Algorithms for Traffic Control Challenges in Softwarized Networks

Mahmoud Parham

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Thesis in a Nutshell

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Adaptable and Data-Driven Softwarized Networks: Review, Opportunities, and Challenges. Kellerer, W.; Kalmbach, P.; Blenk, A.; Basta, A.; Reisslein, M.; and Schmid, S. *Proceedings of the IEEE*, 107(4): 711–731. April 2019.

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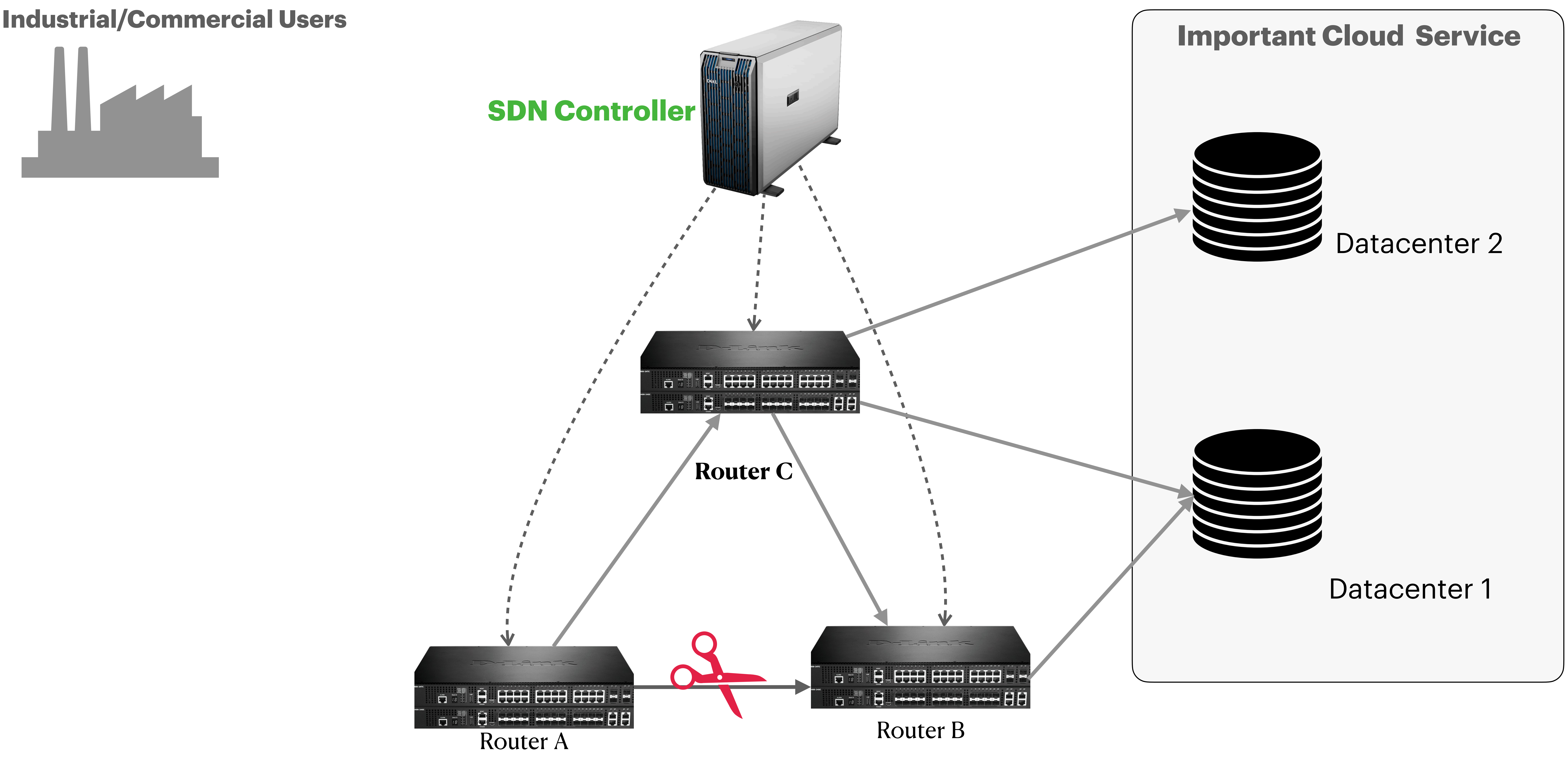

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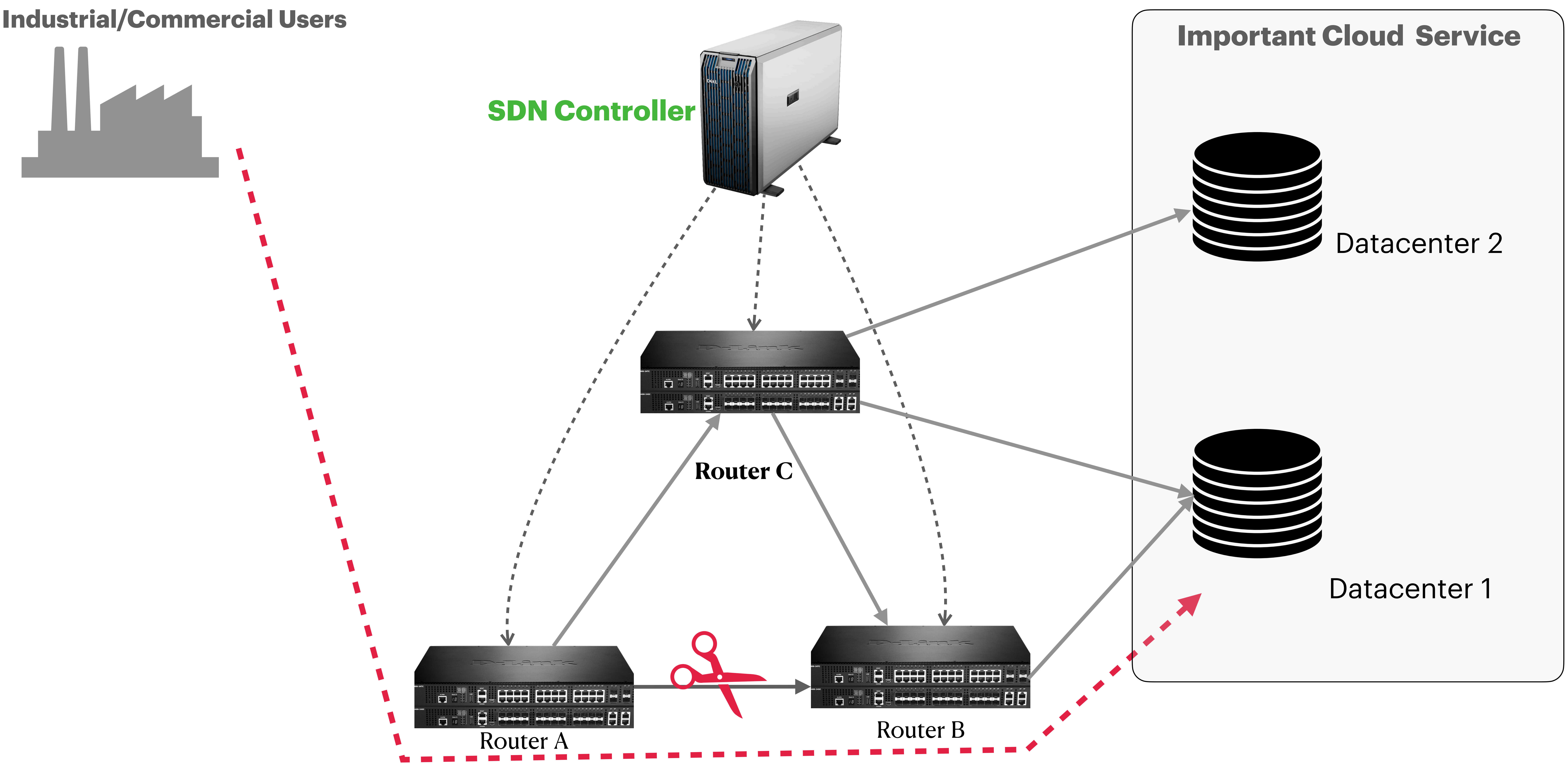

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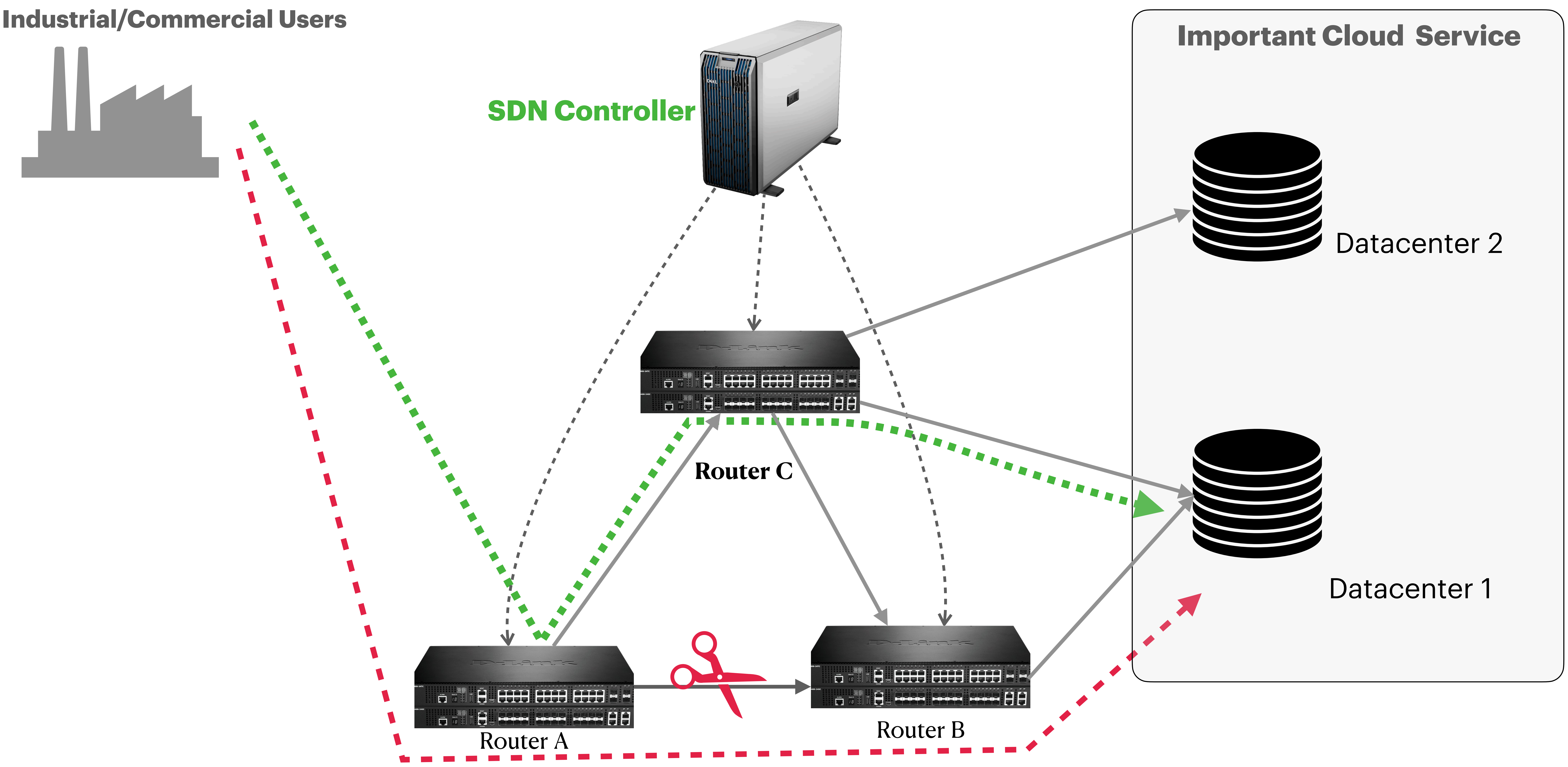

