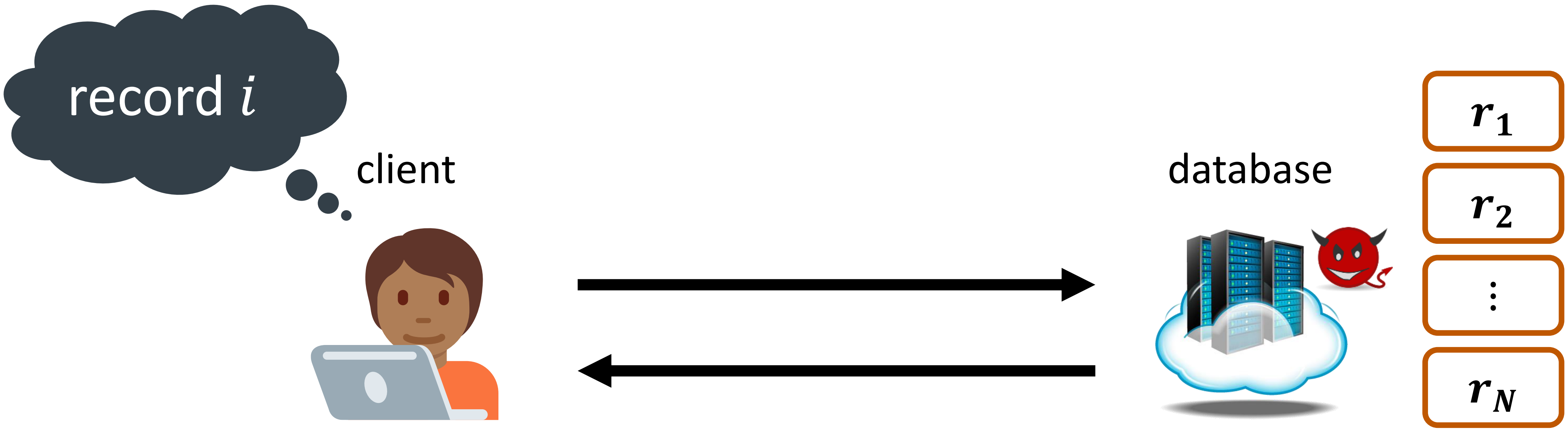
Private Information Retrieval: Recent Advances and Challenges

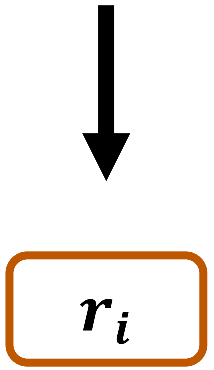
David Wu

June 2024

Private Information Retrieval (PIR)

[CGKS95]





Privacy: Does <u>not</u> learn index i

Efficiency: communication is *sublinear* in database size (ideally: $\text{polylog}(N)$)

Private Information Retrieval (PIR)

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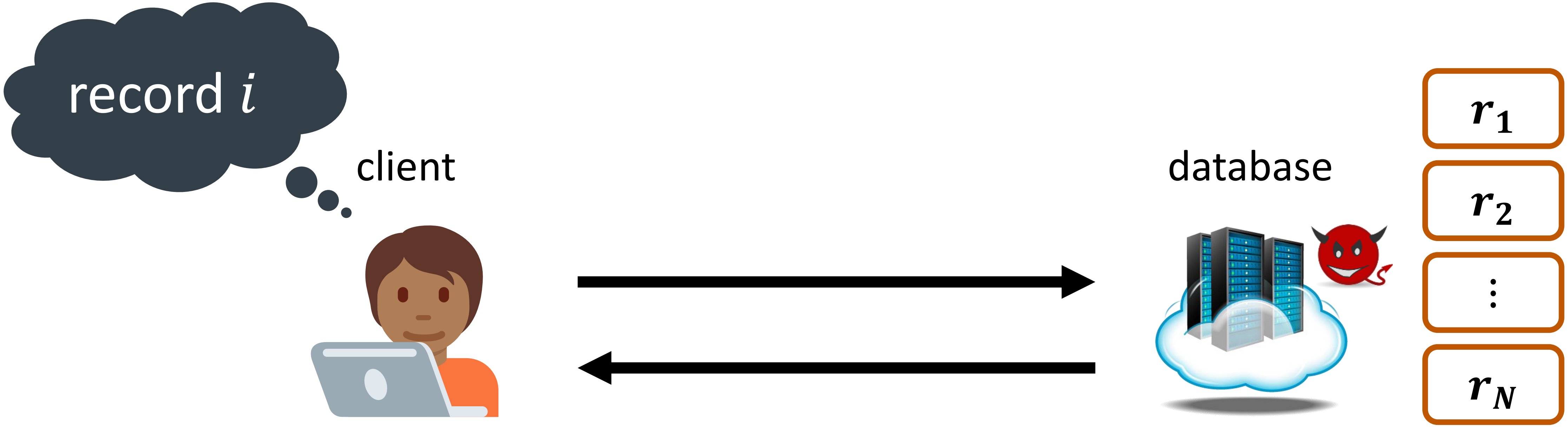
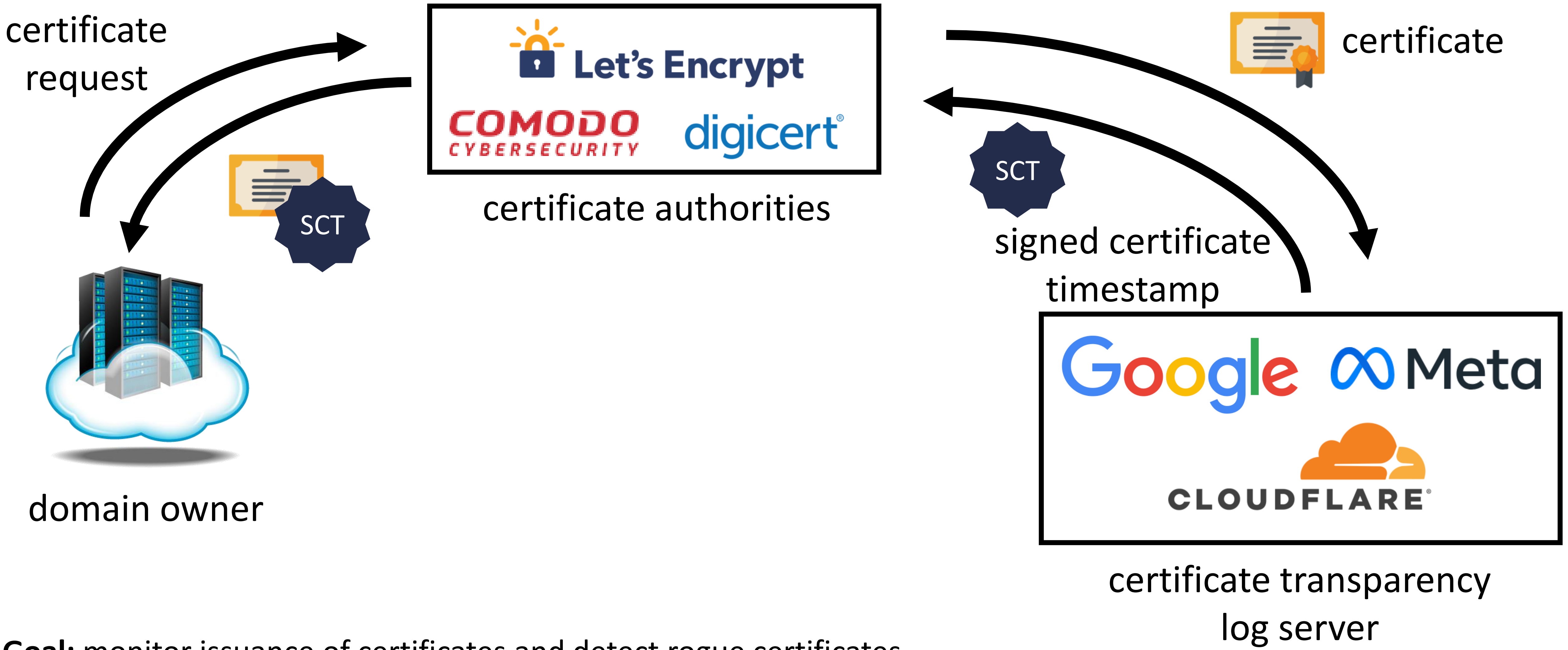


