Using Explicit (Host-to-Network) Flow Measurements (EFM) for Network Tomography

Ike Kunze, Constantin Sander, Niklas Rieken, Alexander Ruhrmann, Klaus Wehrle

Ike Kunze
ANRW ‘25, July 22nd 2025
Madrid

COM SYS Communication and Distributed Systems
RWTH AACHEN UNIVERSITY

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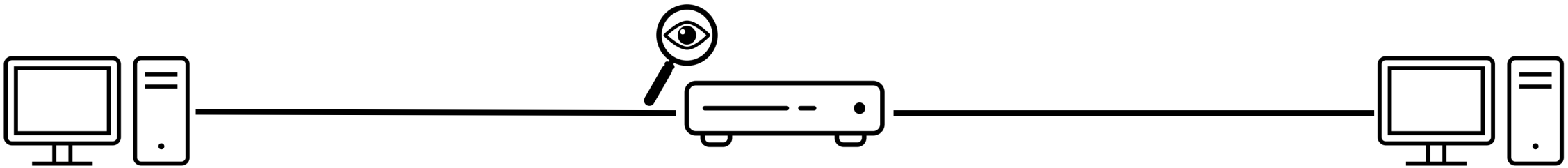
- TCP performance measurements often use implicit semantics



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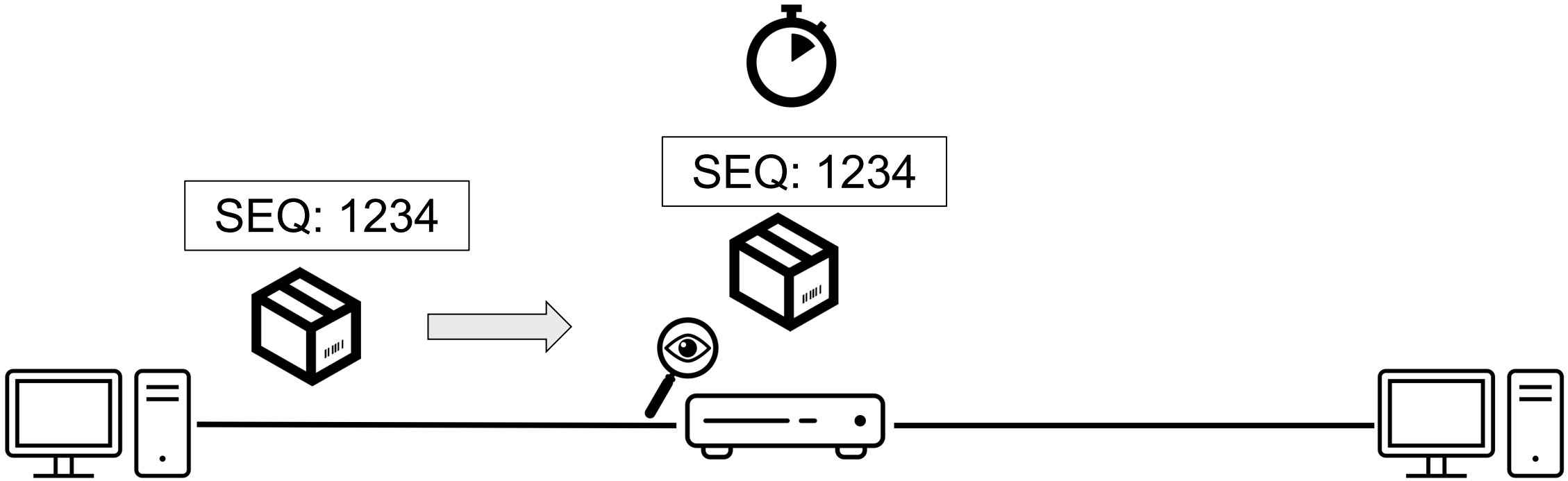

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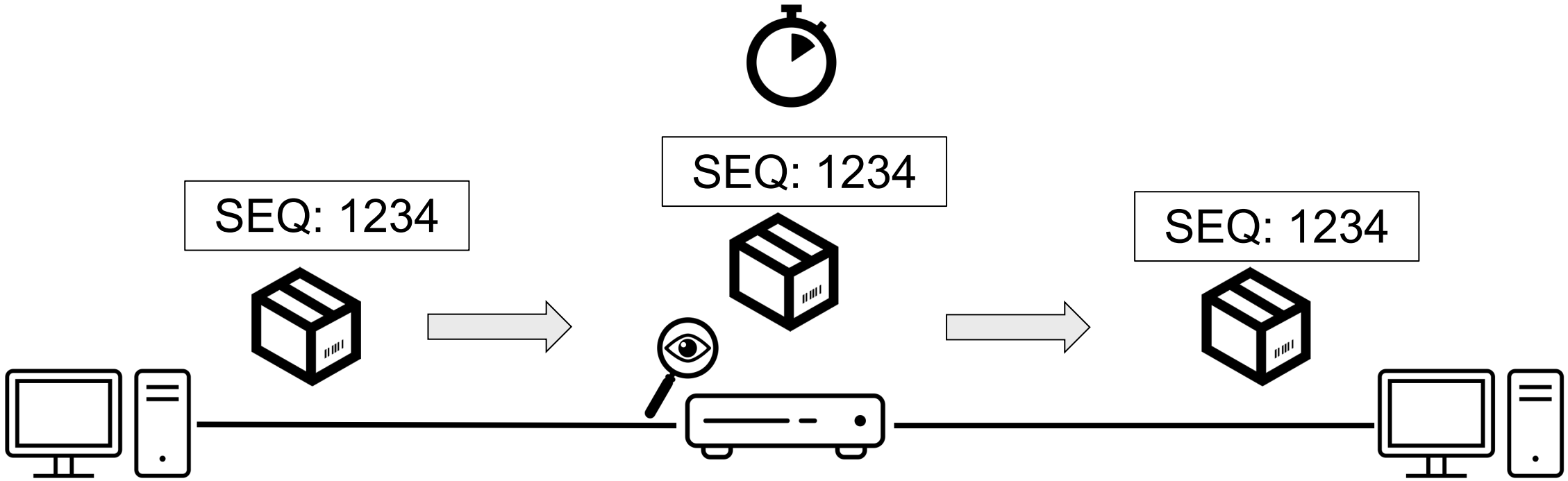

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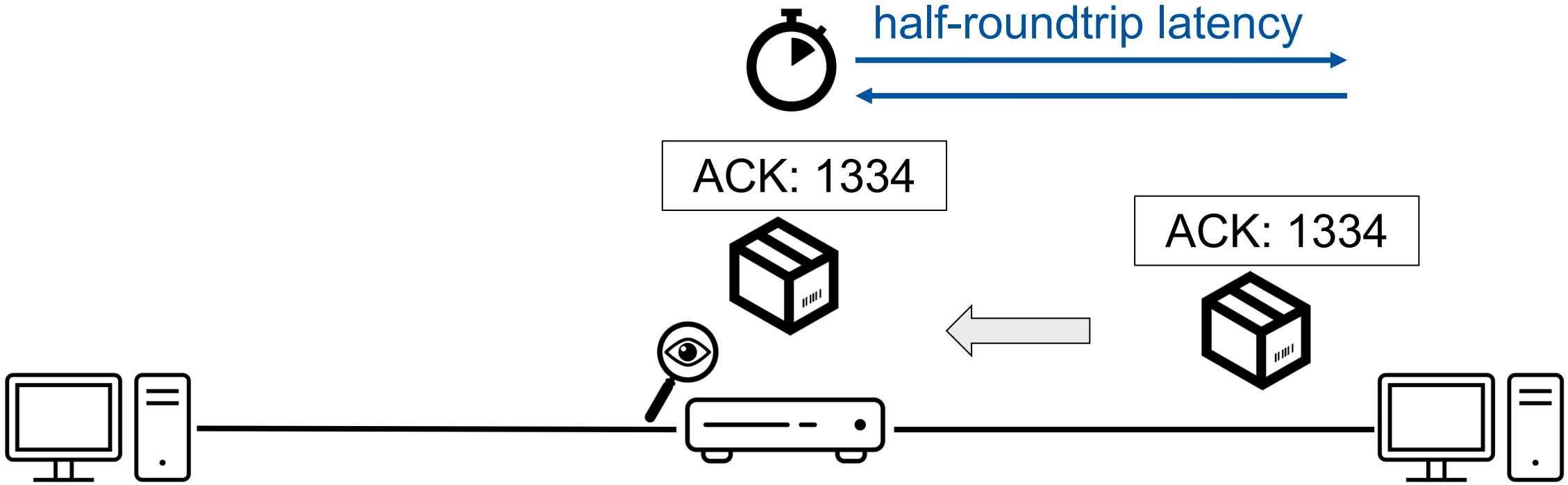

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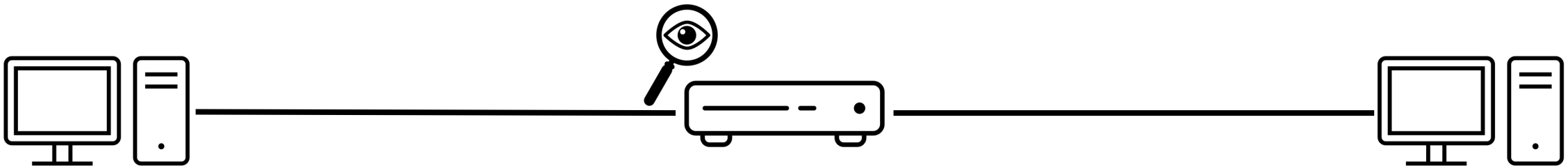

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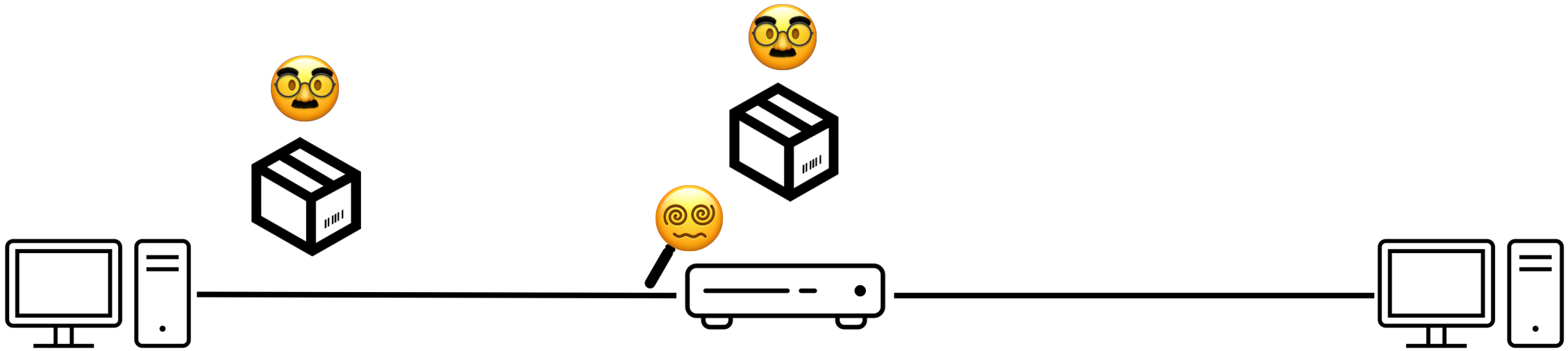

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  - Latency (spin bit; RFC 9000) and packet loss (L,Q,R,T; RFC 9506)

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- Evaluation of the four spin bit cousins L, Q, R, and T
  - Testbed & adapted aioquic variant available
- **Measurement Accuracy**
  - L-Bit has highest accuracy, but requires end-host loss detection
  - Longer algorithmic intervals of Q/R/T decrease accuracy in times of burst and prolong measurement stabilization
- **Decision for Opera**
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- The spin bit indeed sees use in the wild
  - ~10 % of domains with QUIC support use it
  - 50 – 60 % of underlying hosts

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  - Less than 25 % relative difference for 30 % of connections
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Can we use EFM for general network management tasks?

