Data Driven Connectivity

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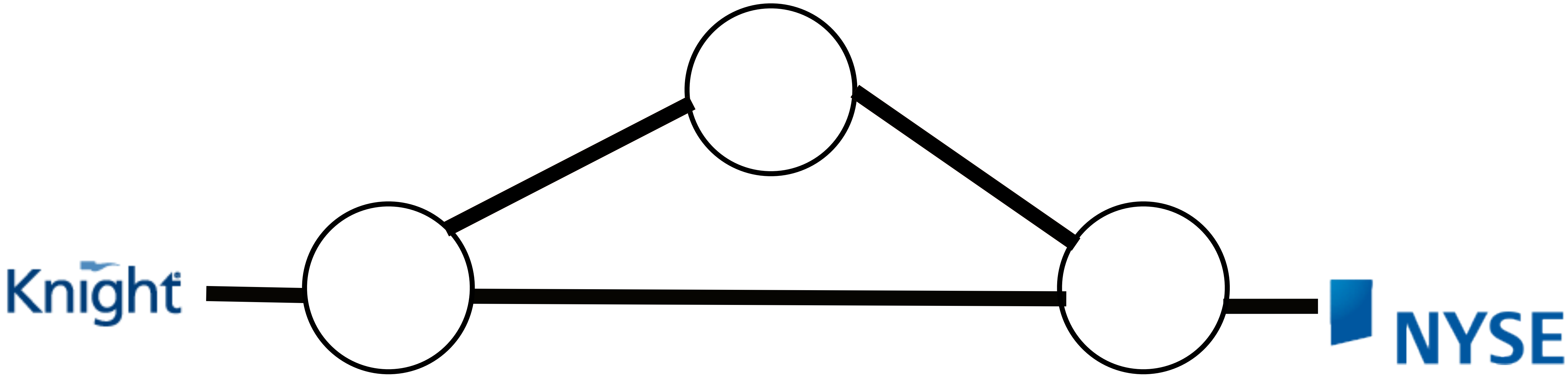
Brighten Godfrey, Michael Schapira,
Scott Shenker

Division of Concerns



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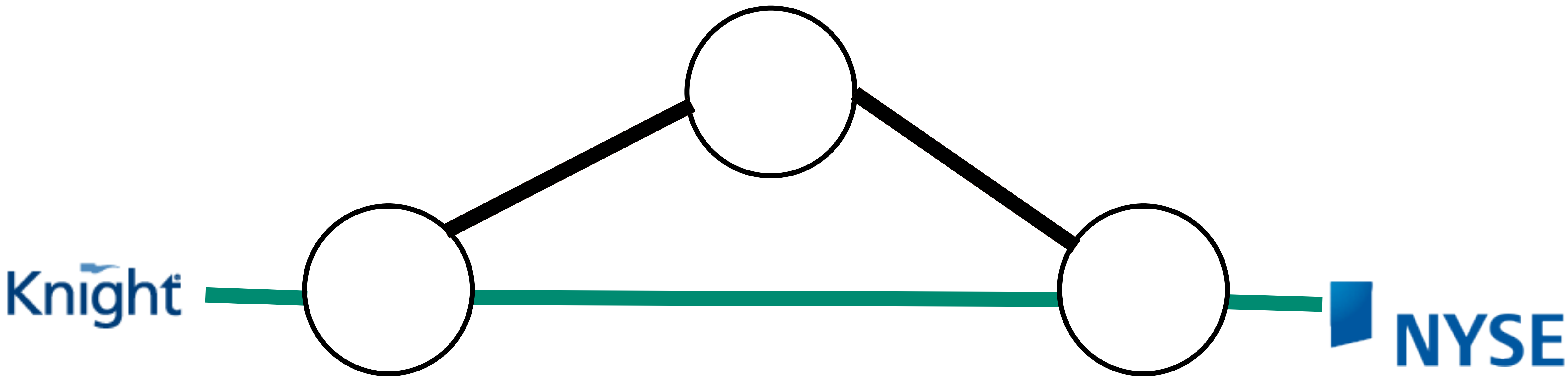

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  - Operates in the order of milliseconds.

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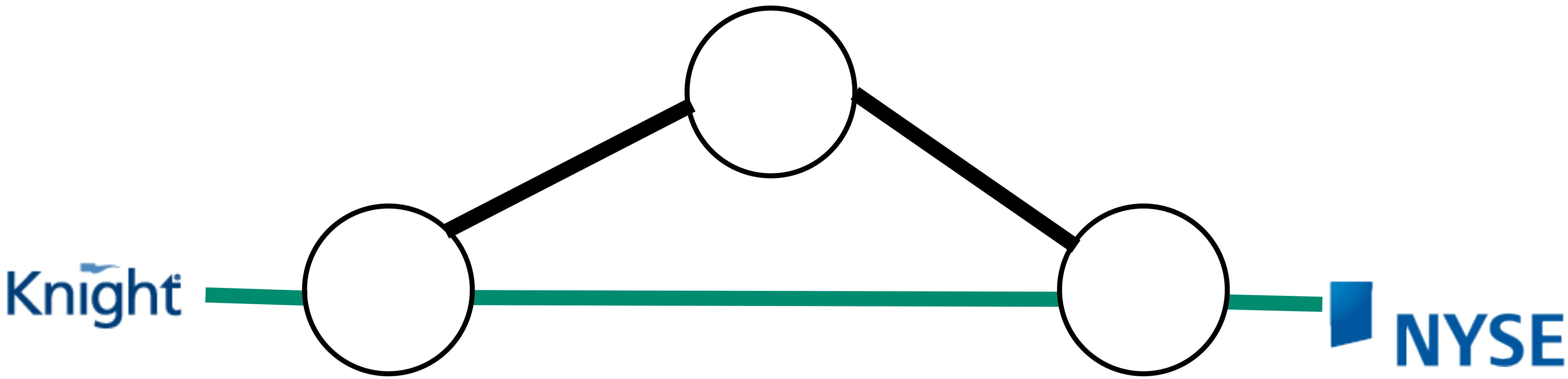
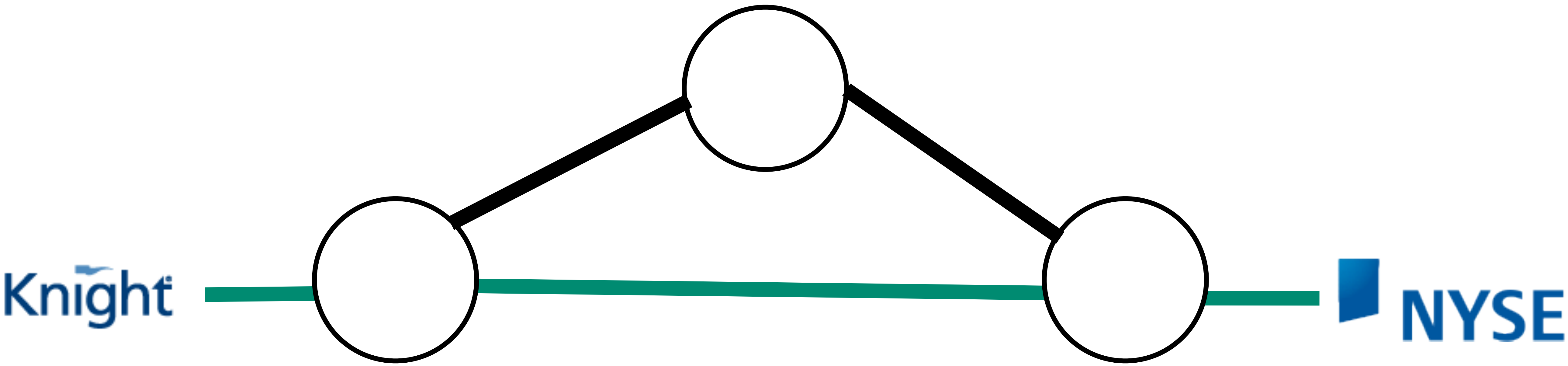


- Routing is a **control plane** operation.
  - Operates in the order of milliseconds.
- Packet forwarding is a **data plane** operation.
  - Operates in the order of microseconds.

Link Failures Hard



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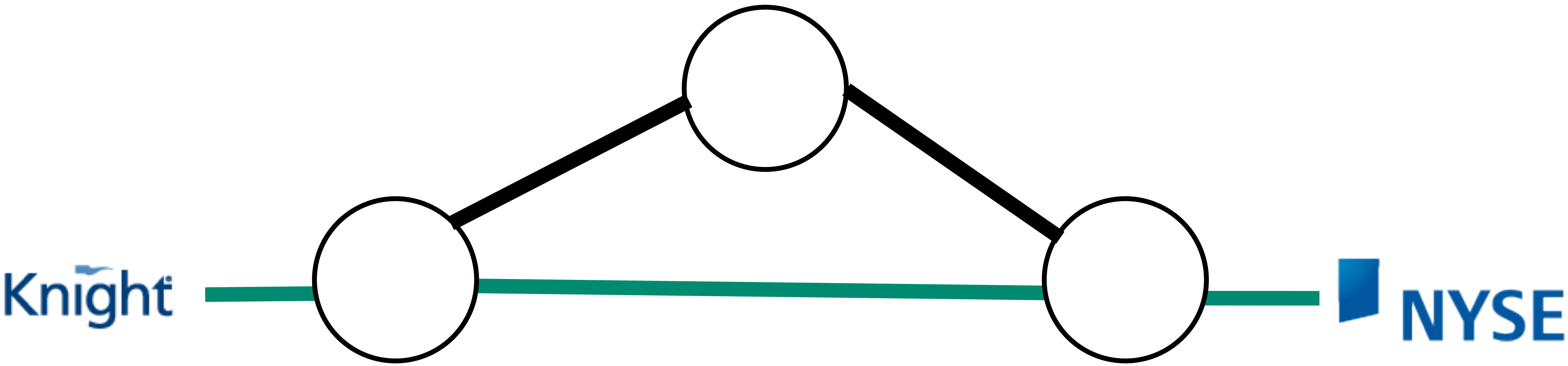

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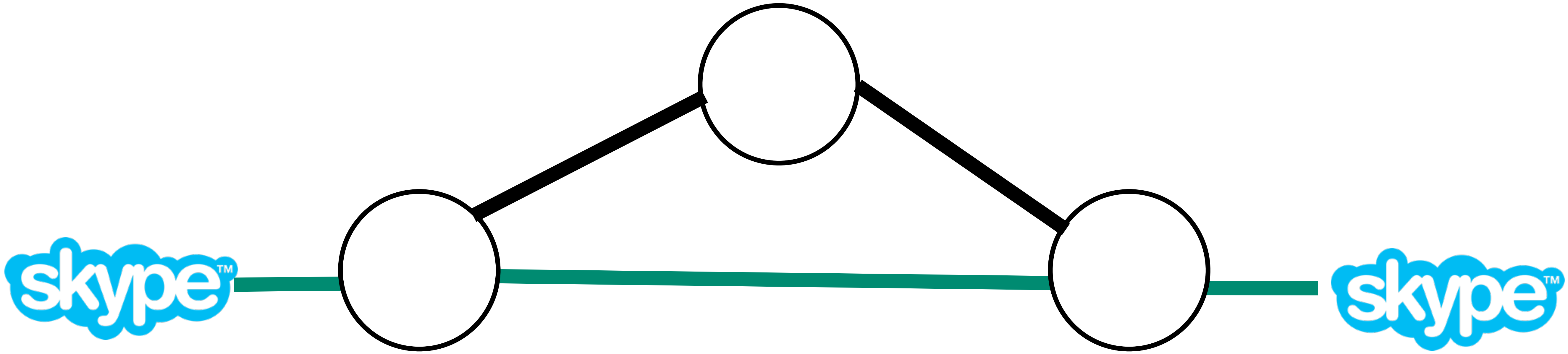

