FABLE: Batched Evaluation on Confidential Lookup Tables in 2PC

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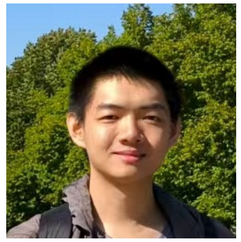
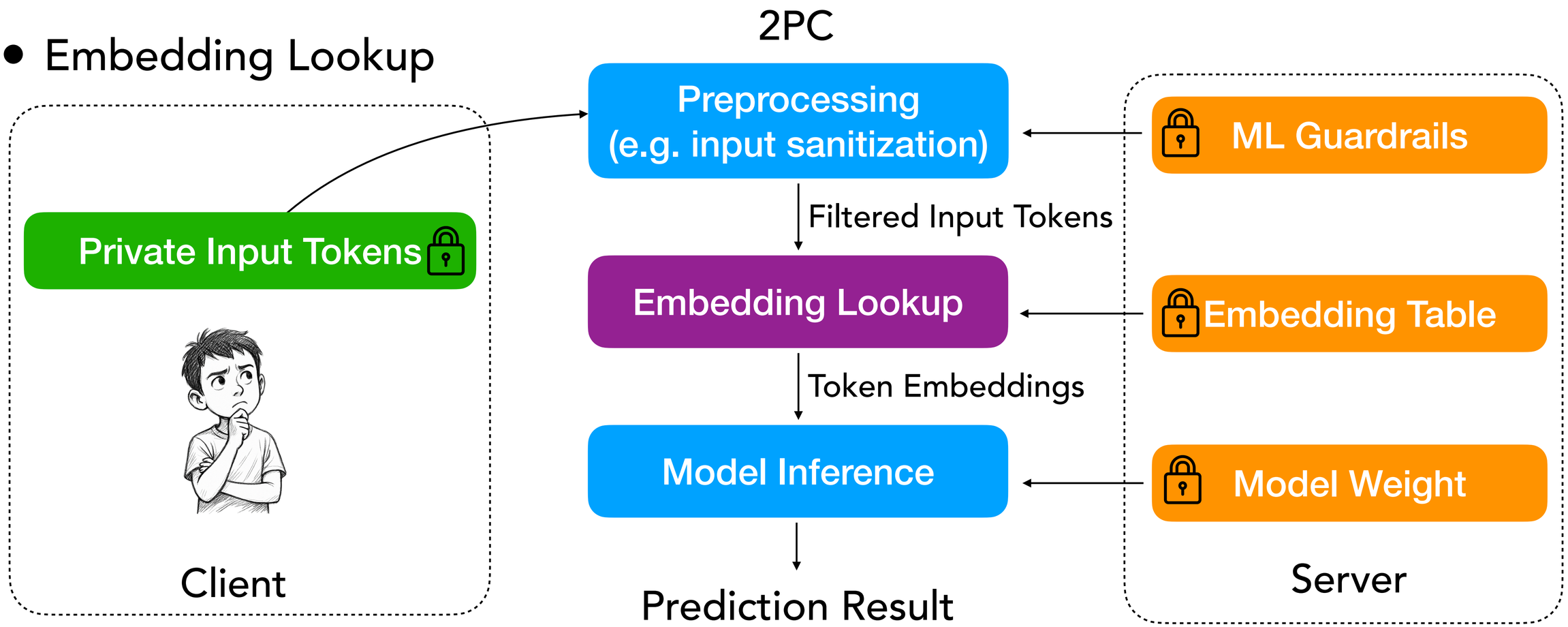