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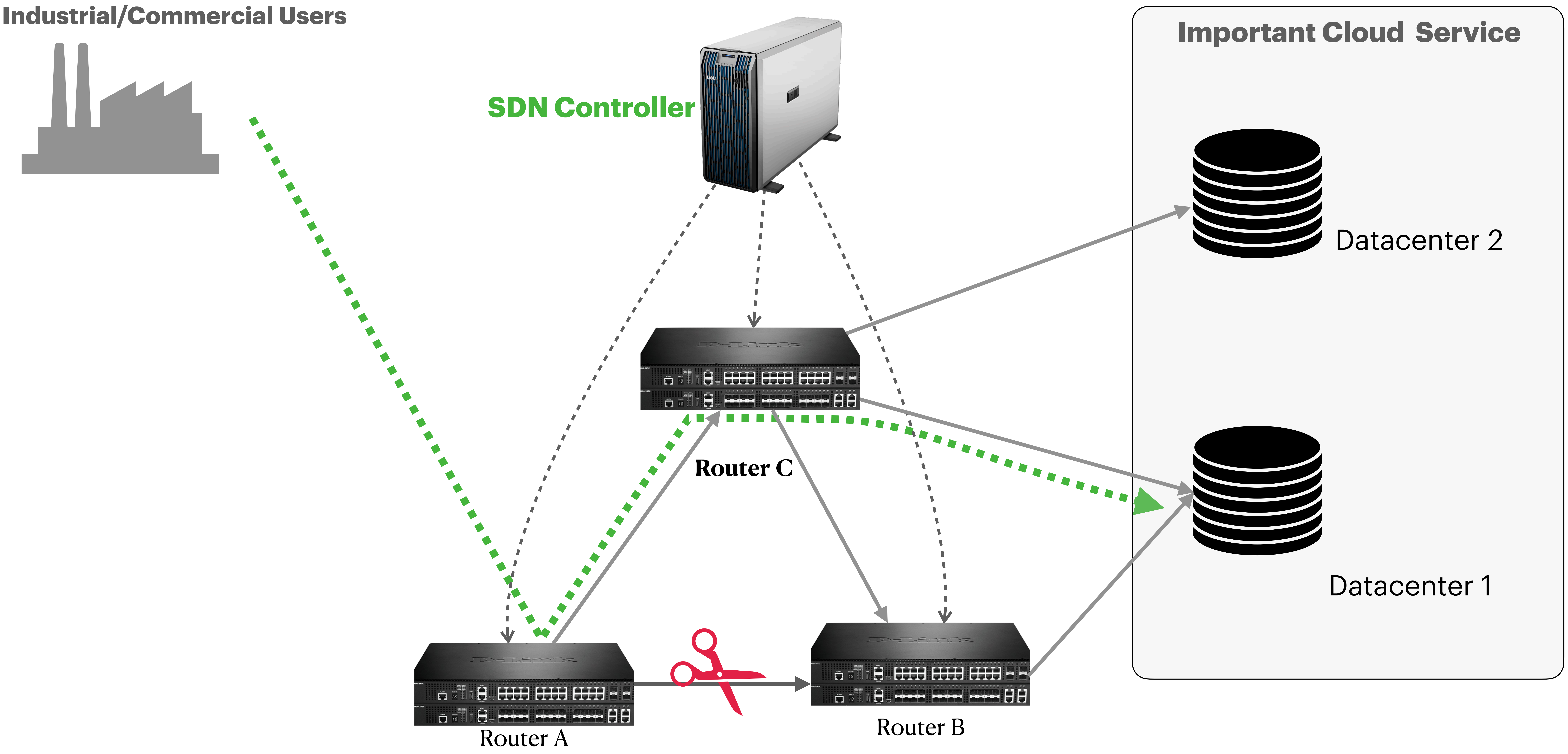

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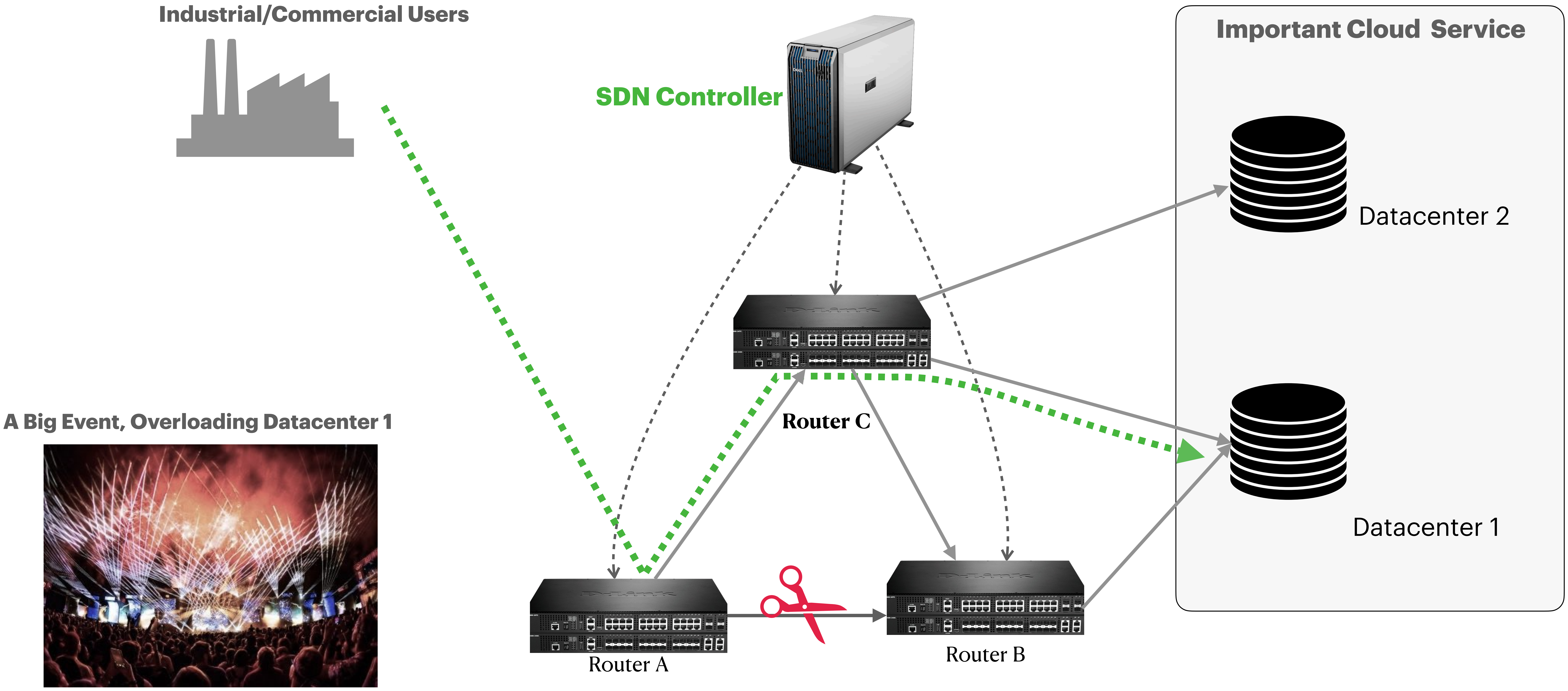

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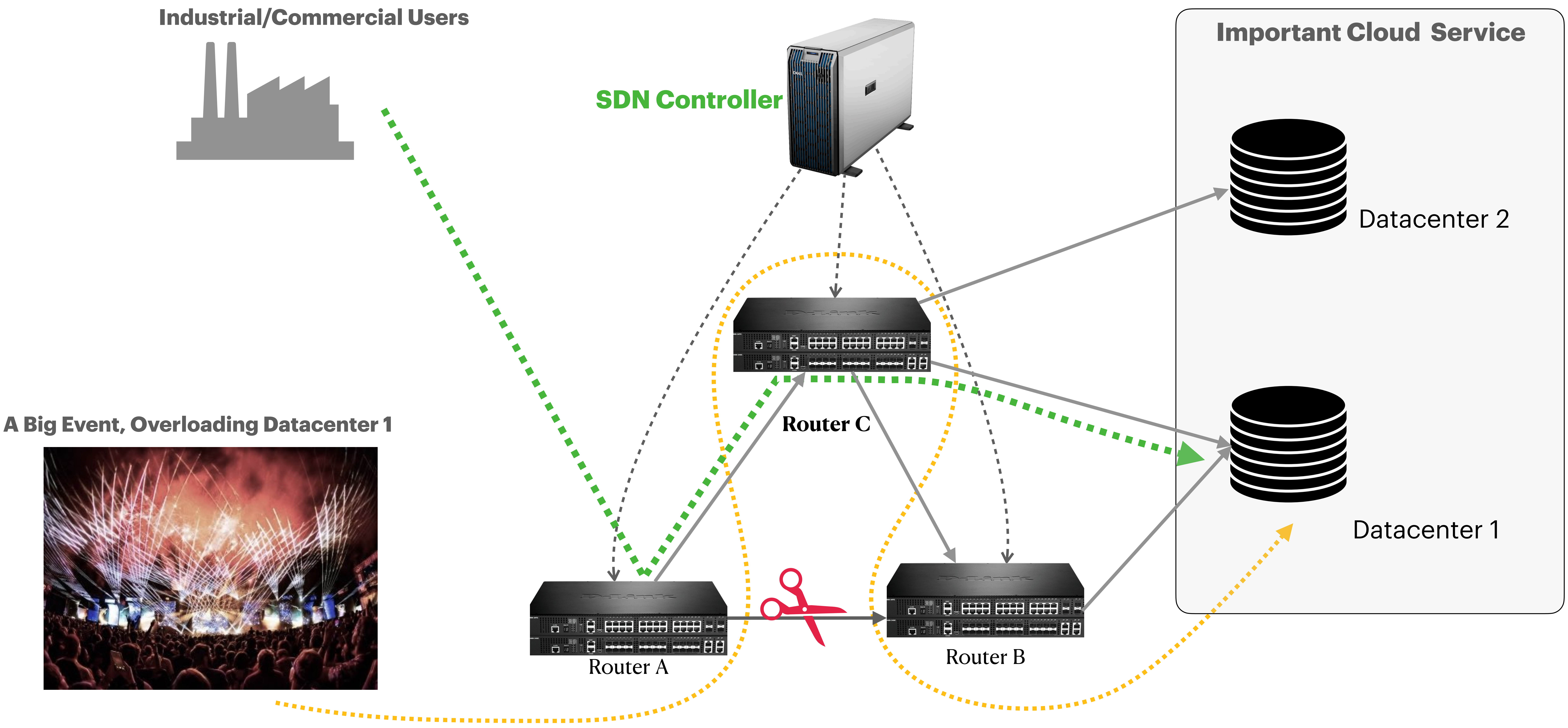