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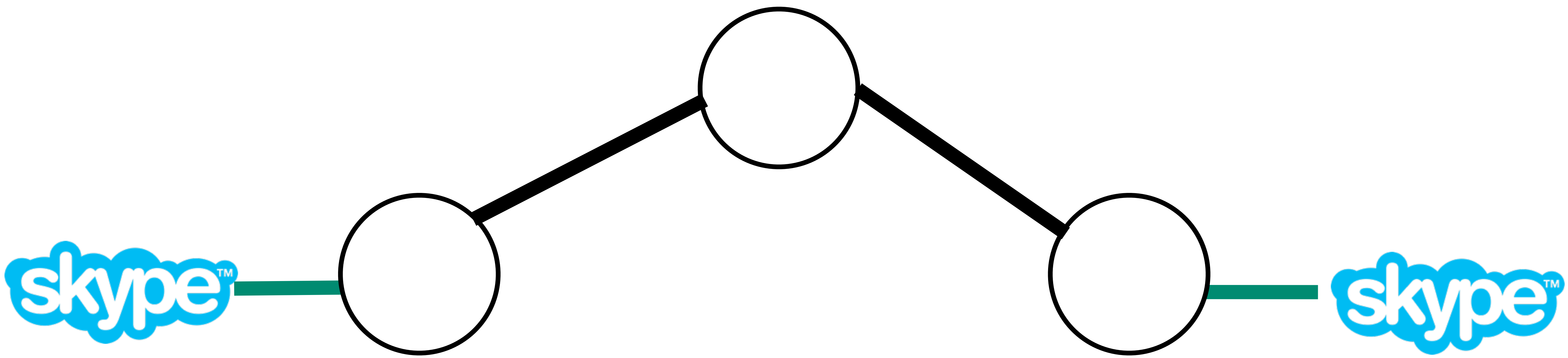
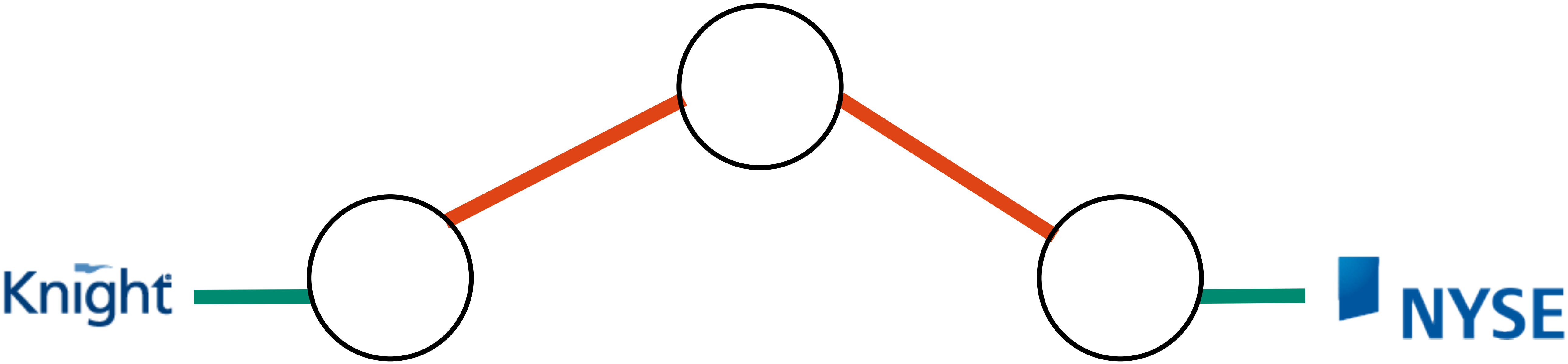


- Some users require low latency packet delivery.
- Some users require high reliability.
- Control Plane response to link failure is too slow.

Today's Solution



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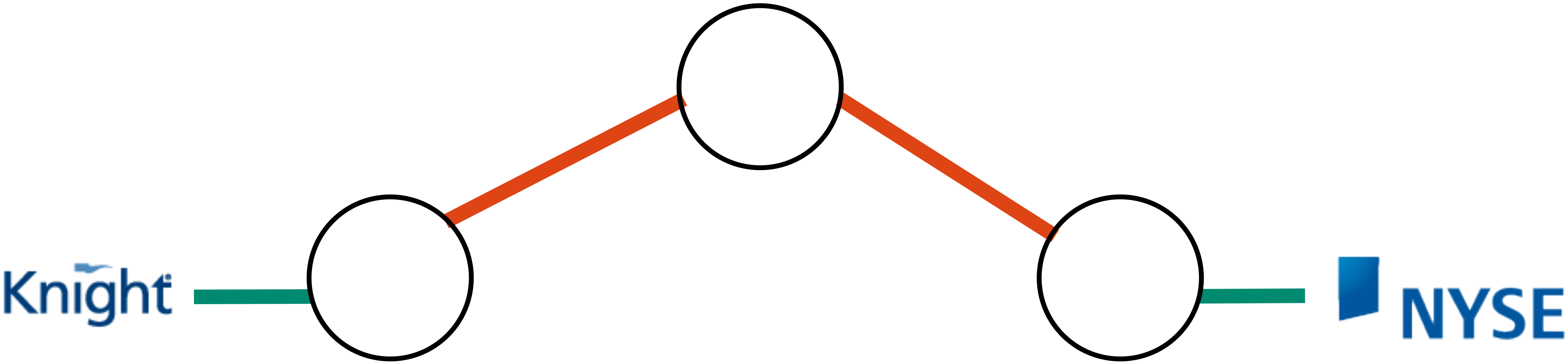

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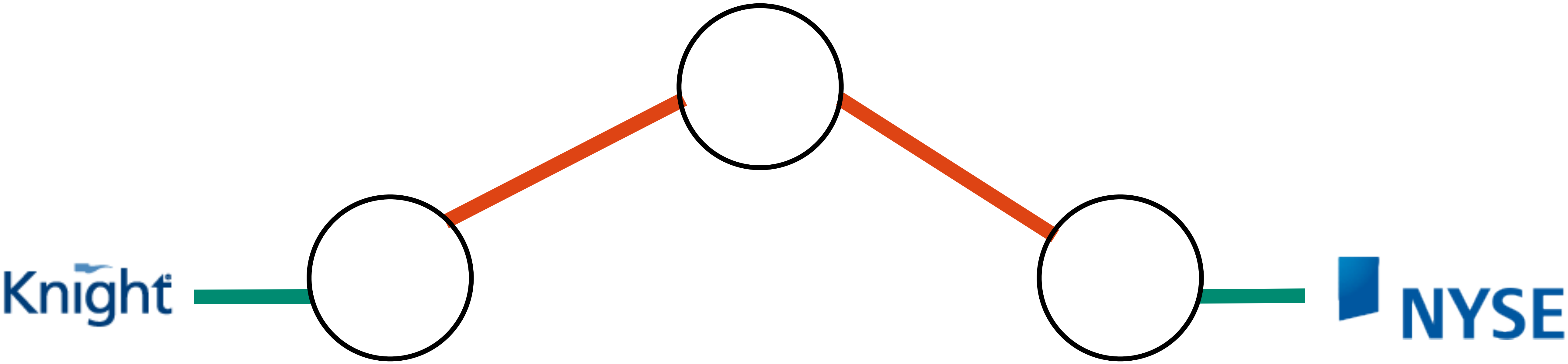

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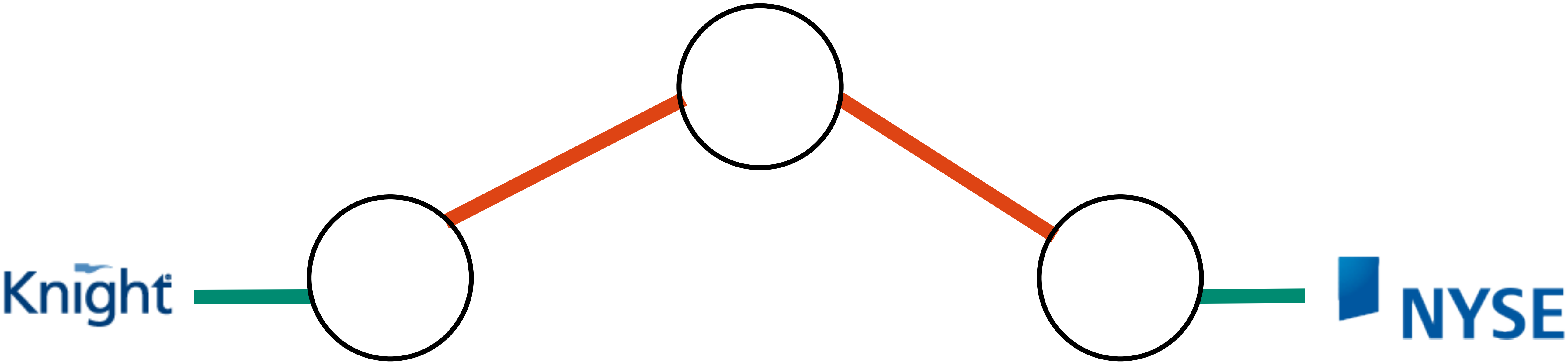

- Rely on precomputed backup paths
  - Typically support single link failures.
  - State grows exponentially for more links.
- Hard to generalize. Hard to configure.

Routing is the Problem!

- Routing conflates two functions
  - Optimality - Use good paths
    - Inherently global, requires coordination.
  - Connectivity - Deliver packets
    - Can it be local?

Data Plane Connectivity

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  - No additional data in packet header.
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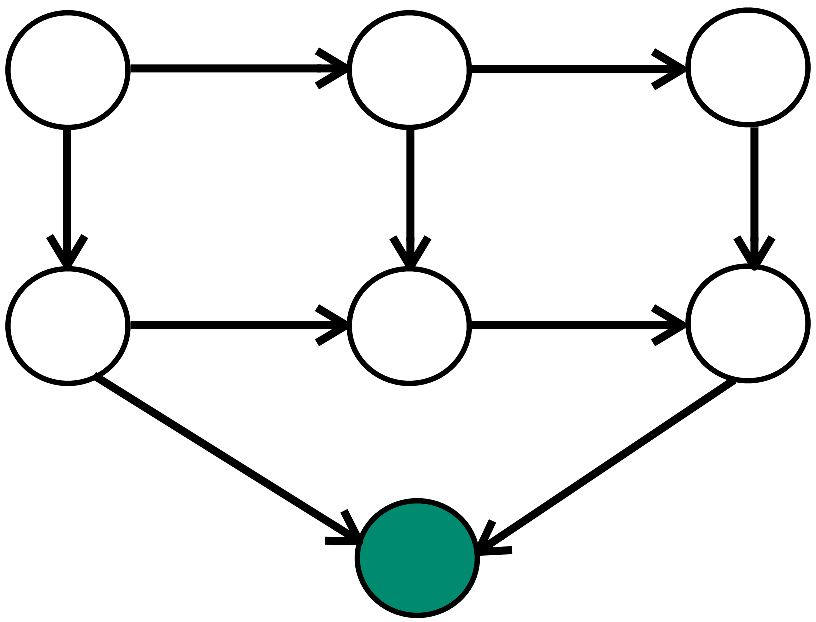
Data Plane Connectivity

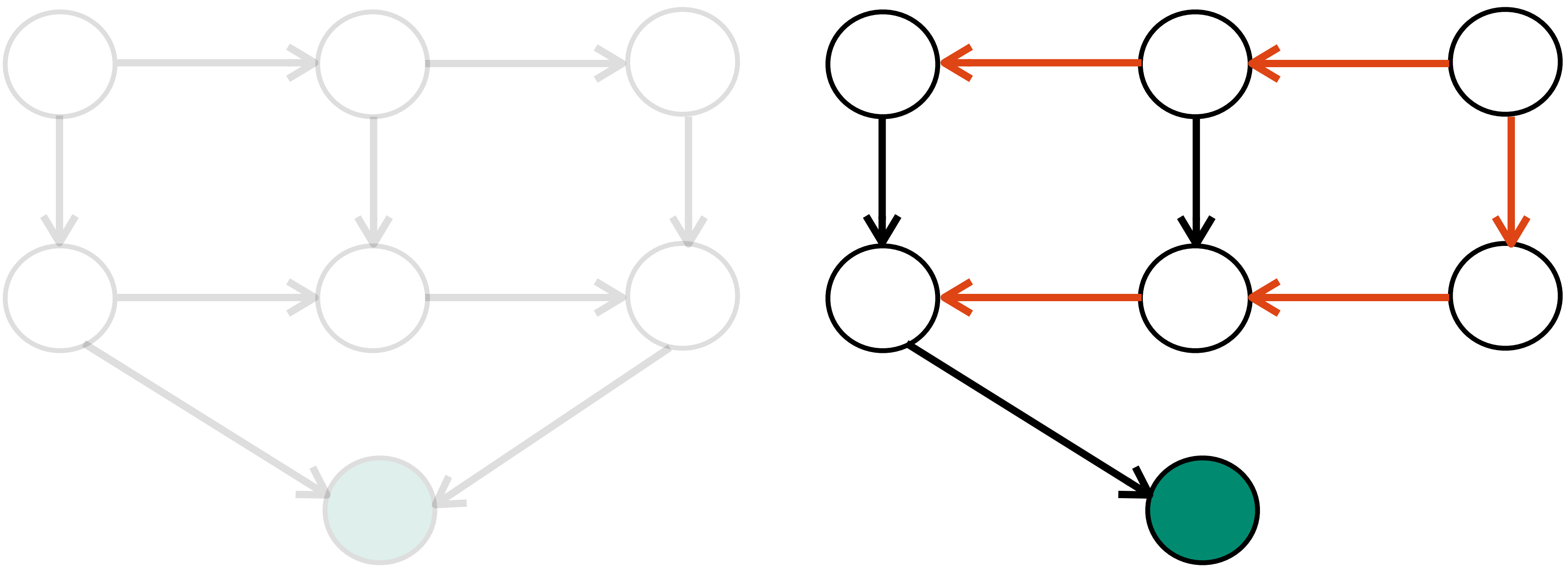
- Relax constraints
    - Change a few bits in FIB at packet rates.
- Clearly feasible, but is it enough?