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  - Traditionally uses active measurements

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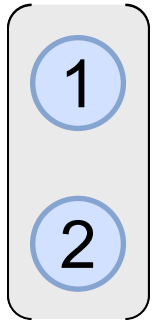

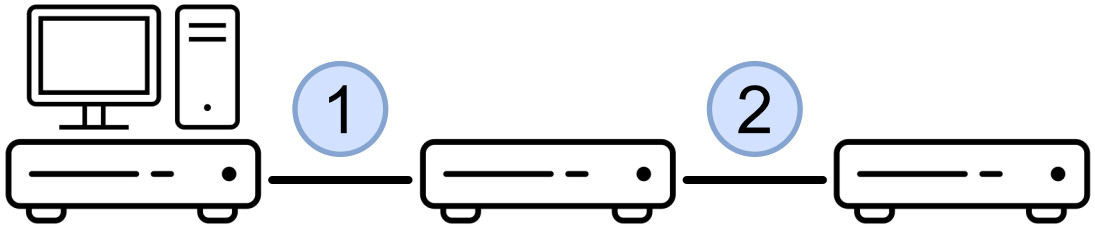

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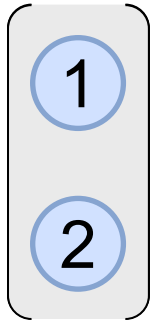

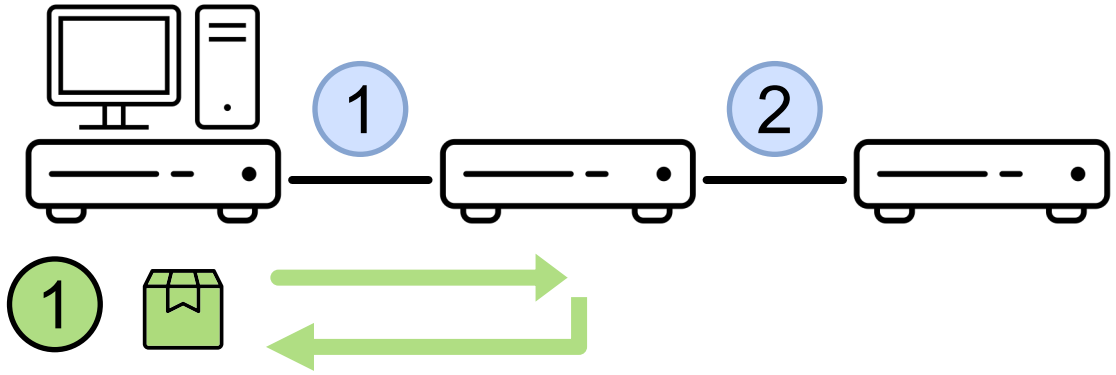

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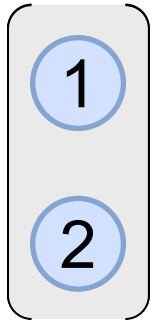

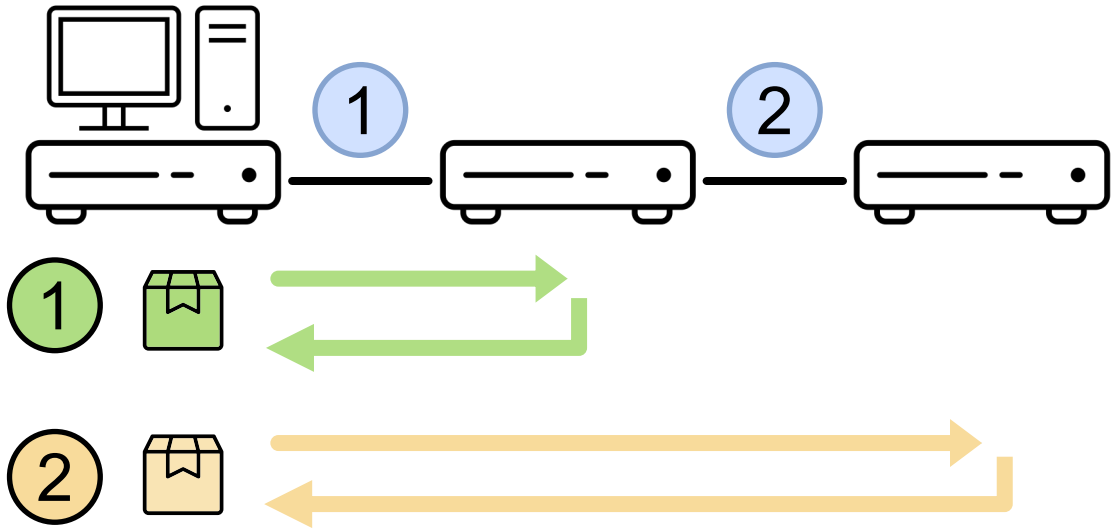

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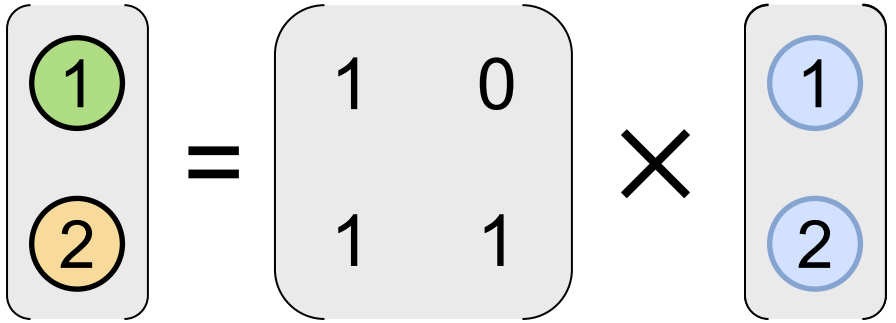

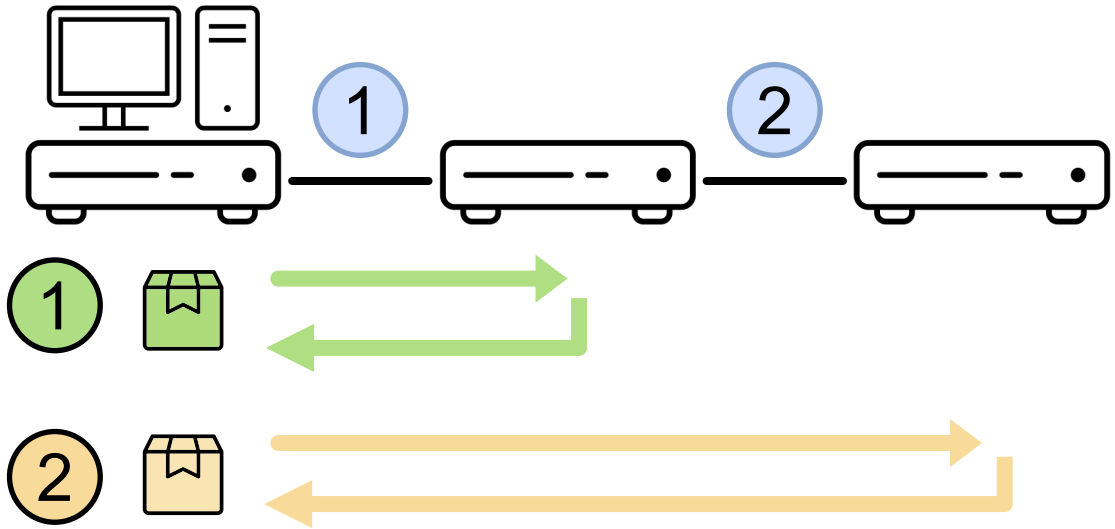

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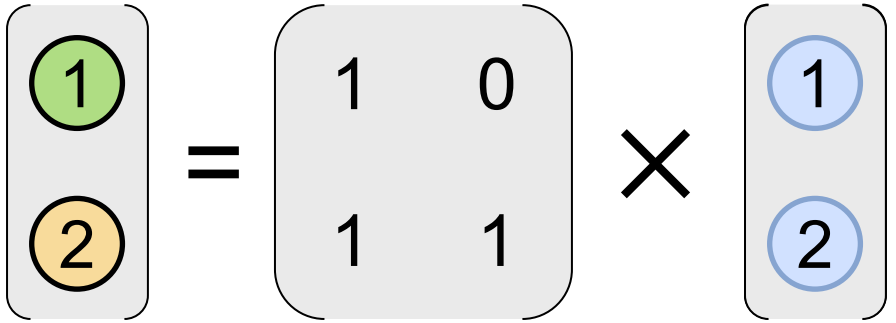

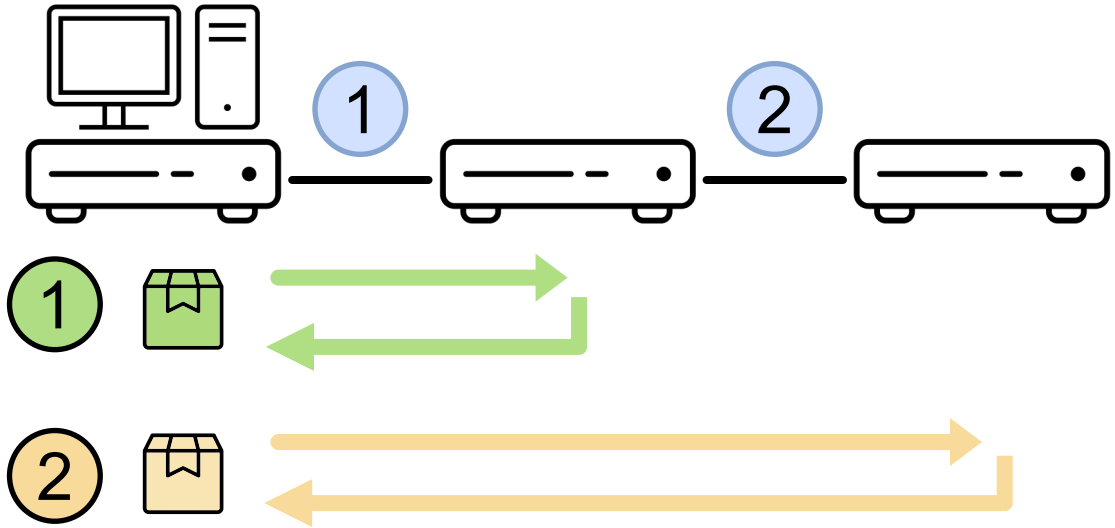

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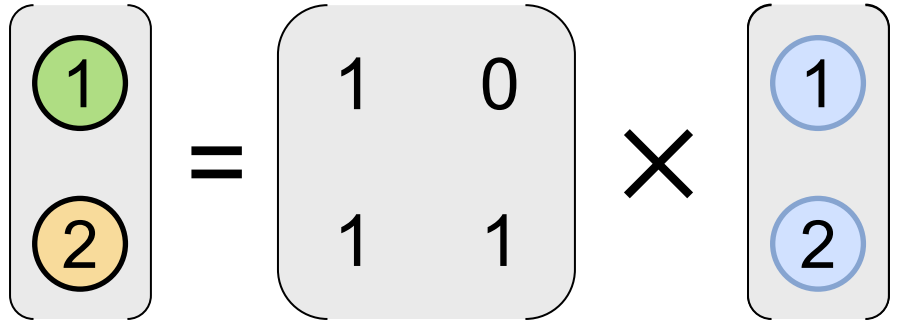

