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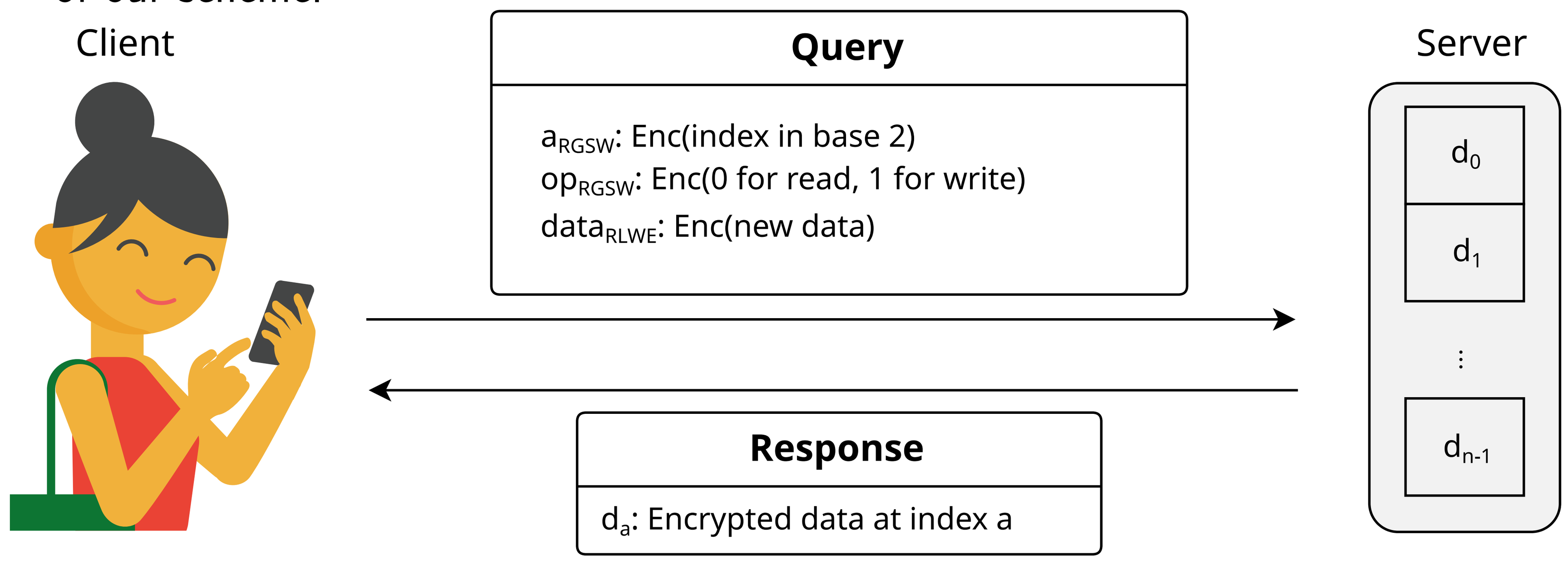
Panacea: Non-interactive and Stateless Oblivious RAM

Background and Motivation

- ORAM allows clients to obliviously read from or write to an encrypted database.
- But prior designs, e.g., [CCR19,SDSCF18], are interactive and/or stateful.
- Our goal is to design an ORAM protocol that can
  - Submit a query, go offline, and collect the server's response without interaction;
  - Query the same server from multiple devices without having to synchronize states;
  - Create batched read/write queries.