Guaranteeing Connectivity



1. Take advantage of available redundancy.

Guaranteeing Connectivity



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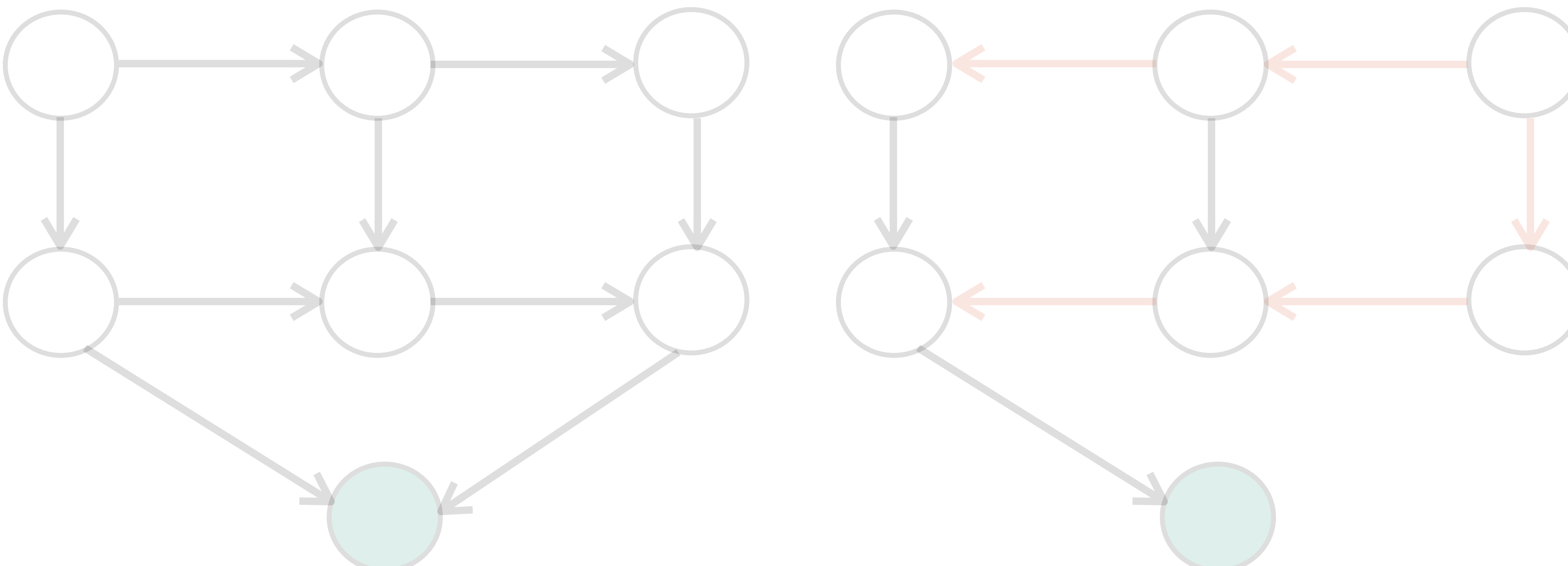
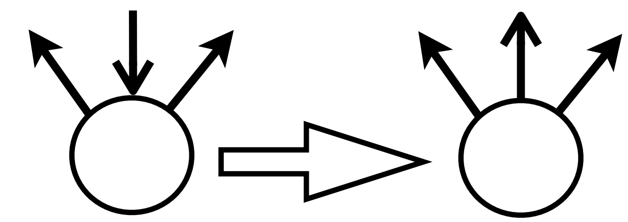
2. Restore connectivity at data speeds.

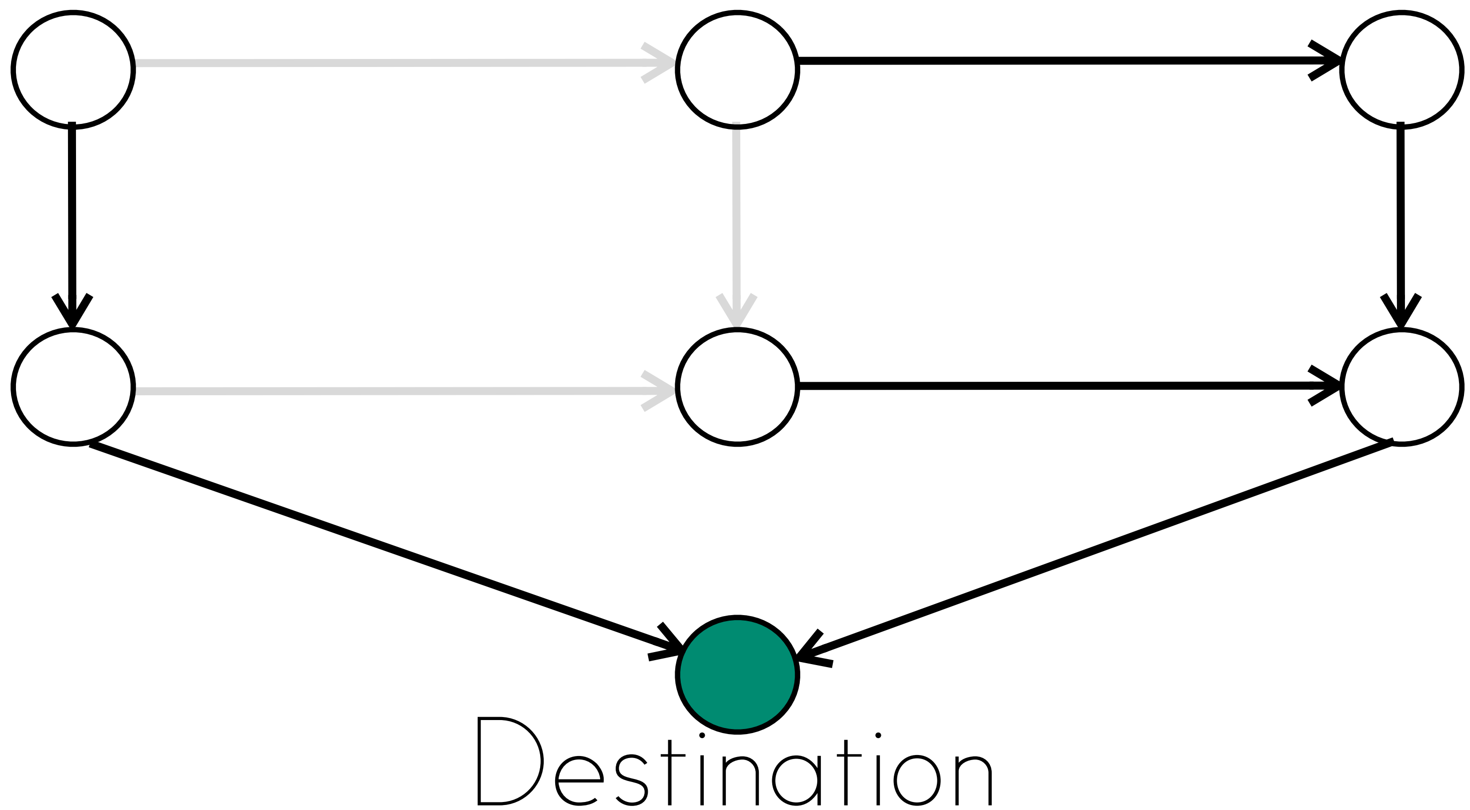
Guaranteeing Connectivity



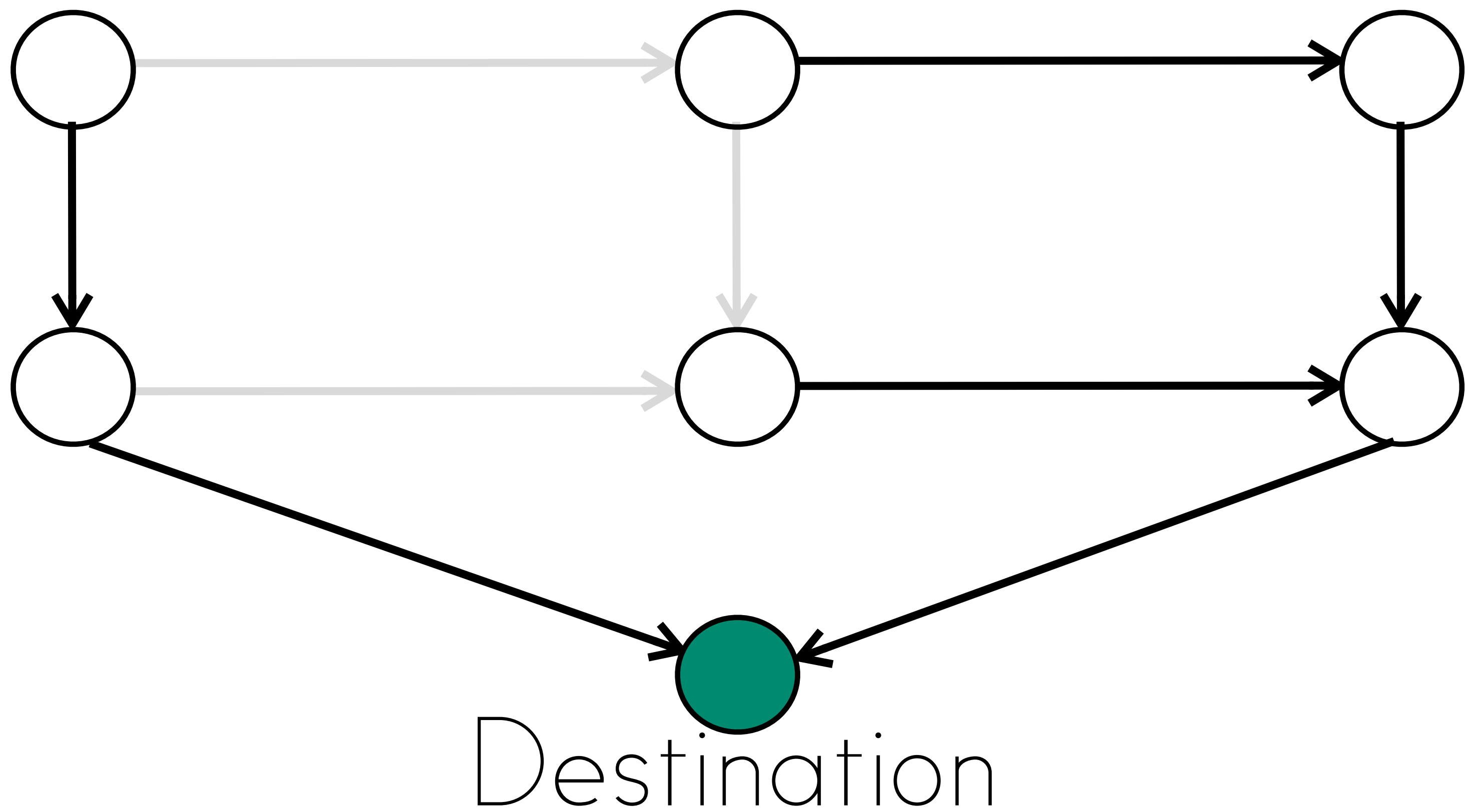


1. Take advantage of available redundancy.
2. Restore connectivity at data speeds.
3. Achieve optimality at control speeds.

