Secure Maximum Weight Matching Approximation on General Graphs

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ENCRYPTO CRYPTOGRAPHY AND PRIVACY ENGINEERING

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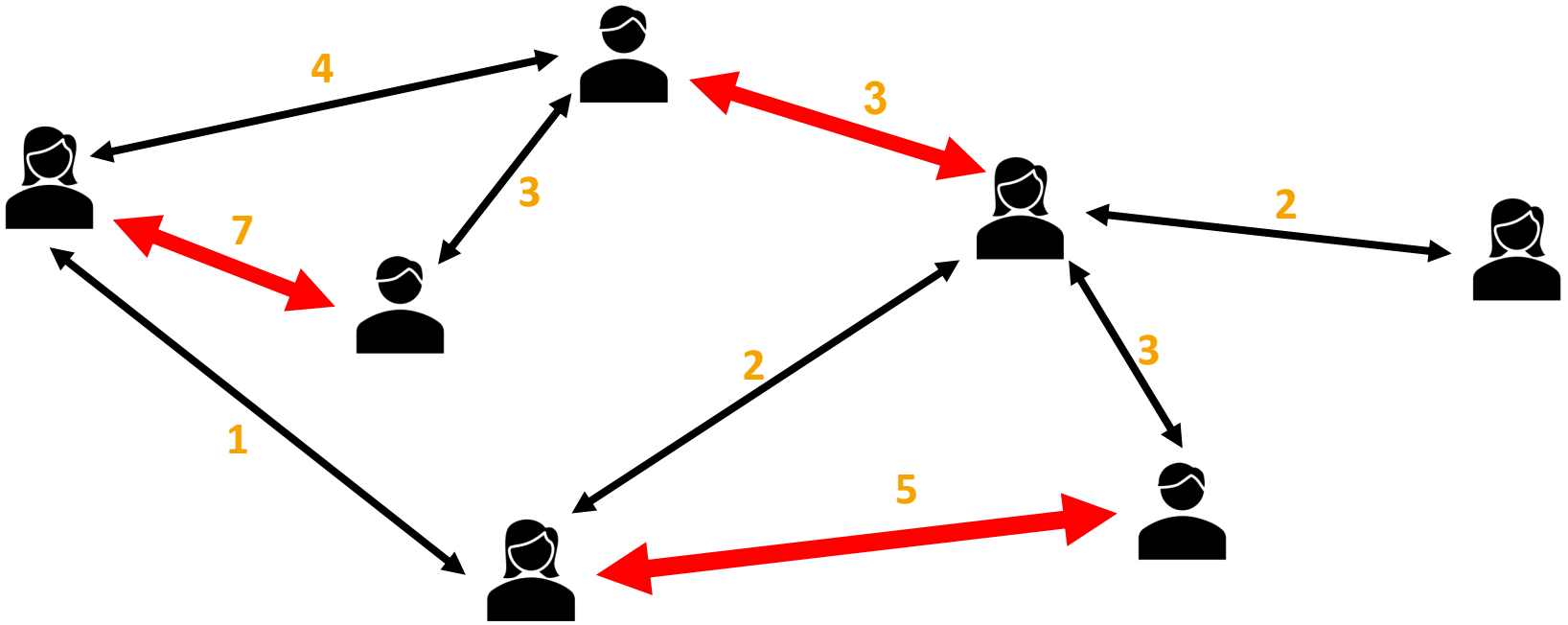

In This Talk

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- Maximum weight matching and its applications
- Privacy? → Secure Multi-Party Computation
- Approximation
- Observations & Results