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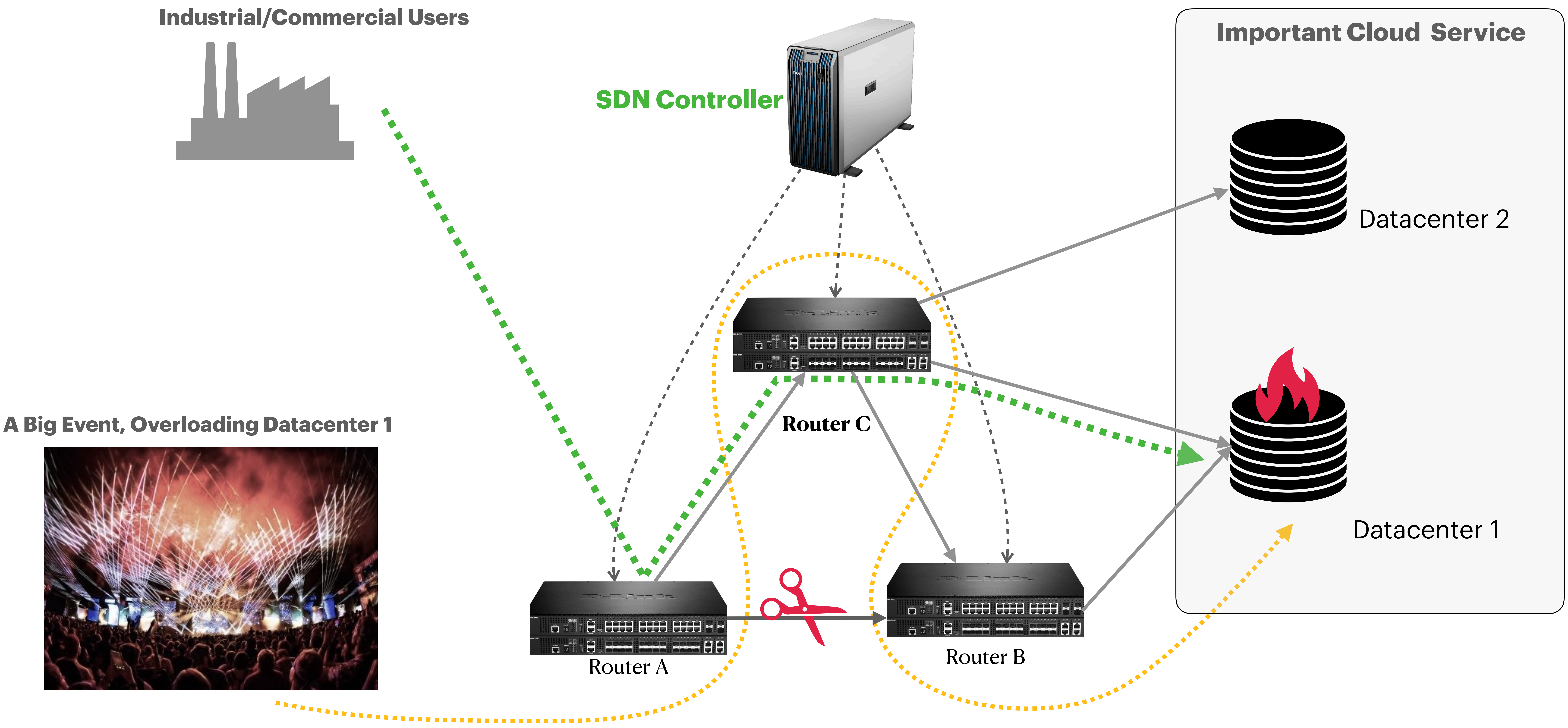

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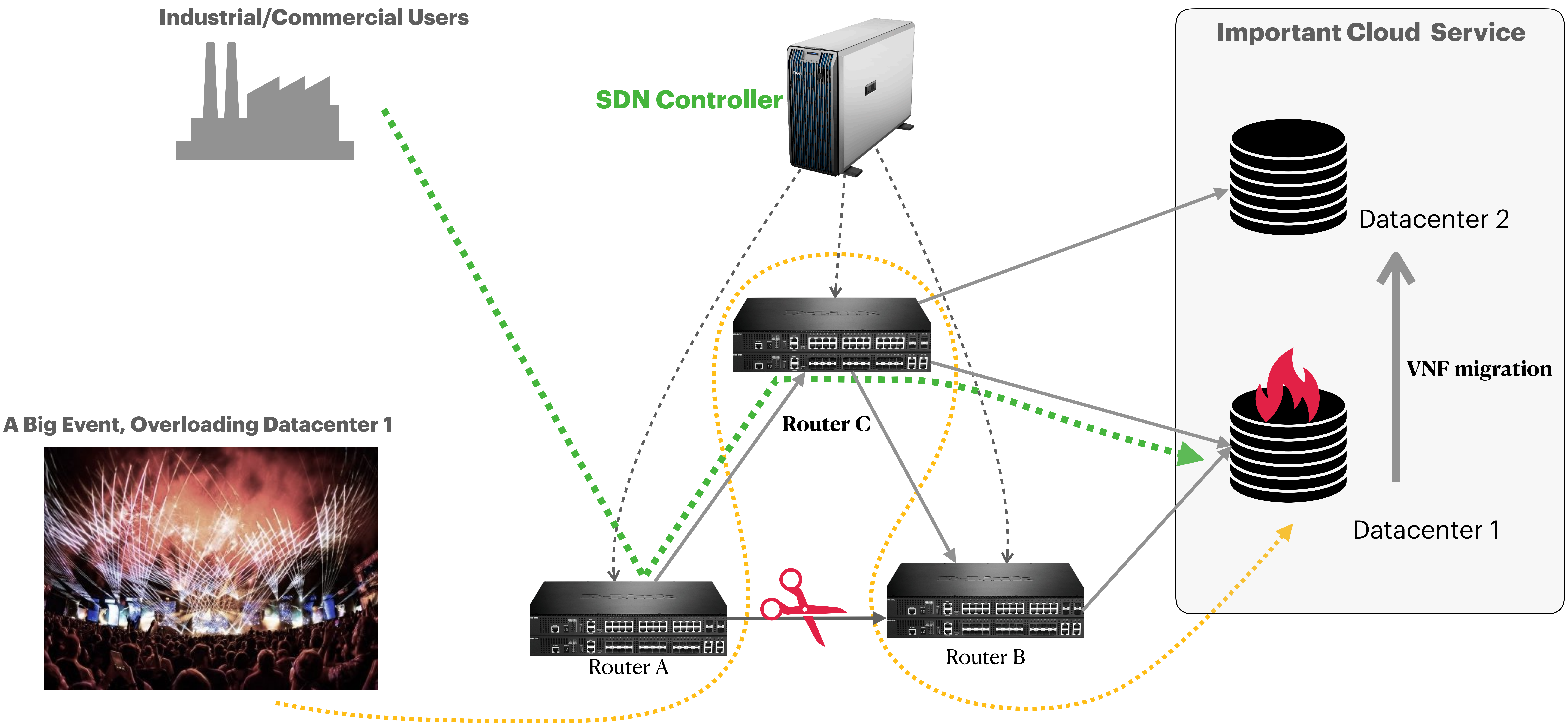

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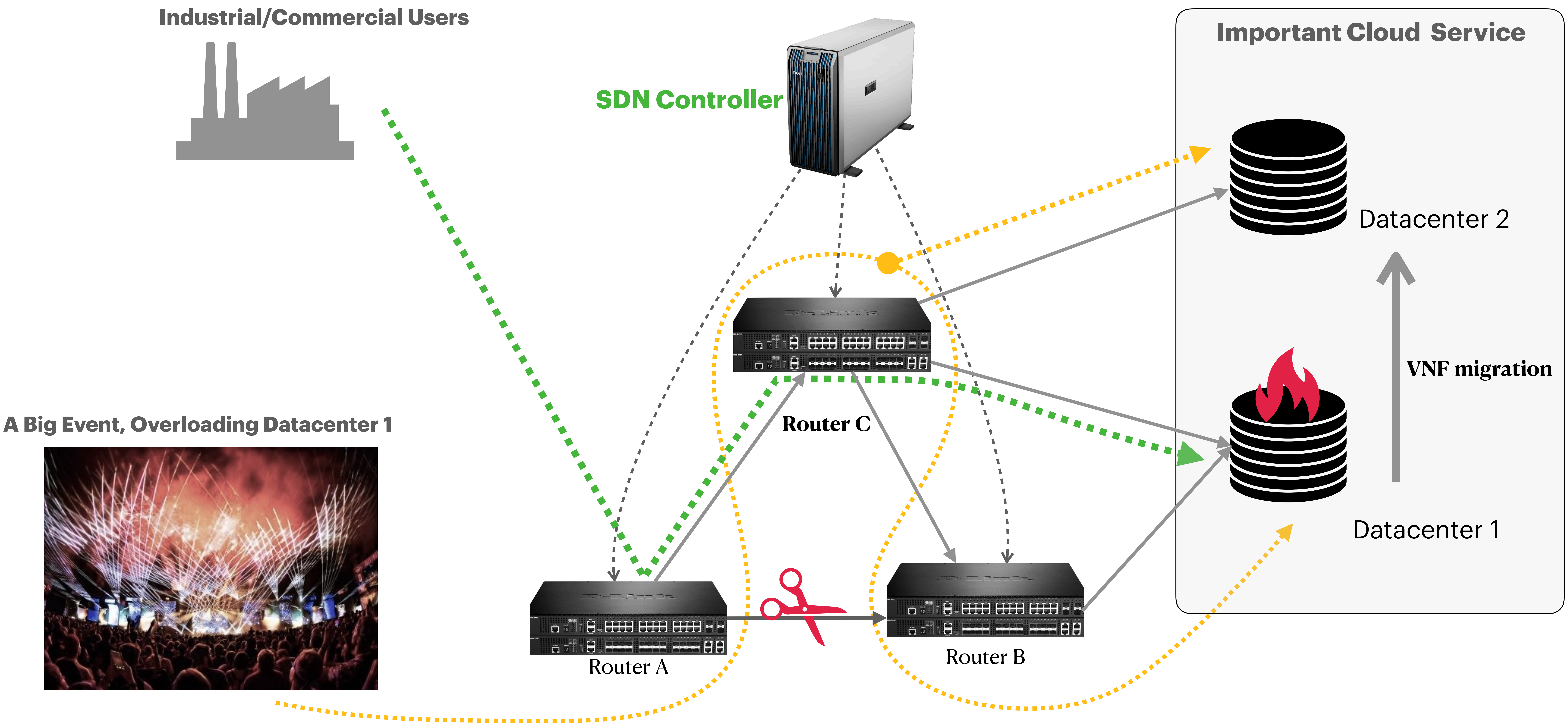