Using Redundancy: DAGs



Using Redundancy: DAGs



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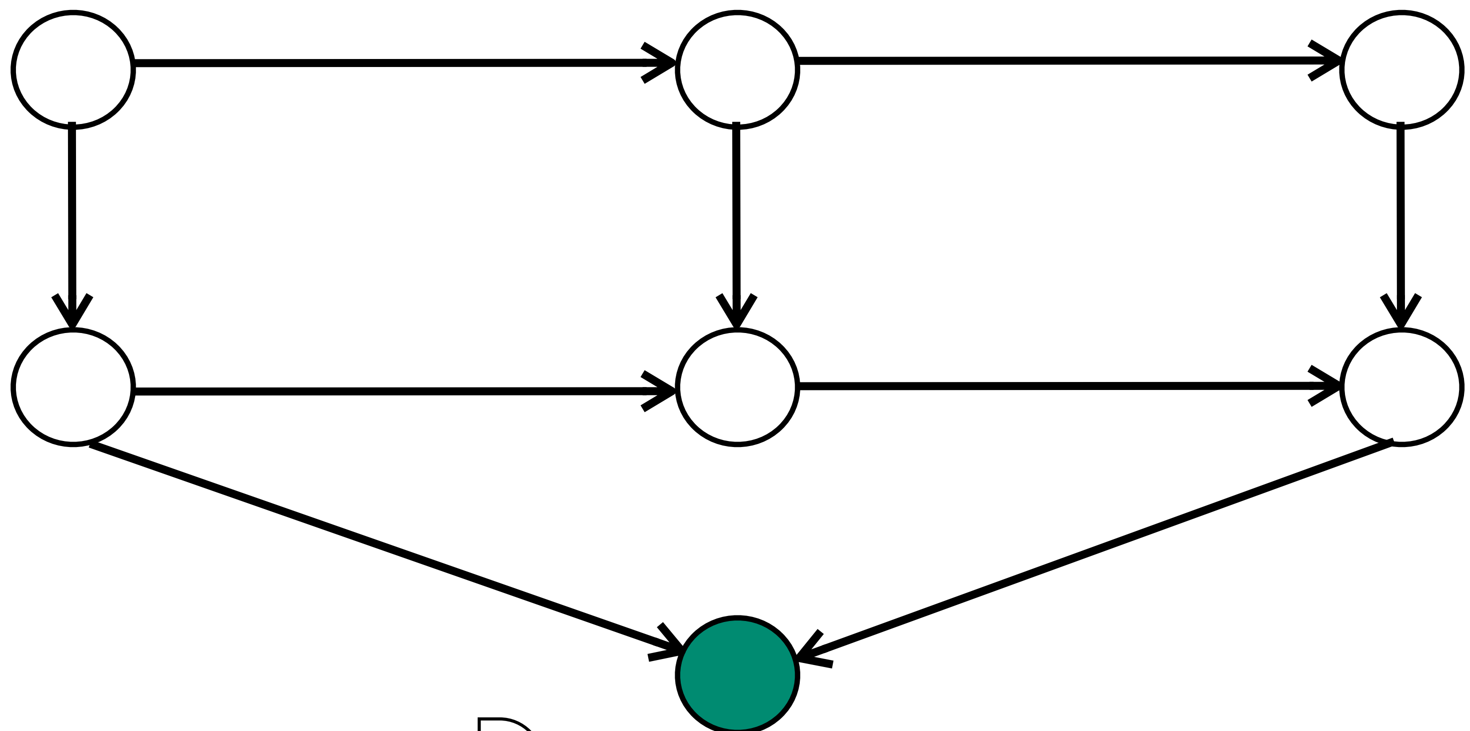
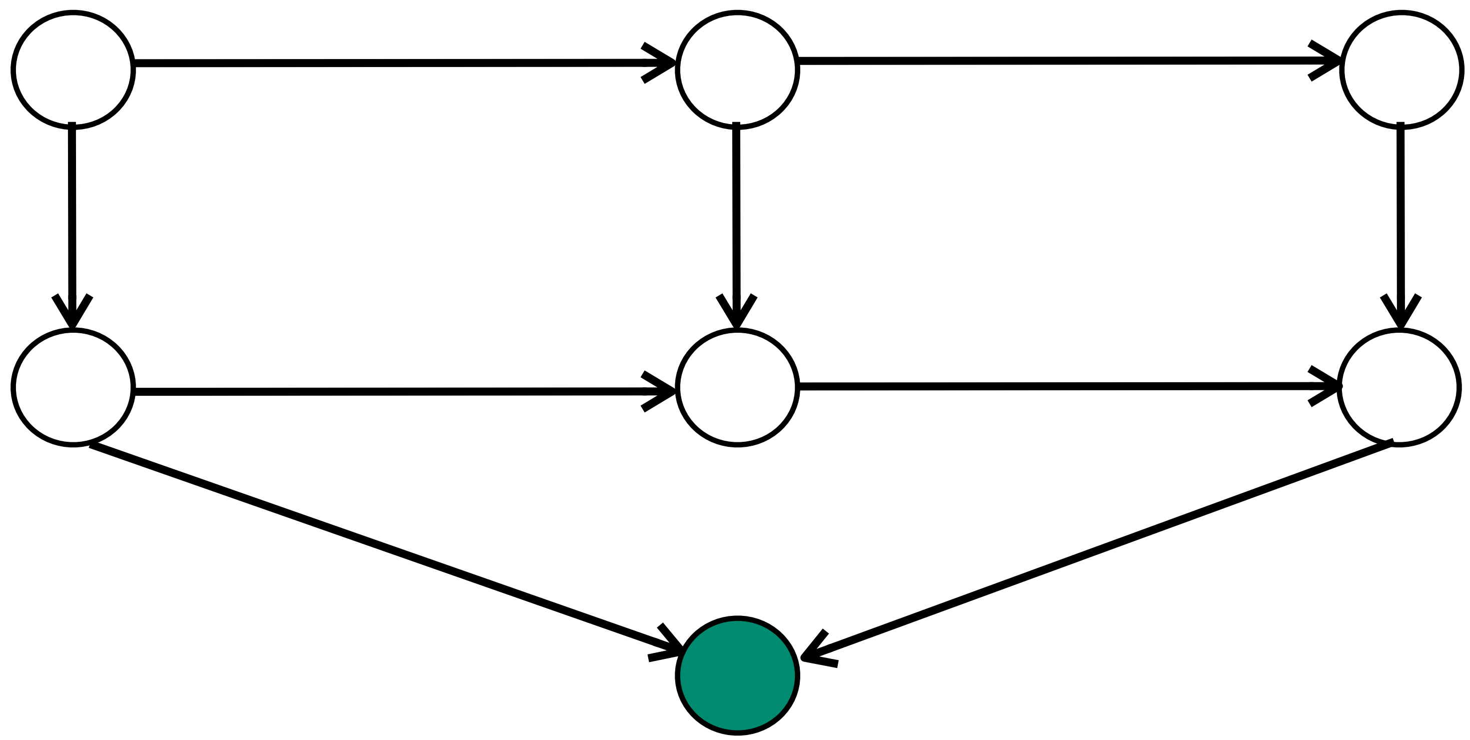


- Current paths to a destination do not use all links
- Extend routing tables to increase redundancy.

Restoring Connectivity

Reverse to Reconnect



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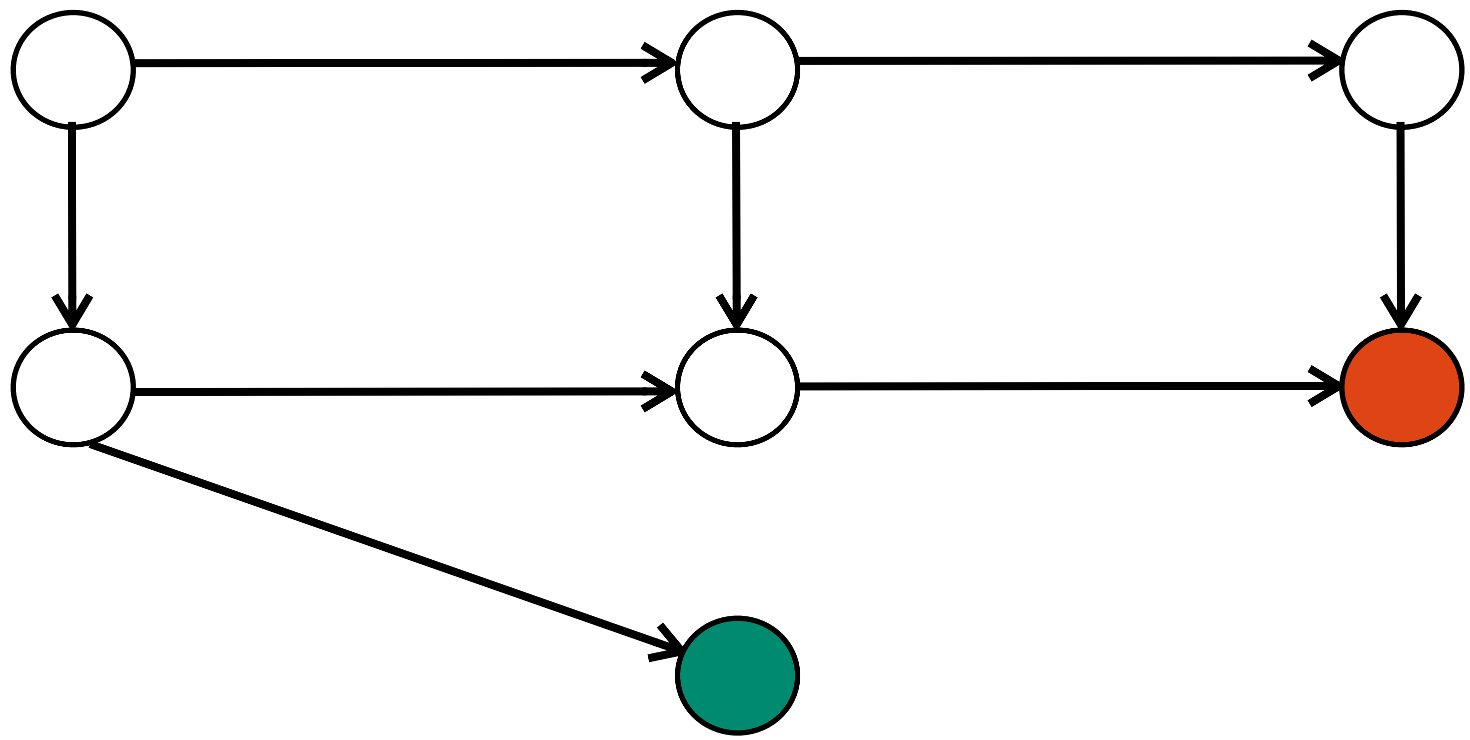

- Link failure can disconnect a DAG.

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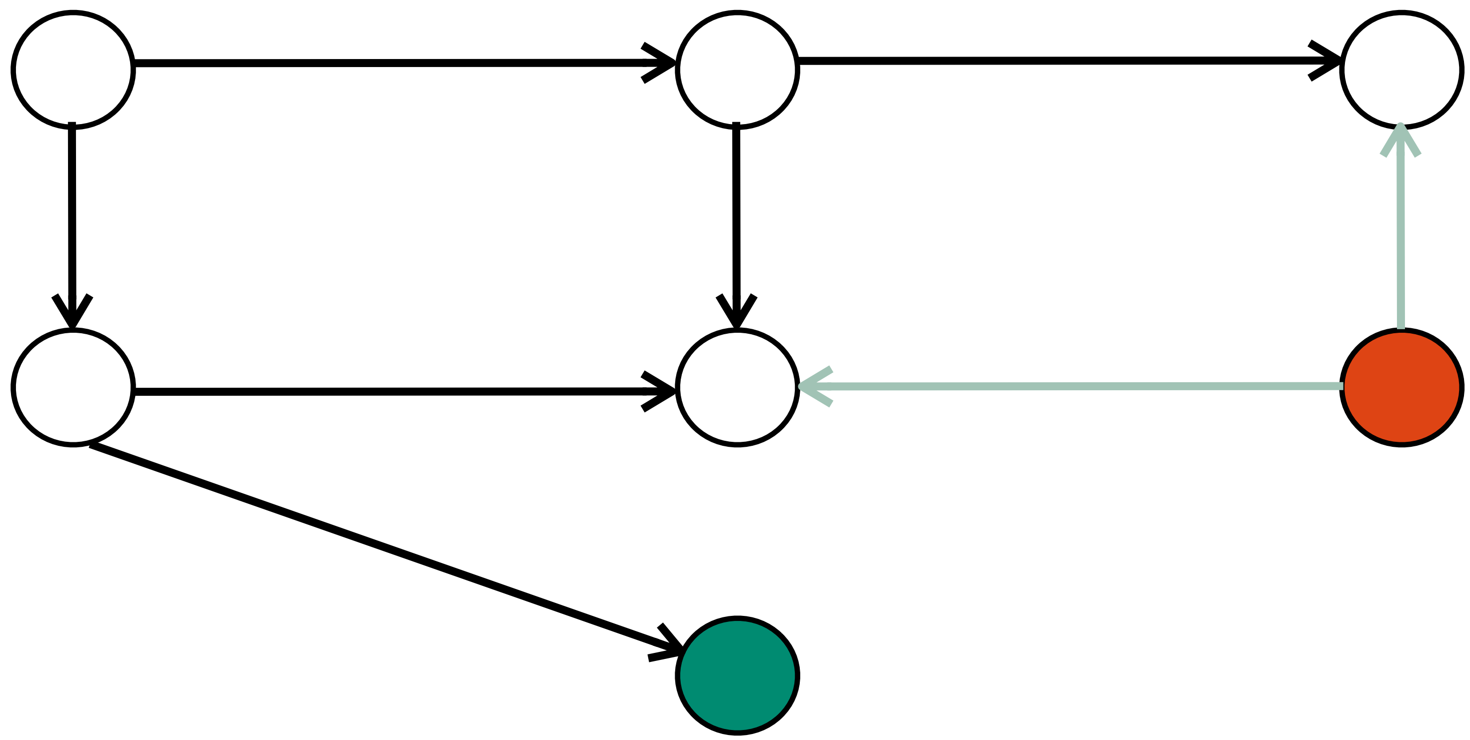