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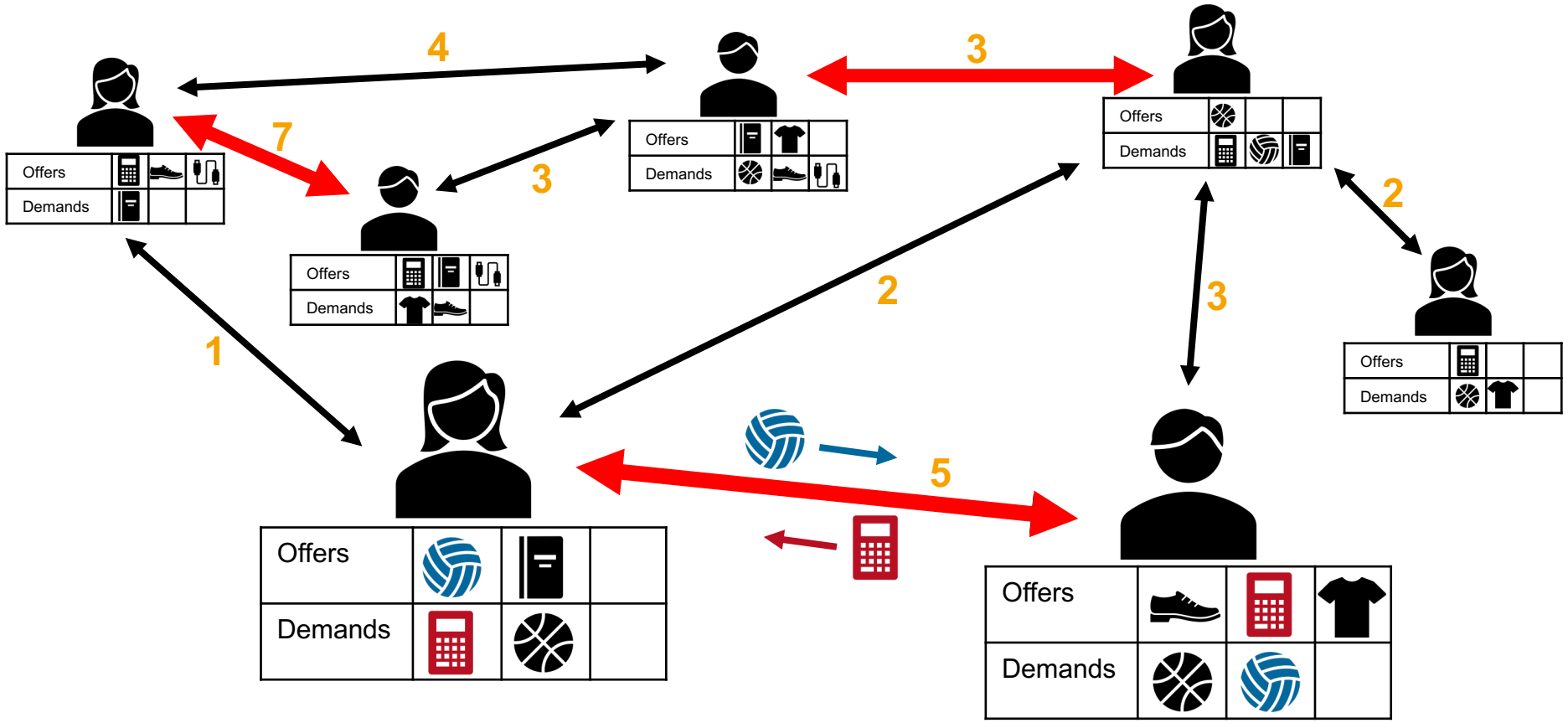