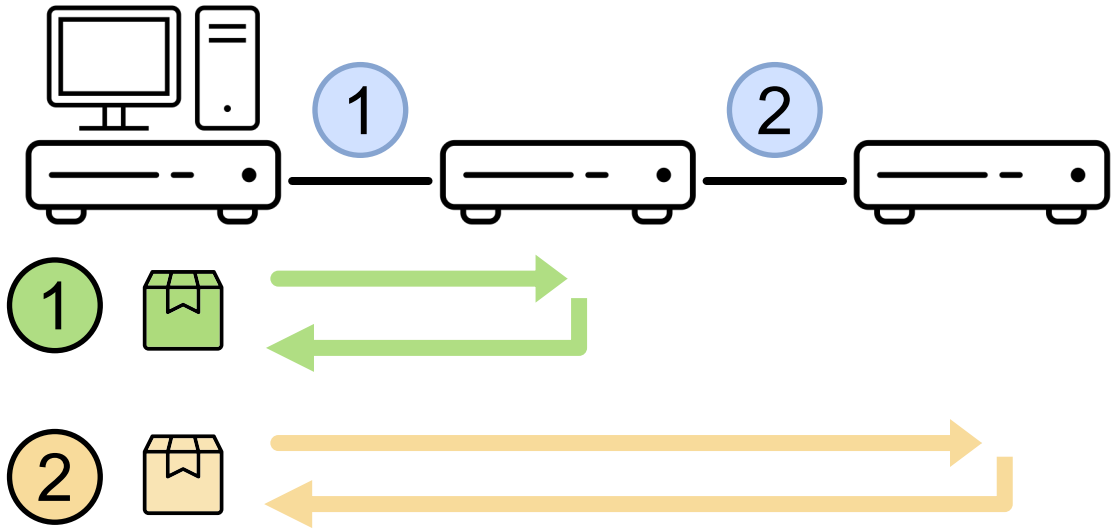

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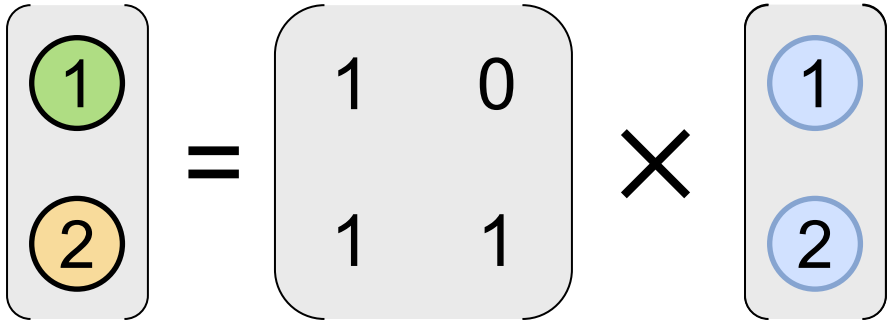
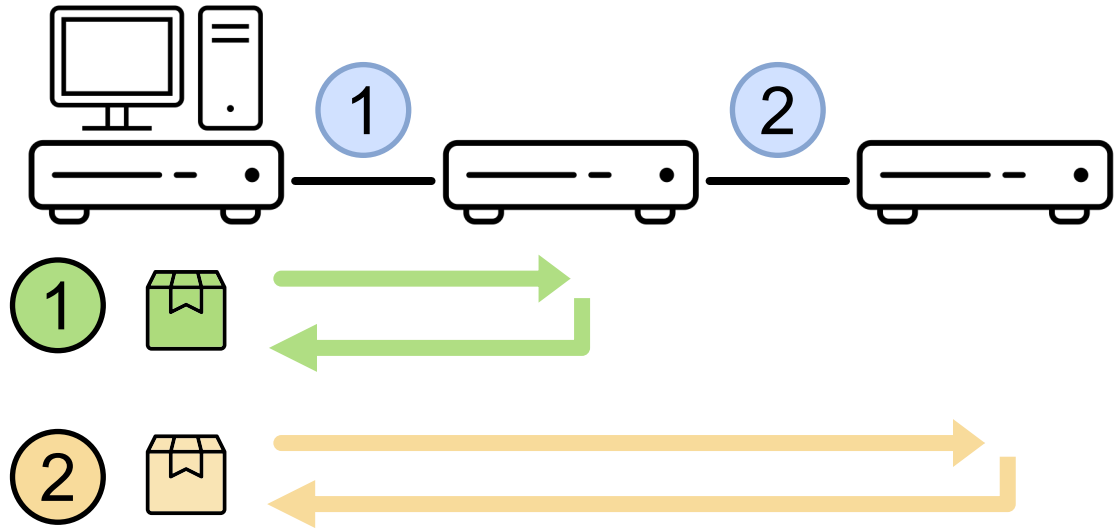


- Compare three network tomography foundations
  - Active measurements: “ping”
  - EFM: spin, L, Q, R bits
  - TCP semantics: Dart (RTT), RouteScout (packet loss)



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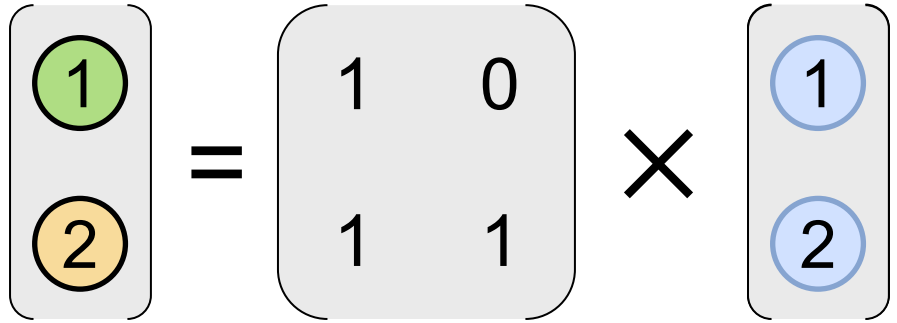

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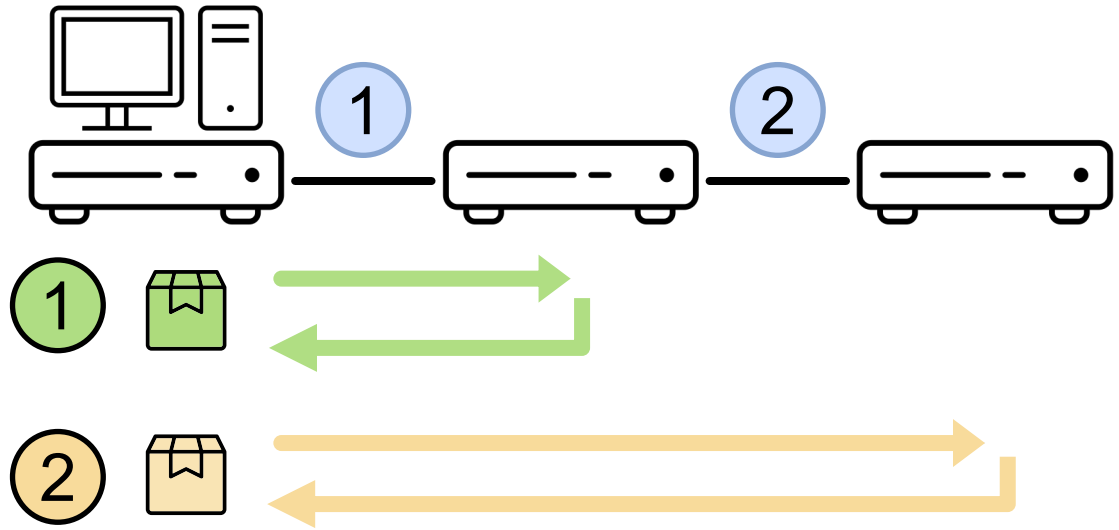

- Network simulation with ns-3
  - Topologies: CESNET, GÉANT, Telekom
  - More details in the paper

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Latency Tomography

- Deduce configured latencies from measurements
  - GÉANT: Speed of light latency (0.2 - 9.5 ms)
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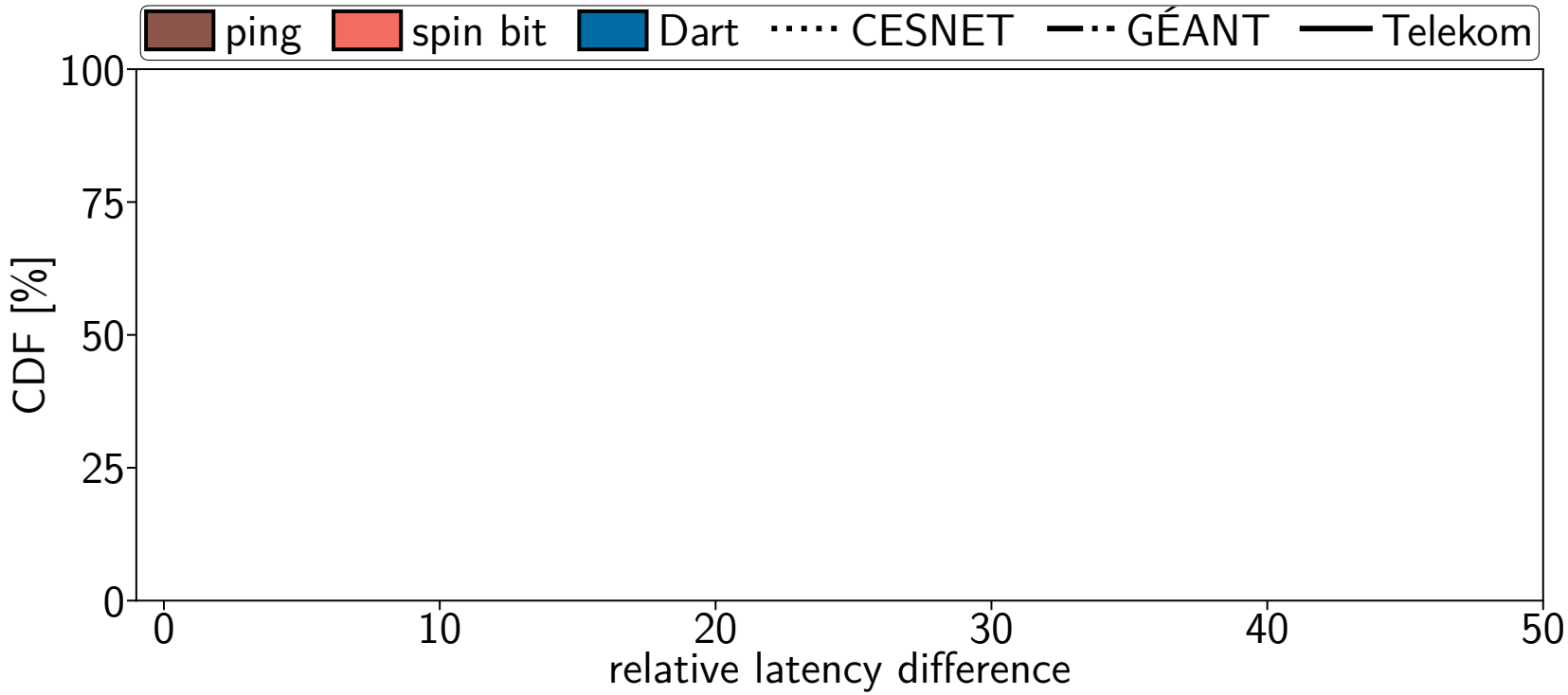