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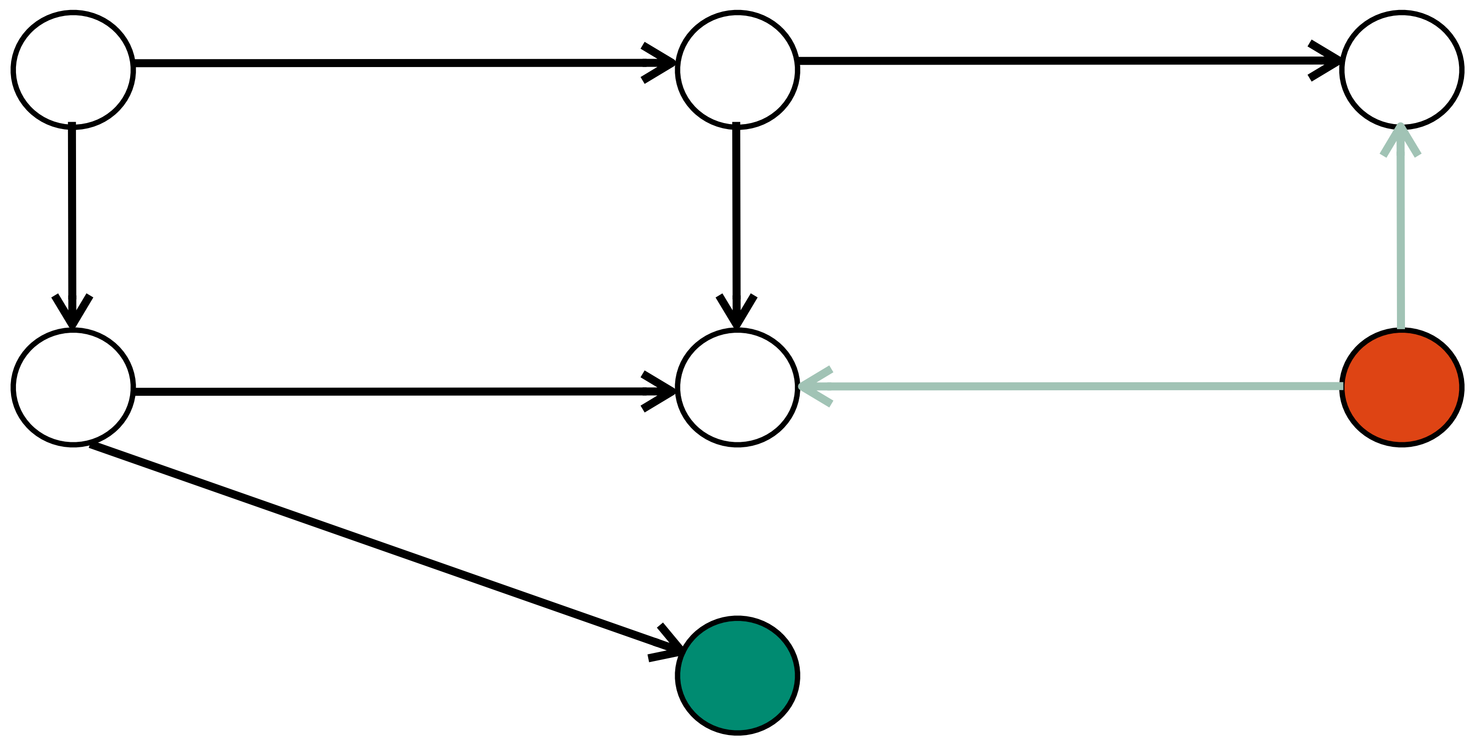

- Link failure can disconnect a DAG.
- Disconnected node reverses all links to point out.
- Finite set of reversals reconnect DAG.

Reversals in Data Plane

- Two challenges must be addressed

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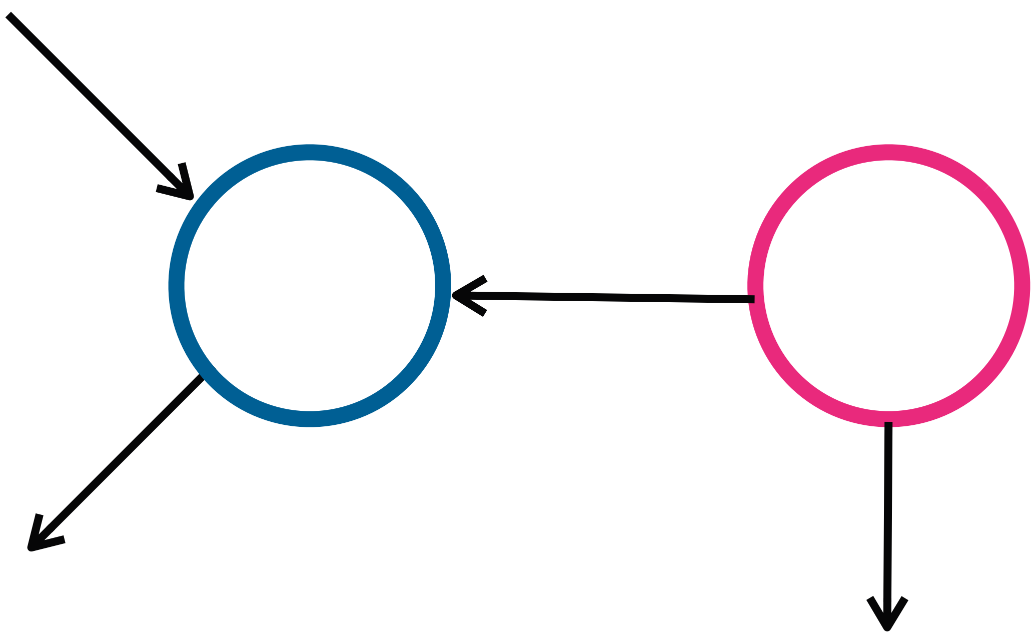
    - Notifications can be lost.
    - Notifications can be delayed.

Walk Through



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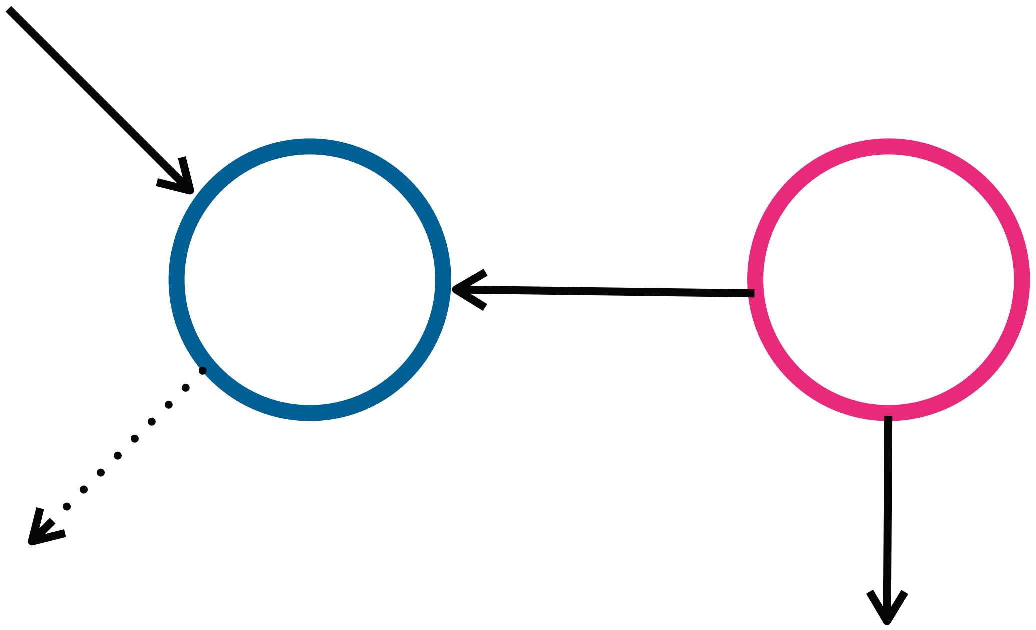
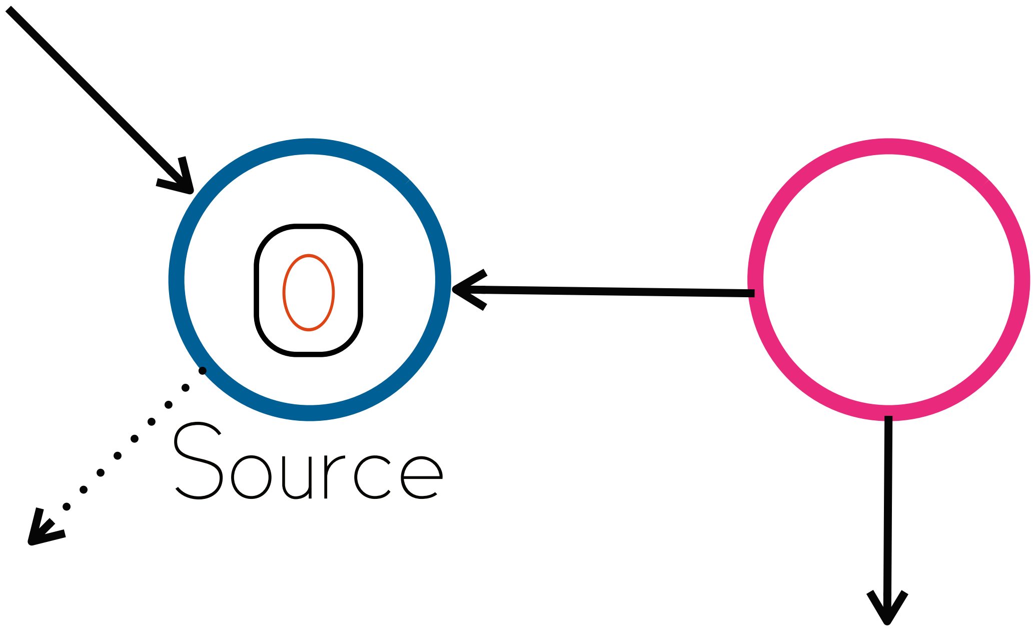
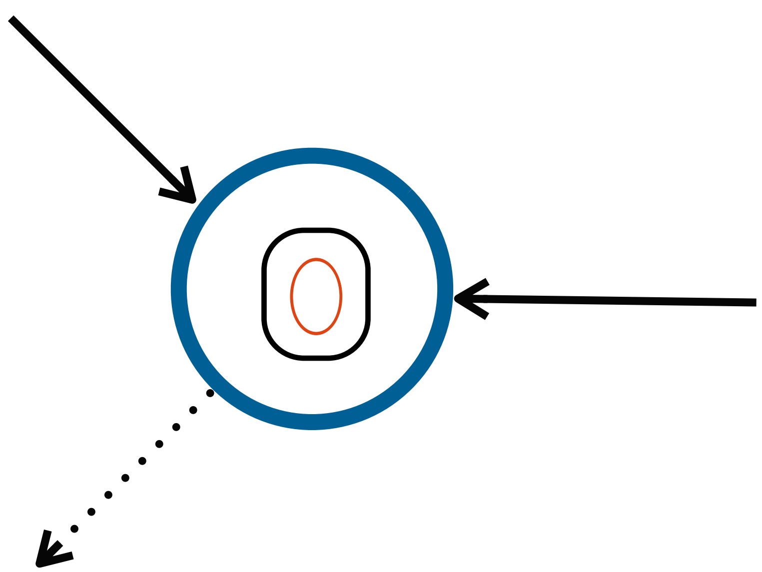


Walk Through



Create an OUT Link



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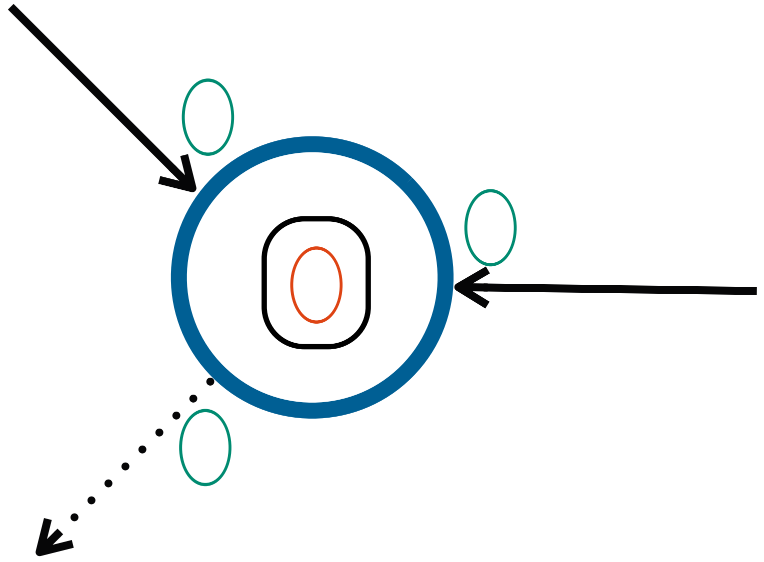
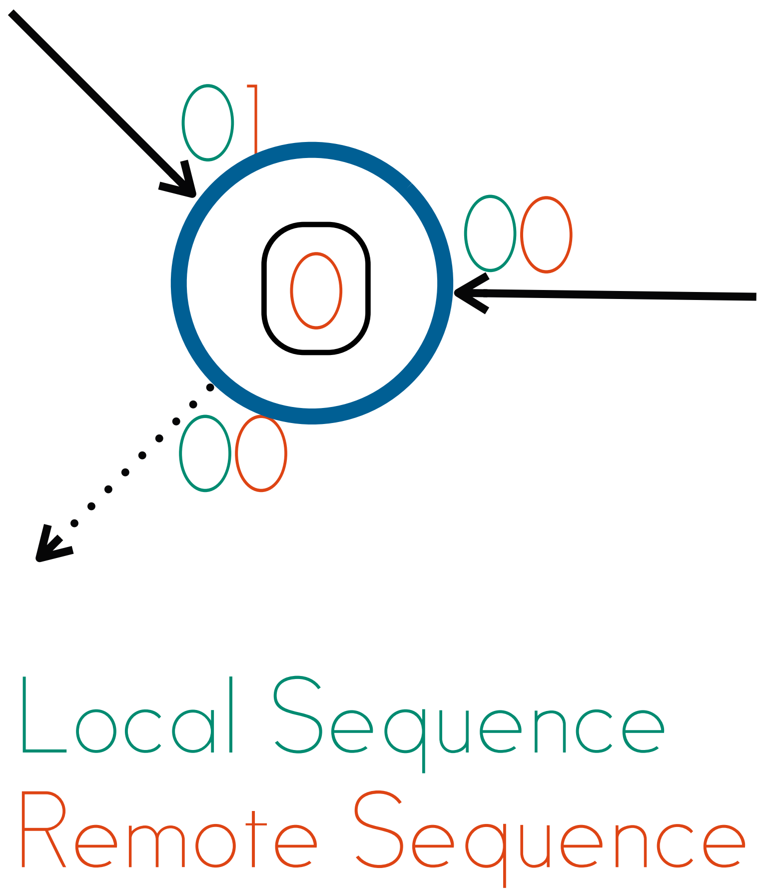