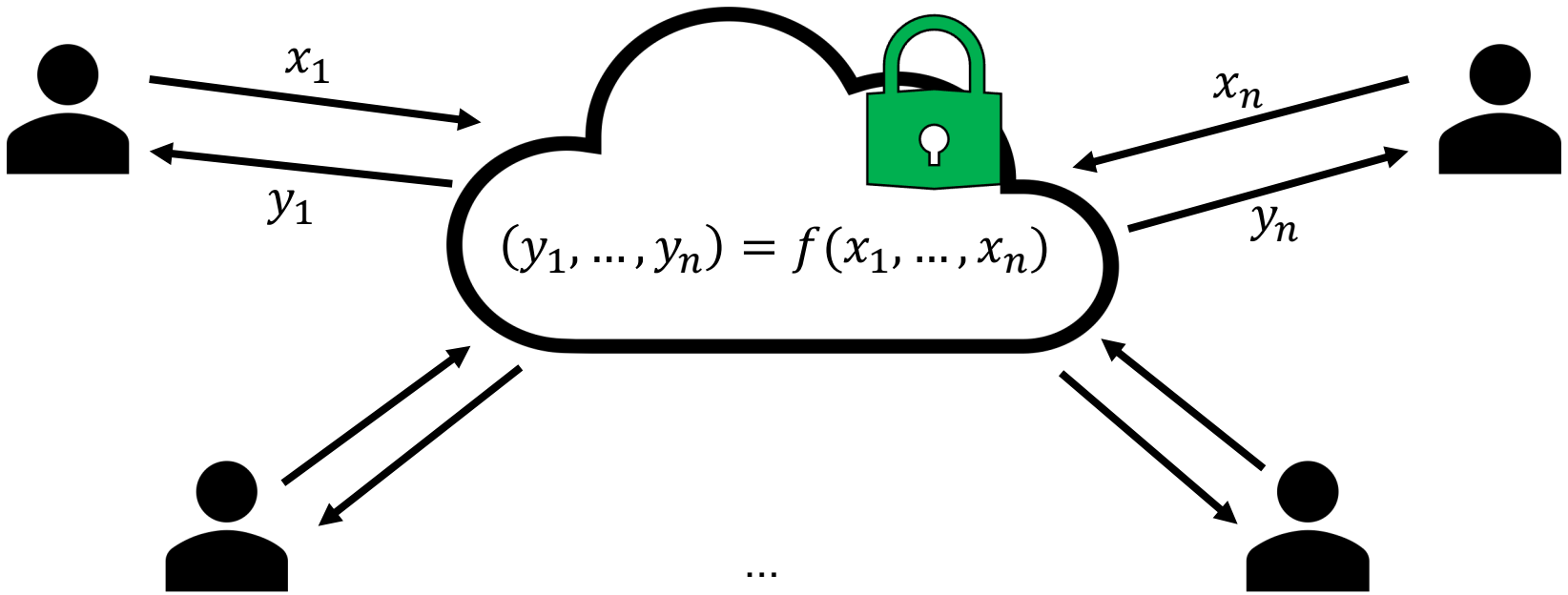
Maximum Weight Matching (for Bartering)