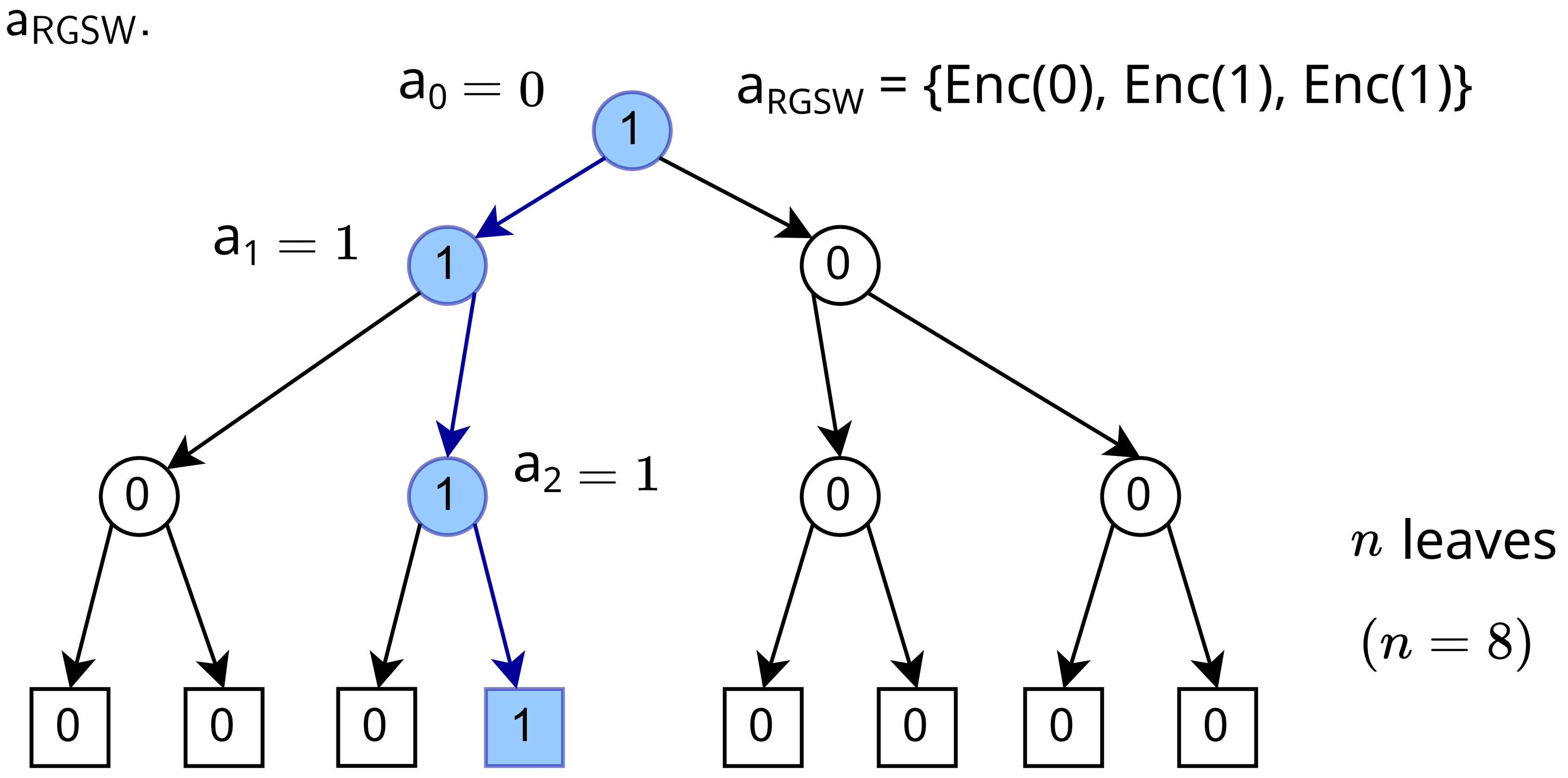
Our Result

- Panacea aims to achieve all goals above by leveraging FHE techniques and offloading all of the expensive computation to the server.
- We provide variants that support querying more than one data element at a time with significantly better amortized computational cost.
- Benchmarks of our proof of concept implementation demonstrate the practicality of our scheme.