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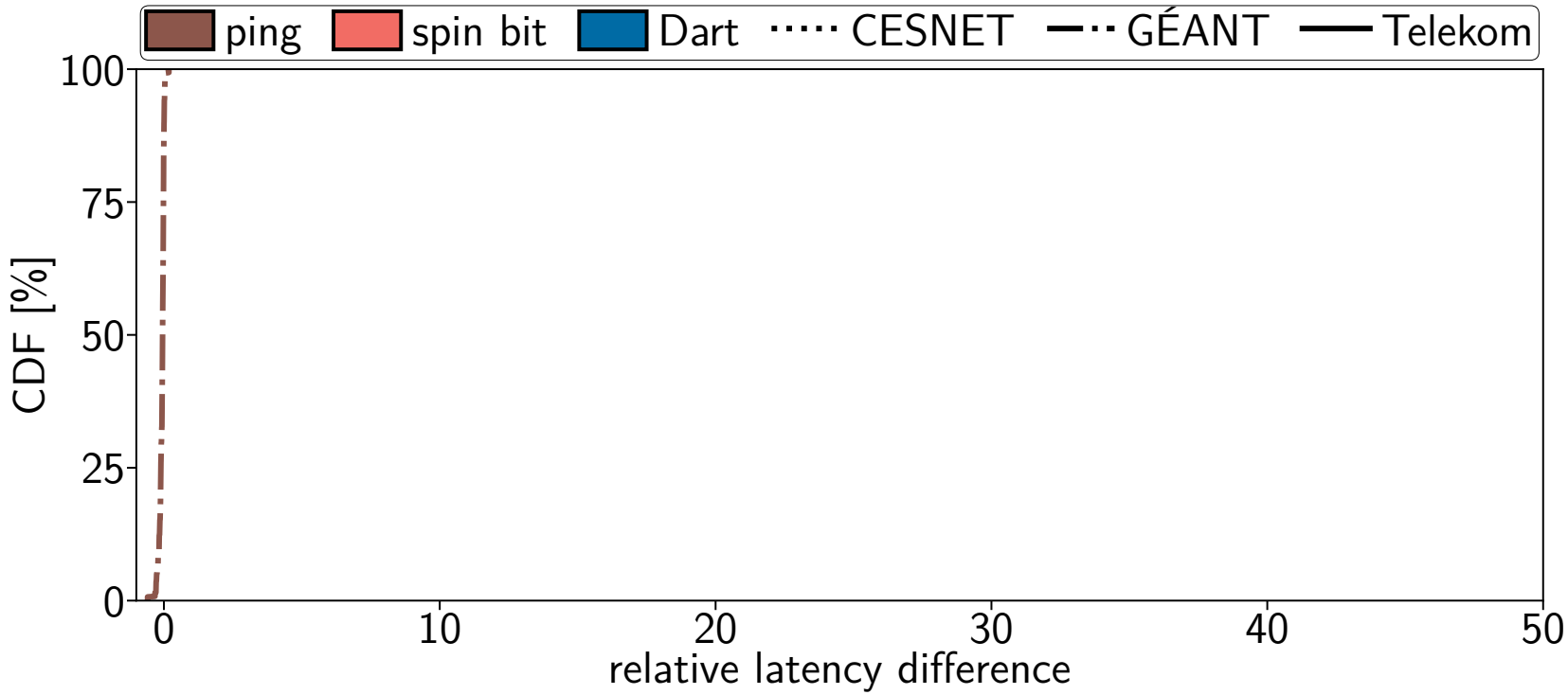

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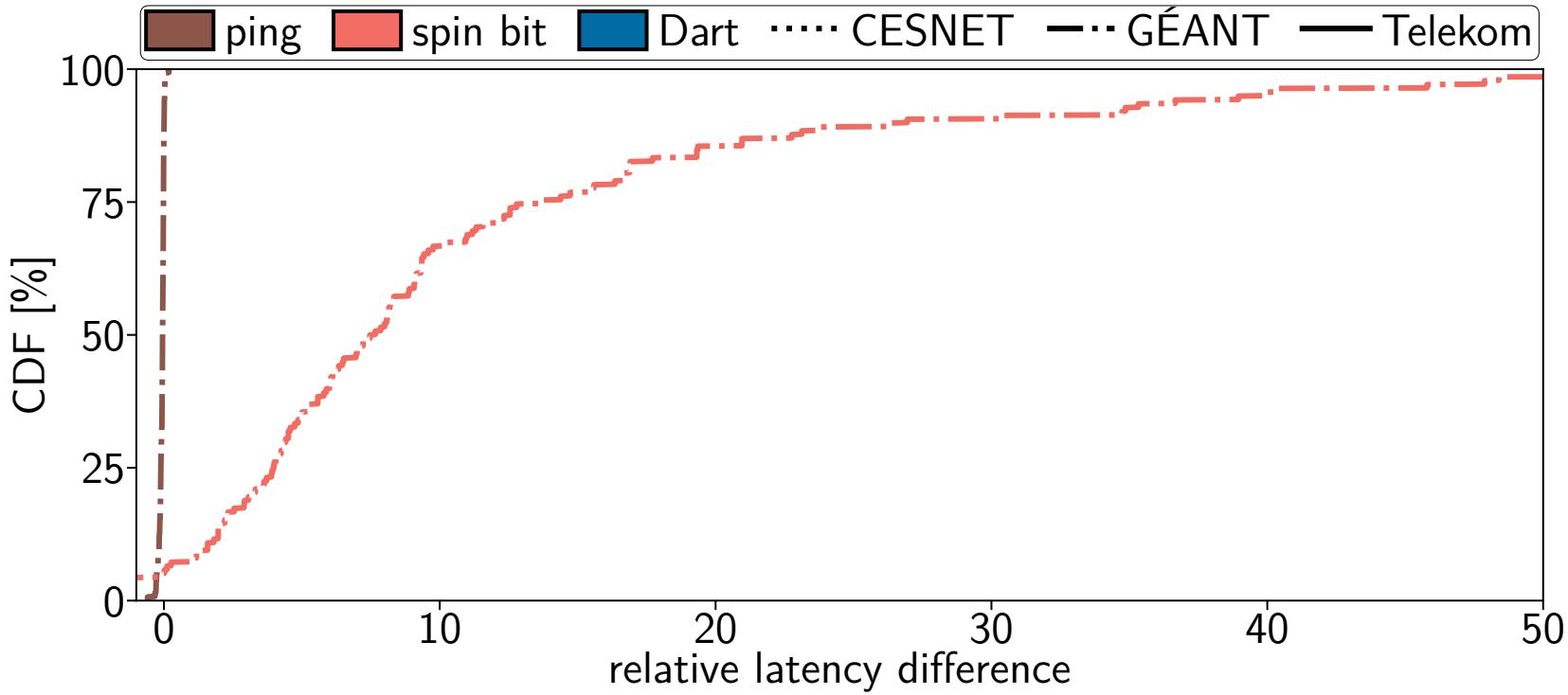

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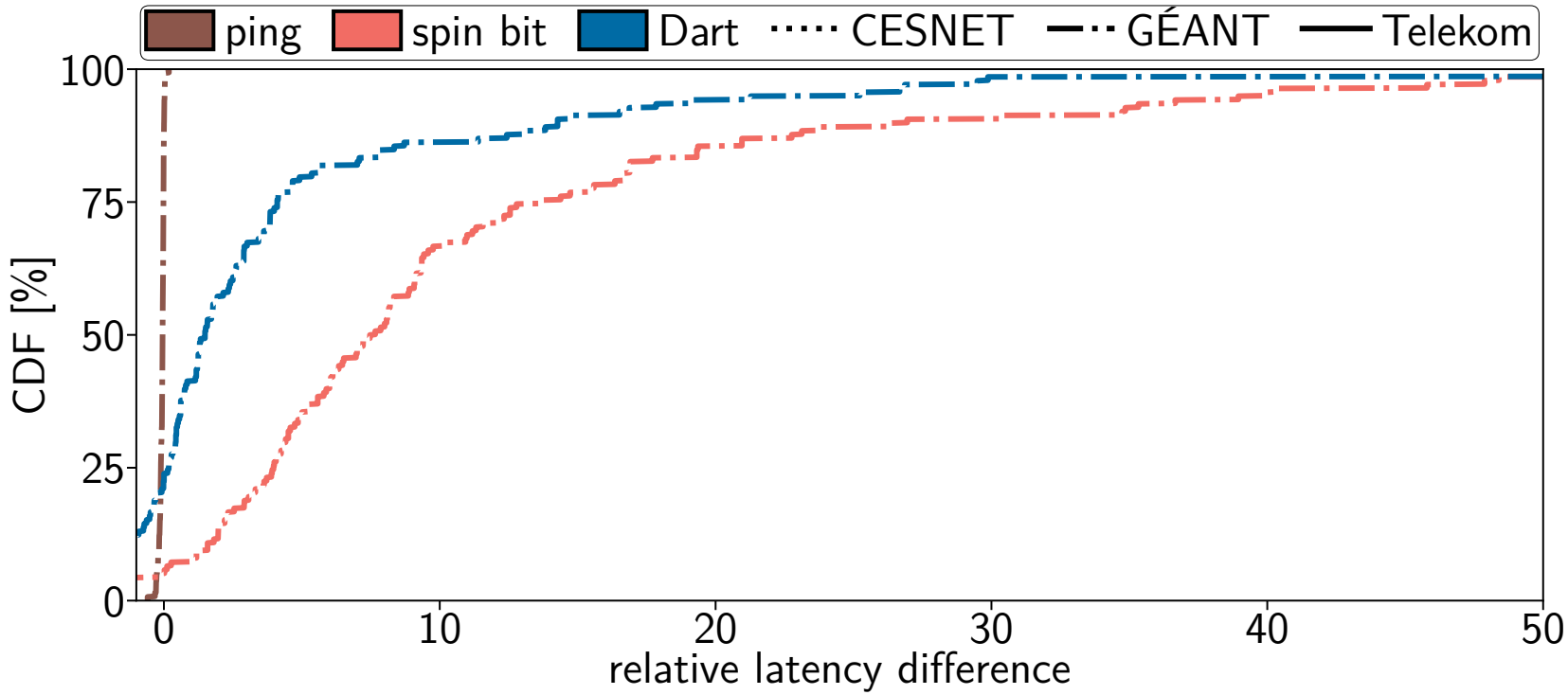

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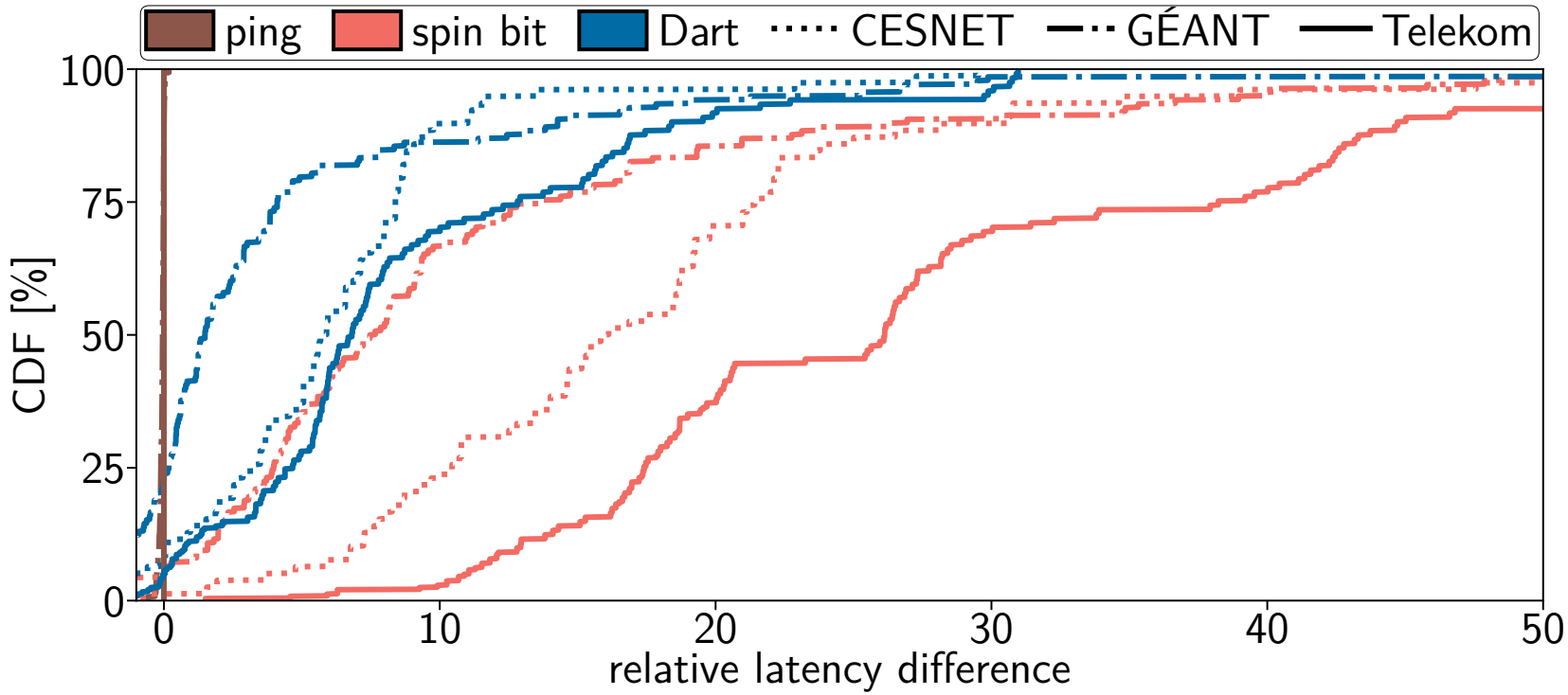