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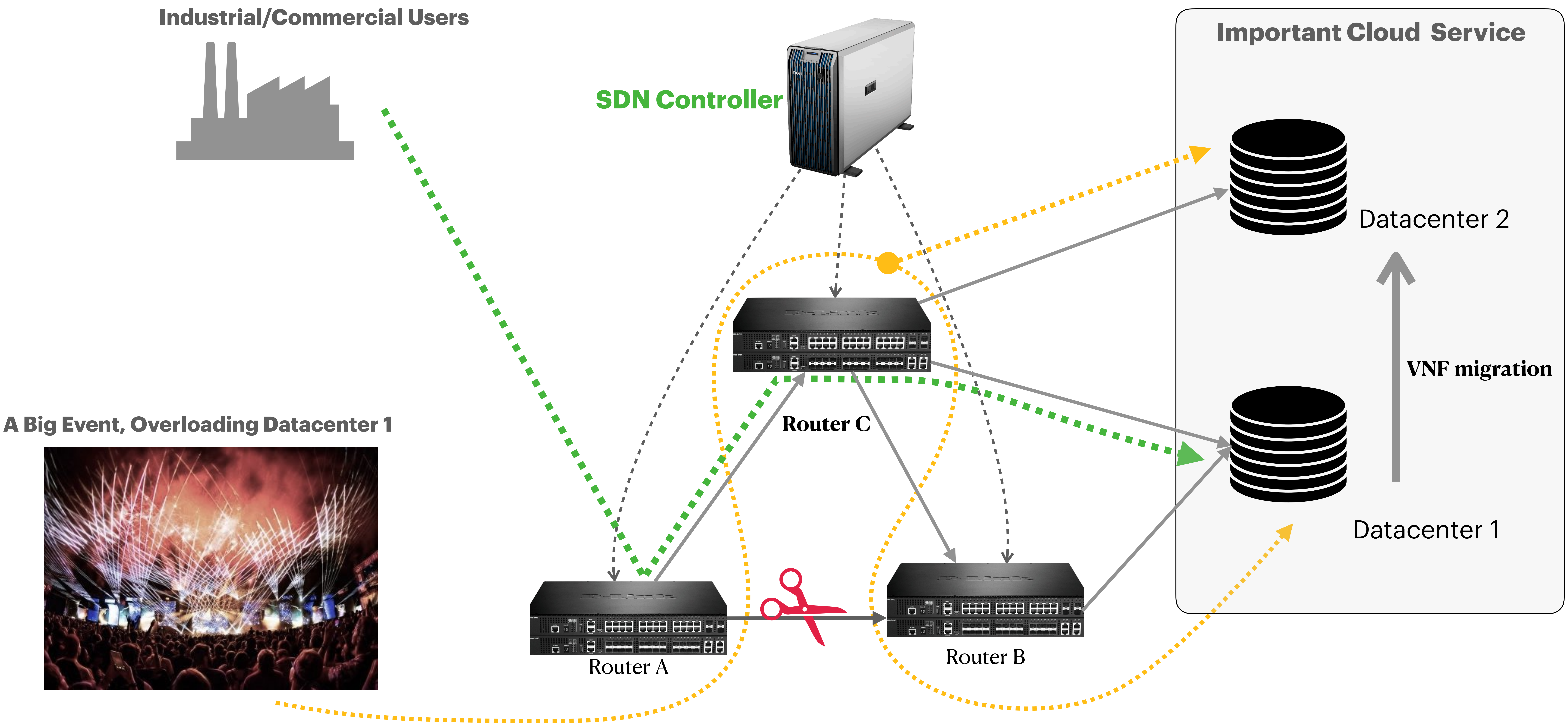
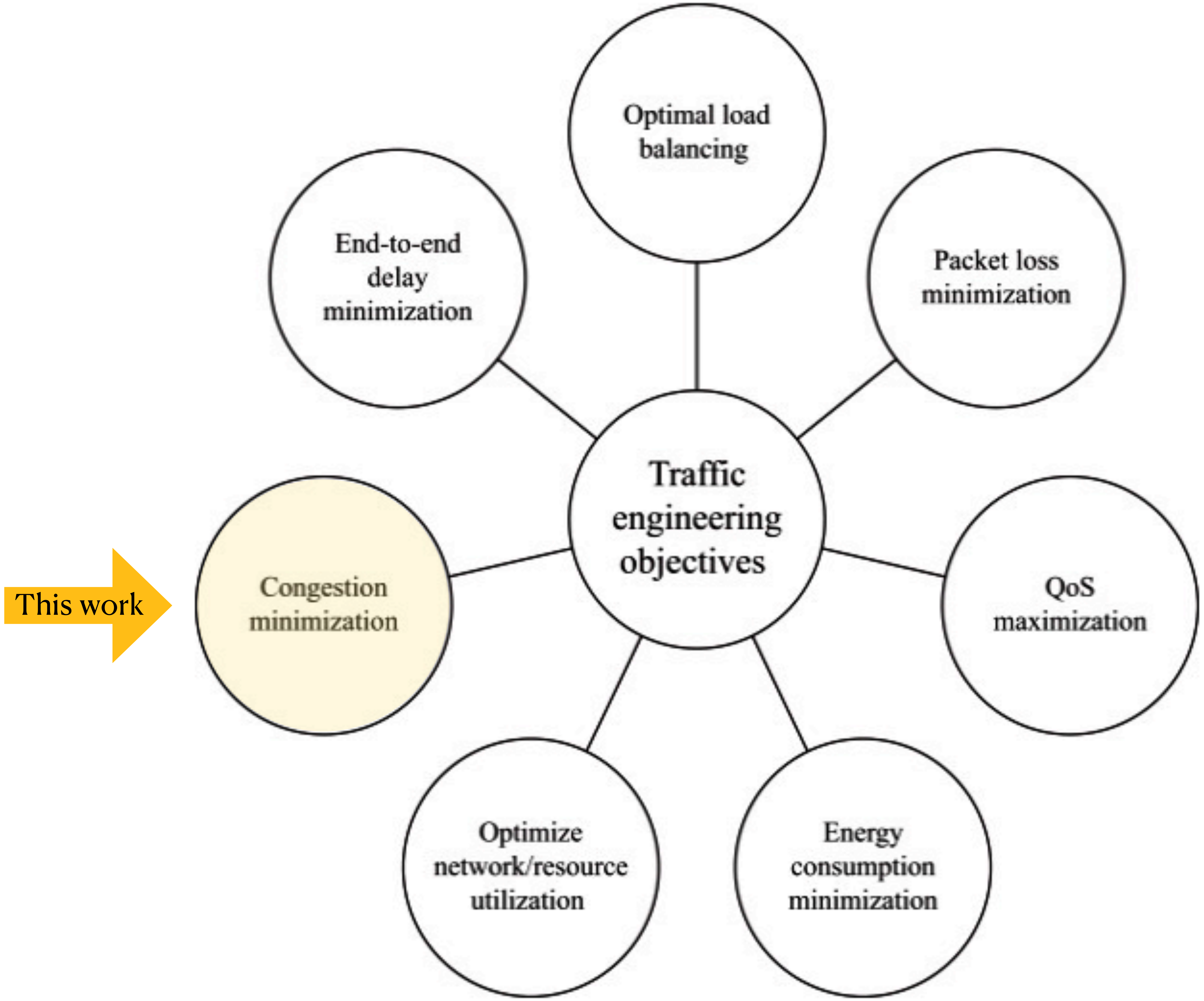


- **Traffic Engineering**
- Fast Traffic Rerouting
- Traffic Partitioning

Traffic Engineering (TE)



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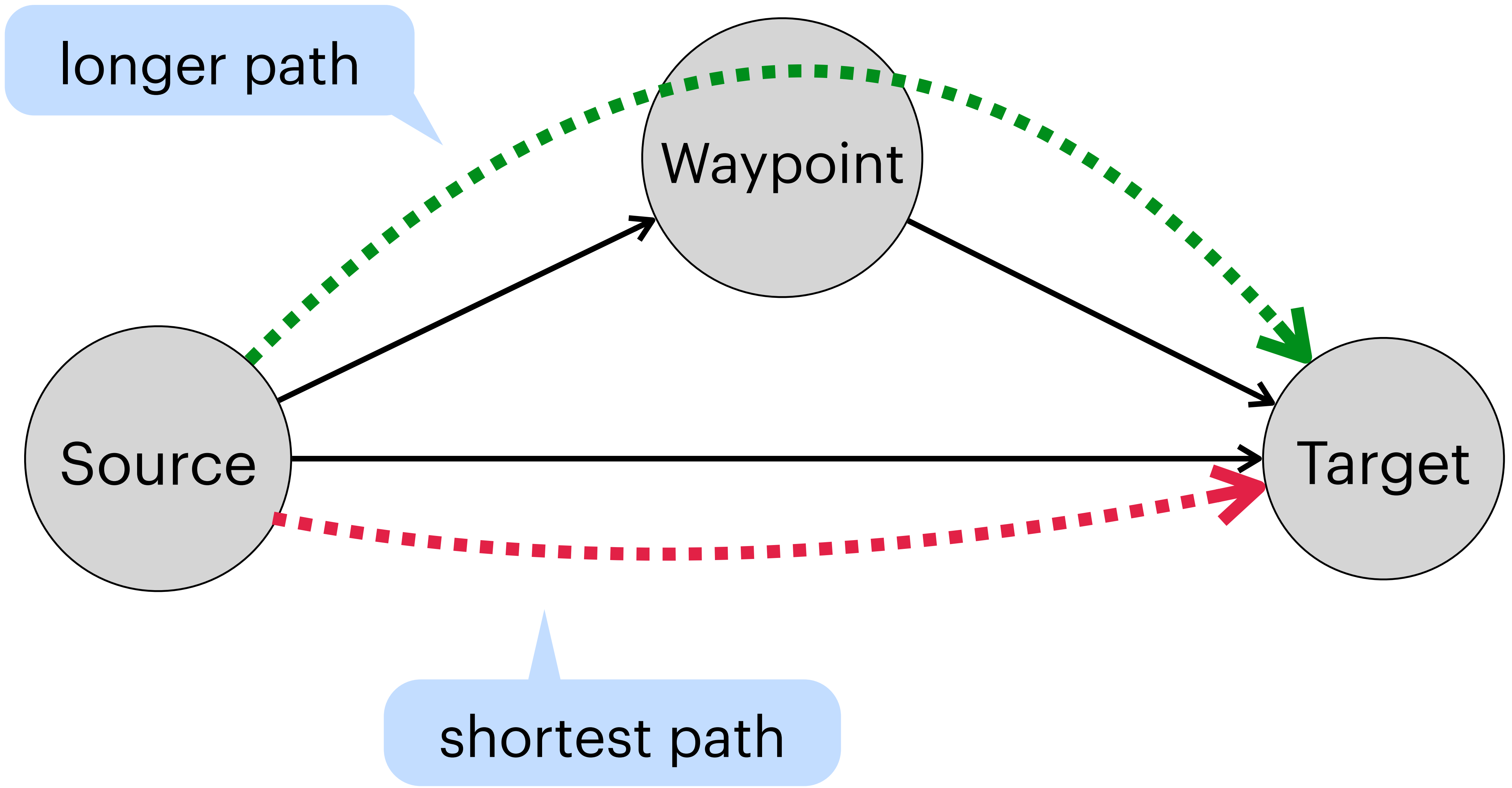