Basic building block in many privacy-preserving protocols

- Metadata-private messaging
- Certificate transparency auditing
- Private content delivery
- Contact discovery
- Private web search
- Private navigation
- Private contact tracing
- Private DNS
- Password breach checking

Certificate Transparency

[LLK13, Lau14]



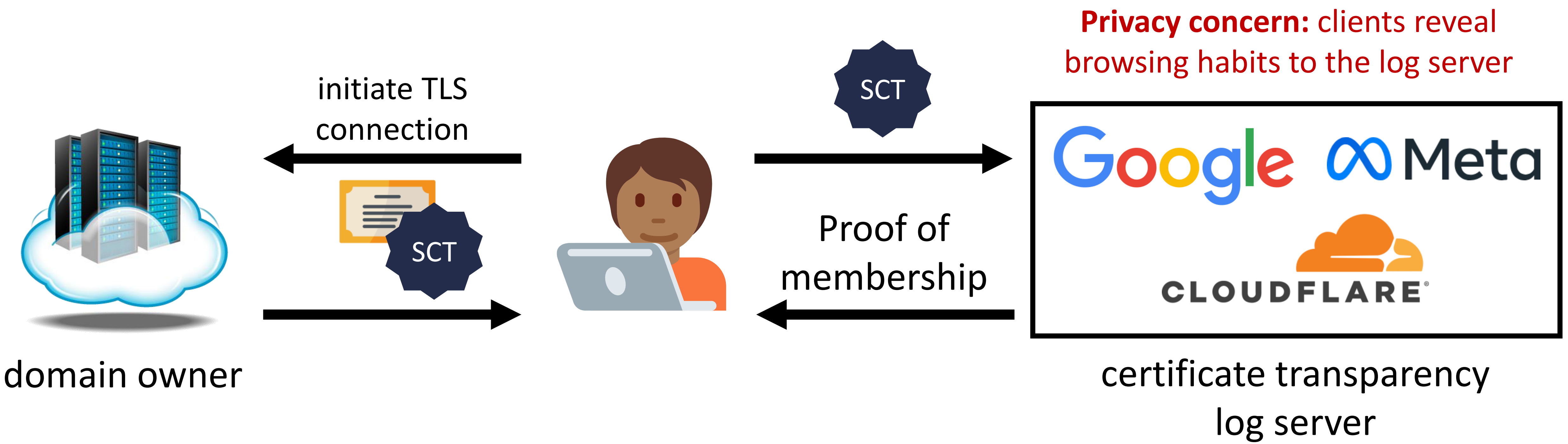
Goal: monitor issuance of certificates and detect rogue certificates

Certificate Transparency

[LLK13, Lau14]

A valid SCT means that the certificate was deposited into a log server

But is the log server honest? Clients will periodically **audit** log server to check that SCT is actually present



Goal: monitor issuance of certificates and detect rogue certificates

PIR for Certificate Transparency Auditing

[LG15, KOR19, HHCMV23]

Google Chrome's approach *(opt-out SCT auditing)*: reveal a ≈20-bit hash of the SCT to the log server

Log server replies with all websites with the particular hash (≈ 1000 websites)

Scheme provides k-anonymity notion of privacy (client visited one of 1000 possible websites)

Can we do better?

View this problem as a private information retrieval (PIR) problem

Option 1: Hash SCTs into buckets; client uses PIR to privately retrieve all SCTs in the target bucket

Option 2: Use a Bloom filter to represent the set of SCTs and use PIR to retrieve relevant *bit(s)* of the Bloom filter

Advantage: Provides cryptographic privacy: server learns **nothing** about client's browsing habits

But is PIR actually practical?