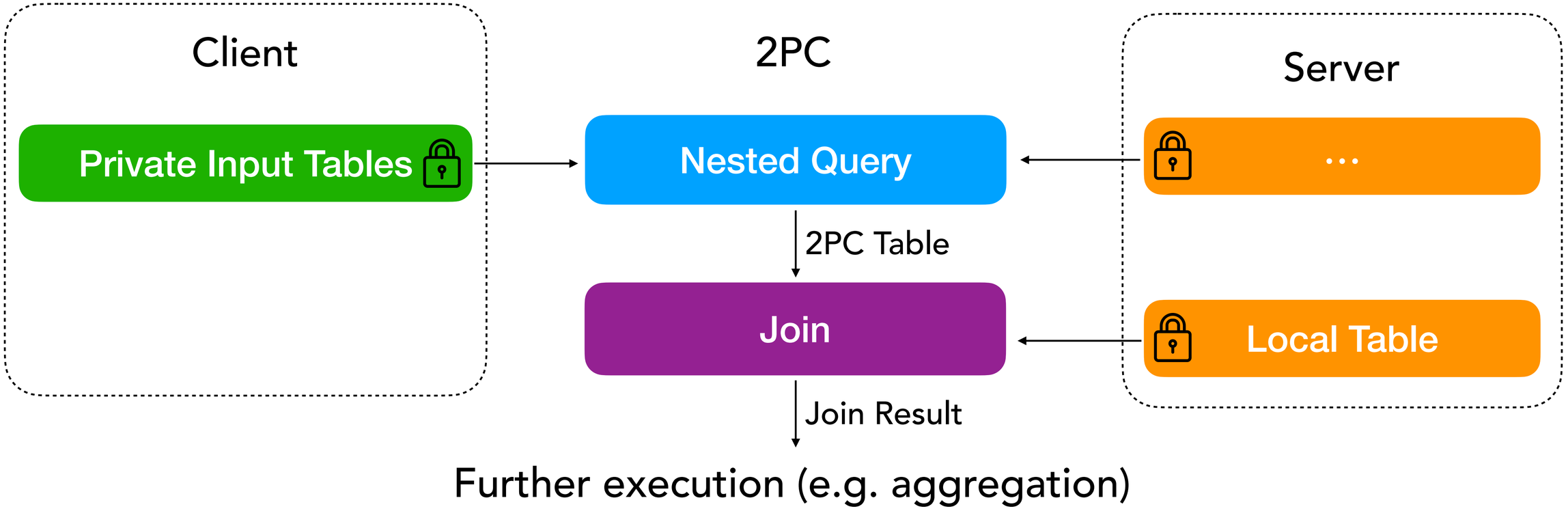

Secure LUT Evaluation is Commonly Used in 2PC

- Embedding Lookup



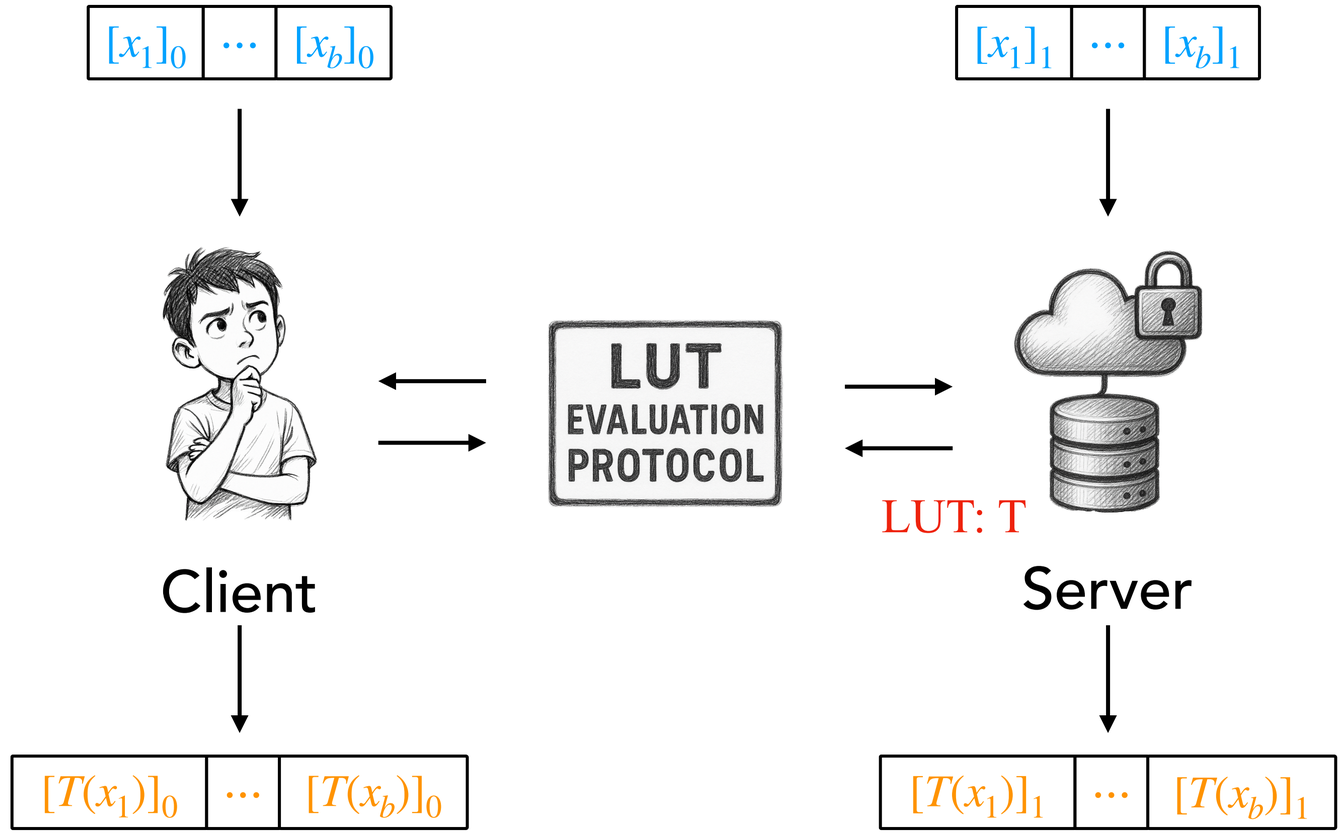
Secure LUT Evaluation is Commonly Used in 2PC