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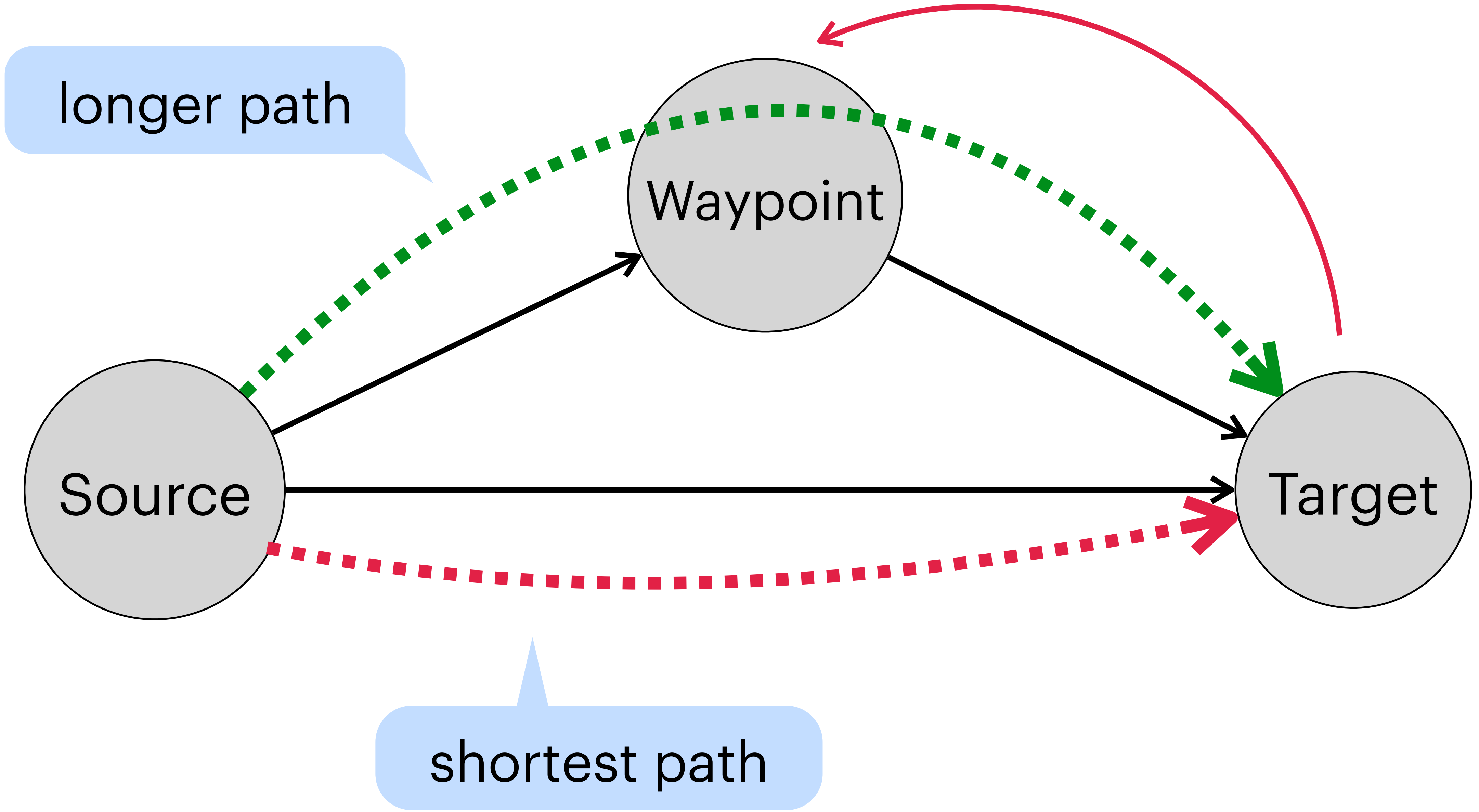

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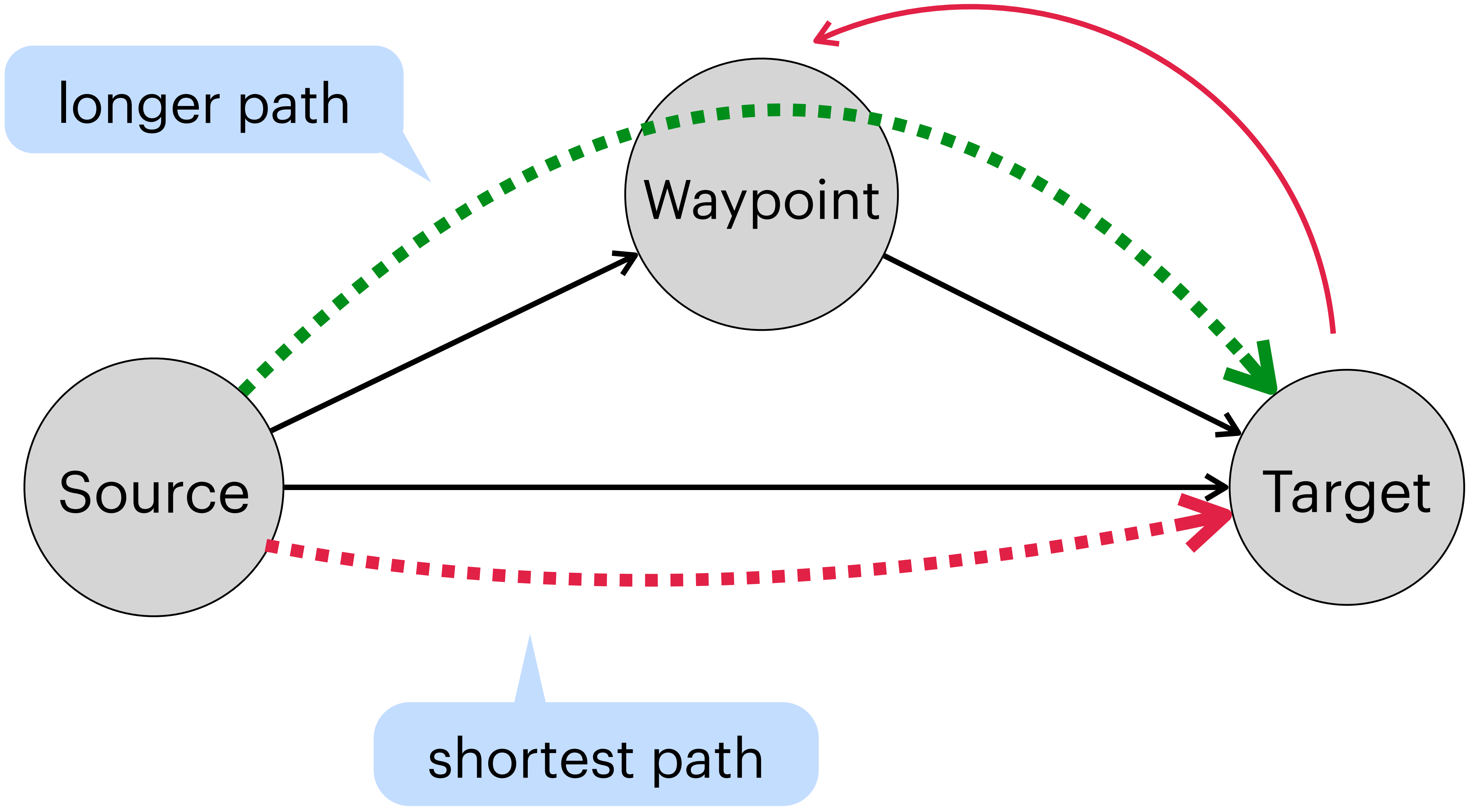
- **R.Q.**: can we combine A and B for a more fine-grained TE?



The Joint Optimization

- Link Weight Optimization (**LWO**): find link weights minimizing MLU
- Waypoint Optimization (**WPO**): find waypoints (per flow) minimizing MLU
- **JOINT**: find a link-weight-waypoint setting minimizing MLU

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JOINT $\neq$ LWO $\cup$ WPO

JOINT vs (LWO ∪ WPO)

- The **Gap** is a ratio comparing JOINT with the best of the other two.
- For any network instance I:

JOINT vs LWO

$$R_{\text{LWO}}(\mathcal{I}) := \frac{\text{LWO}(\mathcal{I})}{\text{JOINT}(\mathcal{I})}, \text{ and } \qquad R_{\text{WPO}}(\mathcal{I}) := \frac{\text{WPO}(\mathcal{I})}{\text{JOINT}(\mathcal{I})}$$