Efficiency of PIR

On the Computational Practicality of Private Information Retrieval

Radu Sion *
Network Security and Applied Cryptography Lab
Computer Sciences, Stony Brook University
sion@cs.stonybrook.edu

Bogdan Carbunar
Pervasive Platforms and Architectures
Motorola Labs
carbunar@motorola.com

Abstract

We explore the limits of single-server computational private information retrieval (PIR) for the purpose of preserving client access patterns leakage. *We show that deployment of non-trivial single server PIR protocols on real hardware of the recent past would have been orders of magnitude less time-efficient than trivially transferring the entire database. We stress that these results are beyond existing knowledge of mere "impracticality" under unfavorable assumptions. They rather reflect an inherent limitation with respect to modern hardware, likely the result of a communication-cost centric protocol design. We argue that this is likely to hold on non-specialized traditional hardware in the foreseeable future. We validate our reasoning in an experimental setup on modern off-the-shelf hardware. Ultimately, we hope our results will stimulate practical designs.*

Here we discuss single-server computational PIR *for the purpose of preserving client access patterns leakage*. We show that deployment of non-trivial single server private information retrieval protocols on real hardware of the recent past would have been orders of magnitude more time-consuming than trivially transferring the entire database. The deployment of computational PIR would in fact *increase* overall execution time, as well as the probability of *forward* leakage, when the deployed present trapdoors become eventually vulnerable – e.g., today's queries will be revealed once factoring of today's values will become possible in the future.

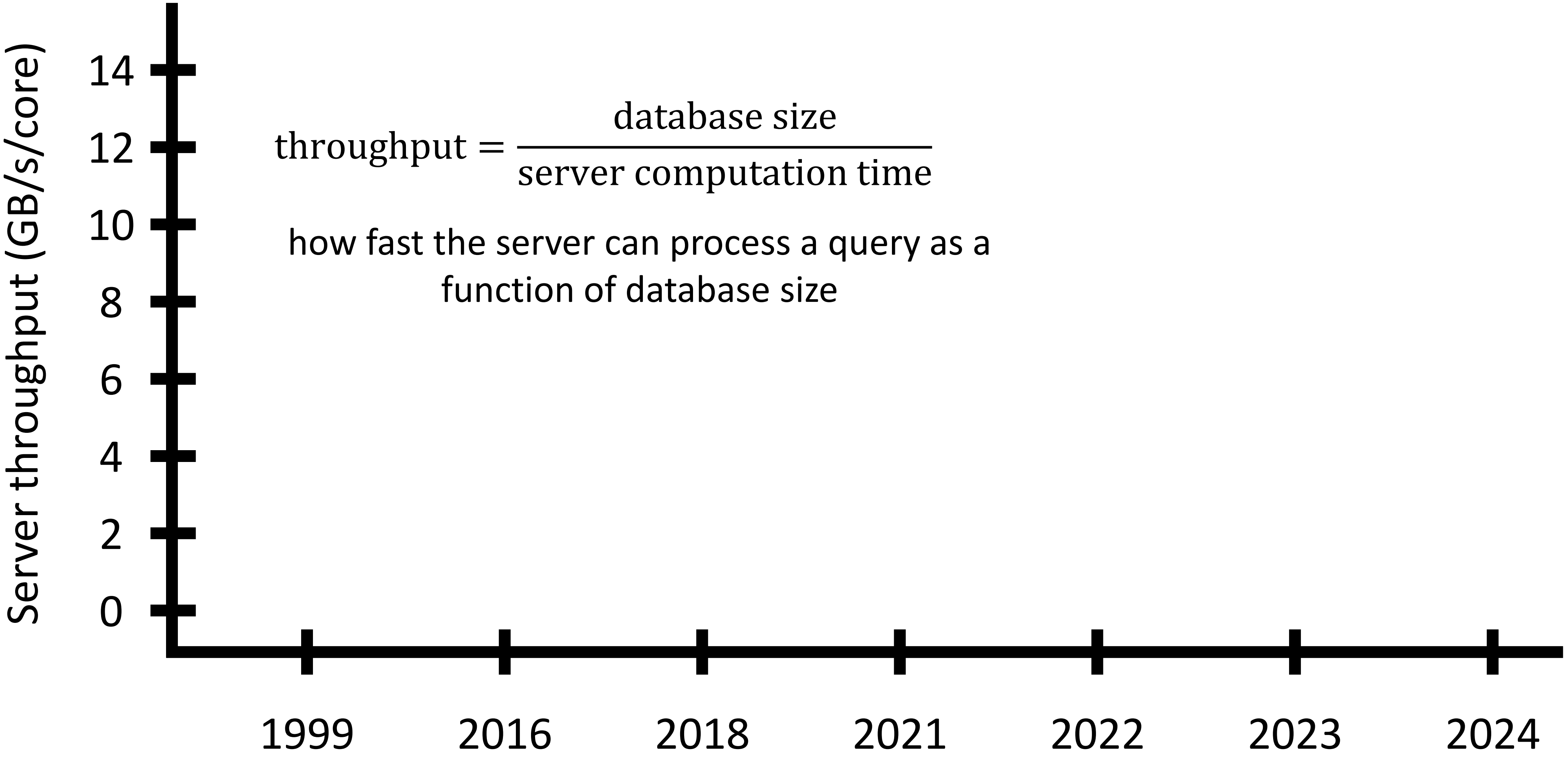
We stress that this is beyond existing knowledge of mere "impracticality" under unfavorable assumptions. On real hardware, *no* existing non-trivial single server PIR protocol could have possibly had outperformed the trivial client-to-server transfer of records in the past, and is likely not to do so in the future either. This is due to the fact that on any

NDSS 2007

Take-away (2007): PIR schemes are too expensive and better to just have client download the database; need **new** constructions

Recurring theme in cryptography: powerful tools, but often (concretely) expensive