- Query Execution



Setting & Threat Model

- Semi-honest parties
- Server has the confidential LUT
- Server and client hold a batch of secret shared inputs in 2PC
- Server and client obtain batched secret shared outputs in 2PC



Prior Works

- LUT as a 2PC primitive[IKM+13, DKS+17, BHS+23]
  - Target small and public LUTs
  - Communication linear/superlinear in table sizes
- Distributed ORAM's read[DS17, VHG23]
  - Target two-server settings

Not scalable & LUT is not confidential

Heavyweight client

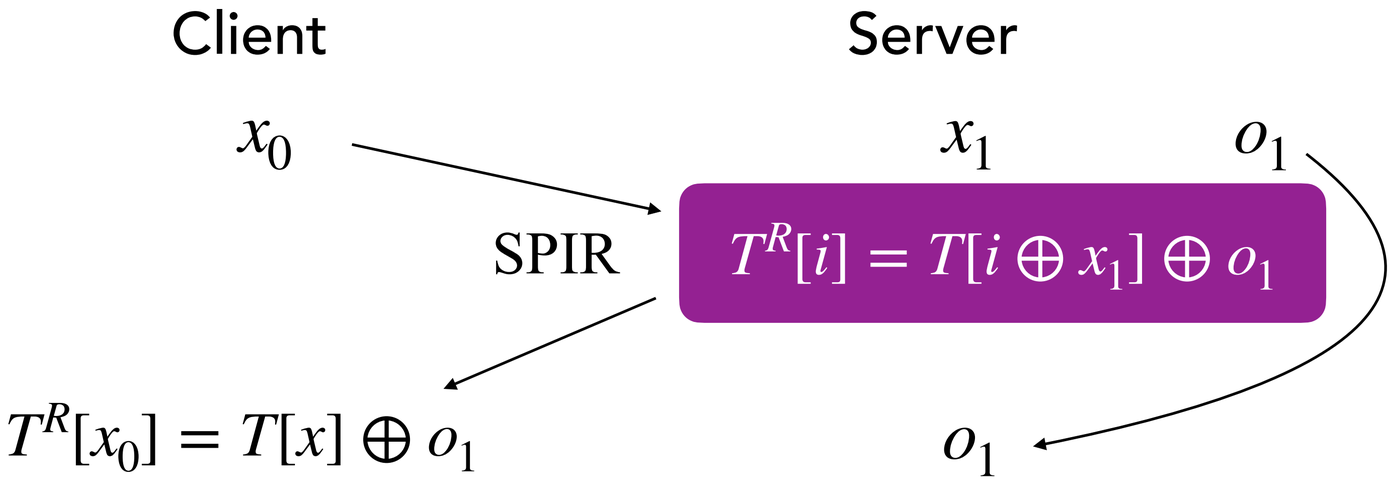
Can we design a secure LUT evaluation protocol that can scale to **large tables**, guarantee **LUT confidentiality**, support **lightweight client** and have **concrete server efficiency**?