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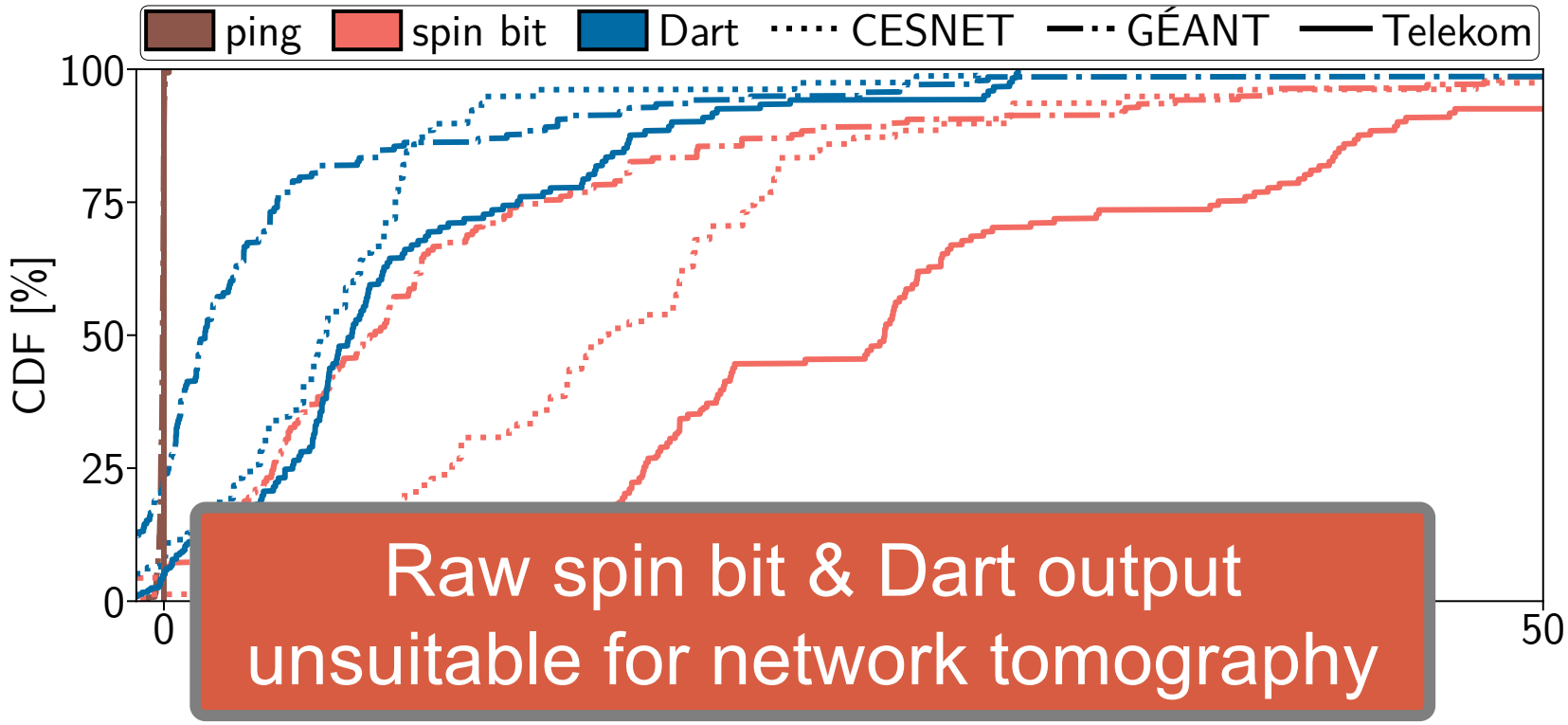

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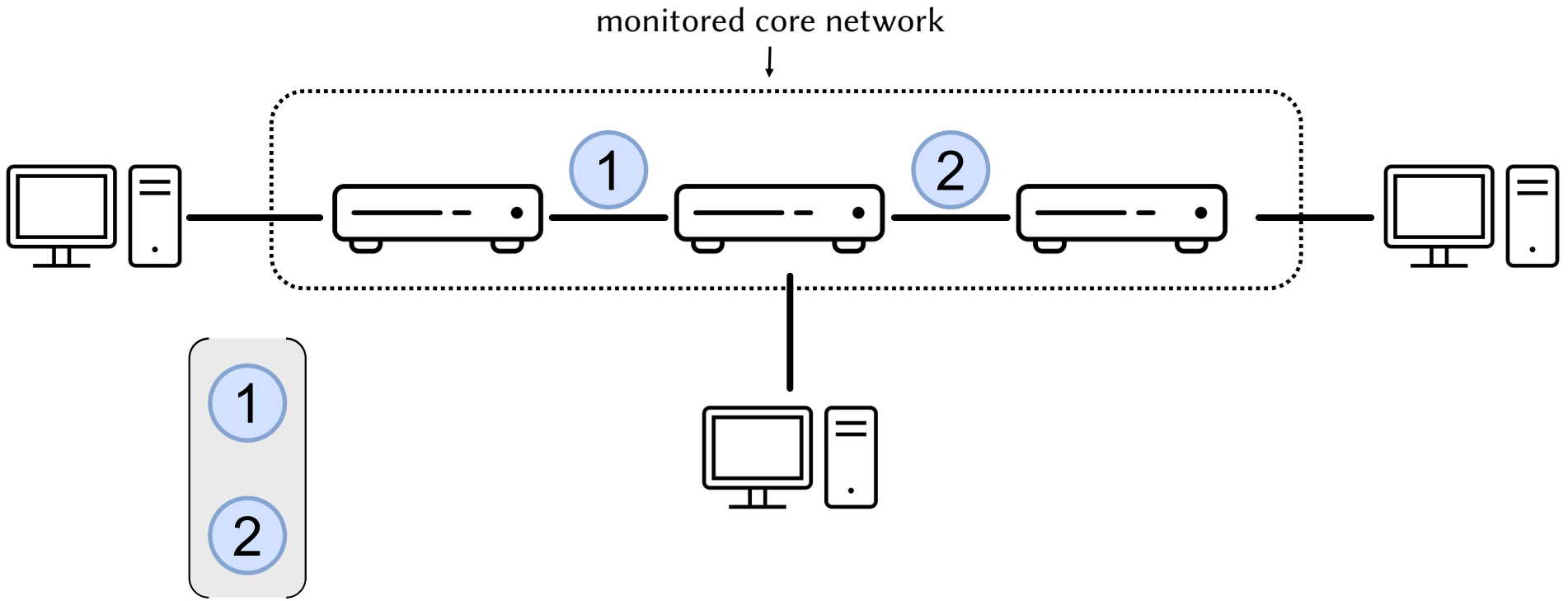

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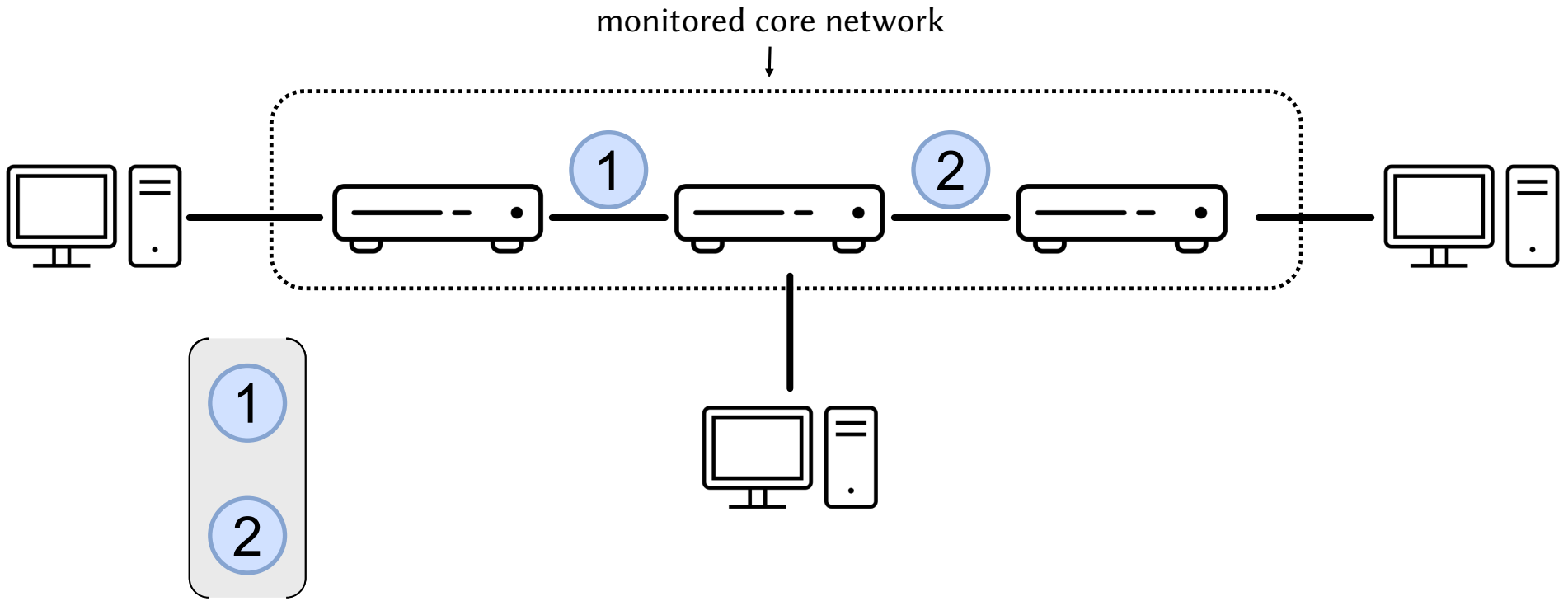

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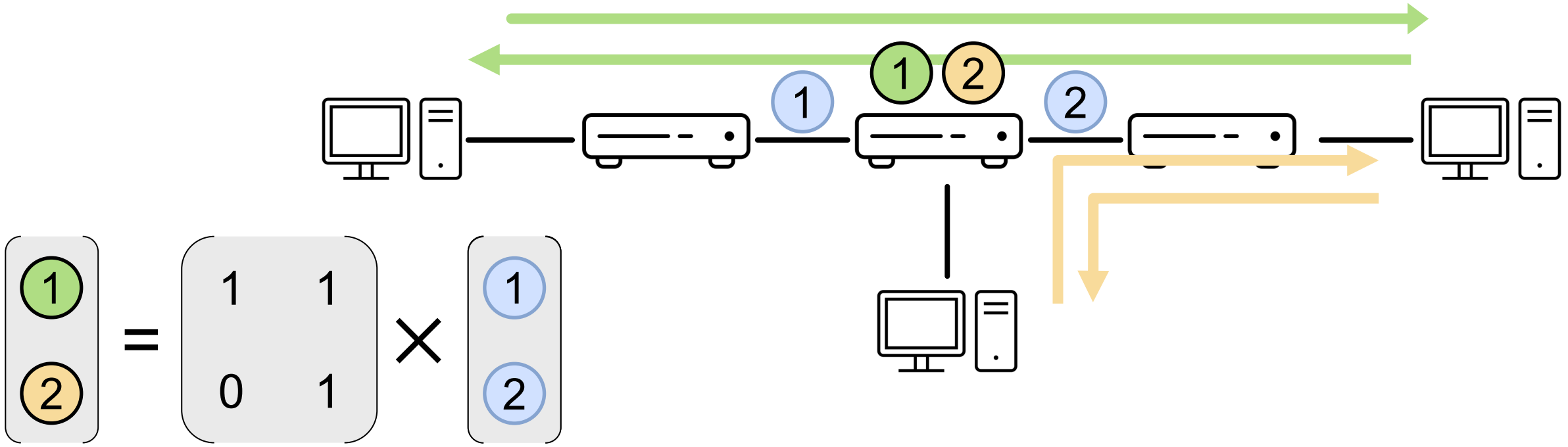