25 Years of PIR Research

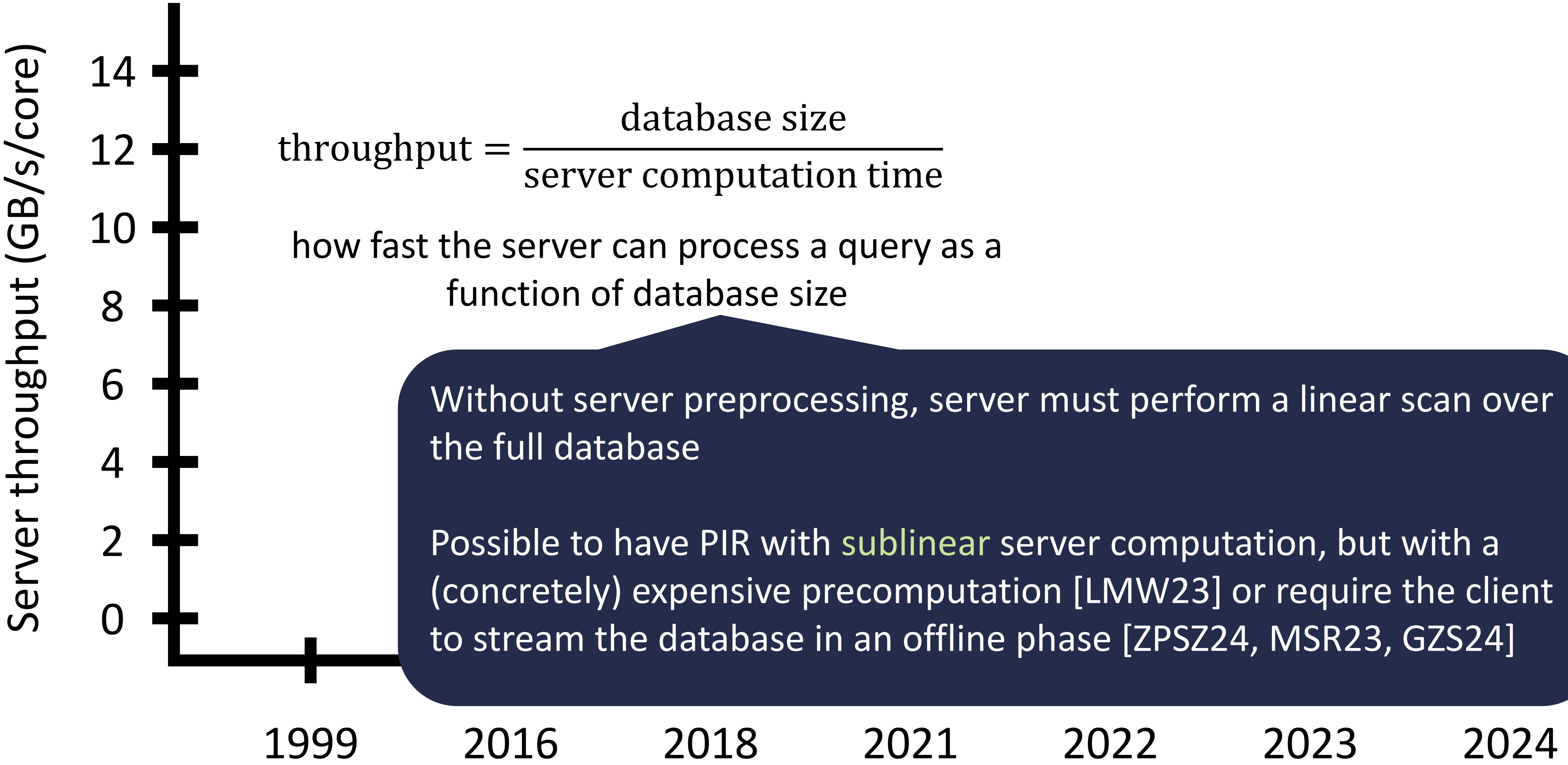


$$\text{throughput} = \frac{\text{database size}}{\text{server computation time}}$$

how fast the server can process a query as a function of database size

Slide adapted from similar one by Henry Corrigan-Gibbs

25 Years of PIR Research



$$\text{throughput} = \frac{\text{database size}}{\text{server computation time}}$$

how fast the server can process a query as a function of database size

Without server preprocessing, server must perform a linear scan over the full database

Possible to have PIR with sublinear server computation, but with a (concretely) expensive precomputation [LMW23] or require the client to stream the database in an offline phase [ZPSZ24, MSR23, GZS24]

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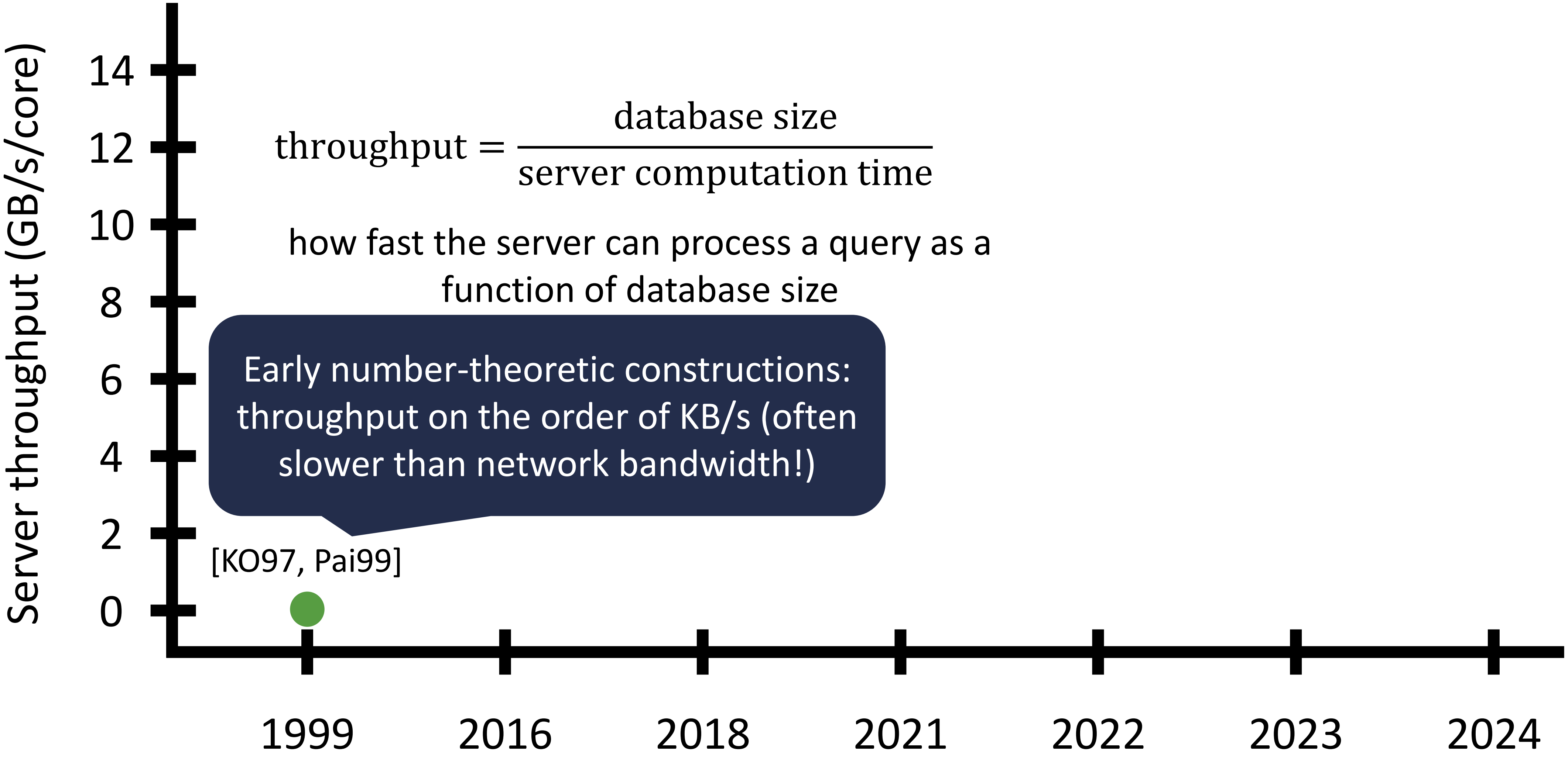

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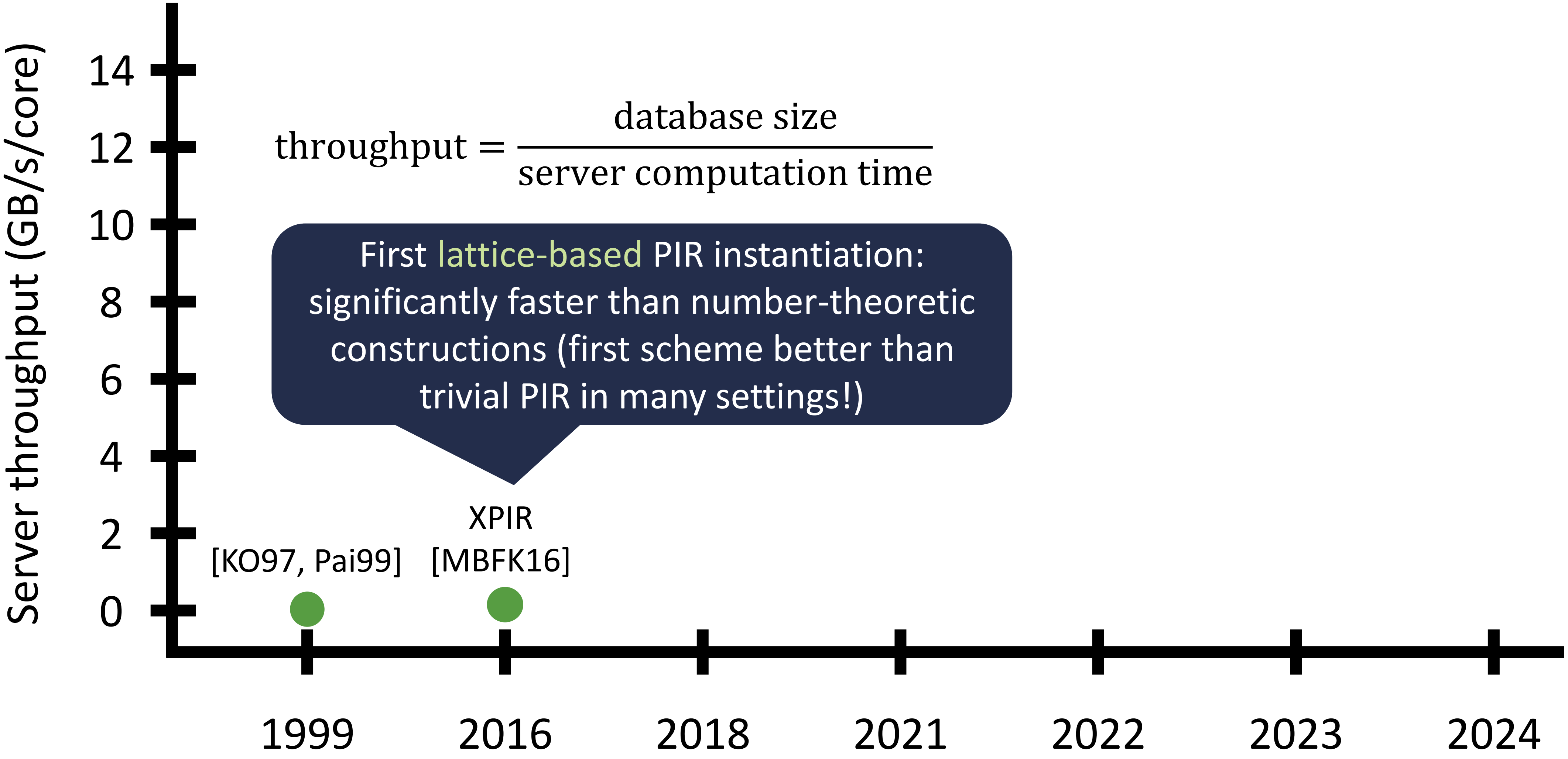

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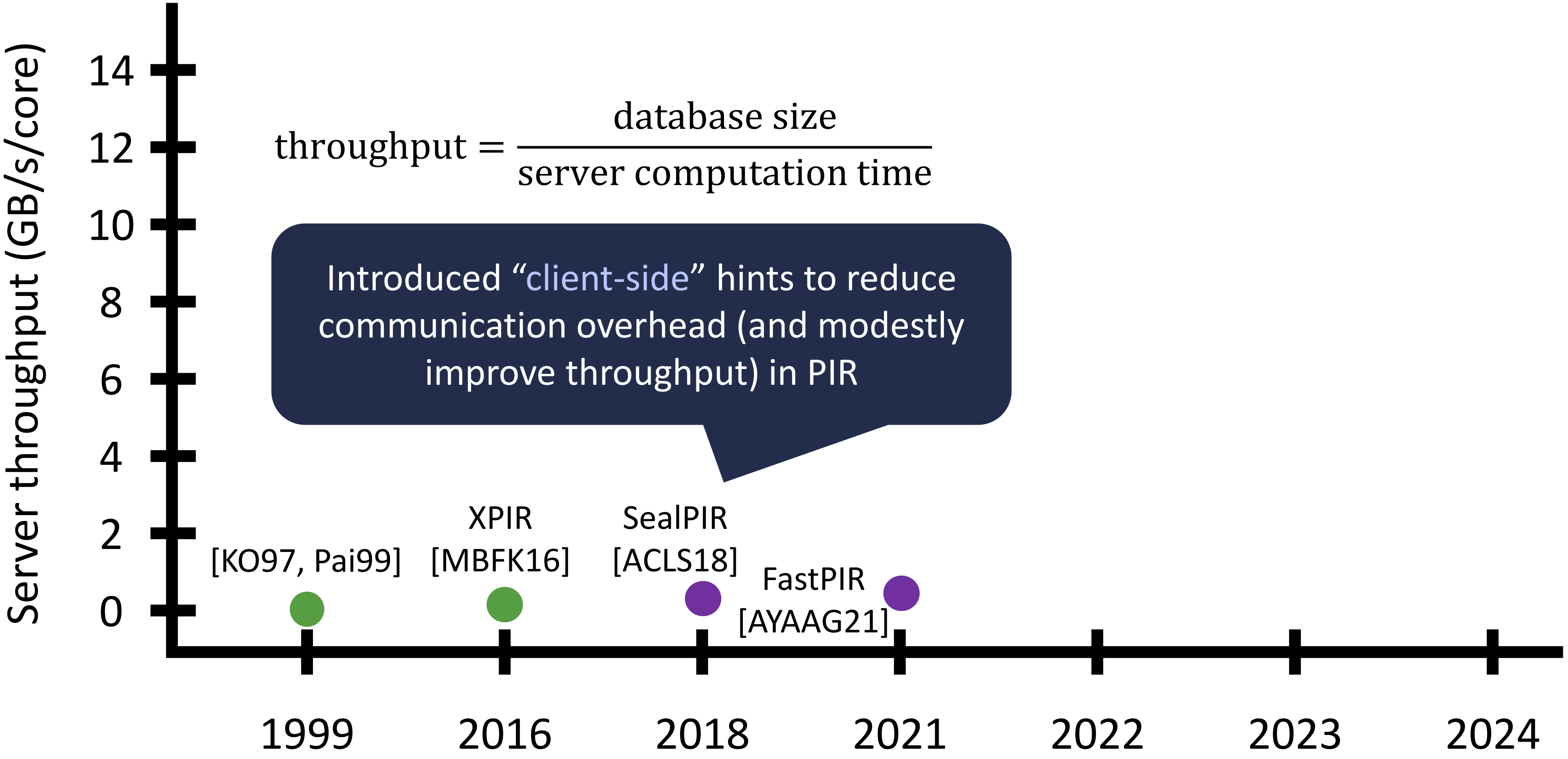

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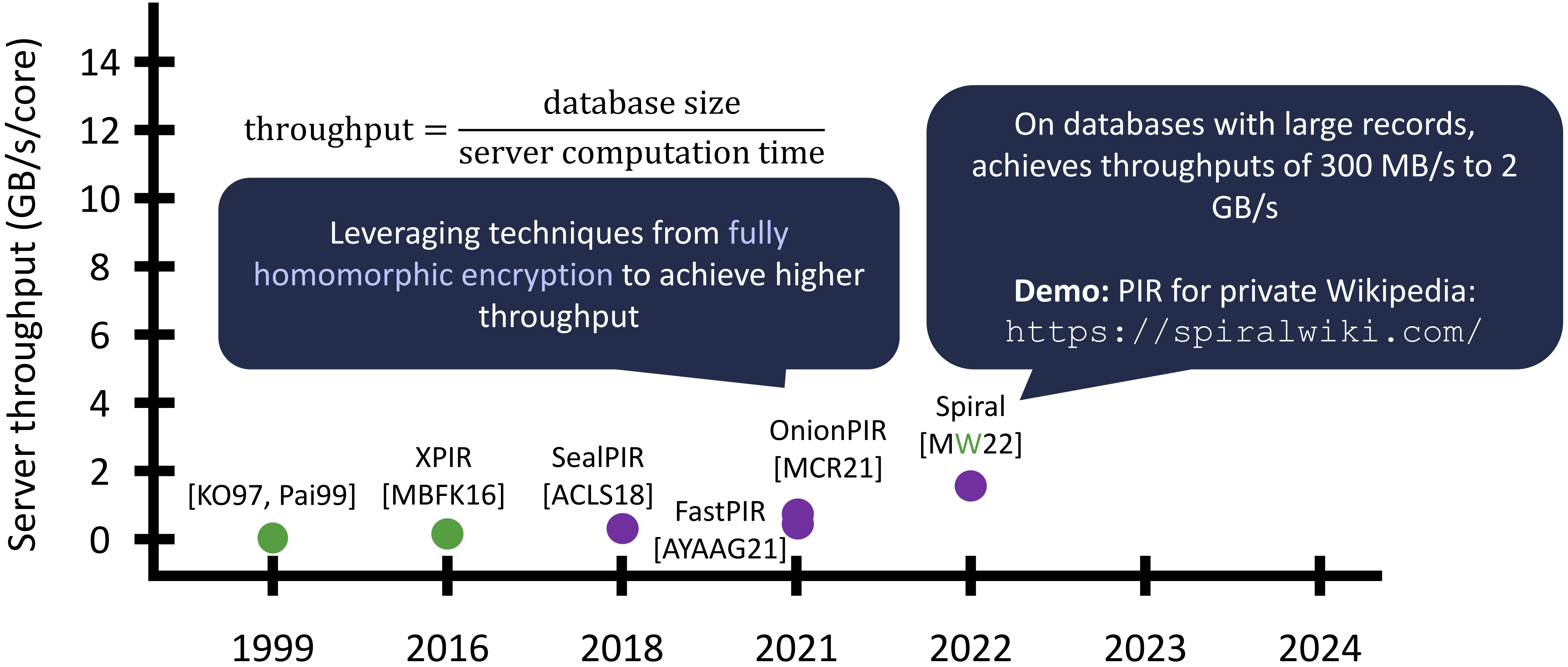

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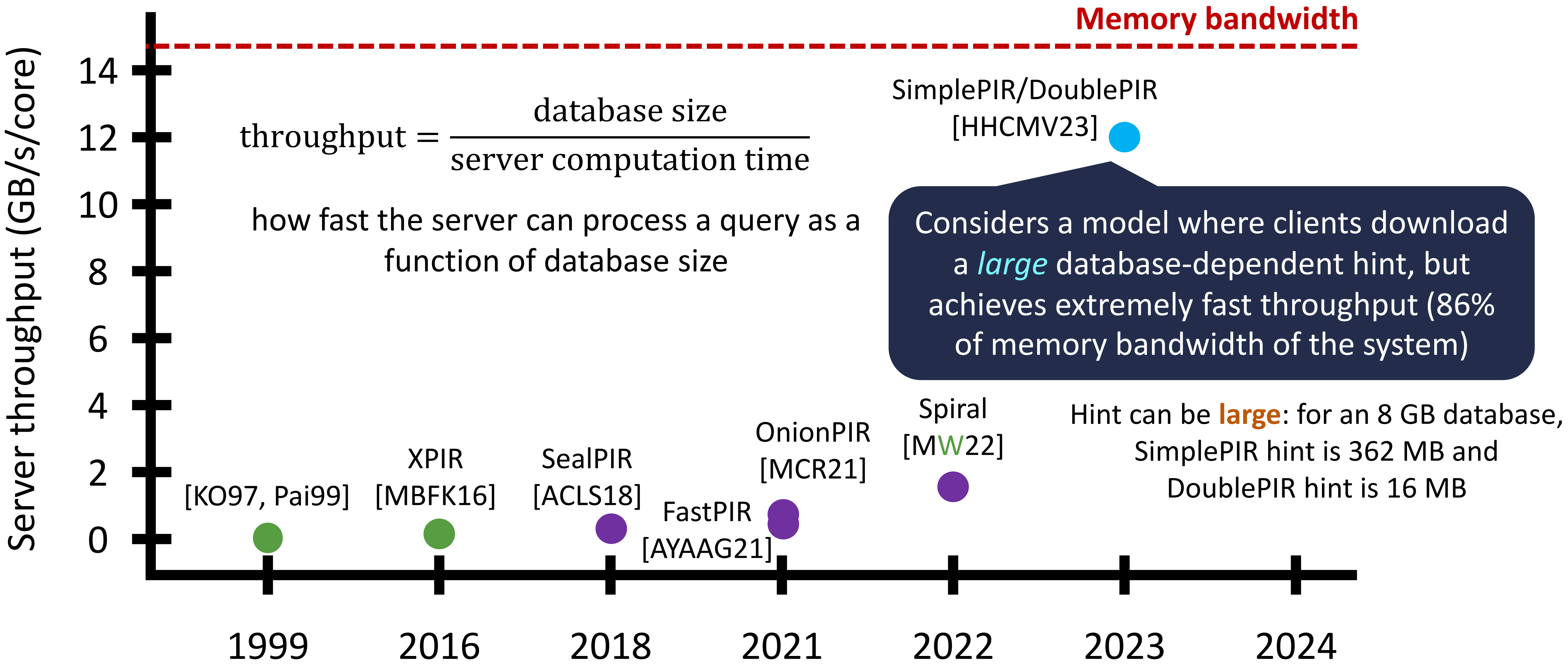

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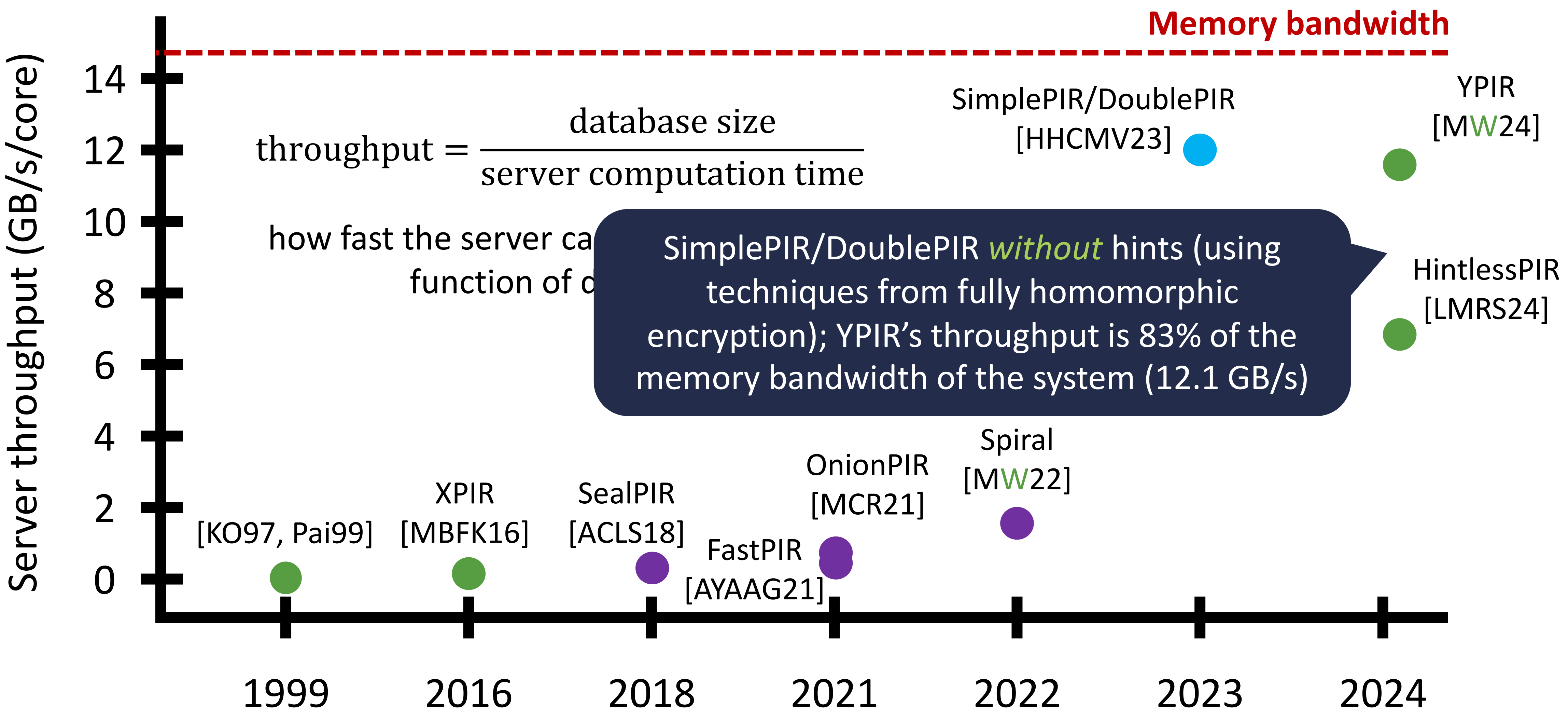

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PIR for Certificate Transparency

Assuming a client makes 10^4 TLS connections each week and performs 20 audits each week (same assumptions described in Chrome's approach)

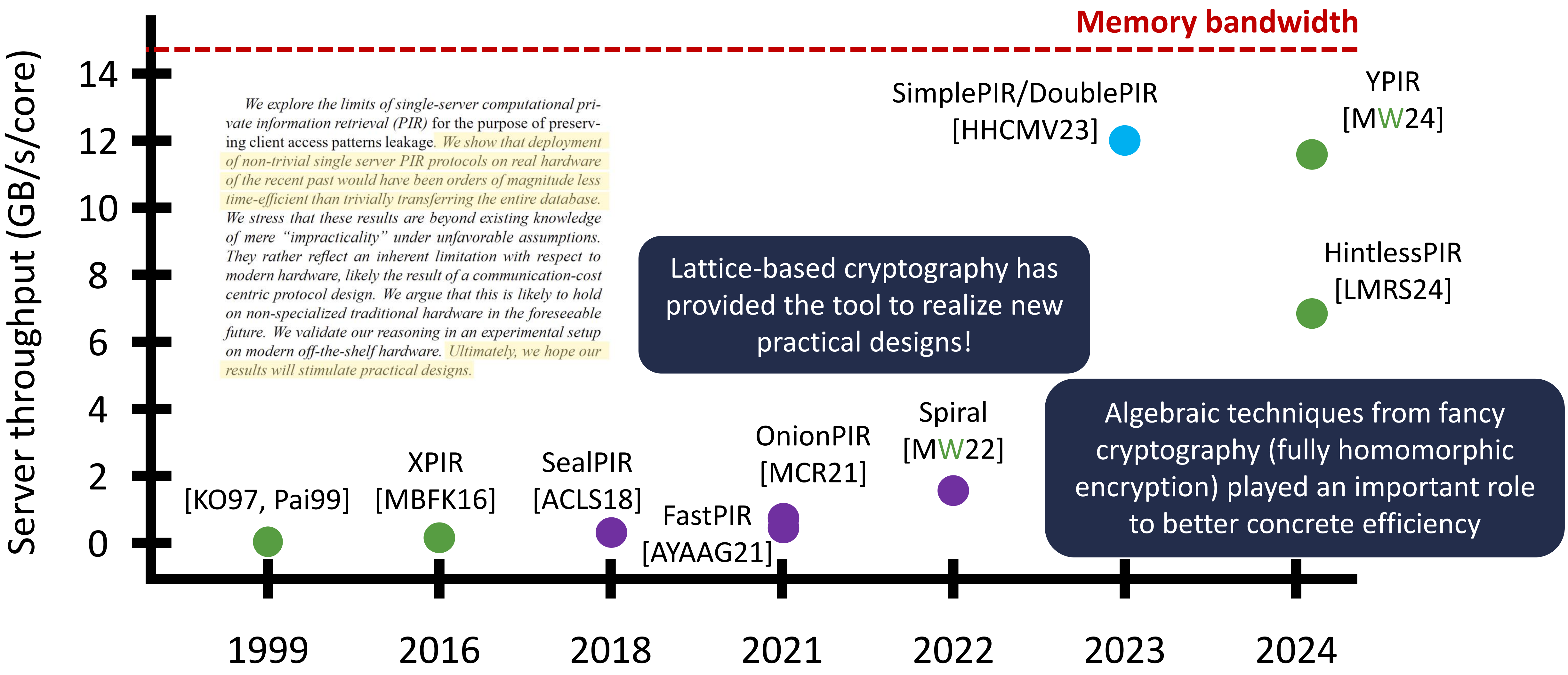
Assume certificate transparency log server contains 5 billion SCTs

Using YPIR: 29 MB of communication per client, 13.7 core-seconds of computation
(Estimated AWS costs: $228/million clients/week)

Chrome's k-anonymity approach: 2.3 MB of communication per client

Bottom line: 12.6× **communication overhead** to achieve **cryptographic privacy**

25 Years of PIR Research



The Next 5 Years of PIR Research

Two classes of constructions:

- **High throughput schemes:** $\approx$ memory bandwidth throughput, need to communicate a few MB to retrieve a bit/byte of payload
- **High rate schemes:** communication overhead is small ($< 2\times$ over direct retrieval), but throughput is limited (300-400 MB/s)

Can we combine ideas to get the best of both worlds?

Can we build concretely-efficient PIR with sublinear server computation (without having the client first stream the database)?

Can we leverage techniques from efficient PIR schemes to other domains (e.g., private set intersection, privacy-preserving machine learning)?

What will it take for companies to use PIR to better safeguard user privacy?