Our Solution — FABLE

- Our idea: PIR + symmetric security + batching techniques
  - PIR: scalability and client lightweightness
  - Symmetric security: LUT confidentiality
  - Batching: concrete efficiency

PIR-based LUT Evaluation — A Naive Construction

- A variant of 2P-DUORAM[VHG23]
- Pros
  - Sublinear communication
  - Lightweight client
  - LUT confidentiality
- Cons: poor concrete performance
  - Table needs to be re-prepared for every input

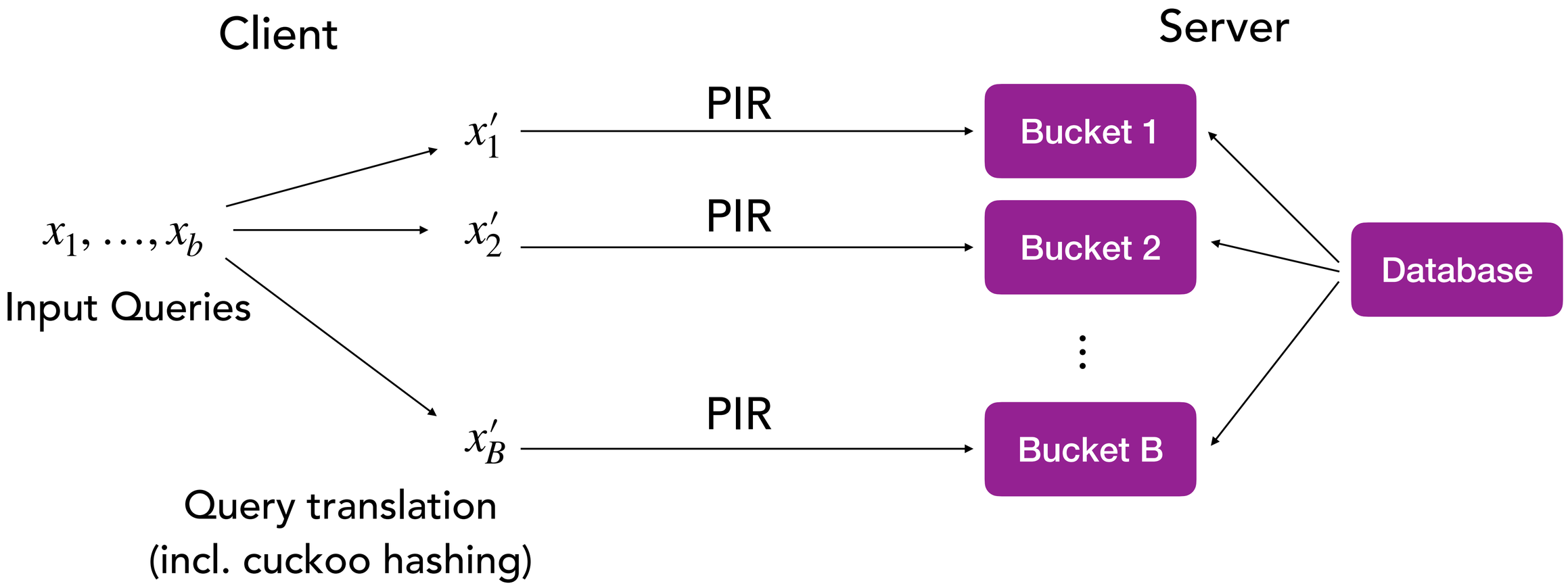


Insight: Batching is a Common Workload!