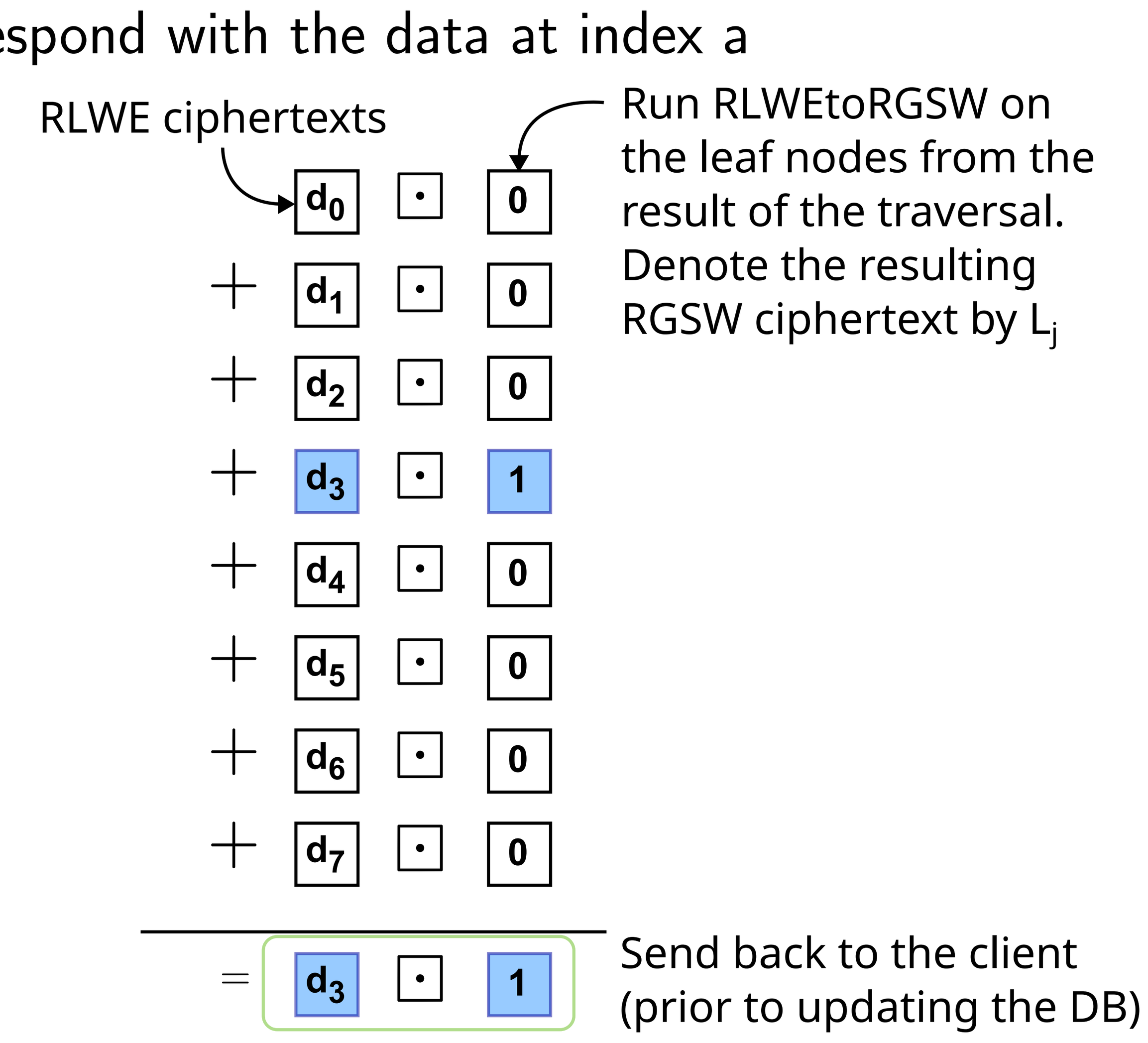


Response Phase (by the Server)

Step 1: Perform traversal to obtain a 1 at the index encrypted by a_{RGSW}.



Step 2: Respond with the data at index a



Update Phase

- Select data if the operation is write, otherwise the old data d_j

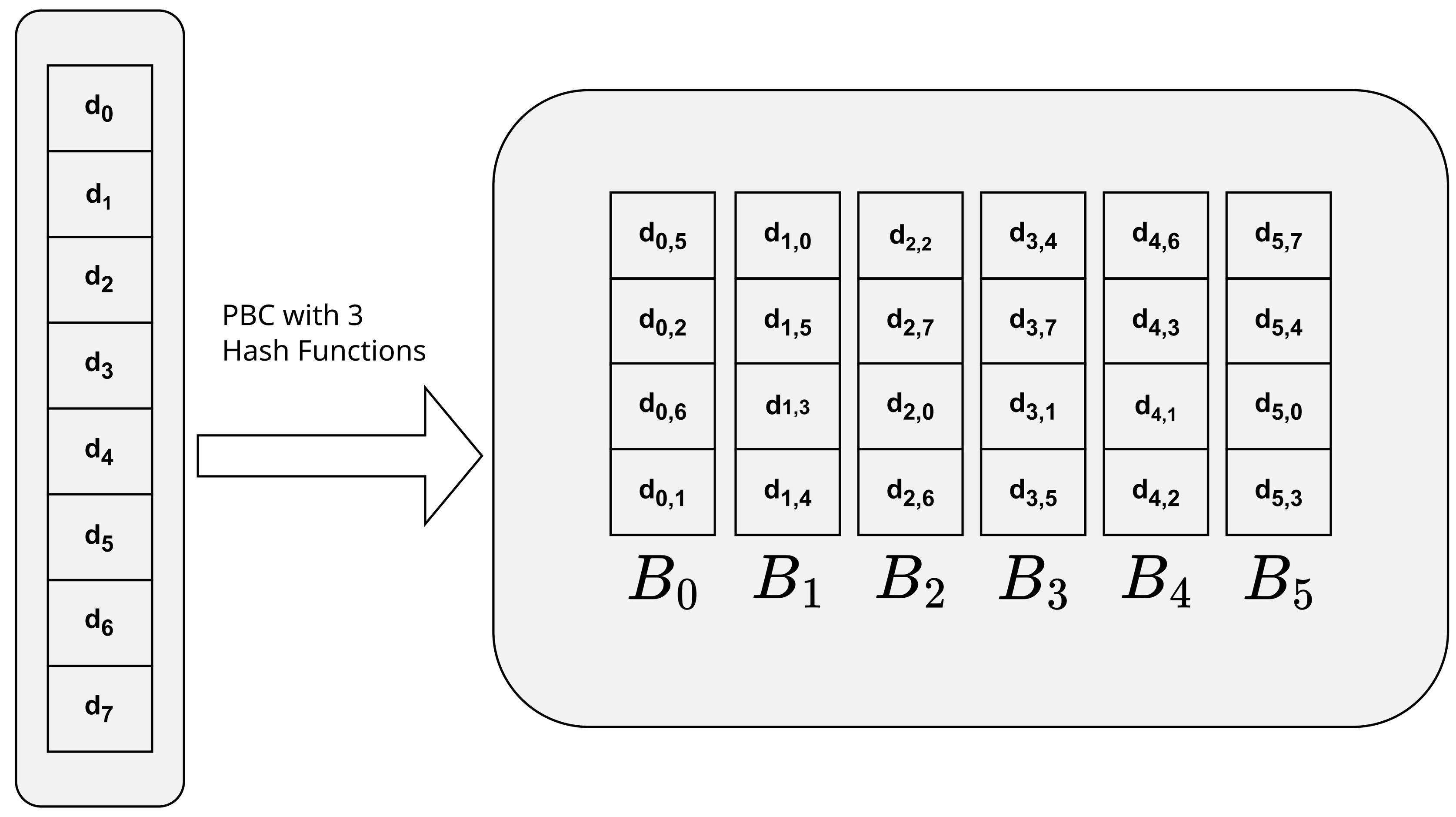
$$\mathrm{temp} \leftarrow \mathrm{CMUX}(\mathrm{op}, \mathrm{data}, d_j), j \in [n]$$

