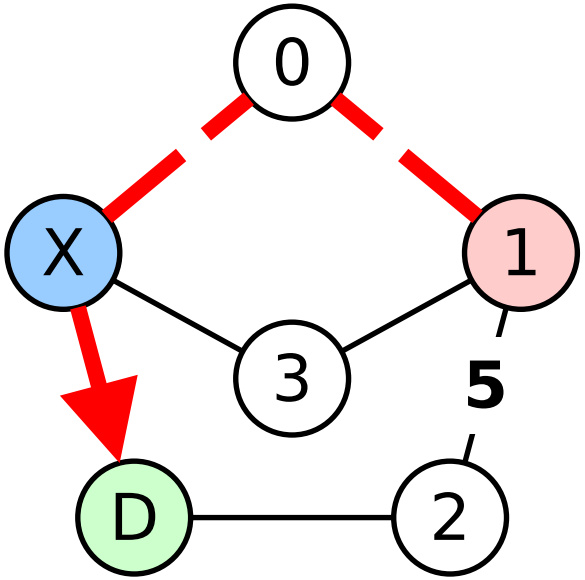

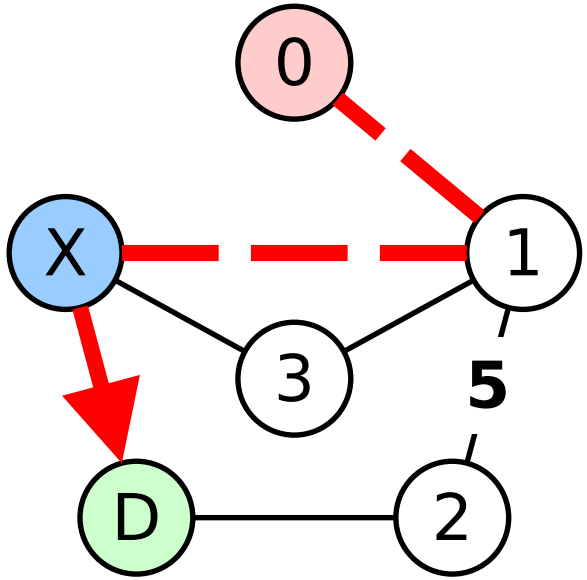

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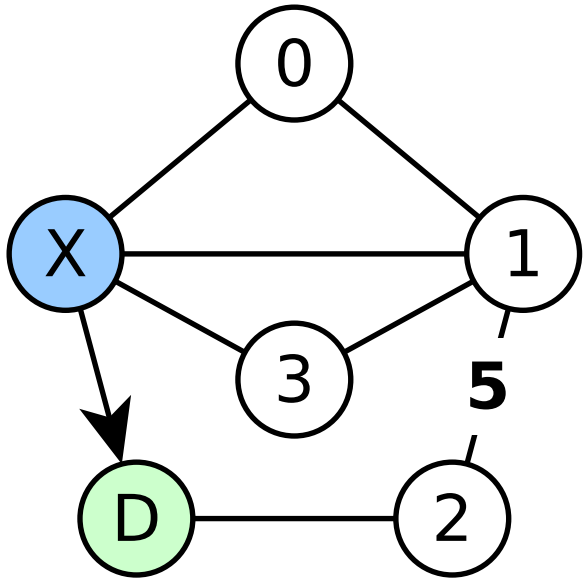