- Embedding Lookup
  - A piece of text contains hundreds of words
  - Embedding lookup receives a large batch of tokens
- Query Execution
  - Tables normally have thousands of rows
  - Table join = LUT lookup for each row

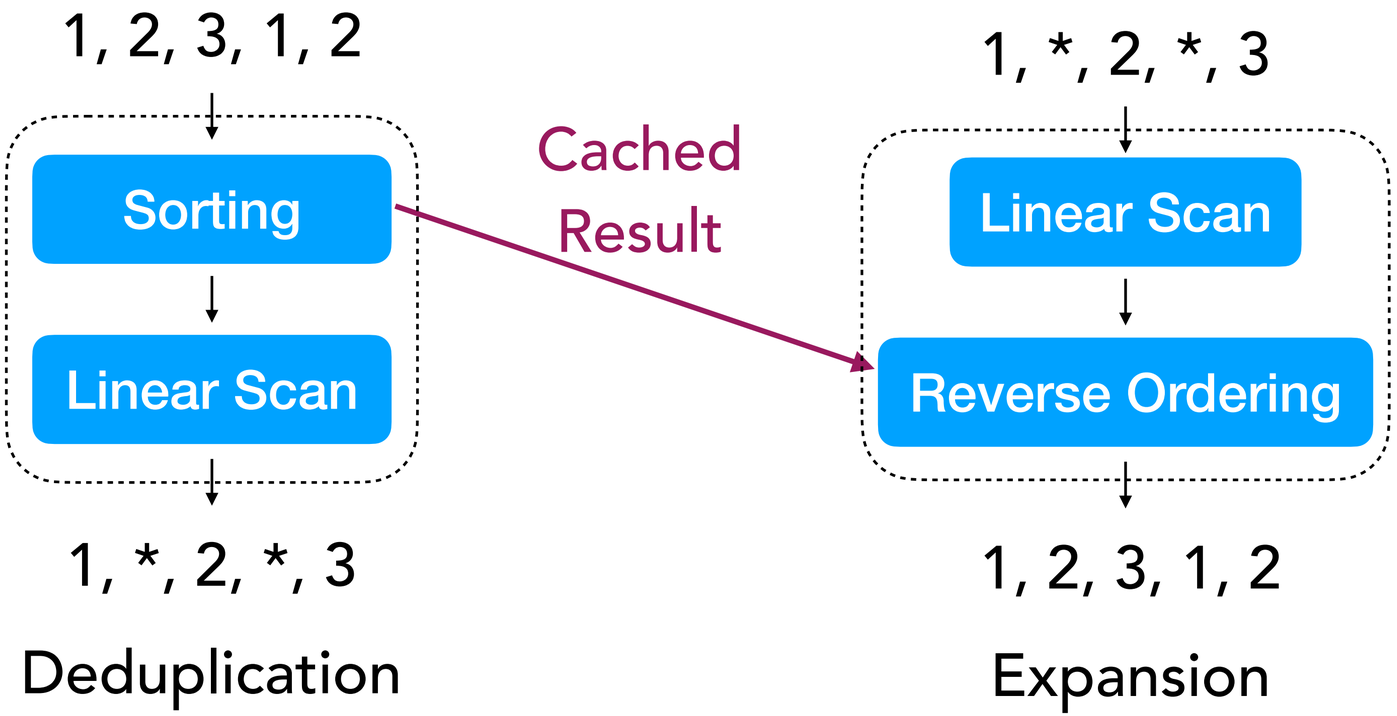
LUT evaluation protocol based on batch PIR for better amortized performance!