- Update the data on the leaf correspondent to a

$$d_j \leftarrow \mathrm{CMUX}(L_j, \mathrm{temp}, d_j)$$

Batching with PBCs

- The client can submit a batch of k queries at a time.
- The server needs to store $b = 1.5 \cdot k$ buckets (parameterized for correctness).
- Every data element is copied h times, where h is the number of hash functions.



Consistency Correction (Batch Only)

If one out of the three data elements $d_{i_1,j_1}, d_{i_2,j_2}, d_{i_3,j_3}$ is updated, the equation below outputs the updated element obliviously.

$$d_\iota^{new} = d_{i_1,j_1} \boxdot (1 - L_{i_1,j_1} \boxdot op_{i_1} - L_{i_2,j_2} \boxdot op_{i_2} - L_{i_3,j_3} \boxdot op_{i_3}) + (d_{i_1,j_1} \boxdot L_{i_1,j_1} \boxdot op_{i_1} + d_{i_2,j_2} \boxdot L_{i_2,j_2} \boxdot op_{i_2} + d_{i_3,j_3} \boxdot L_{i_3,j_3} \boxdot op_{i_3})$$

Implementation and Experimental Results

Our open source implementation is based on `concrete-core` [CJLOT20] and can be found at https://github.com/KULeuven-COSIC/Panacea.

n	Response Duration	Update Duration	Total Time
2^{12}	2.47 (0.0096)	1.01 (0.0004)	3.48 (0.014)
2^{14}	9.53 (0.037)	2.89 (0.011)	12.42 (0.049)
2^{16}	38.08 (0.15)	11.04 (0.043)	49.13 (0.19)
2^{18}	147.92 (0.58)	48.02 (0.19)	195.94 (0.77)
2^{19}	296.43 (1.16)	94.83 (0.37)	391.26 (1.53)

Table: Computation time in seconds required by the server for database size n, with n from 2^{12} to 2^{19}, for the size of the batch $k = 256$ with PBC. Numbers in brackets are the amortized cost.

References

[CGGI20] Chillotti, I., Gama, N., Georgieva, M., and Izabachène, M., "TFHE: Fast Fully Homomorphic Encryption Over the Torus," JoC, 2020.

[CCR19] Chen, H., Chillotti, I., and Ren, L., "Onion ring ORAM: Efficient constant bandwidth oblivious RAM from (leveled) TFHE," ACM CCS, 2019.

[SDSCF18] Stefanov, E., Dijk, M. V., Shi, E., Chan, T.-H. H., Fletcher, C., Ren, L., Yu, X., and Devadas, S., "Path ORAM: An Extremely Simple Oblivious RAM Protocol," J. ACM, 2018

[CJLOT20] Chillotti, I., Joye, M., Ligier, D., Orfila, J.-B., Tap, S., "CONCRETE: Concrete Operates oN Ciphertexts Rapidly by Extending TfhE," WAHC, 2020

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