Privacy? → Secure Multi-Party Computation

- Bartering → Protect users' offers & demands
- Online dating → Protect users' sexual orientation, interests, …
- Kidney transplantation → Protect sensitive medical information



Related Work

- Prior research focused on MPC protocols for bipartite (i.e., between two groups) matchings, e.g., [BS15], [DES16]
- Only one protocol for general graphs (maximum matching) [BMW22]
  → $\mathcal{O}(N^5)$ communication, 127 h run time for $N = 60$ nodes in a LAN

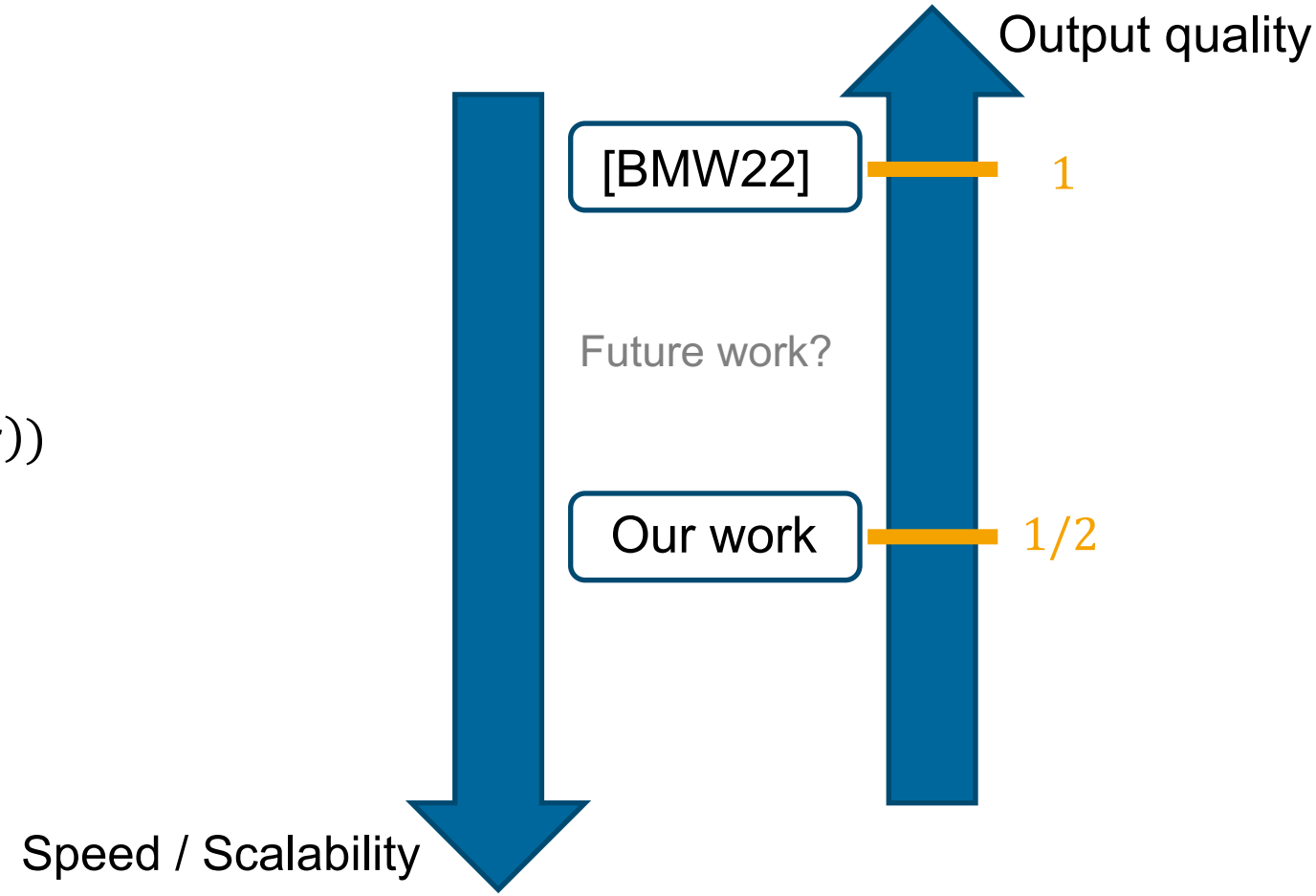
[BMW22] M. Breuer, U. Meyer, and S. Wetzel. **Privacy-Preserving Maximum Matching on General Graphs and its Application to Enable Privacy-Preserving Kidney Exchange.** In ACM CODASPY, 2022.

[BS15] M. Blanton and S. Saraph. **Oblivious Maximum Bipartite Matching Size Algorithm with Applications to Secure Fingerprint Identification.** In ESORICS, 2015.

[DES16] J. Doerner, D. Evans, and a. shelat. **Secure Stable Matching at Scale.** In ACM CCS, 2016.

Approximation: Compute a *Good* but not Optimal Solution

$$\text{gain}(\text{Alg}_{\text{exact}}(x)) \leq c \cdot \text{gain}(\text{Alg}_{\text{approx}}(x))$$



Approach: Greedy 1/2-Approximation

Greedy Algorithm [Avi83, Pre99]:

- Select heaviest edge, add to matching
- Delete this and all incident edges
- Repeat