Local Sequence

Create an OUT Link



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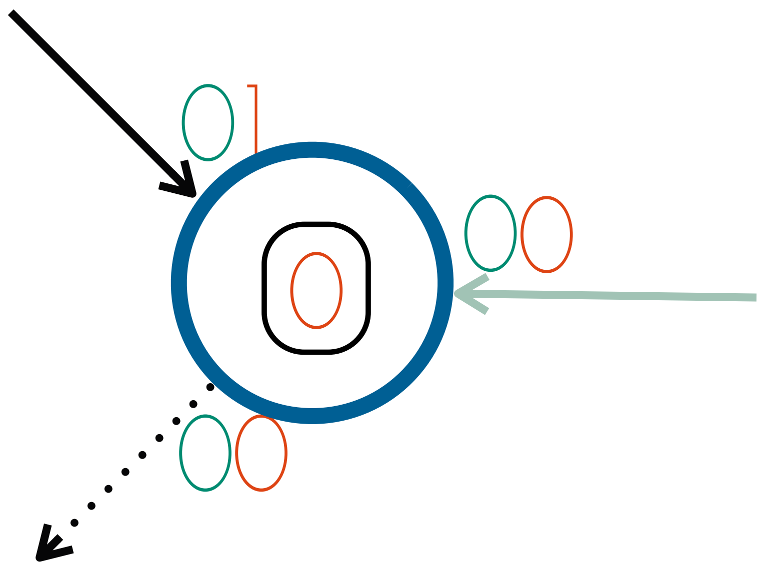

Local Sequence

Remote Sequence

Reversible

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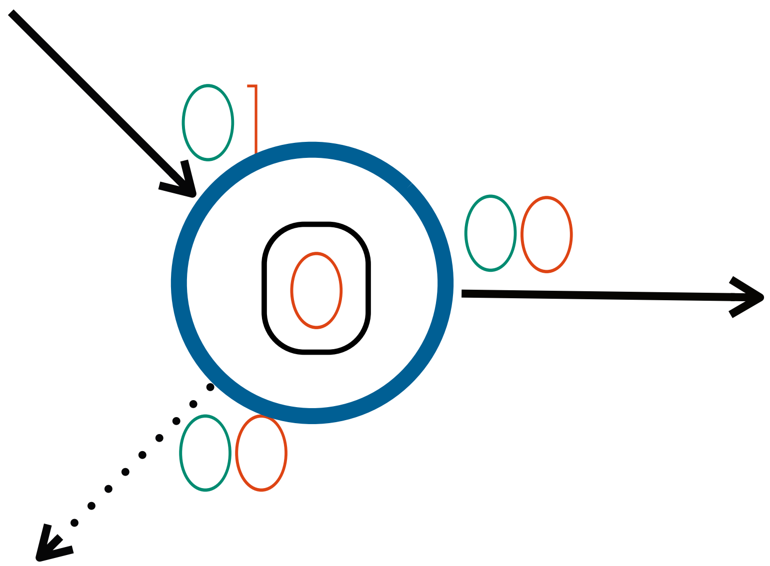
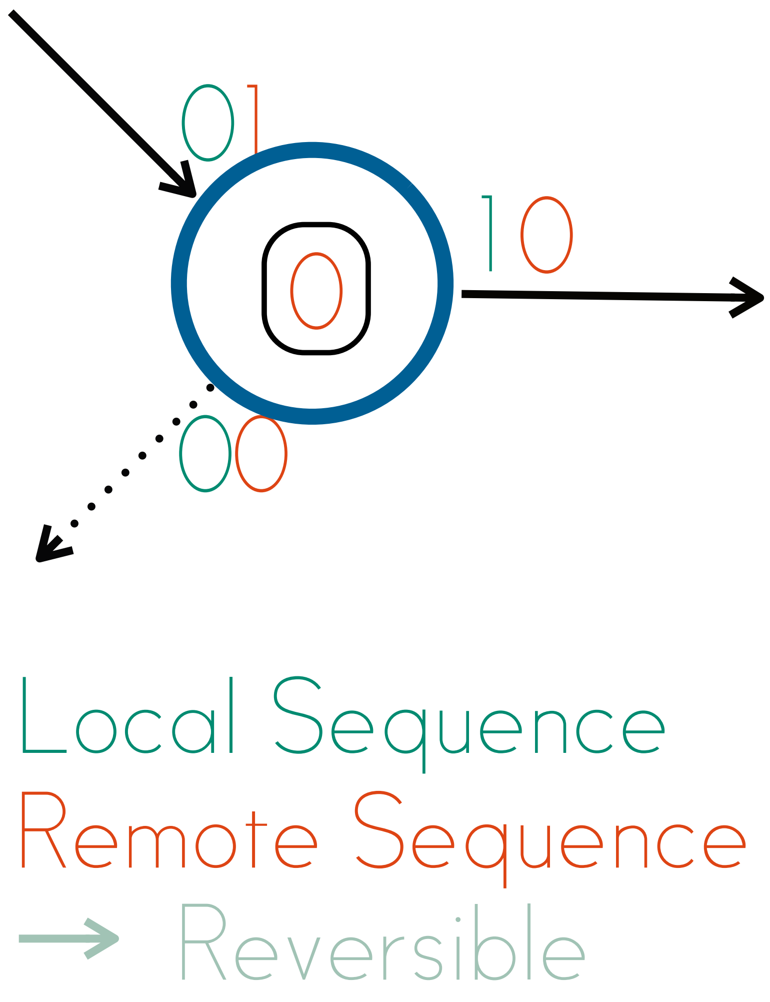


- Reverse link direction

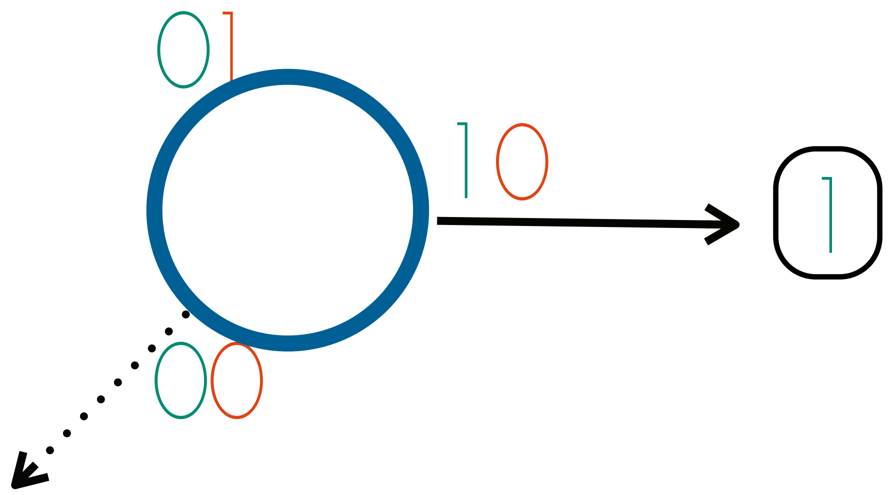
Local Sequence
Remote Sequence
Reversible

Create an OUT Link



- Reverse link direction
- Increment Local Sequence

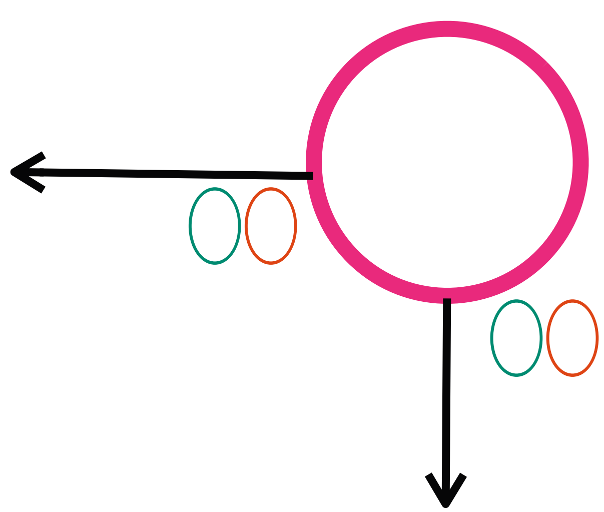
Create an OUT Link



- Reverse link direction
- Increment Local Sequence
- Forward packet

Local Sequence
Remote Sequence
Reversible

Dealing with Notifications



Local Sequence

Remote Sequence

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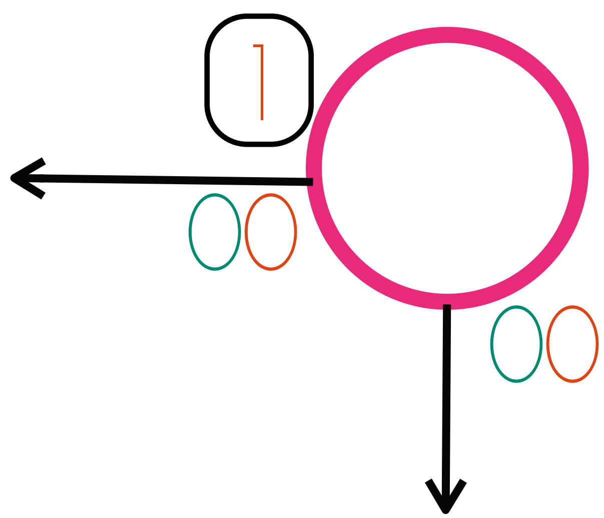

Local Sequence
Remote Sequence
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- Receive on link pointing OUT

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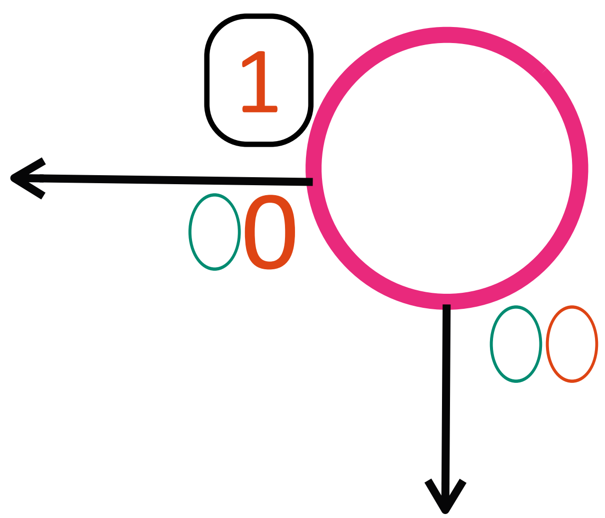

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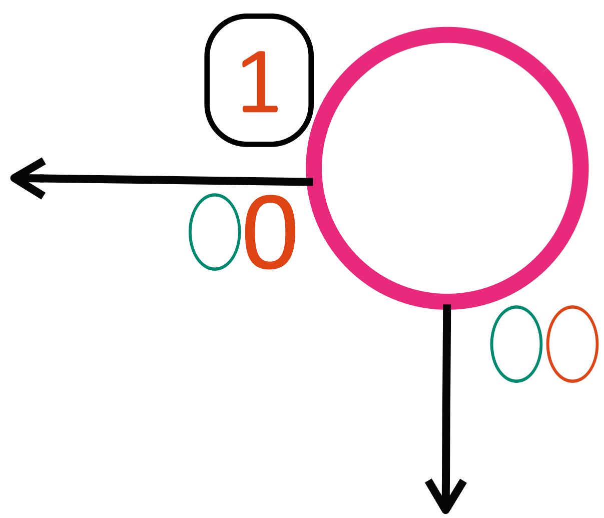