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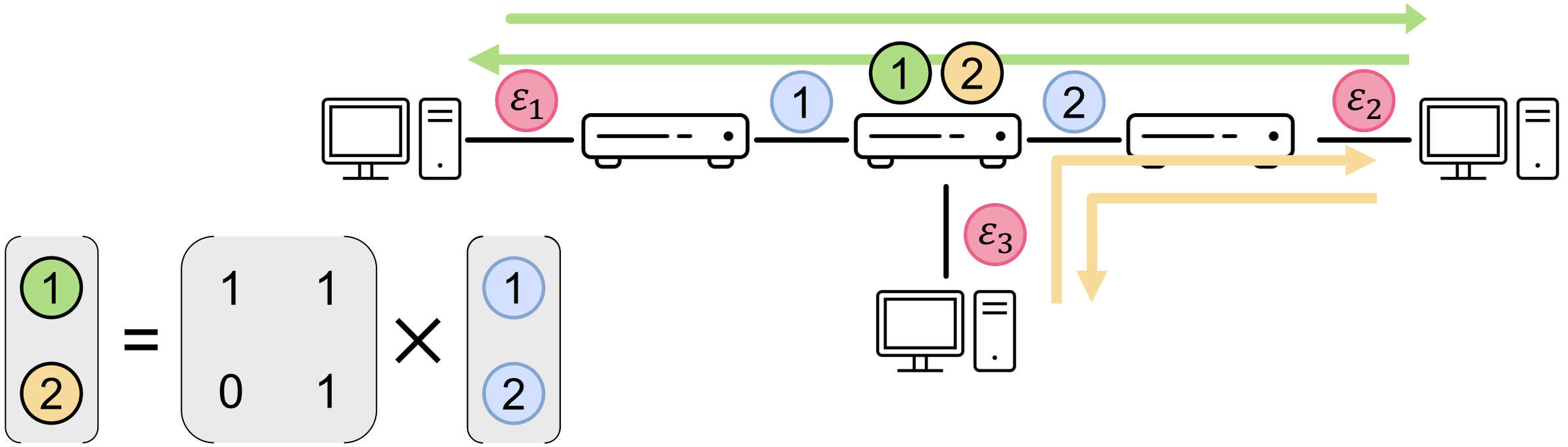

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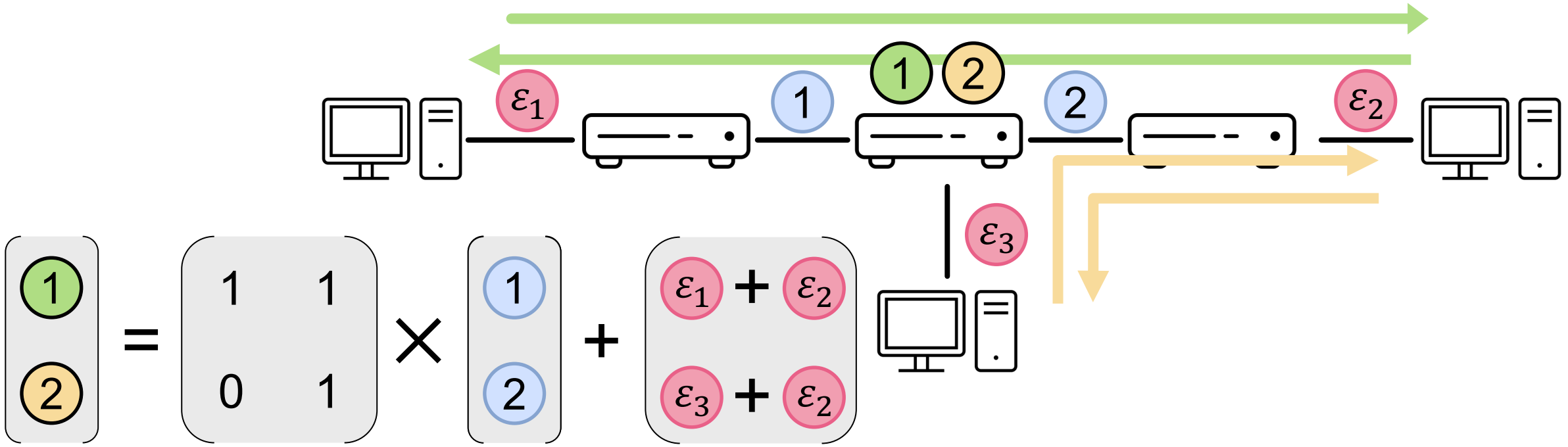

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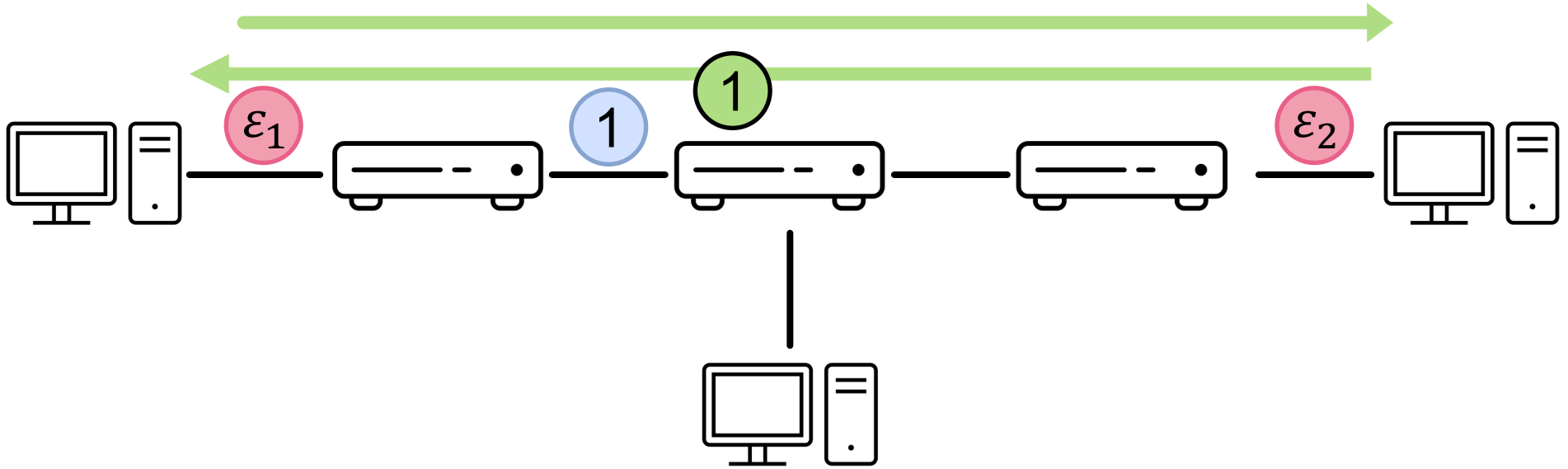

Ike Kunze (kunze@comsys.rwth-aachen.de)

Challenges for Network Tomography based on EFM

- Our network tomography design
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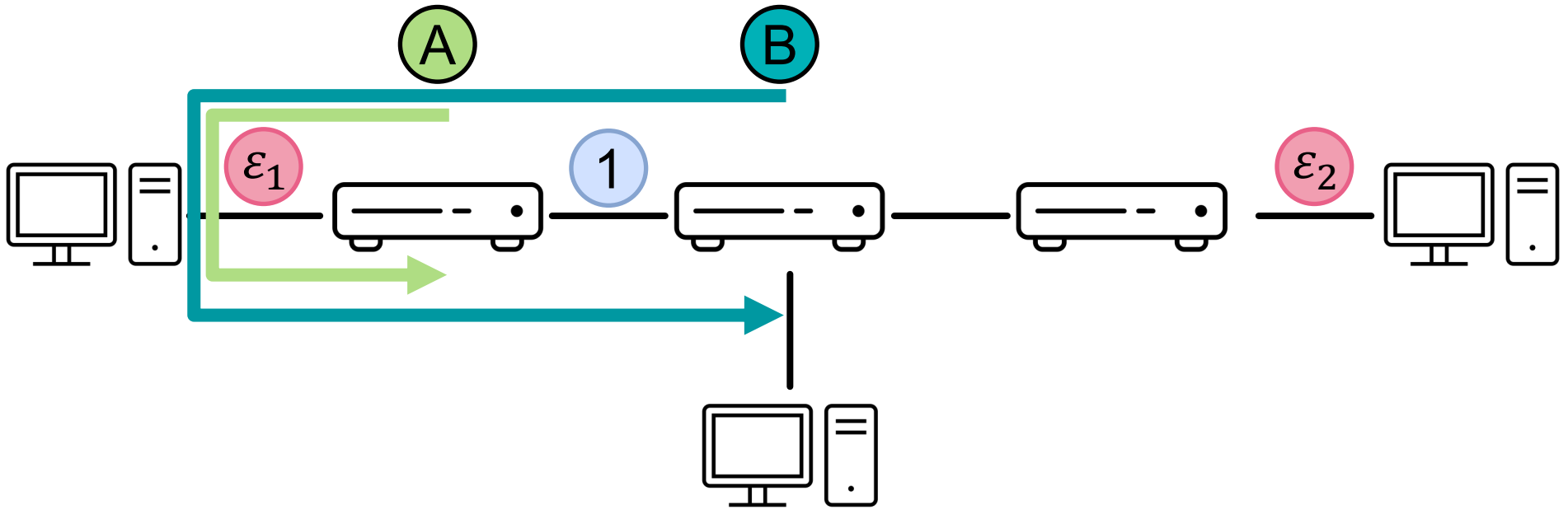

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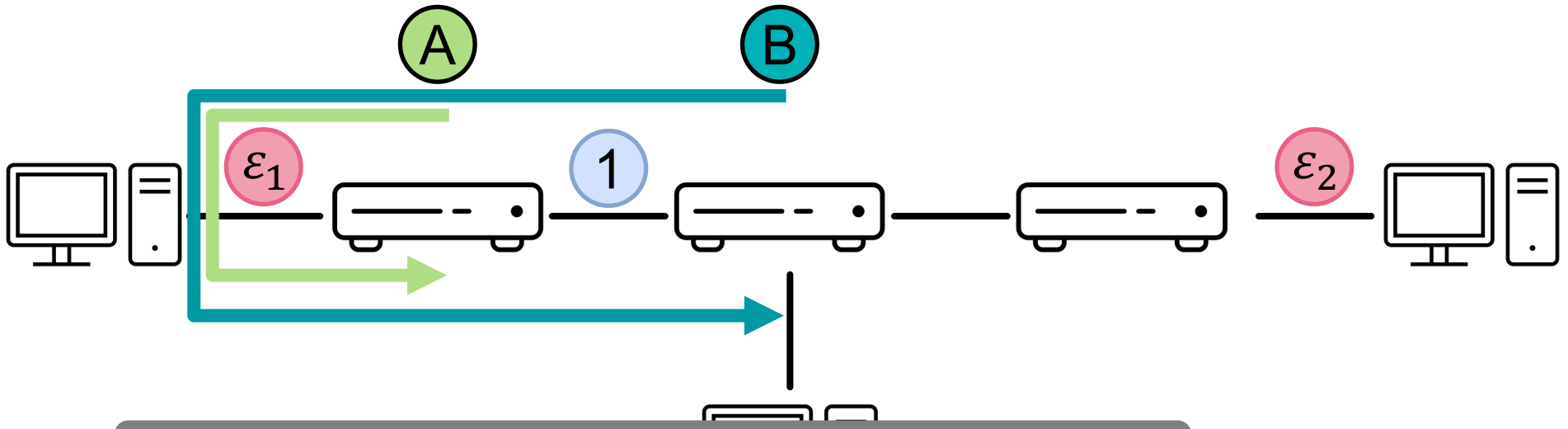

Can path segmentation capabilities of spin bit and Dart help?