Used Techniques

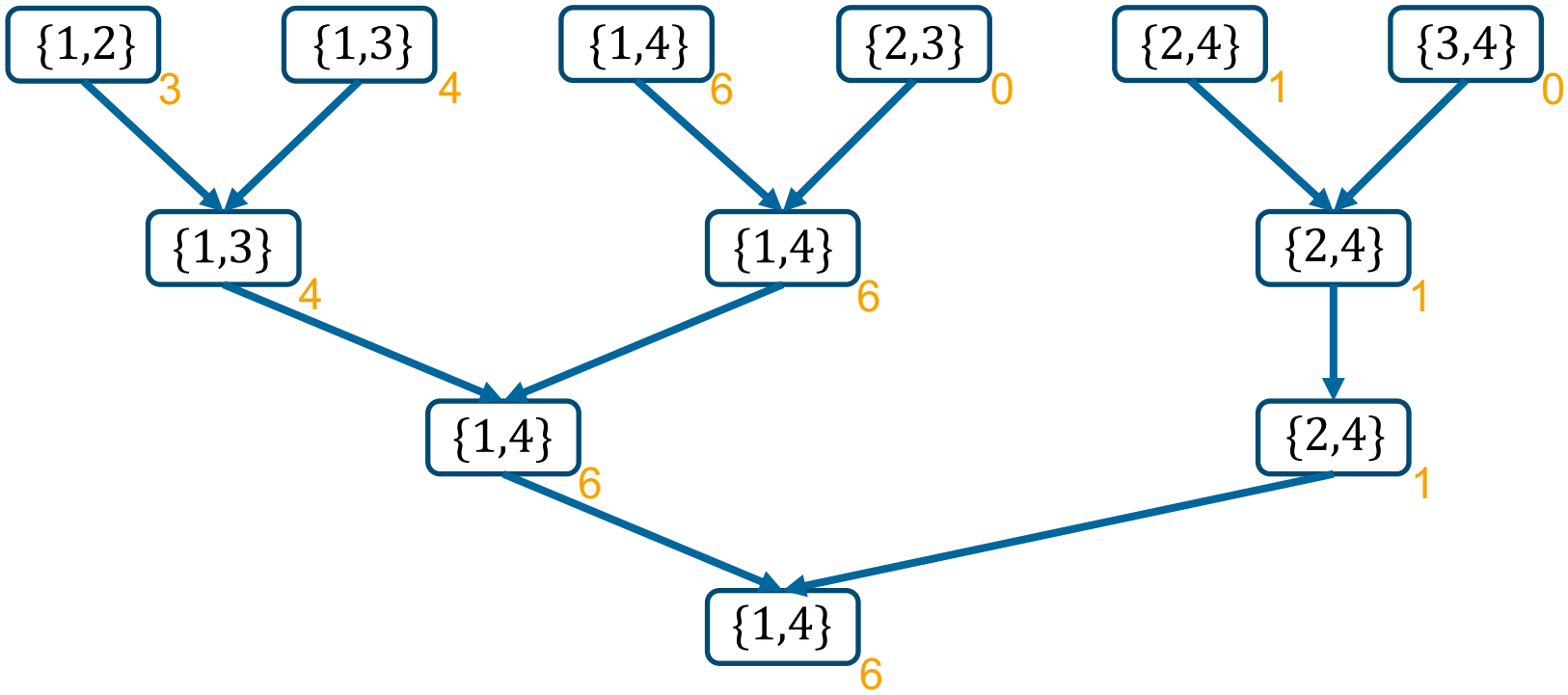
- Parallel reduction trees
- Randomization
- …

[Avi83] D. Avis. **A Survey of Heuristics for the Weighted Matching Problem.** In Networks (13), 1983.

[Pre99] R. Preis. **Linear Time 1/2-Approximation Algorithm for Maximum Weighted Matching in General Graphs.** In STACS, 1999.