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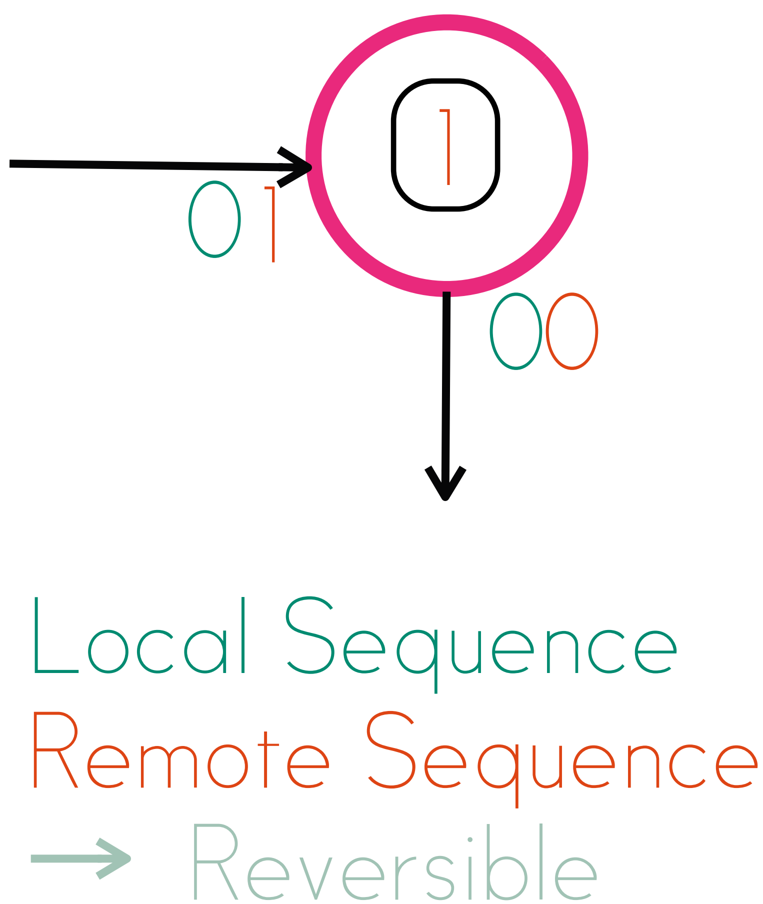

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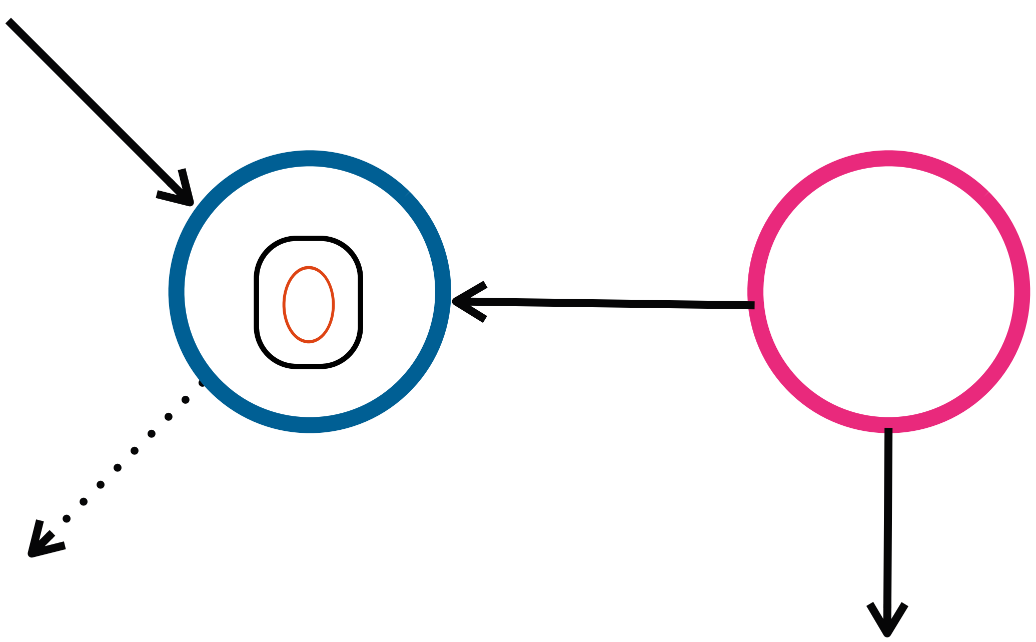
Zooming Out



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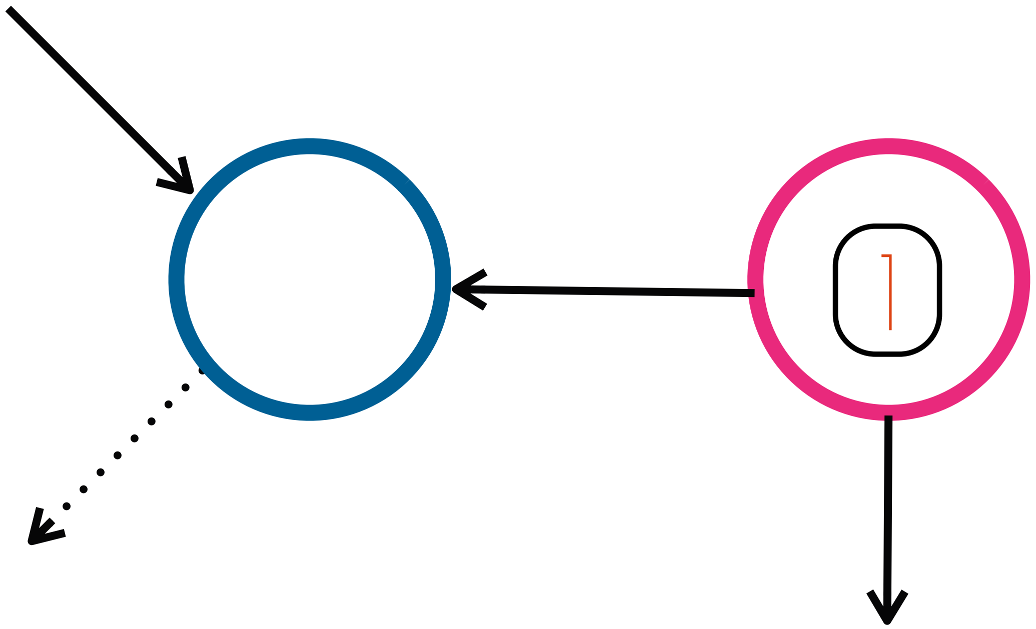

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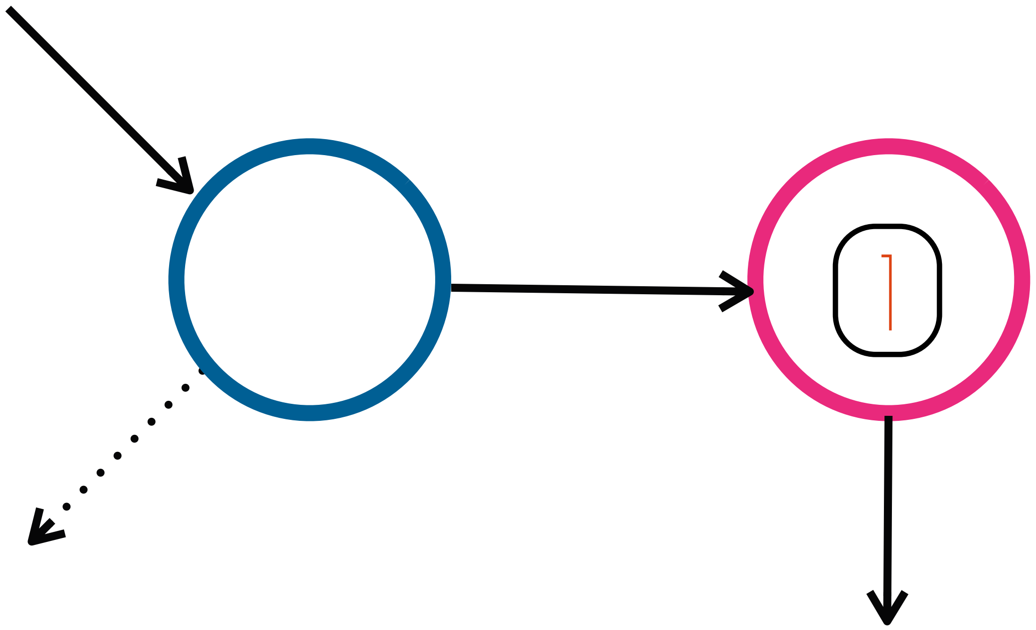
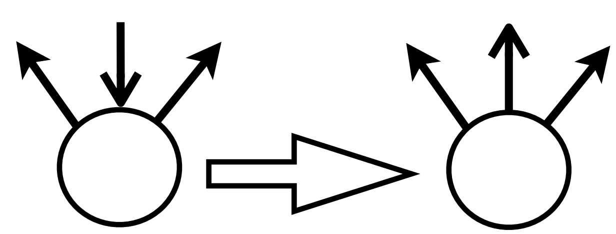


What about Optimality?



Safe Control Plane

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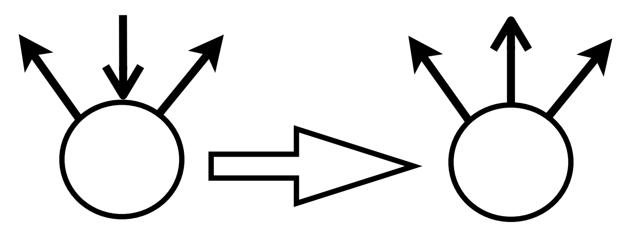

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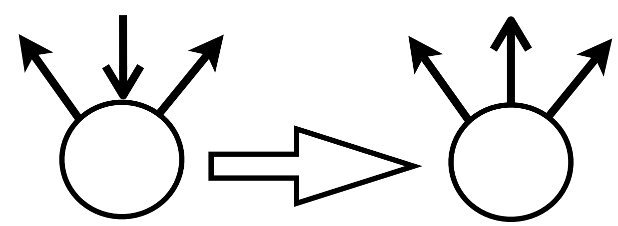

- Cannot interfere with data plane.
- Build a safe primitive
  - Set all edges of a node to point out
- Described in paper

Evaluation

Evaluation Overview

- Test on WAN and datacenter topologies
  - Stretch, Throughput, Latency
- Effect of FIB update delays
  - On latency and throughput
- End-to-end benefits of using DDC.

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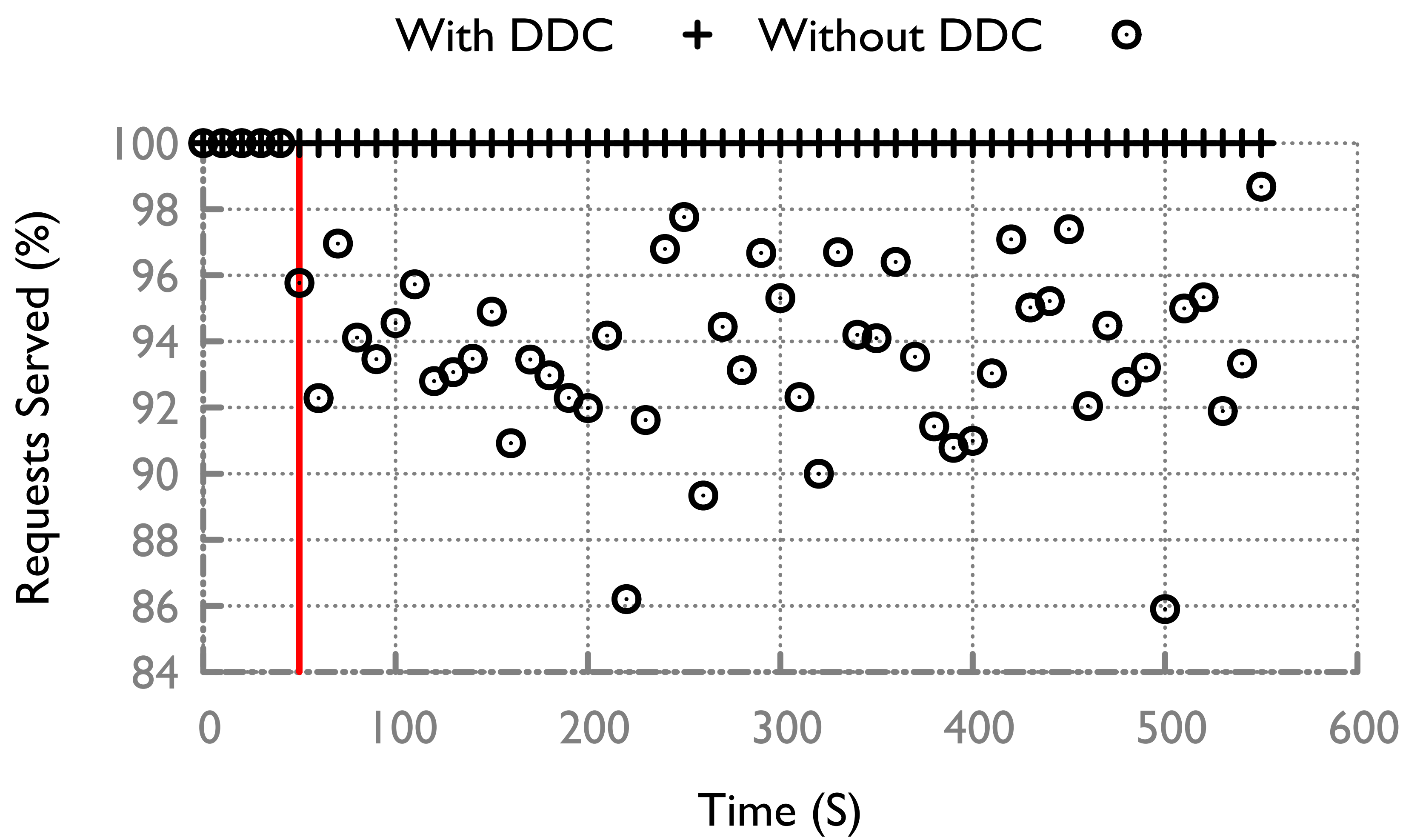
End-to-End Test