Overview of Batch PIR



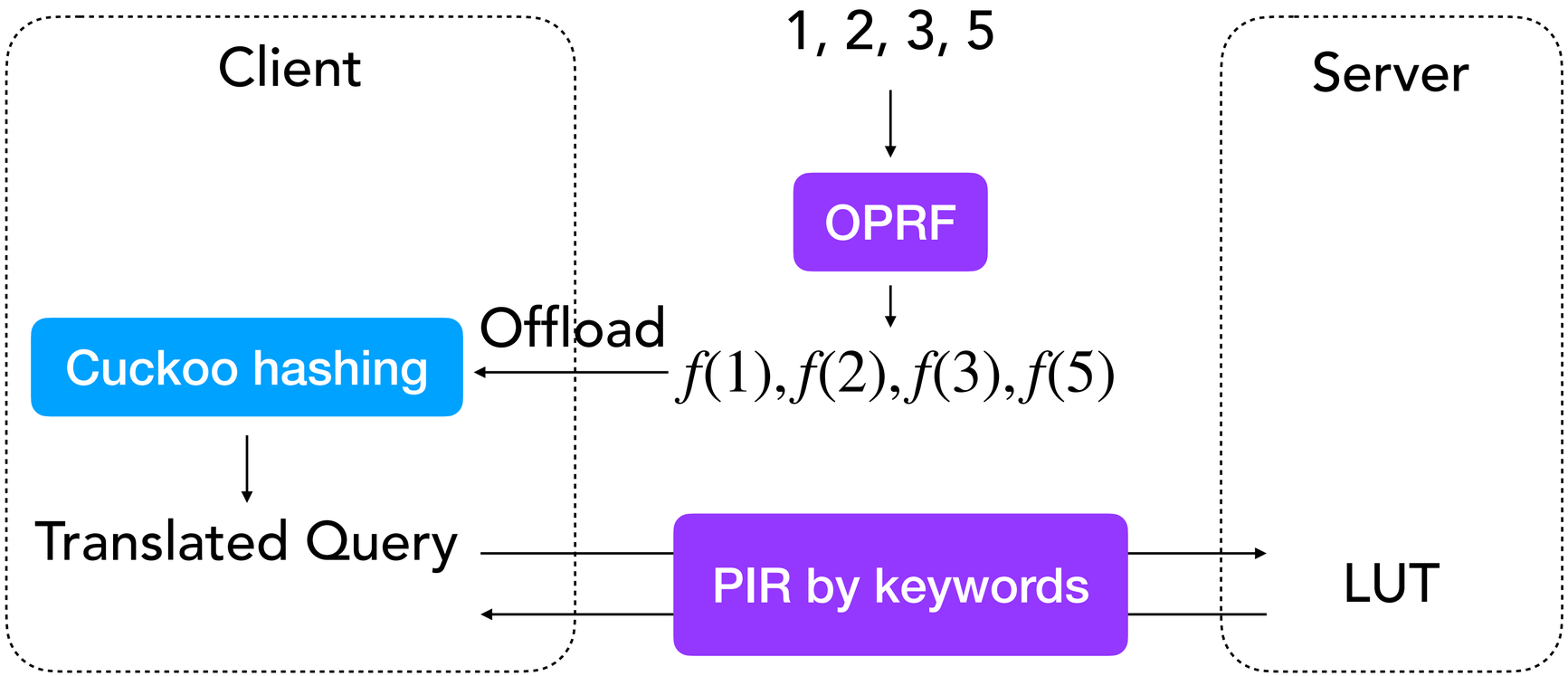
Challenge 1. Efficient Query Translation in 2PC

- Input needs to be deduplicated
  - Novel protocols with caching to avoid recomputation
  - Saved 84.1% comm.



Challenge 1. Efficient Query Translation in 2PC

- Input needs to be deduplicated — Novel protocols with caching
- Cuckoo hashing in 2PC is impractical — Offloading + PIR by keywords



Challenge 2. Protect LUT’s Confidentiality

- SOTA Batch PIRs use HE ciphertexts for interaction
- To prevent information leakage from ciphertexts
  - Encrypted message — Database masking
  - Noise — Noise flooding