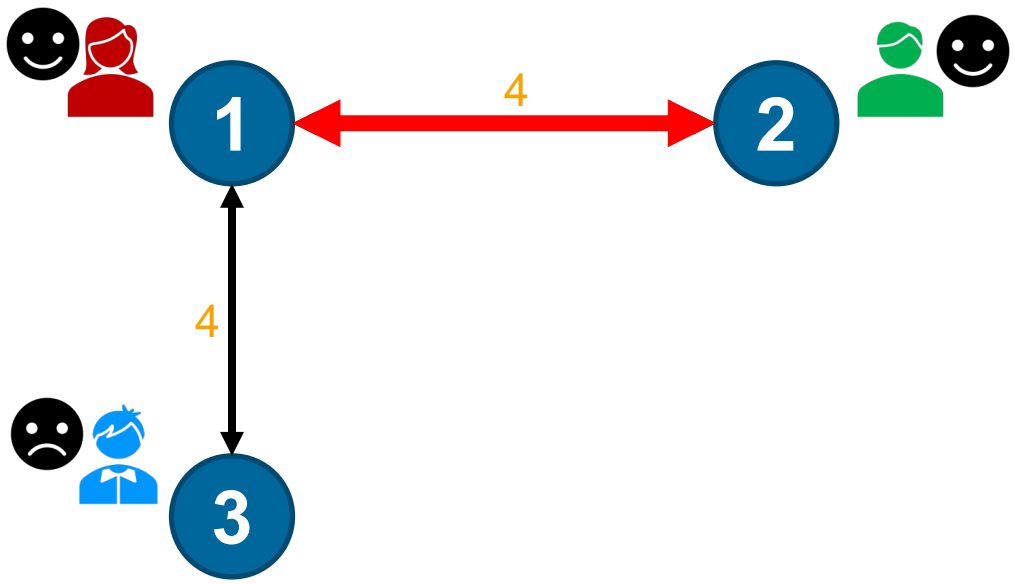
Parallel Reduction Trees

Searching heaviest edge: $\mathcal{O}(N^2)$ communication and rounds

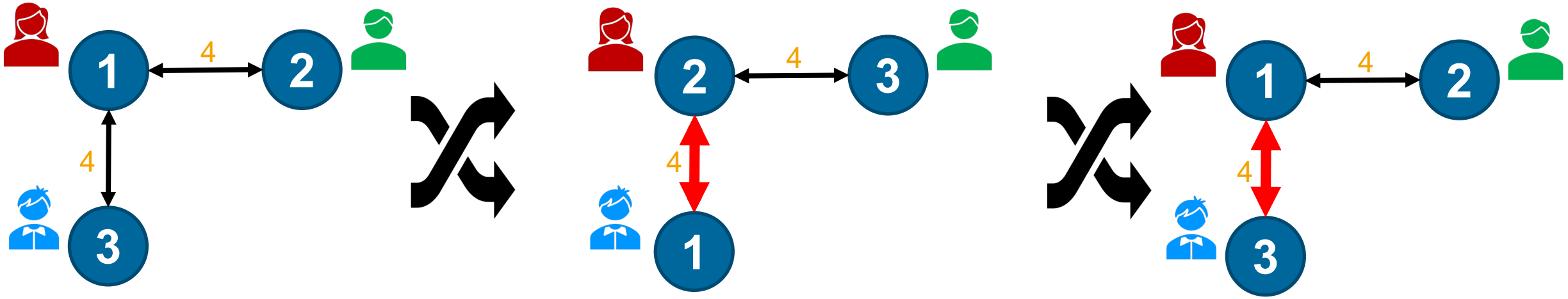


→$\mathcal{O}(N^2)$ communication, $\mathcal{O}(\log N)$ rounds

Node Label Bias



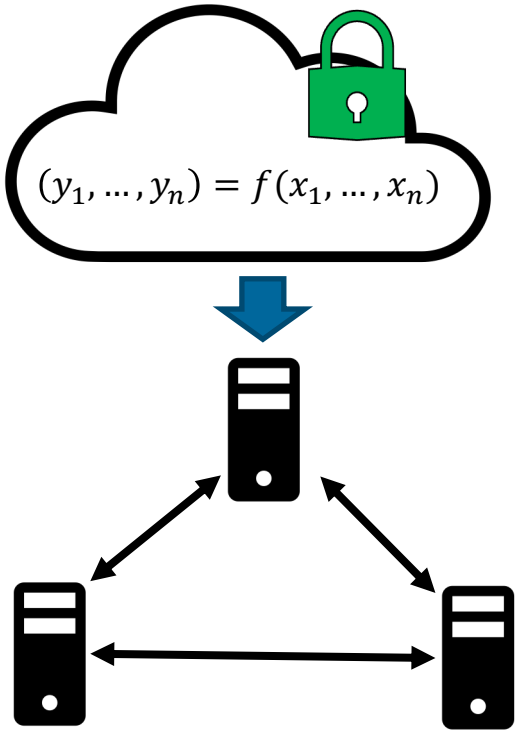
Randomization



Results I

- $\mathcal{O}(N^3)$ communication
- $\mathcal{O}(N \log N)$ rounds

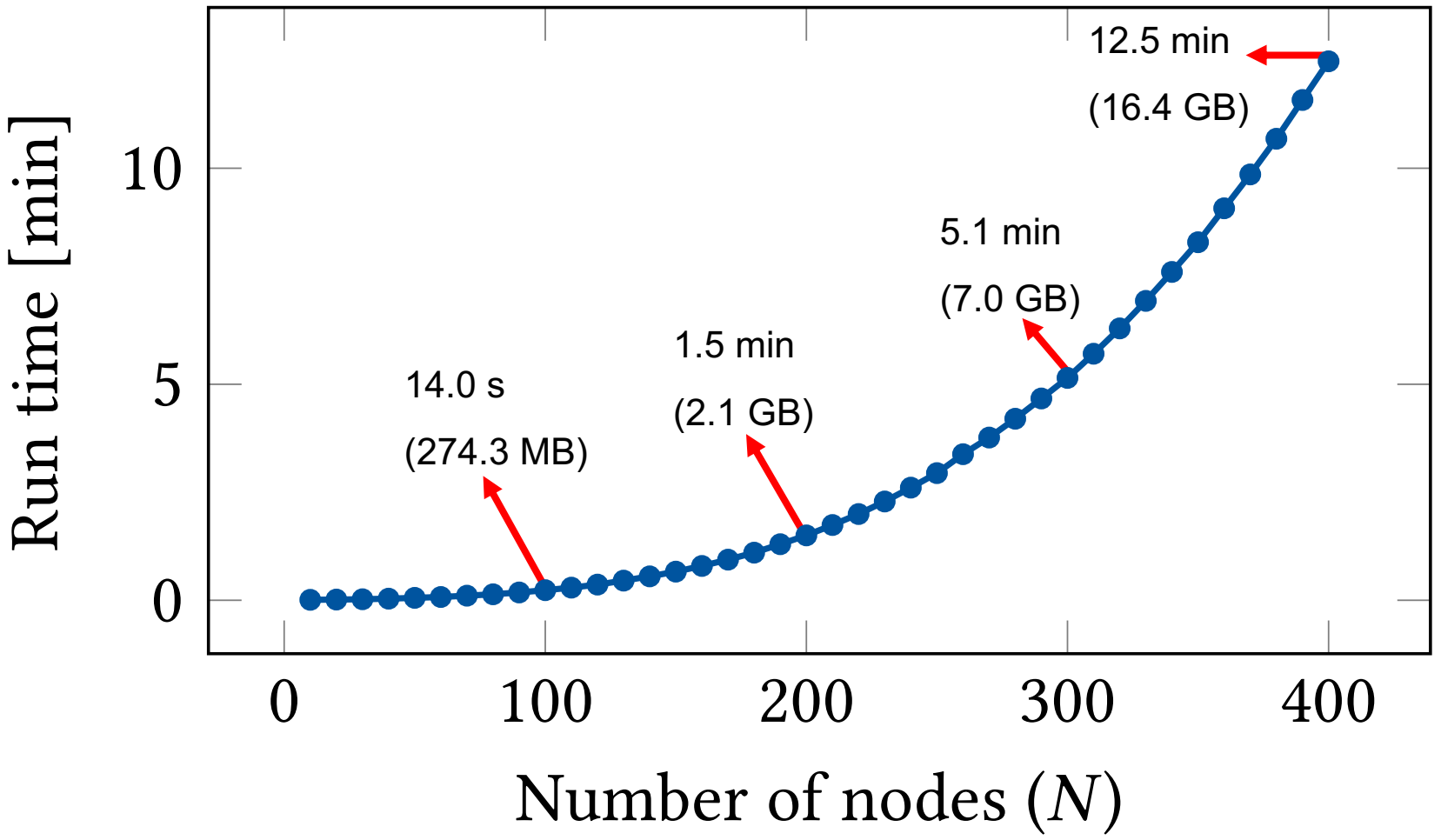
- Implementation in MP-SPDZ [Kel20]
- Three parties
- Replicated Secret Sharing [AFLNO16] (passive security)
- LAN setting: 1Gbit, 1ms RTT



[AFLNO16] T. Araki, J. Furukawa, Y. Lindell, A. Nof, and K. Ohara. **High Throughput Semi-Honest Secure Three-Party Computation with an Honest Majority.** In ACM CCS, 2016.

[Kel20] M. Keller. **MP-SPDZ: A Versatile Framework for Multi-Party Computation.** In ACM CCS, 2020.

Results II


Run time [min]
10
5
0
0
100
200
300
400
Number of nodes (N)
12.5 min
(16.4 GB)
5.1 min
(7.0 GB)
1.5 min
(2.1 GB)
14.0 s
(274.3 MB)

Thank you for your attention!

Paper (Full Version): https://eprint.iacr.org/2022/1173

Contact: https://encrypto.de/brueggemann

References

[AFLNO16] T. Araki, J. Furukawa, Y. Lindell, A. Nof, and K. Ohara. **High Throughput Semi-Honest Secure Three-Party Computation with an Honest Majority.** In ACM CCS, 2016.

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