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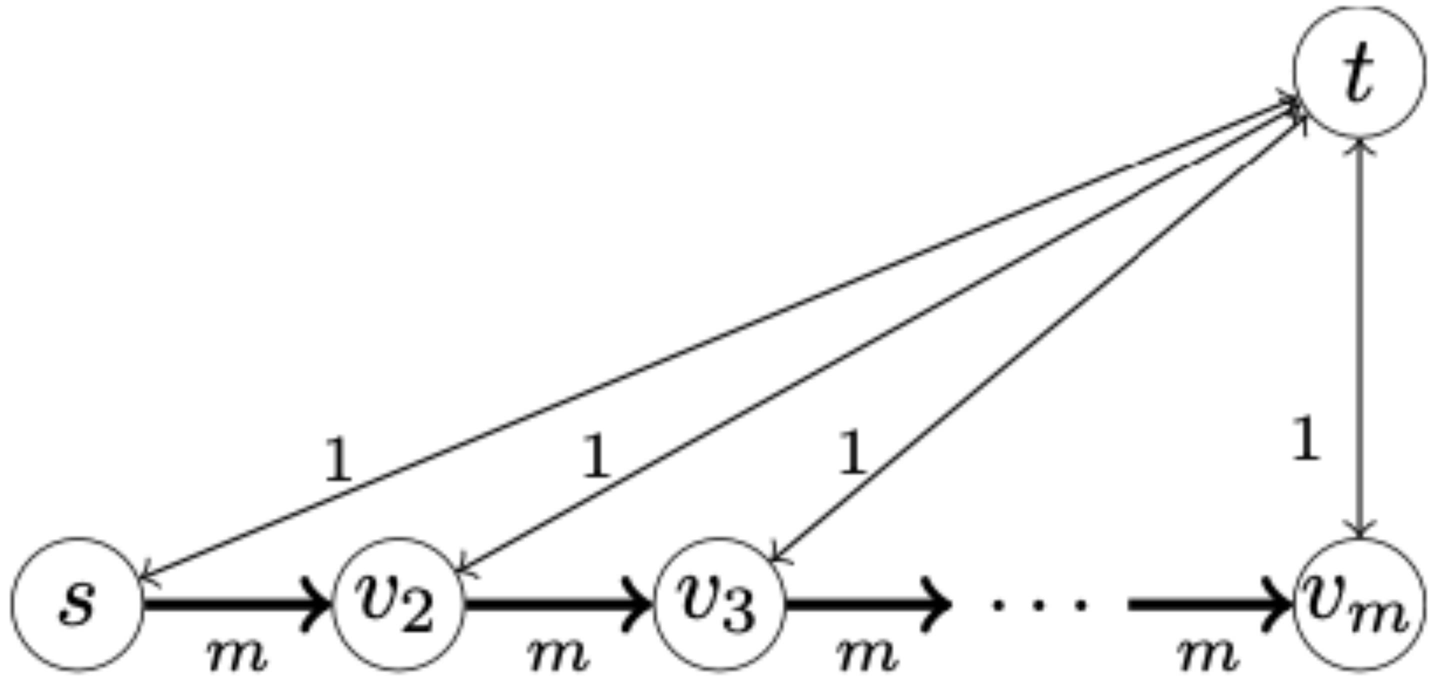
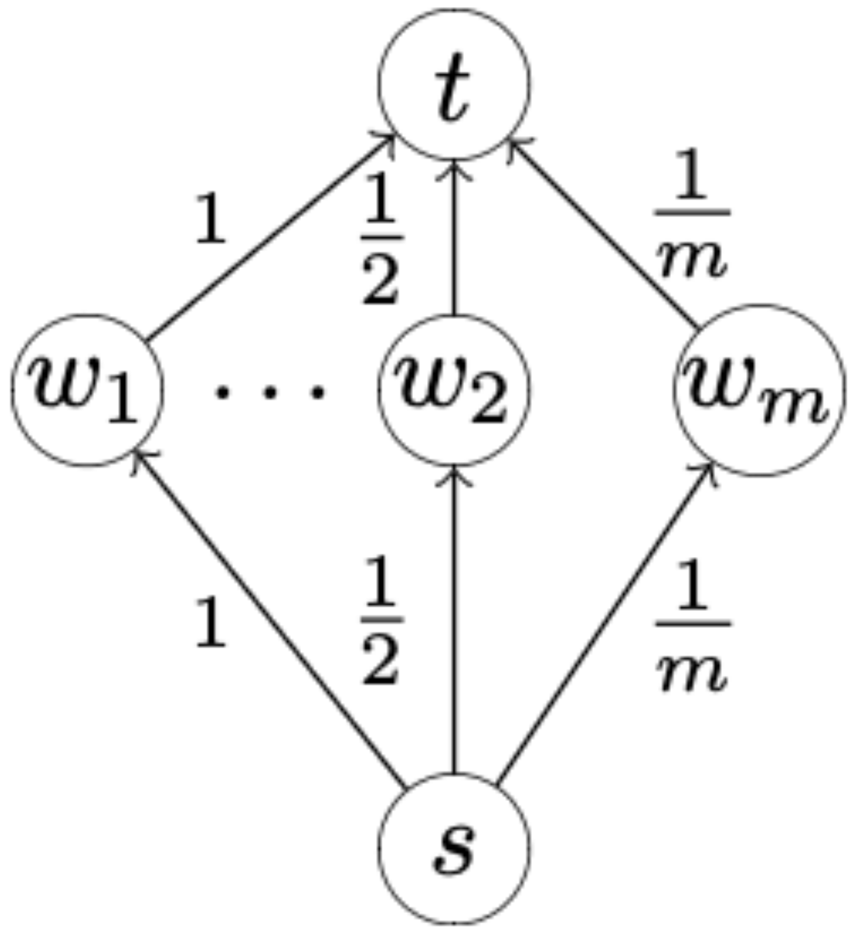
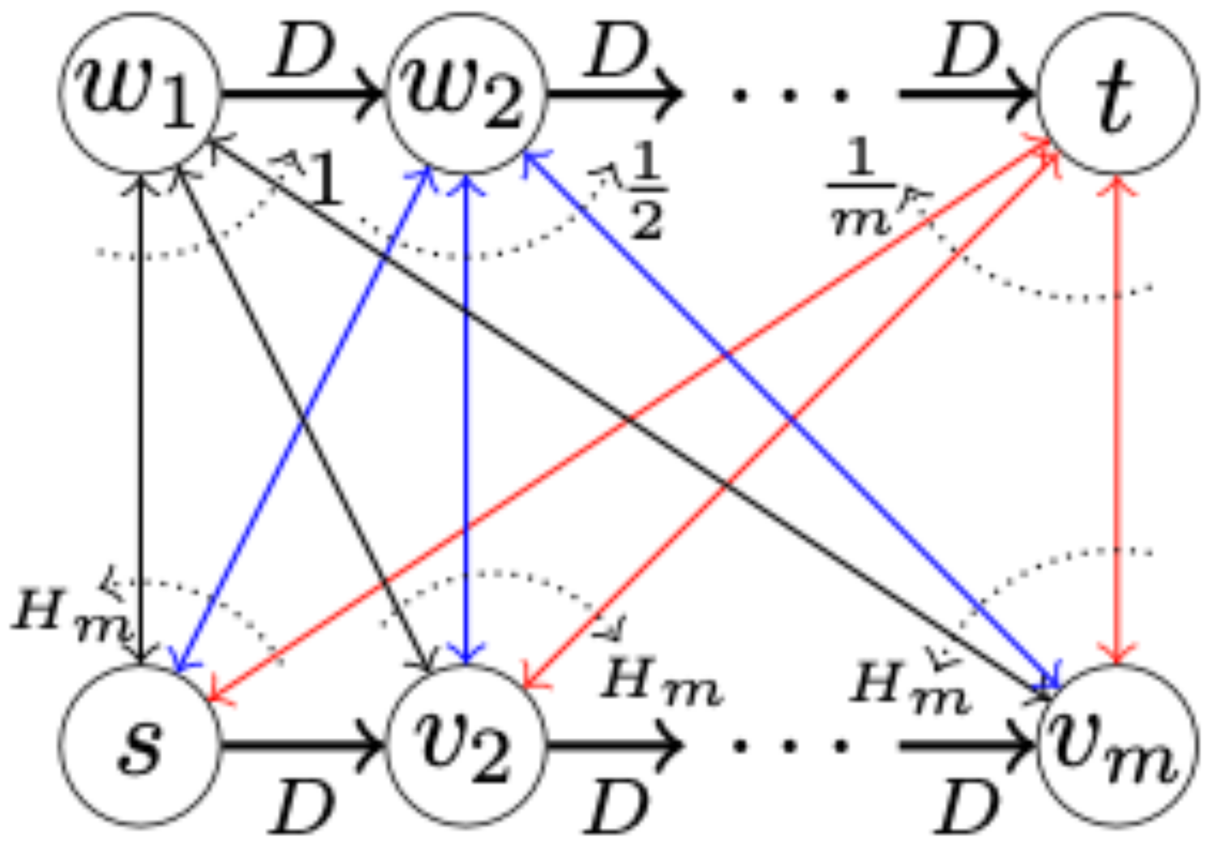
- A larger gap means JOINT is more powerful than LWO and WPO <u>unified</u>.
- Next: find the instance I that brings the largest gap ratio (asymptotically)

Improving Gap Ratio







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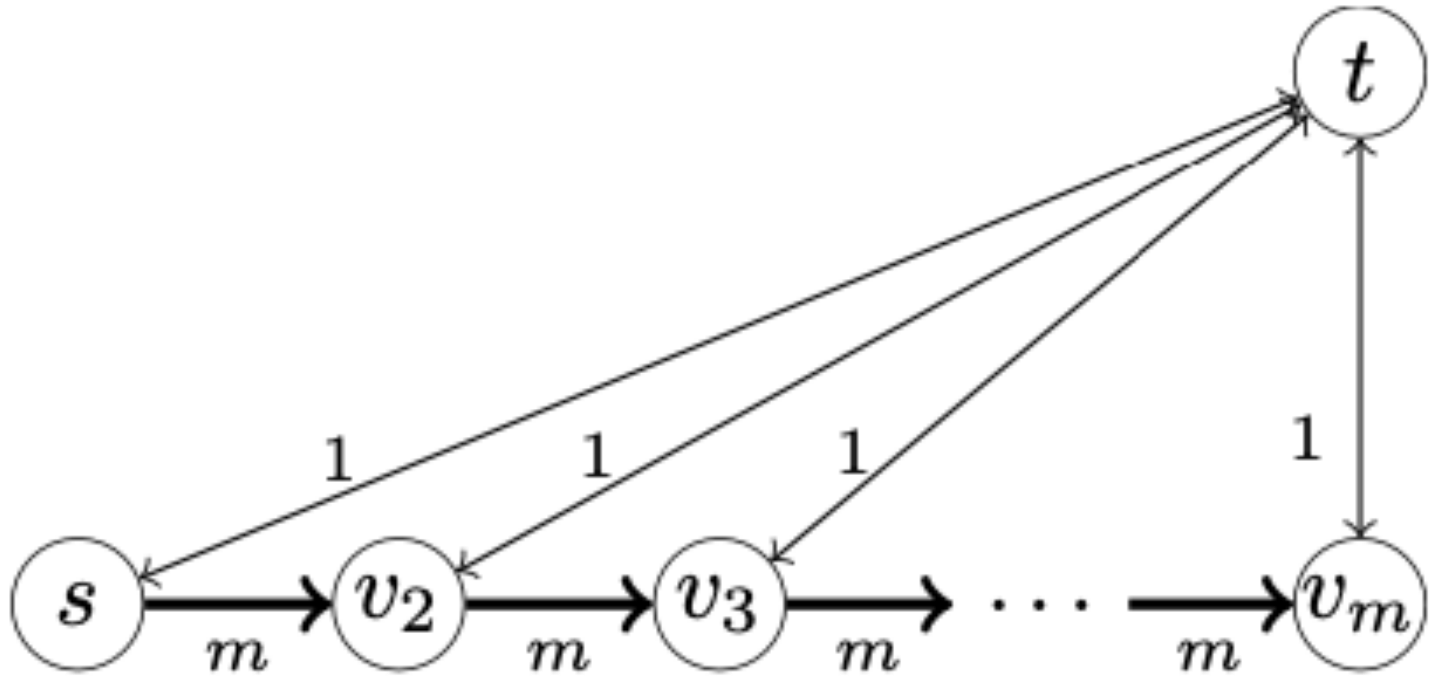