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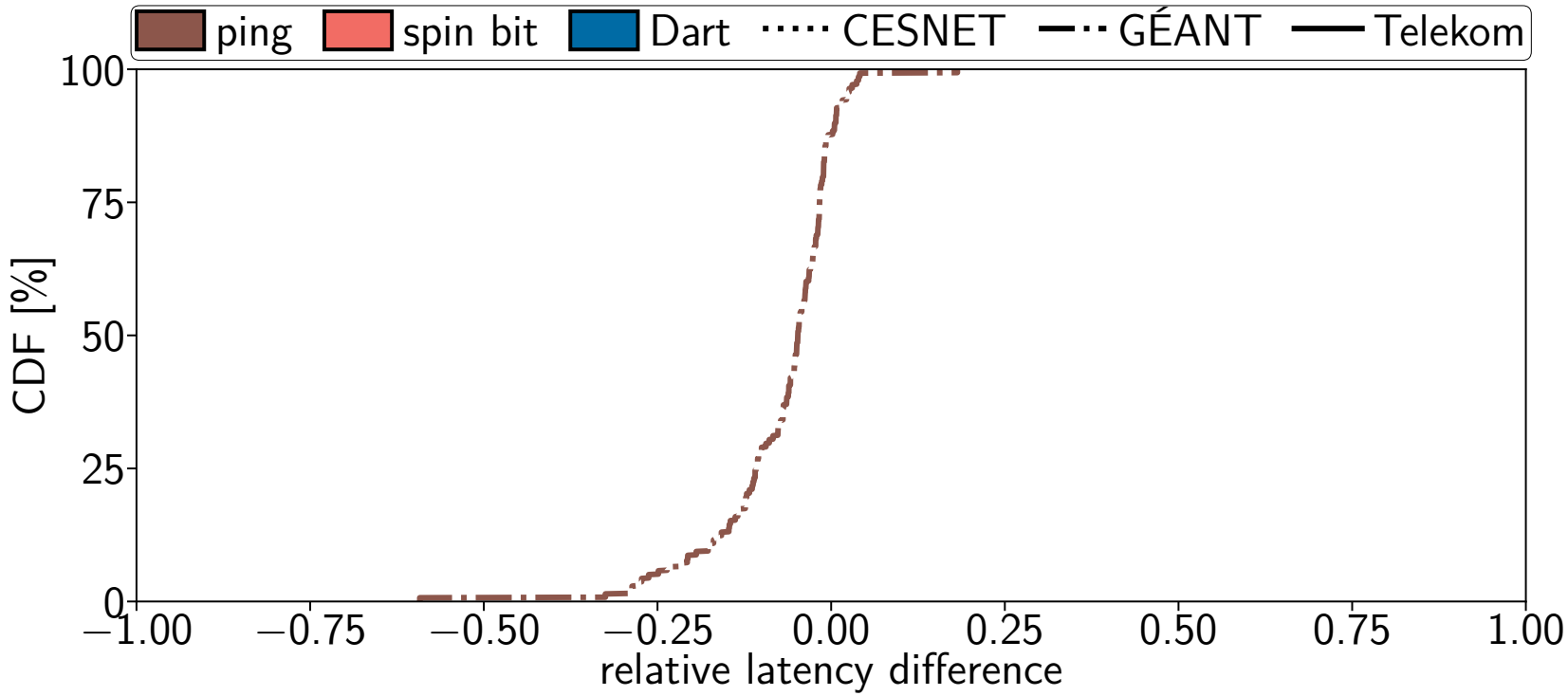
Latency Tomography with Path Segmentation

- Deduce configured latencies from measurements
  - GÉANT: Speed of light latency (0.2 - 9.5 ms)
  - CESNET, Telekom: 1ms on all links



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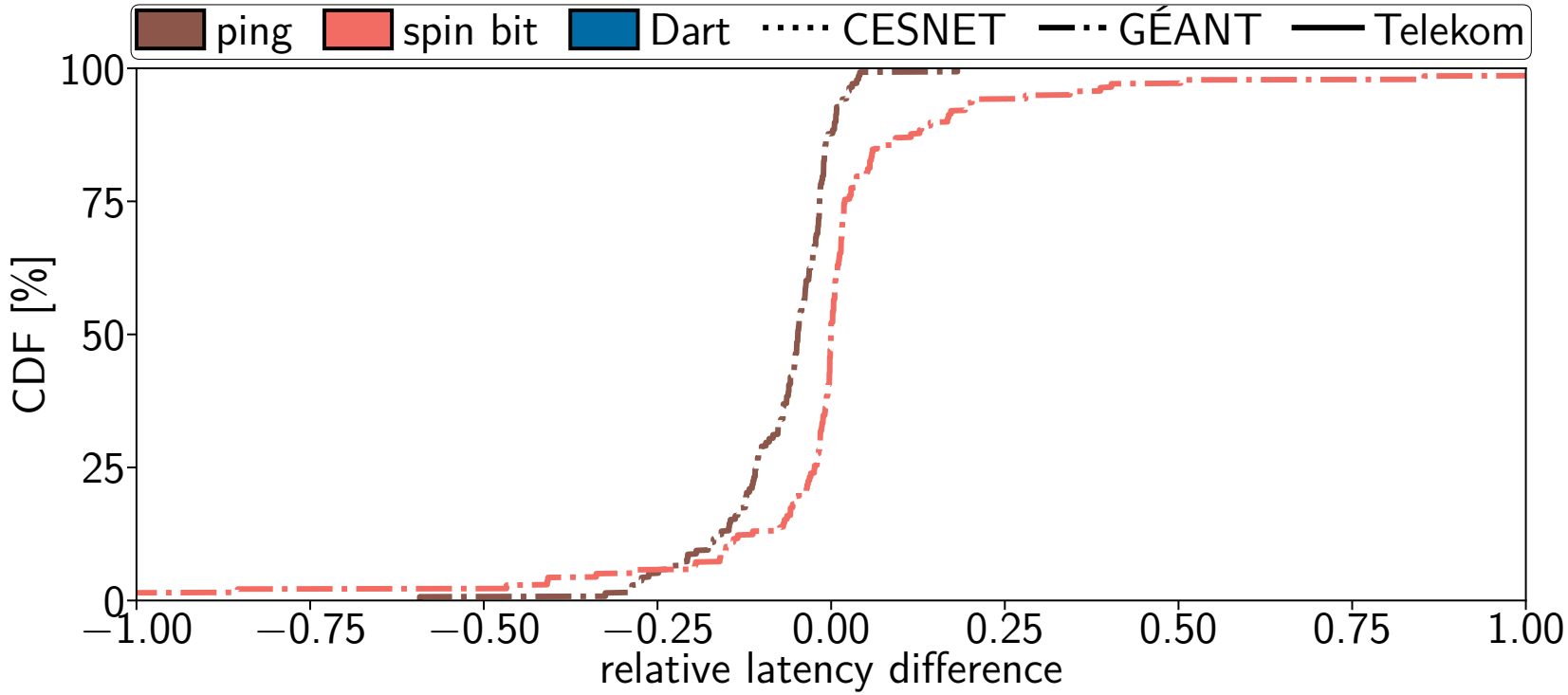

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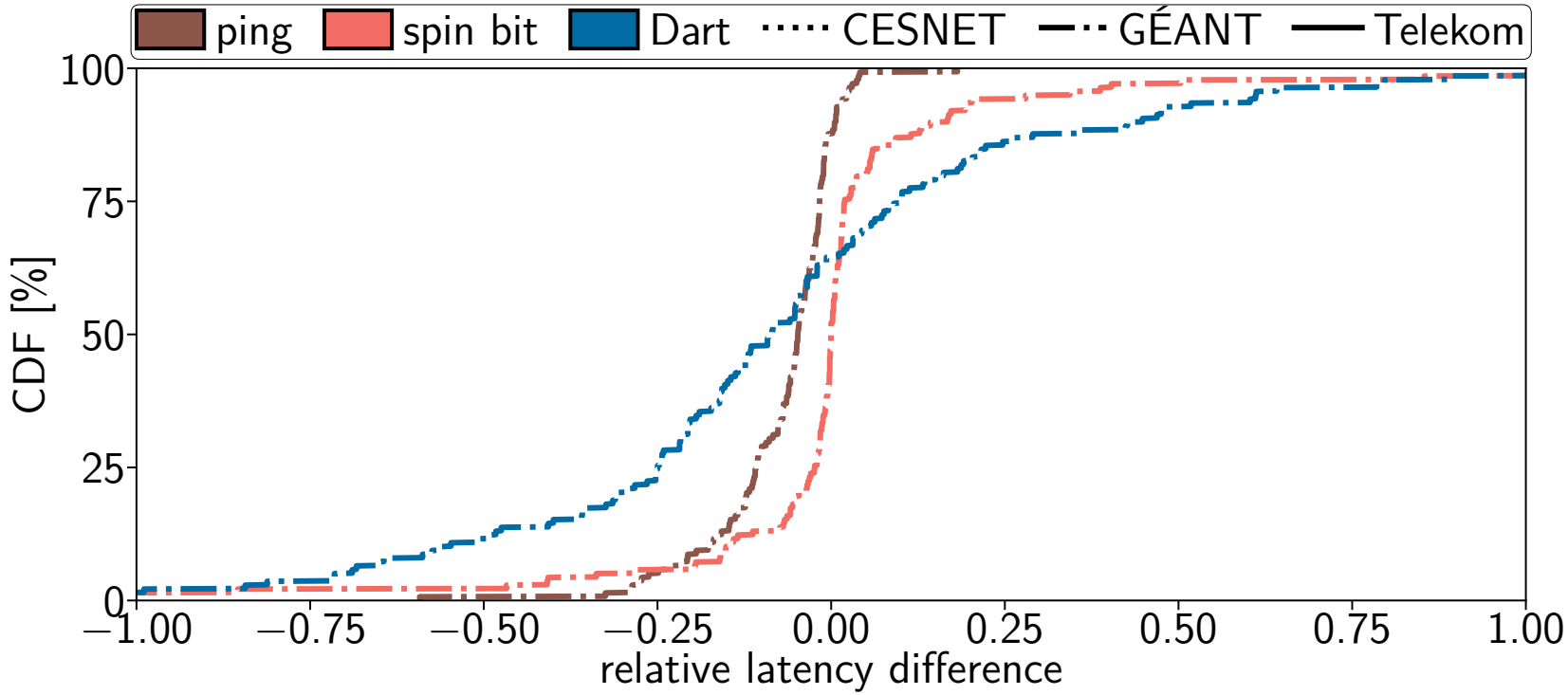