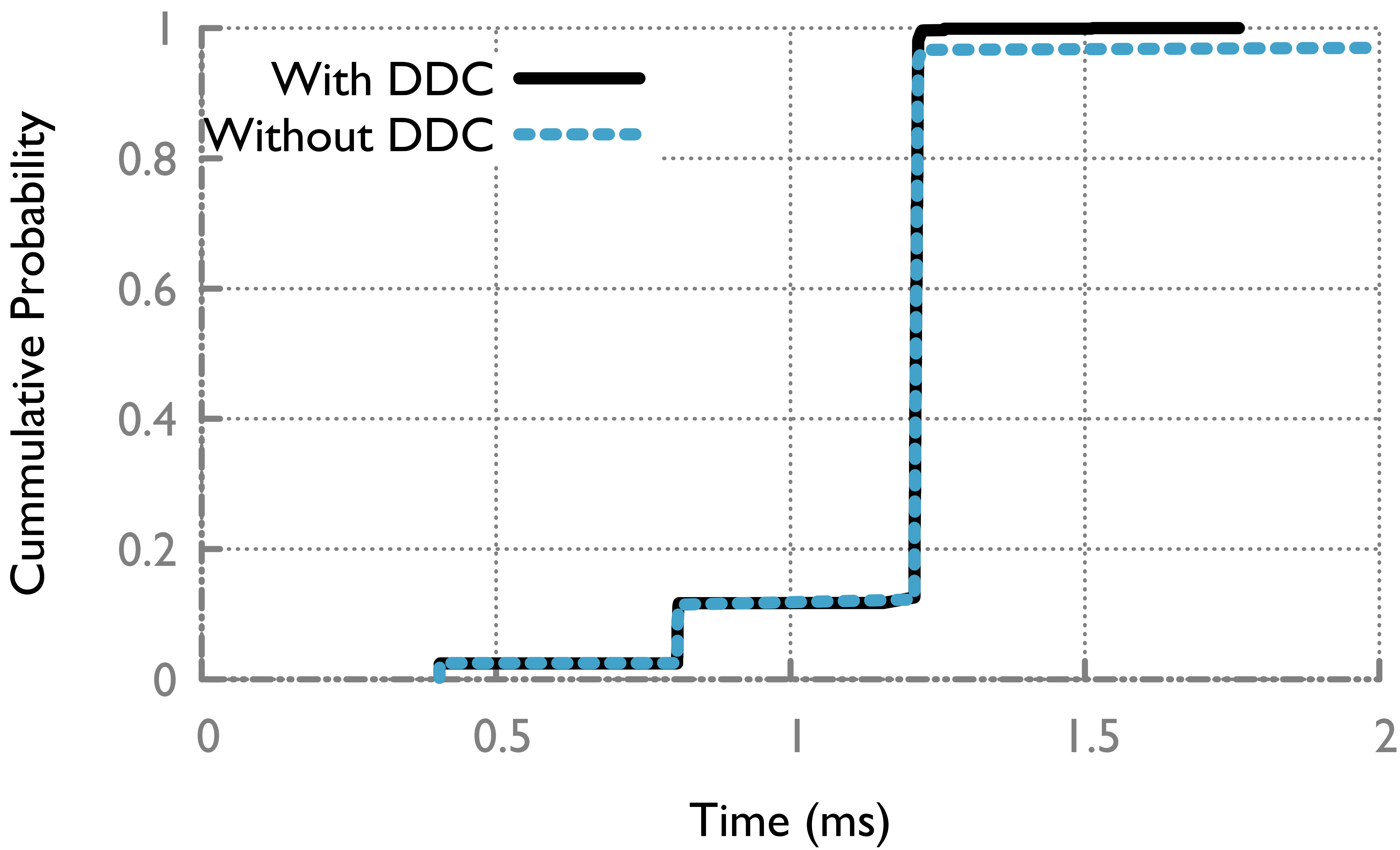
- 8 Pod FatTree
- Partition aggregate workload
- 5 link failures
- Simulated effect for 550 seconds

Requests Fulfilled



- Bucketed 10 second intervals.
- Percentage requests satisfied.

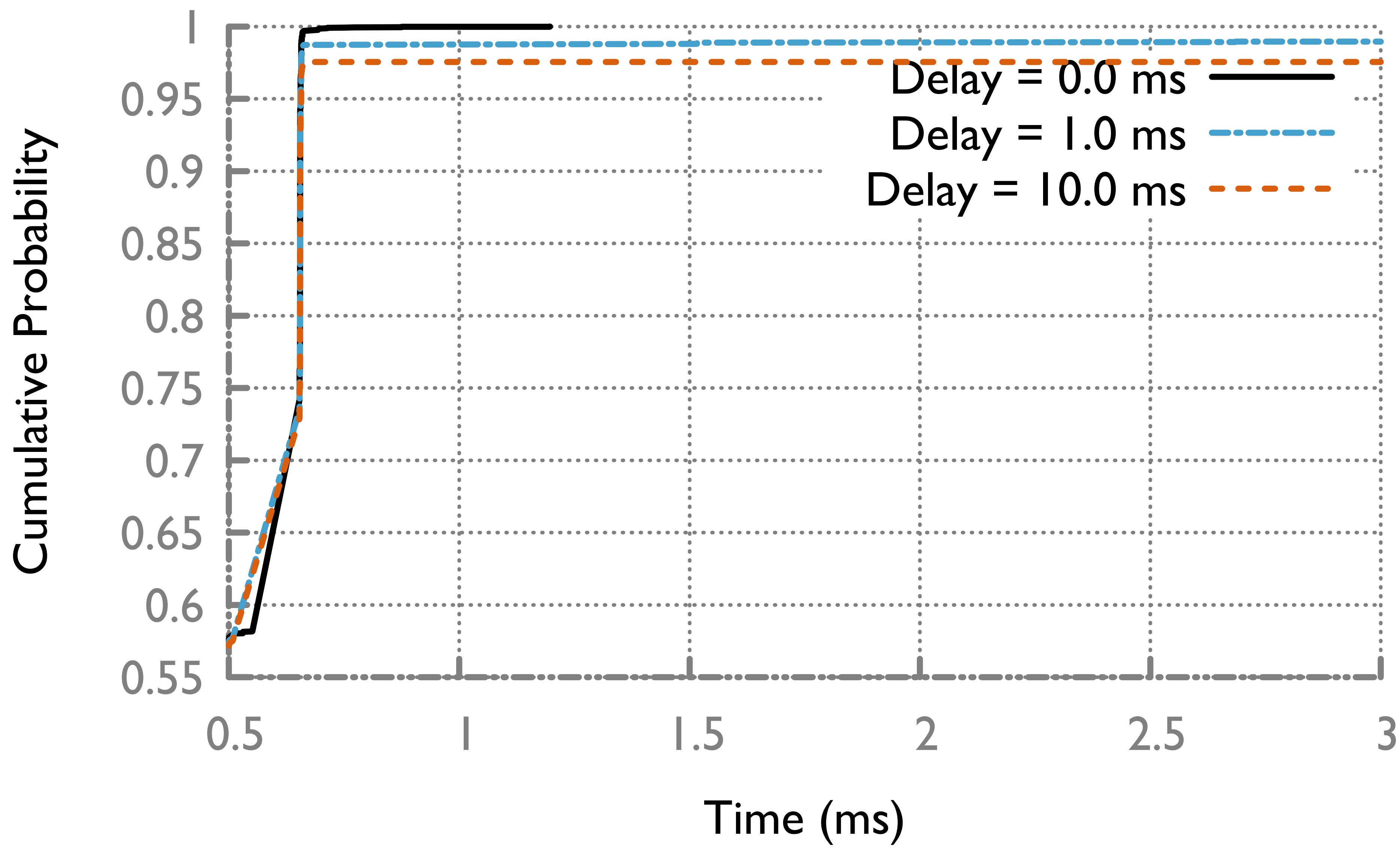
Request Latency



FIB Update Delay

- What is the impact of delayed FIB changes
  - On packet latency?
  - Three link failure: all traffic in test affected.
  - Focus on behavior before convergence.

FIB Update Delay



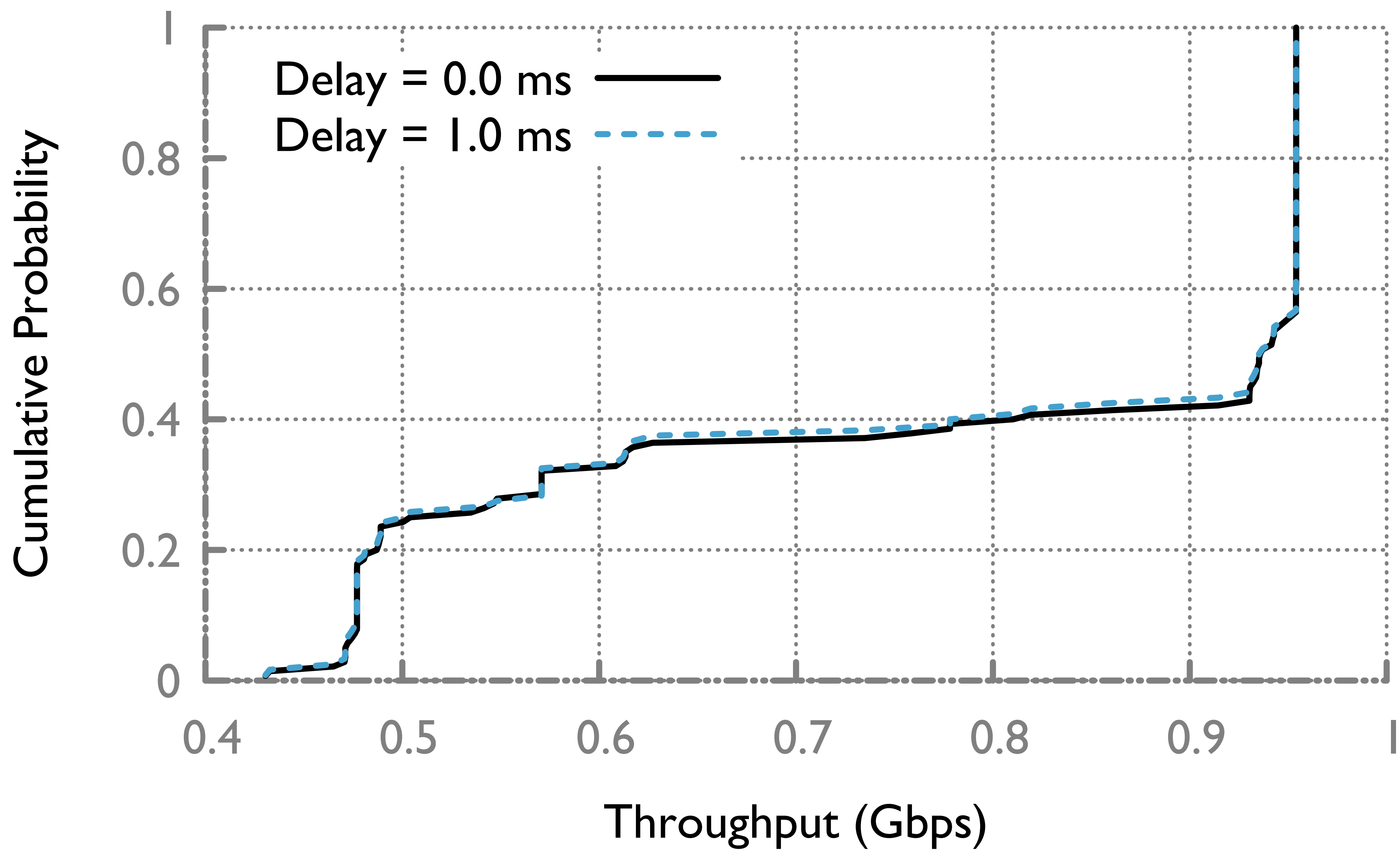
Overall ~99% of packets in under 3 ms.

No packets get dropped, just long tail.

FIB Update Delay

- What is the impact of delayed FIB changes
  - On TCP throughput?
  - Use a WAN topology (AS 2914)
  - 1 Gbps links
  - 5 link failures

FIB Update Delay



In the Same Vein…

- FCP (SIGCOMM '07)
  - Unbounded bits in header
  - Extensive FIB changes on failure packet
- Packet Re-Cycling (HotNets '10)
  - First solve an NP-Complete problem.
  - log(network diameter) bits in header.
  - DDC is simpler.

Potential Impact

- ASICs implement DDC
  - Connectivity guaranteed by the data plane.
  - Control Plane focuses on optimality/functionality.

Questions?