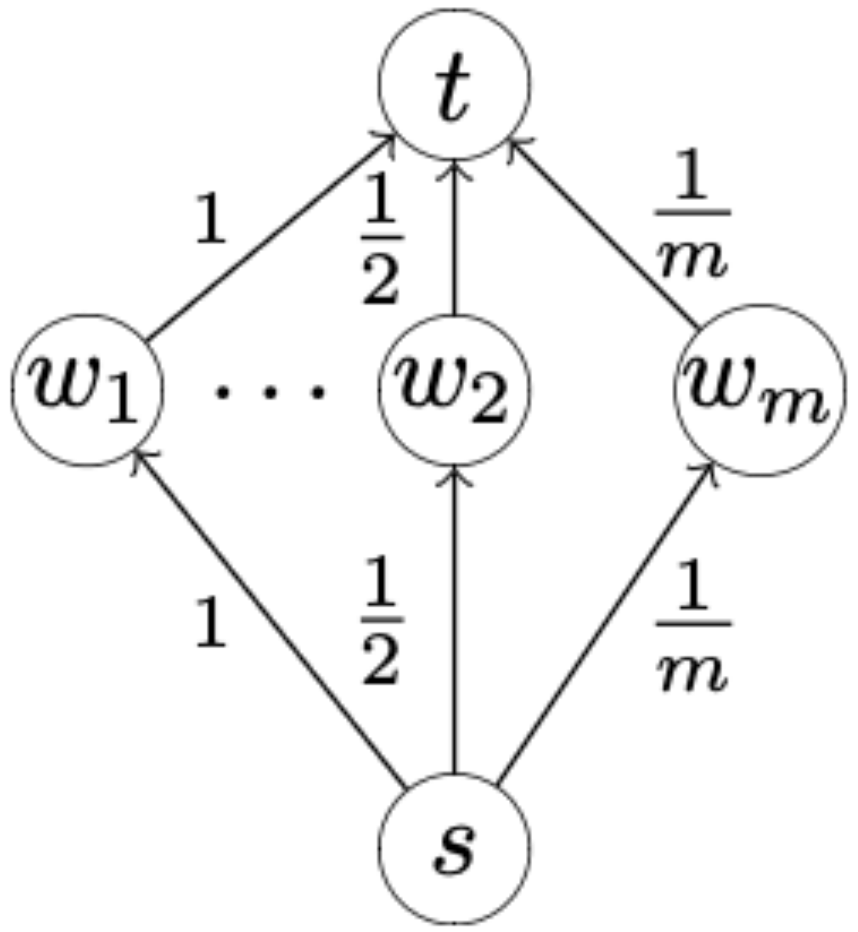

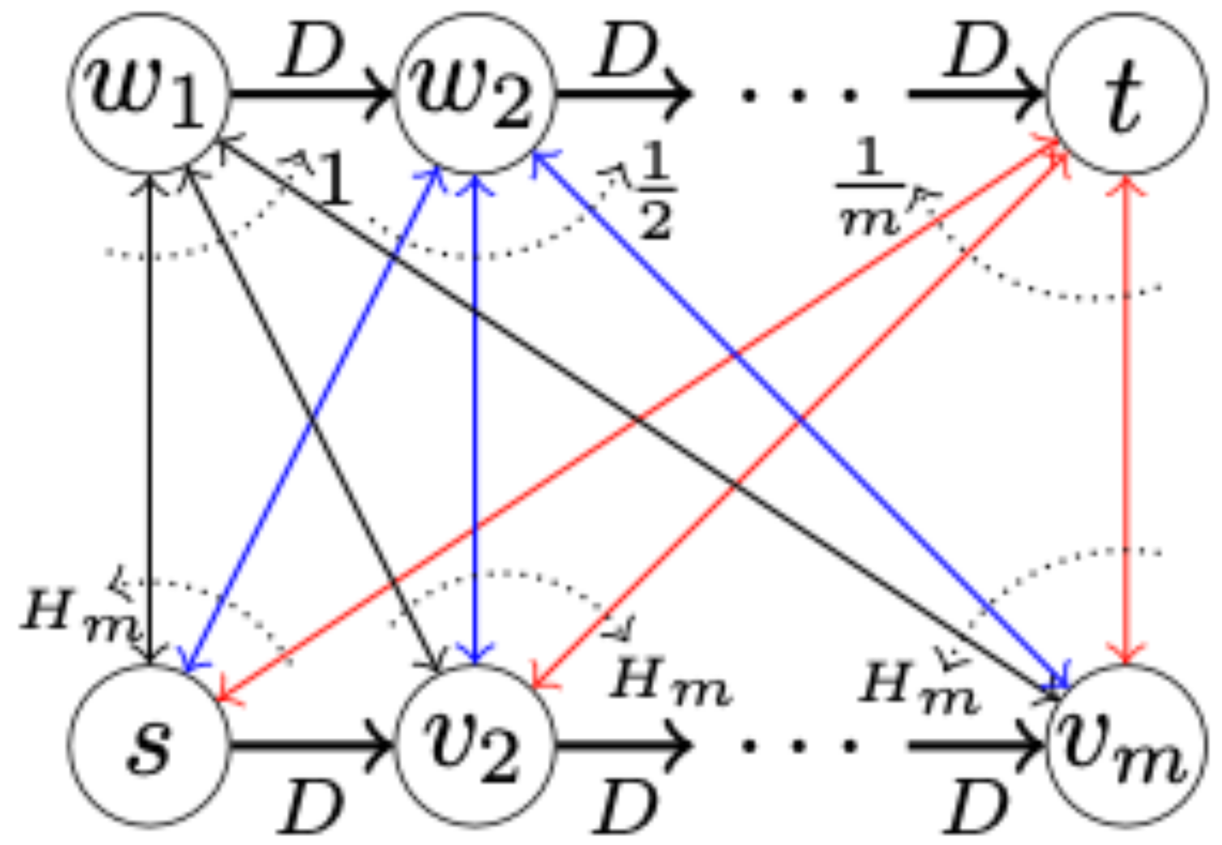

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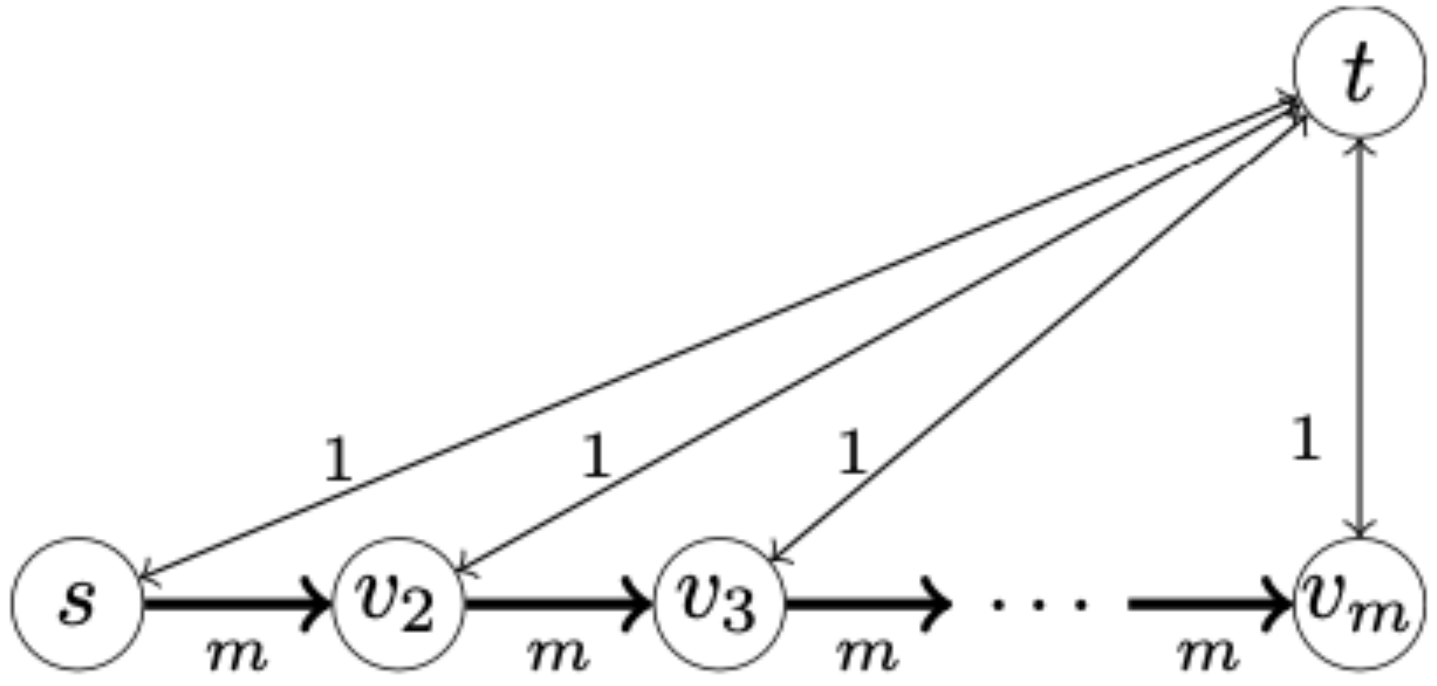