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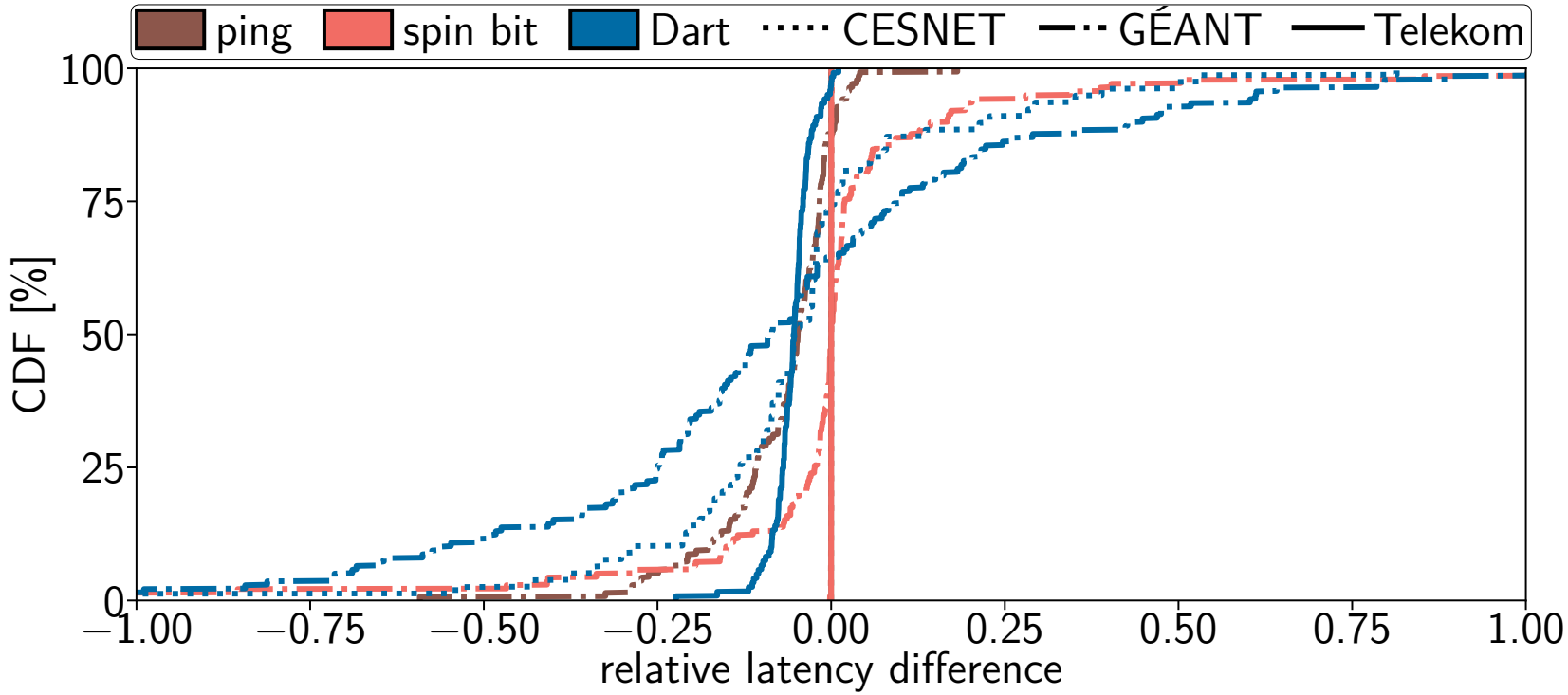

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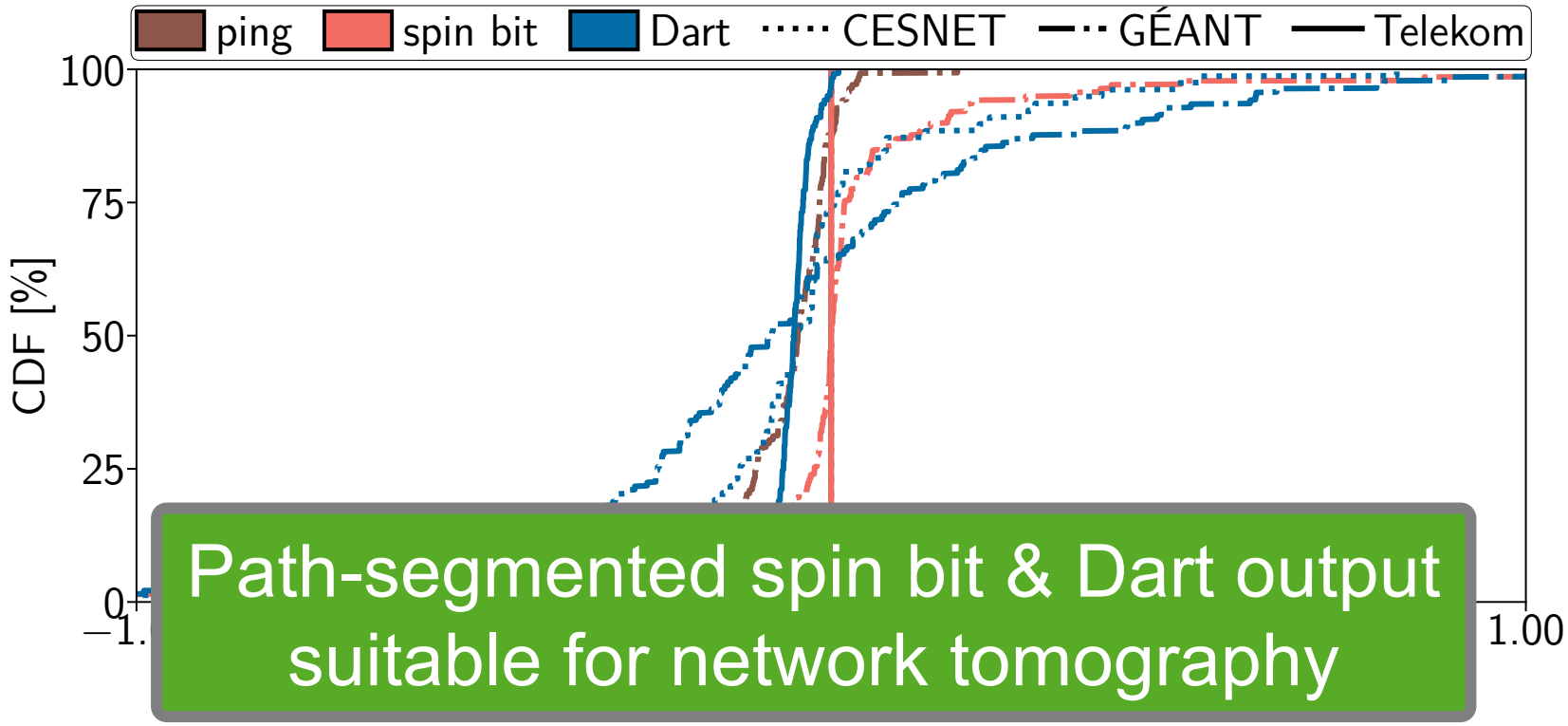

Path-segmented spin bit & Dart output suitable for network tomography

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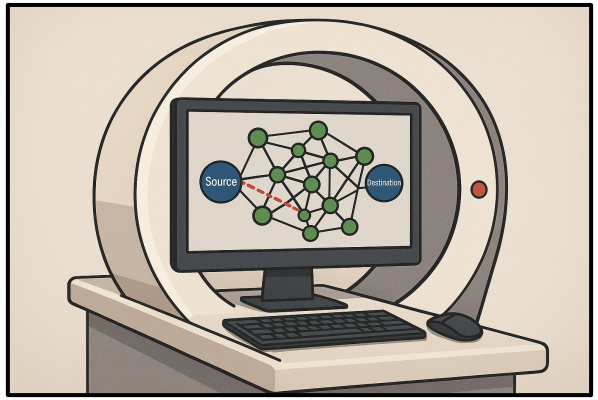
On Fueling Network Tomography with Explicit Flow Measurements



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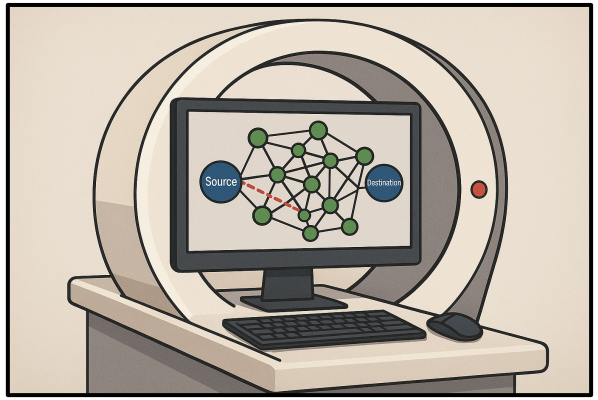

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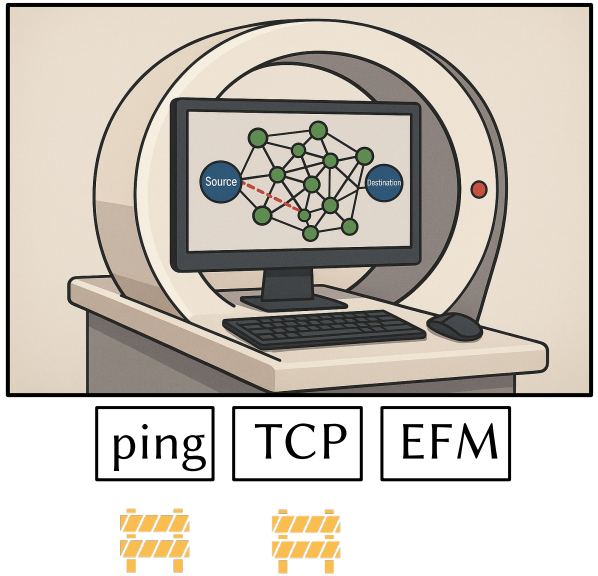

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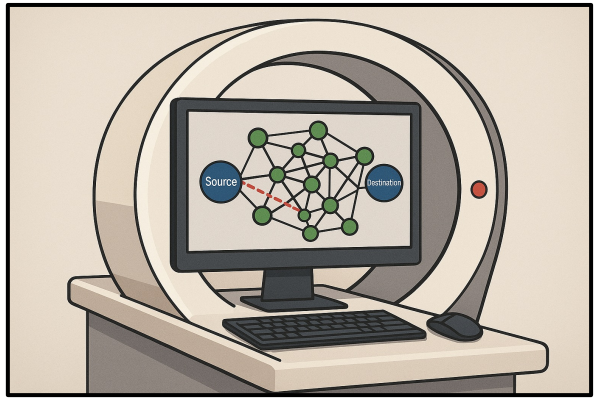

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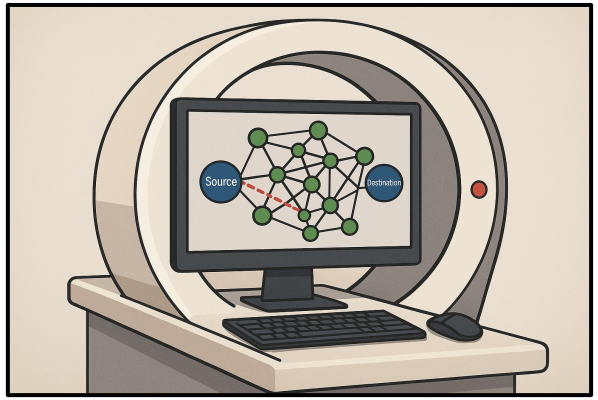

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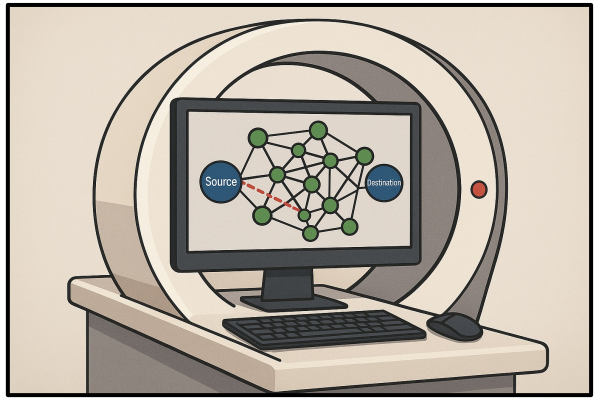

Upcoming dissertation: Combining EFM and Network Programmability for Network Management

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