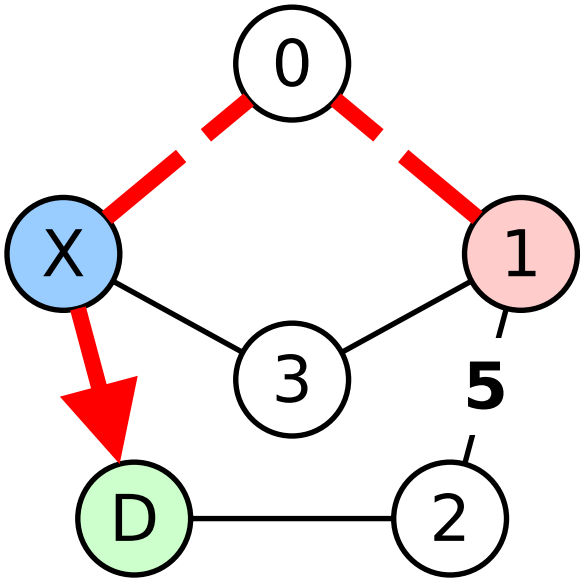

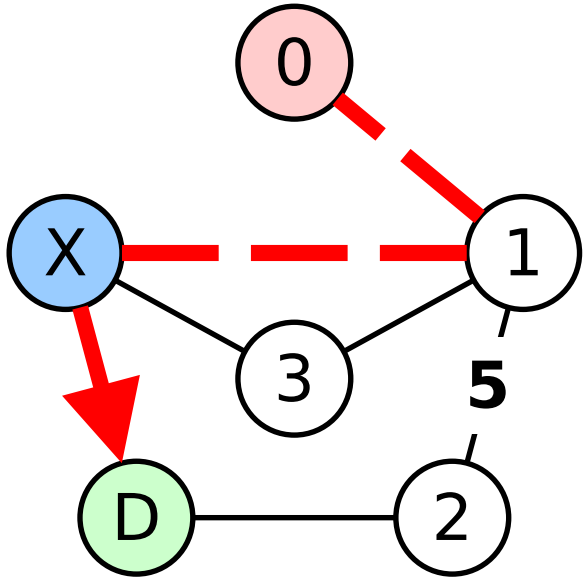

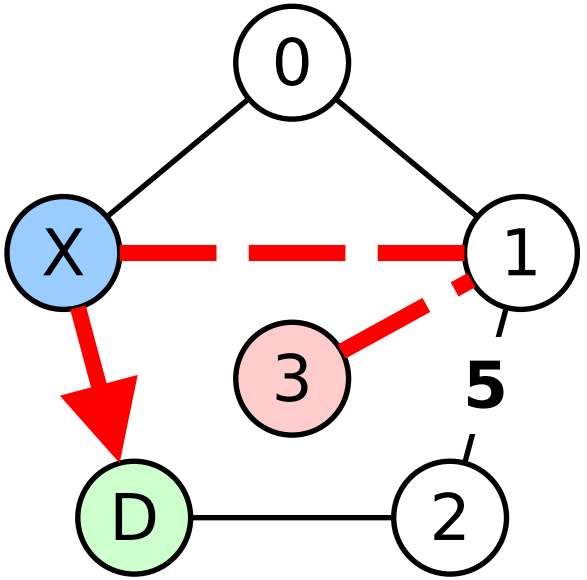

Evaluation

Results of 8 other routing protocols in 9 topologies:

- ALR: Low computational complexity, similar to NLSR.
- UNR: Very low forwarding complexity (only 0.4% to 1.6% of FIB entries need to be changed)

Together: Completely loop-free network with **higher path choice** than loop-free routing for all tested topologies.

Summary

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- Current NDN routing vice versa.

$\Rightarrow$ Achieving both by combining **Almost-Loopfree Routing** with **Loop-removal** at the forwarding layer.

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Future Work:

- Tech Report **coming soon!**

The End

Thank you for your attention!

Questions?

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References I

[1] Giovanna Carofiglio, Massimo Gallo, Luca Muscariello, Michele Papalini, and Sen Wang.
Optimal multipath congestion control and request forwarding in information-centric networks.
In *ICNP*, 2013.

[2] Klaus Schneider, Cheng Yi, Beichuan Zhang, and Lixia Zhang.
A practical congestion control scheme for named data networking.
In *Proceedings of ICN 2016*, pages 21–30. ACM, 2016.

[3] Klaus M Schneider and Udo R Krieger.
Beyond network selection: Exploiting access network heterogeneity with named data networking.
In *Proceedings of the 2nd International Conference on Information-Centric Networking*, pages 137–146. ACM, 2015.