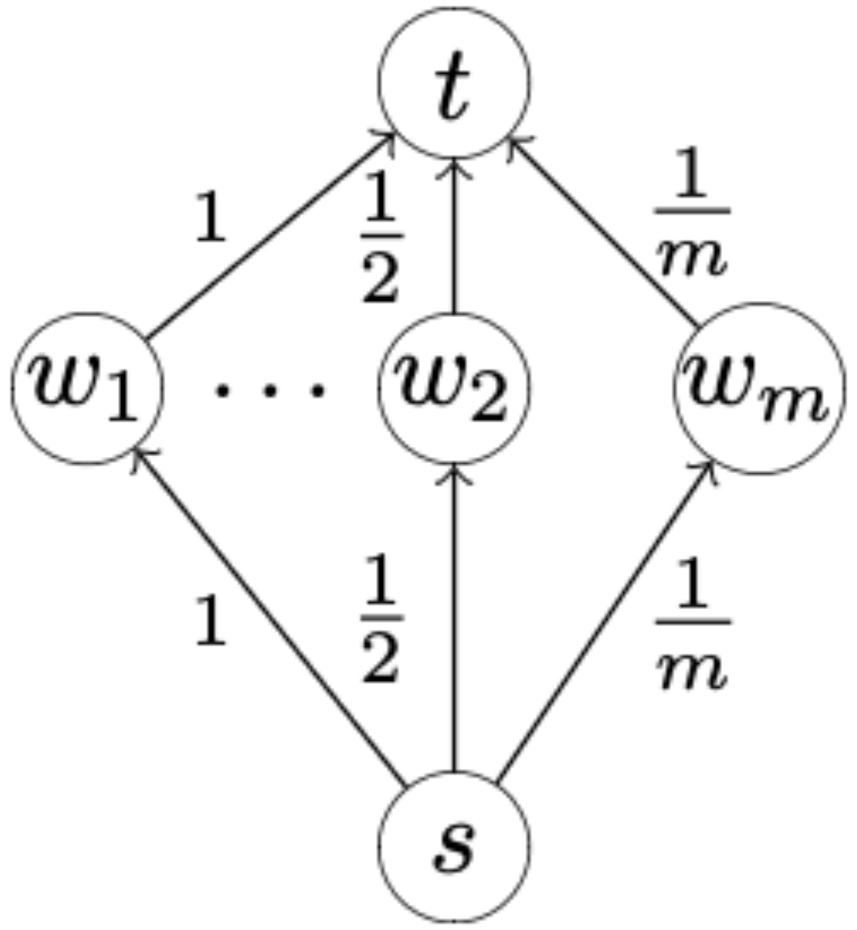

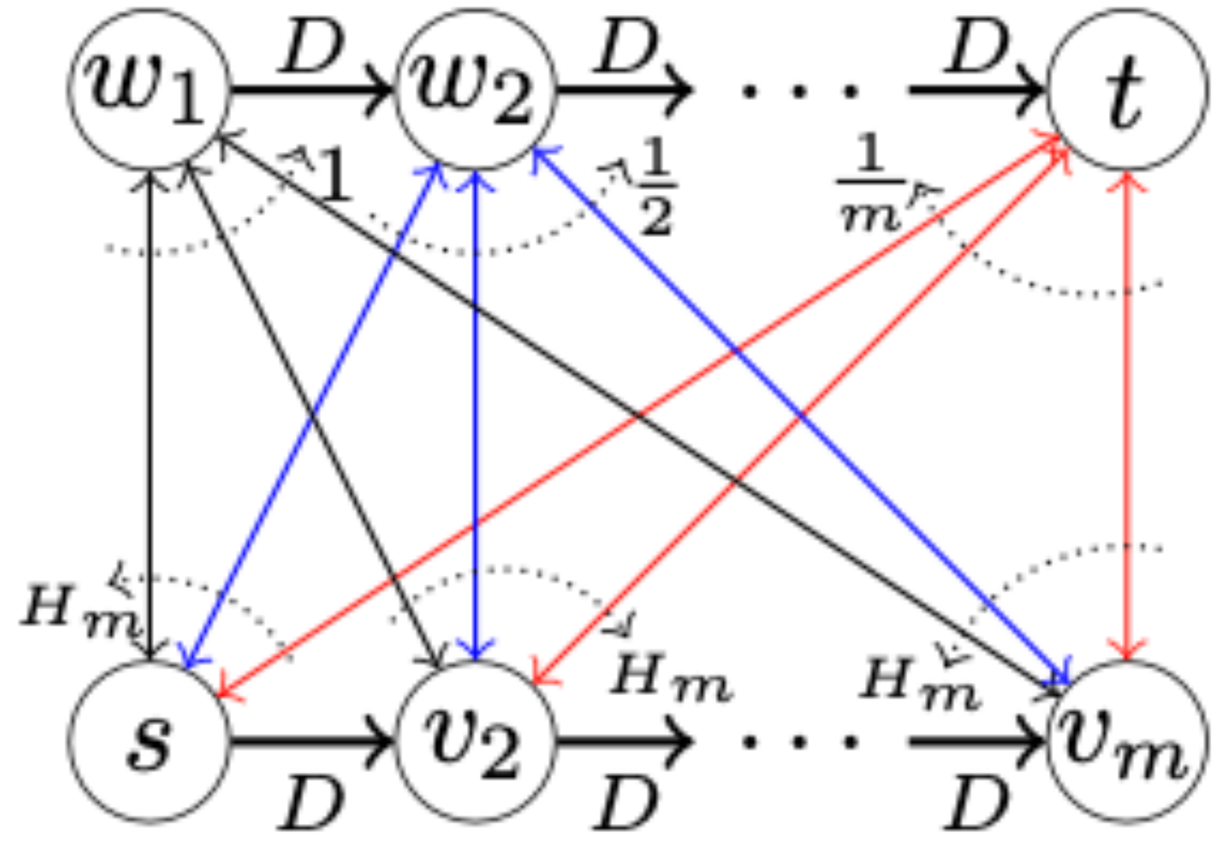

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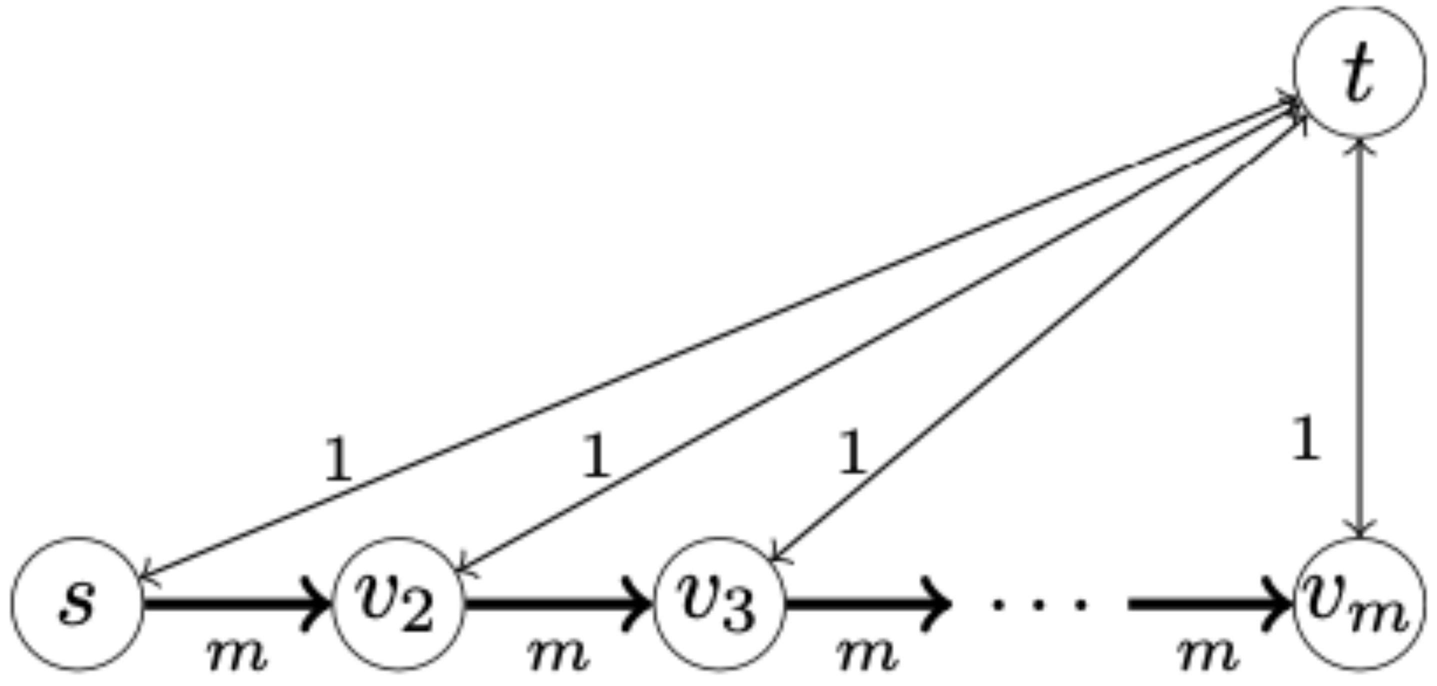

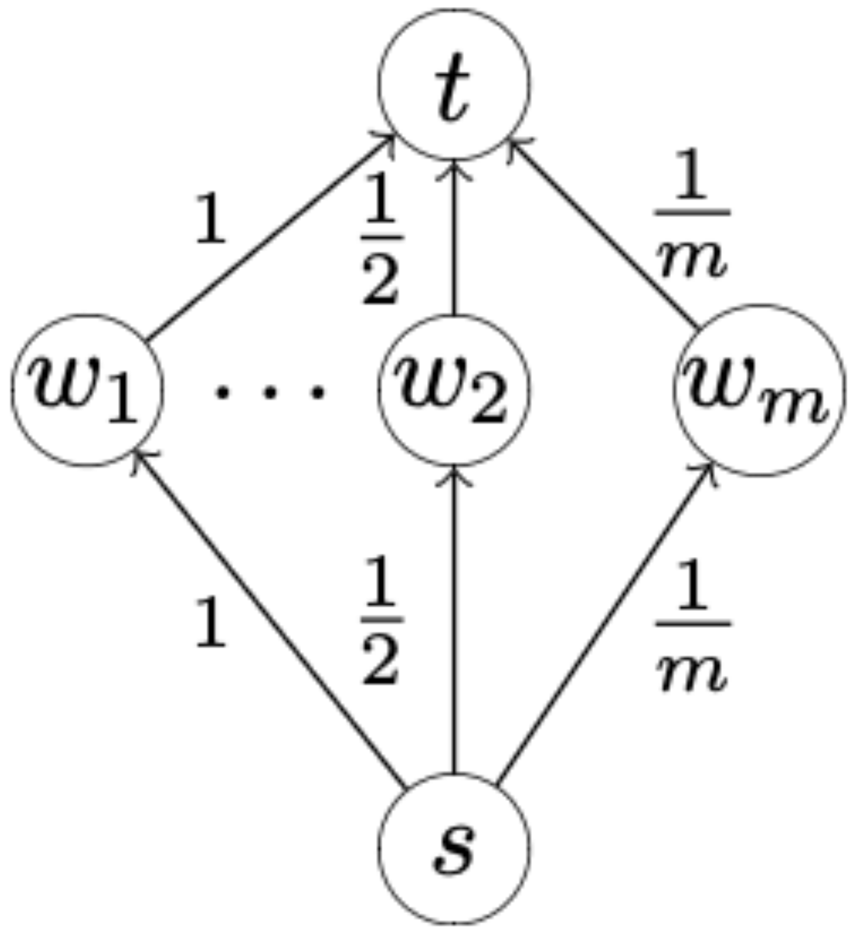

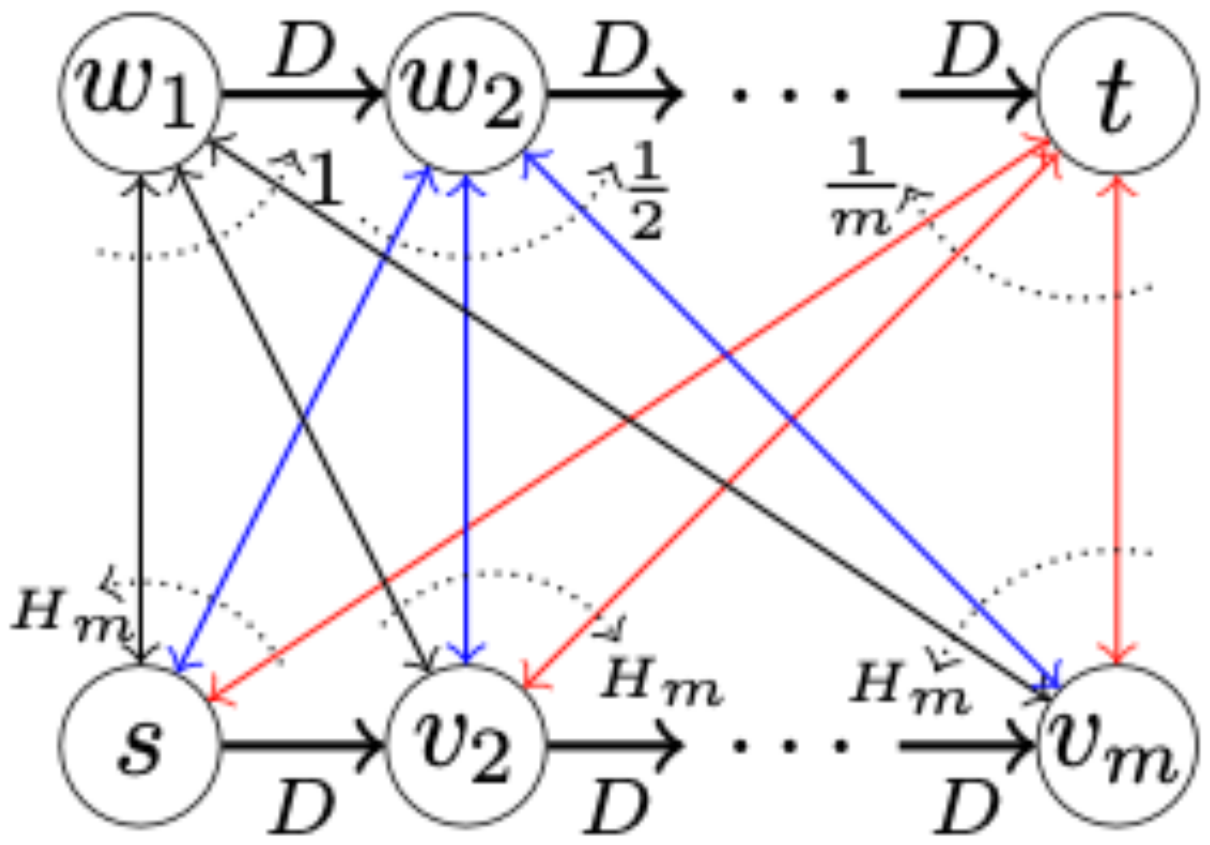

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- A heuristic for the JOINT problem, an extension of Fortz-Thorup's

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- Contributions:
  - Introducing *maximal resiliency* formally with ILP
  - maximally resilient backup paths for hypercubes, complete graphs, torus, and grids
  - Extension of TI-LFA for multi-link failures and its SR analysis

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- Contributions:
  - lower bound in $\Omega(n)$
  - upper bound (online algorithm) in $O(n)$ for a special case called *perfect partitioning*
  - 6-competitive algorithm for the special case $k = 2$

Traffic Partitioning (all results)

Variant	Lower bound	Upper bound
Learning, $k \geq 3$	$\Omega(k\ell), \epsilon = 0$ (Thm. 4.3.1)	$O(k\ell), \epsilon = 0$ (Thm. 4.3.4)
Learning, $k \geq 3$	$\Omega(\ell \log k), \epsilon \leq \frac{1}{32}$ [105]	$O(\ell \log k), \epsilon \leq 1$ [105]
Learning, $k \geq 3$	$\Omega(\ell), \epsilon < 1/3$ (Thm. 4.3.2)	$O(\log k), \epsilon > 1$ [105]
General, $k = 3$	$\Omega(\ell), \epsilon = 0$ (Thm. 4.4.1)	$O(\ell), \epsilon = 0$ (Thm. 4.4.3)
General, $k = 2$	$3, \epsilon = 0$ [19]	$6, \epsilon = 0$ (Thm. 4.4.6)
General, $k > 3$	$\Omega(k\ell), \epsilon = 0$ (Thm. 4.4.1)	$O(2^{O(k)}\ell), \epsilon = 0$ [28]

Additional Works

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- Waypoint Routing

به یاد مادربزرگ مهربان و دلسوزم

In Memory of My Loving and Selfless Grandma