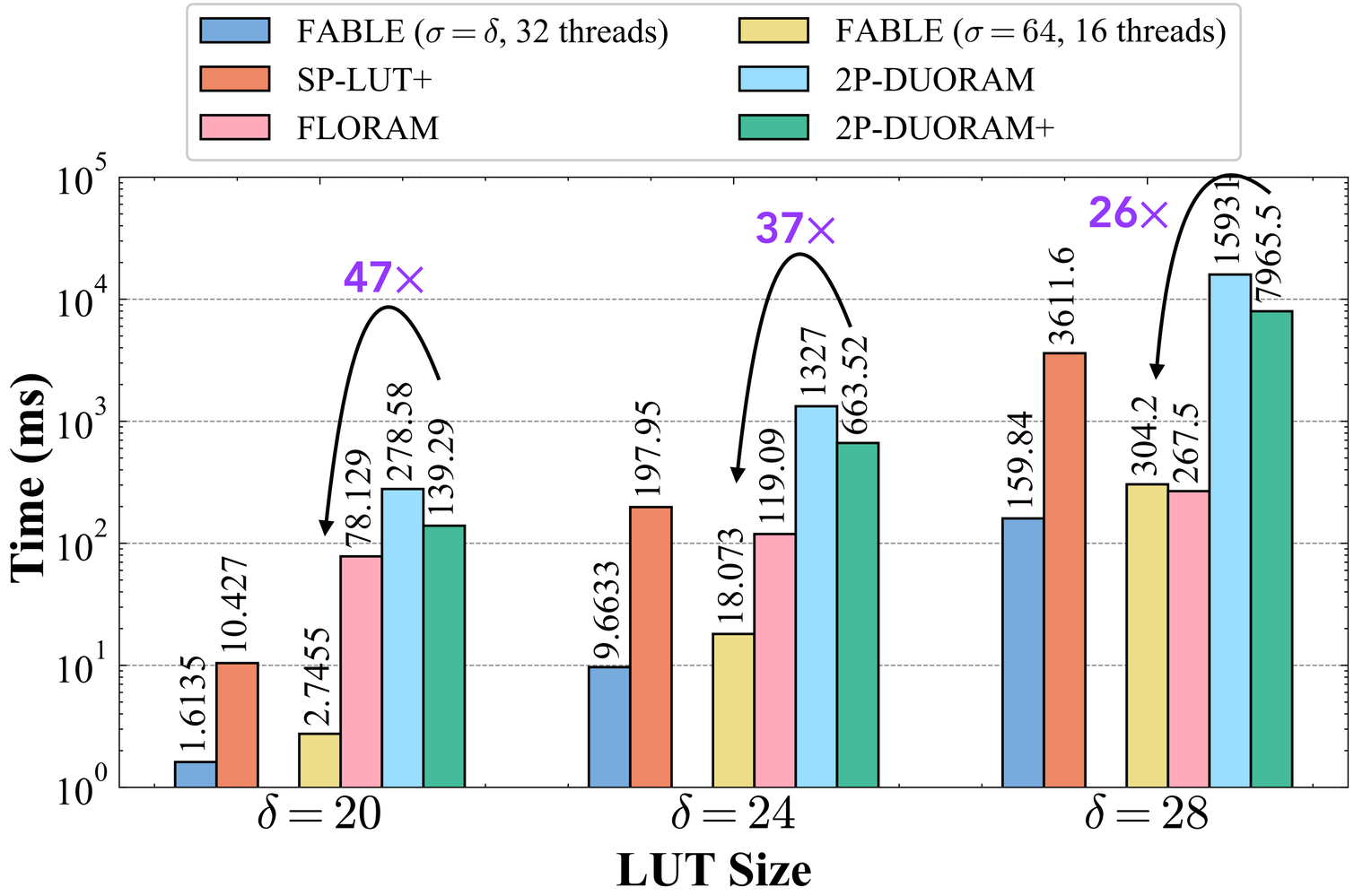
Evaluation — Asymptotic Complexity

- Sublinear client computation and communication

	Client Computation	Server Computation	Communication
FABLE	**$O(\sqrt{N})$**	**O(N)**	**$O(\sqrt{N})$**
SP-LUT+	O(log N)	O(N)	O(N)
FLUTE	$O(N^2)$	$O(N^2)$	O(N)
FLORAM-CPRG	O(N)	O(N)	O(log N)
2P-DUORAM	O(N)	O(N)	O(log N)

Evaluation — Amortized Execution Time

- Concretely efficient
- Orders of magnitude faster



Amortized execution time w.r.t. table size under LAN

Evaluation — Applications

- Secure Embedding Lookup
  - Baseline: Crypten + MOTION (for MT generation)
  - 12,868s → 28.22s (456×)
- Secure Query Execution
  - Baseline: Senate’s sort-compare-shuffle circuit
  - 149s → 10s (15×)

Conclusion

We propose FABLE, a scalable and efficient protocol for confidential LUT evaluation.

FABLE enjoys lightweight client computation, concretely efficient server computation, scalable communication, and LUT confidentiality.

FABLE shows applicability to ML and analytics workloads.

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Paper:

Code: