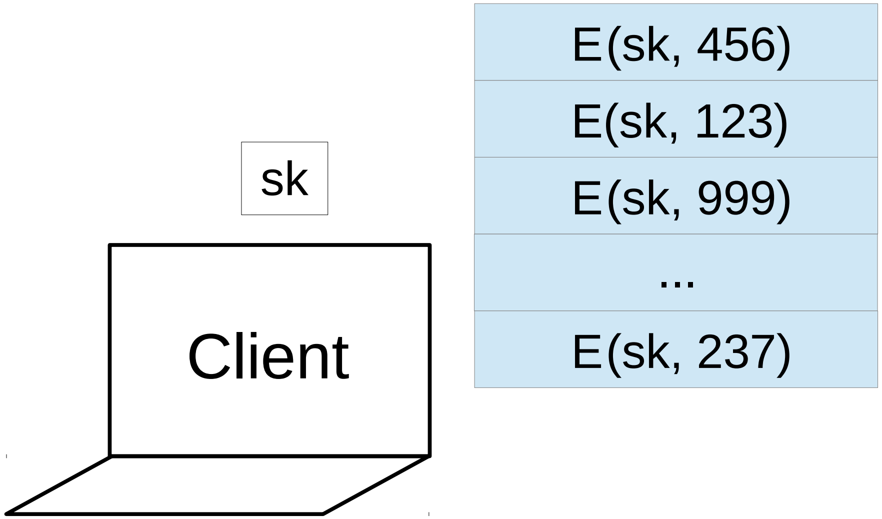
Semantically Secure Order-Revealing Encryption:

Multi-Input Functional Encryption Without Obfuscation

Dan Boneh, Kevin Lewi, Mariana Raykova,
Amit Sahai, Mark Zhandry, **Joe Zimmerman**

Order-Revealing Encryption



E(sk, 456)

E(sk, 123)

E(sk, 999)

...

E(sk, 237)

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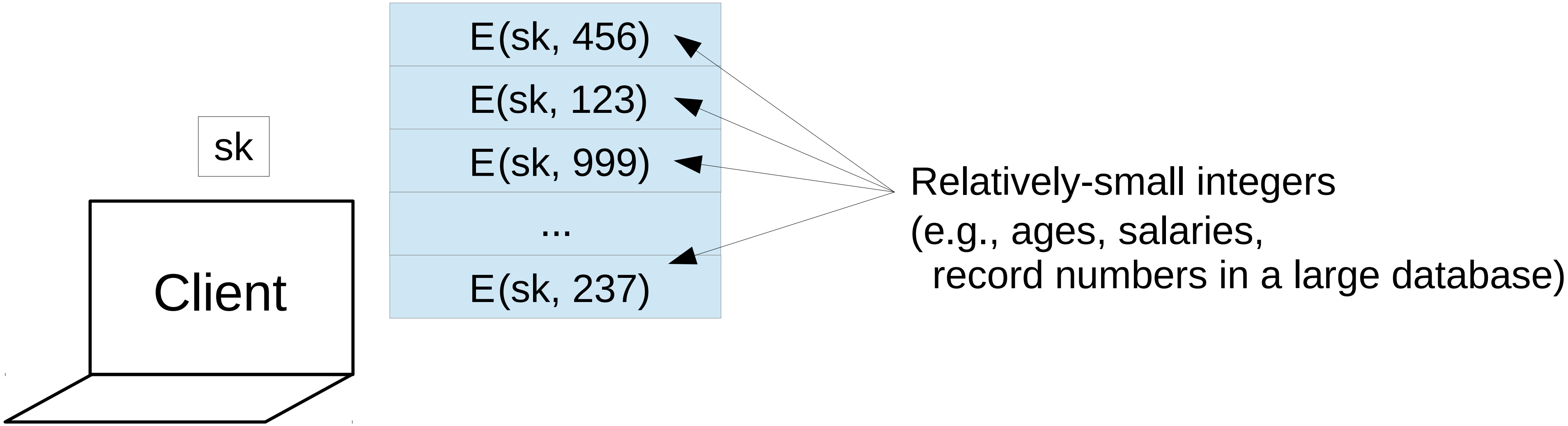

sk

Client

E(sk, 456)

E(sk, 123)

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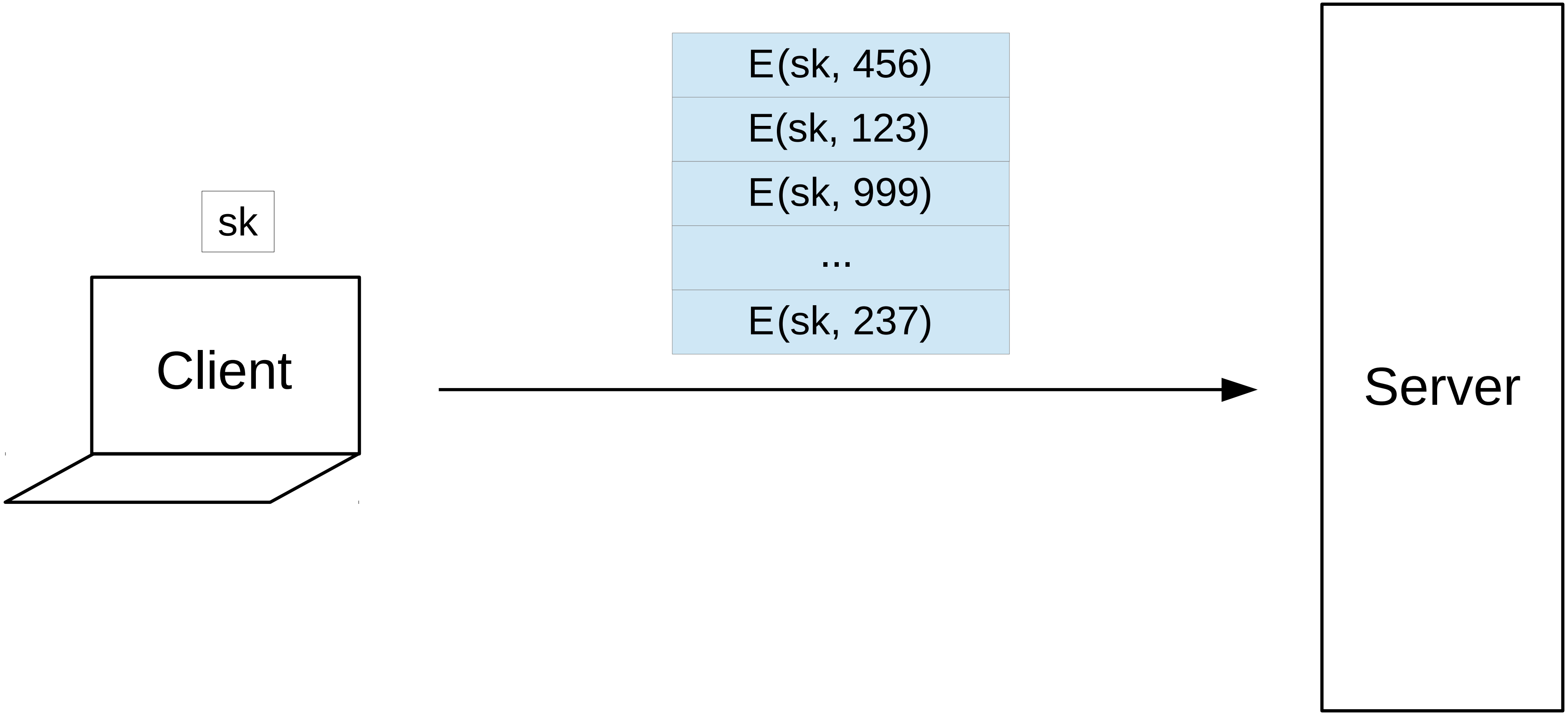
Relatively-small integers
(e.g., ages, salaries,
record numbers in a large database)

Order-Revealing Encryption



sk

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E(sk, 456)

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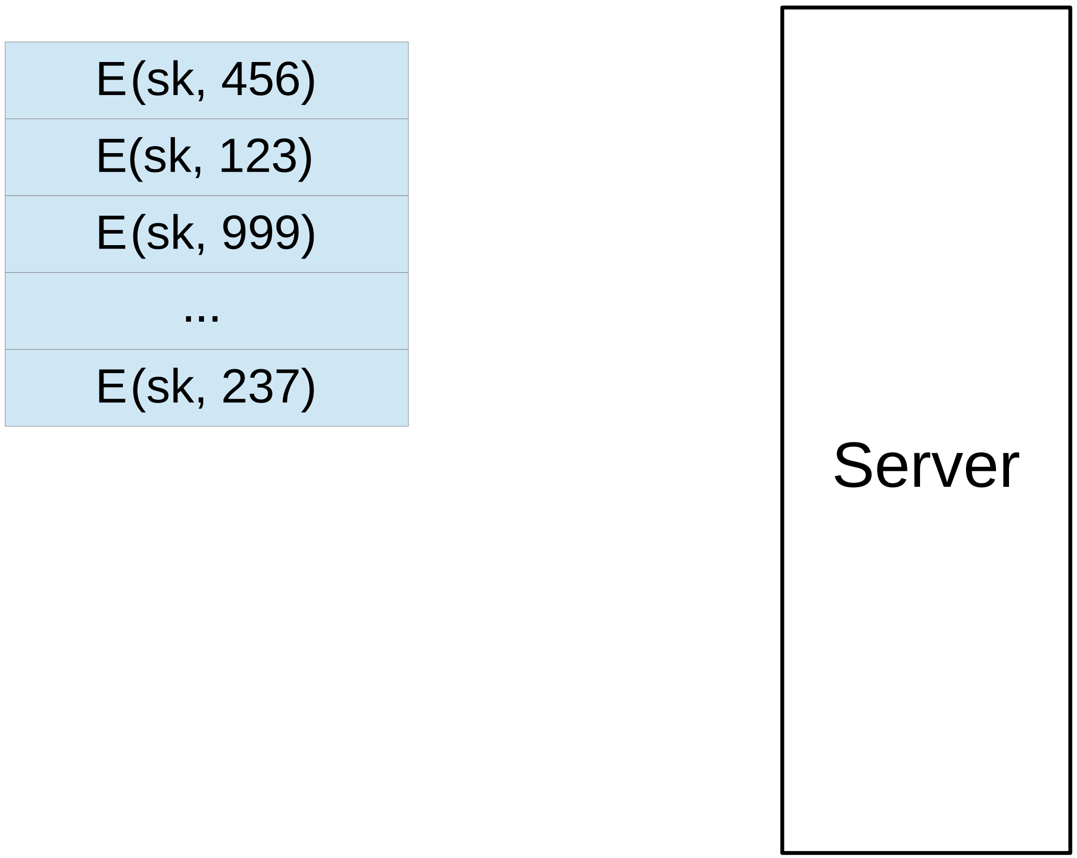
Server

Order-Revealing Encryption



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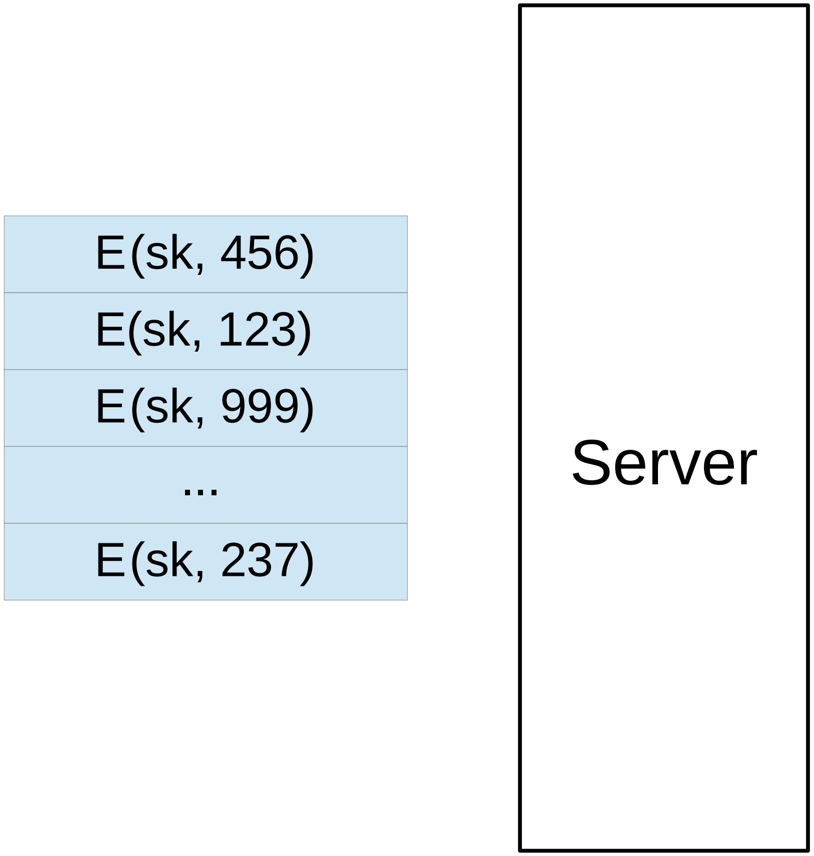

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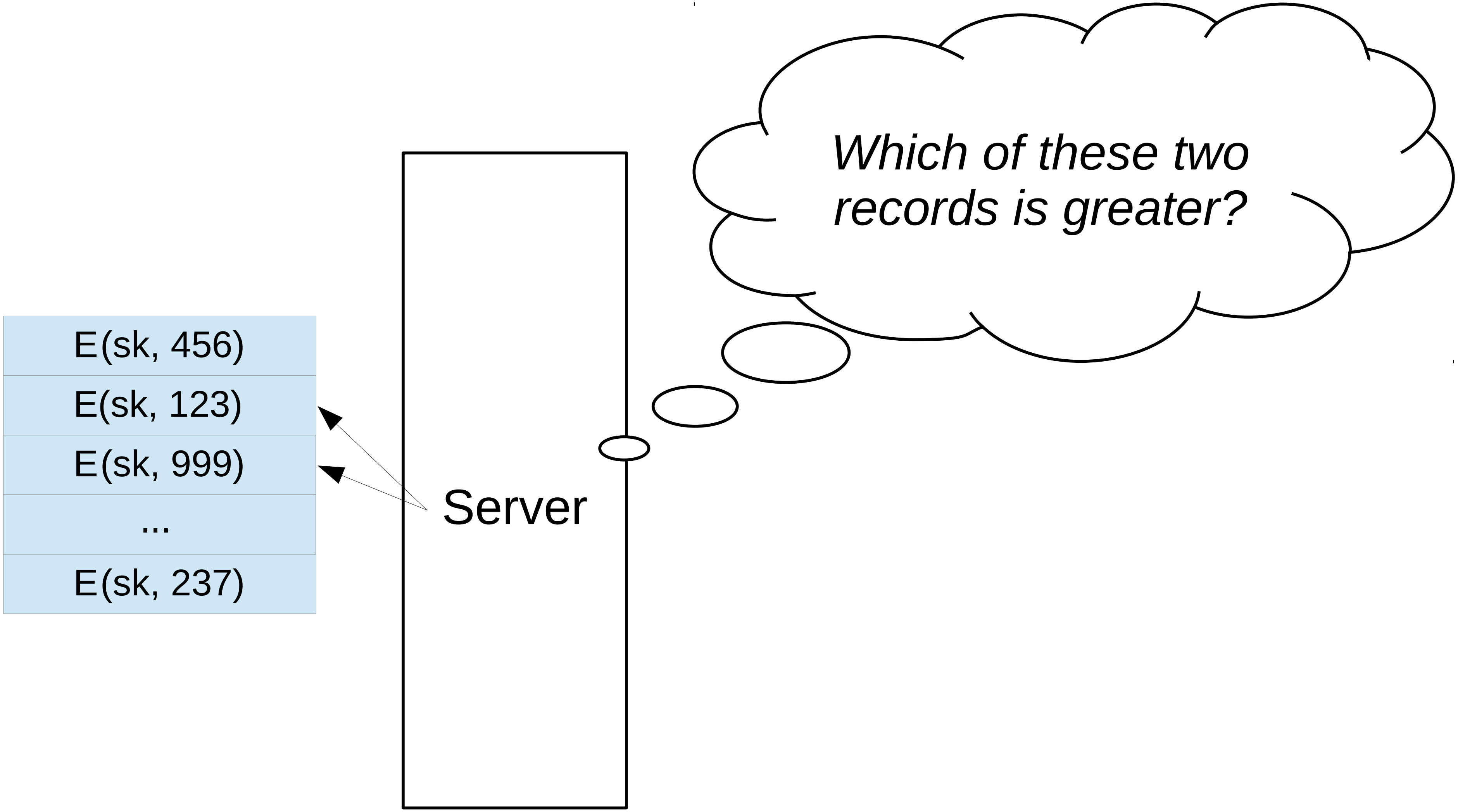

E(sk, 456)

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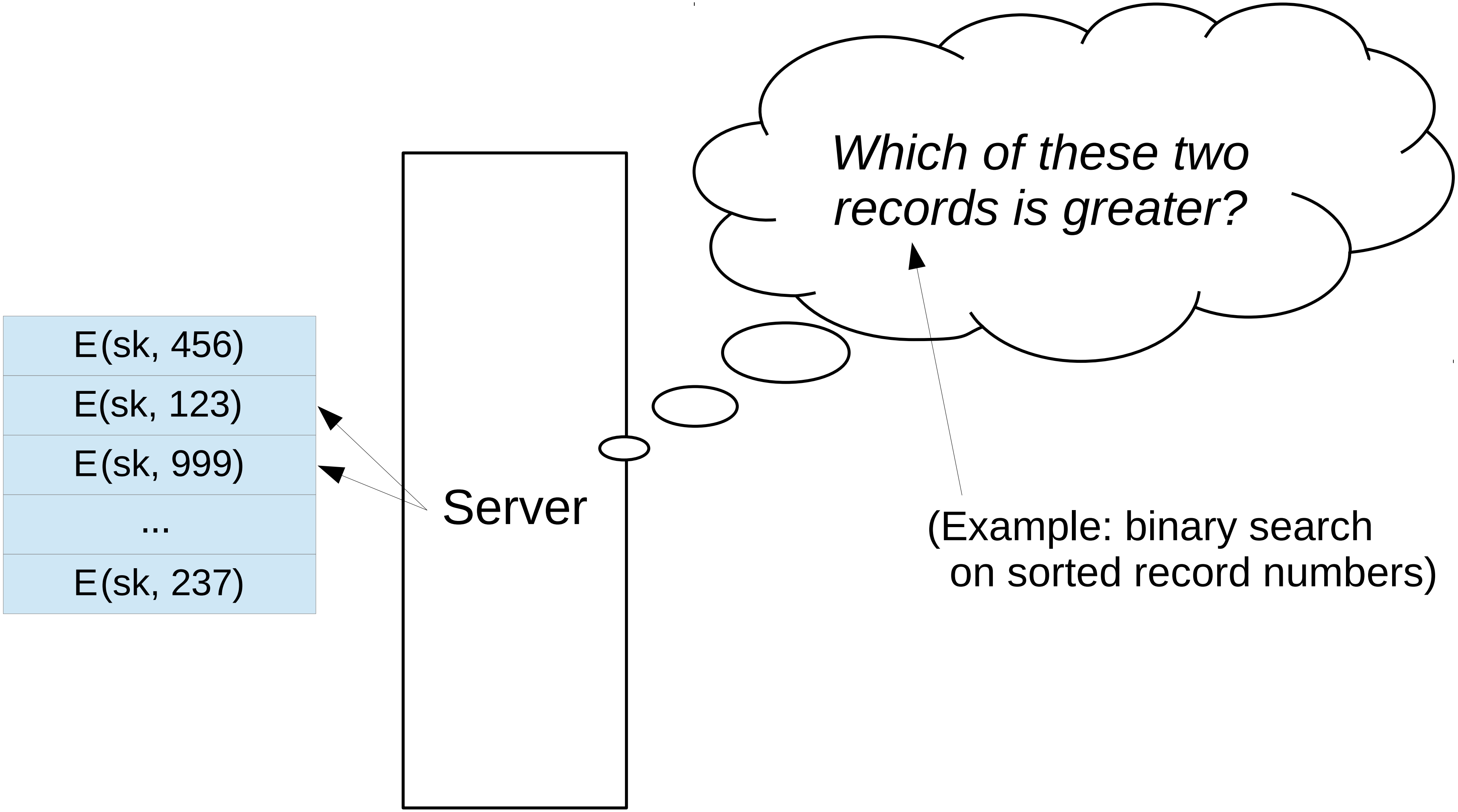
Server

Which of these two records is greater?

Order-Revealing Encryption



E(sk, 456)

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Server

Which of these two records is greater?

(Example: binary search on sorted record numbers)

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Order-Revealing Encryption

Solution 1:

- *Order-Preserving Encryption* [BCLO'04]

$$x < y \implies E(sk, x) < E(sk, y)$$

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Order-Revealing Encryption

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Solution 2:

- Multi-Input Functional Encryption [GGJS'14]

Order-Revealing Encryption

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Solution 2:

- Multi-Input Functional Encryption [GGJS'14]
- Requires obfuscation of a PRF (e.g., AES)

Order-Revealing Encryption

Our results:

- Not order-preserving, but *order-revealing*

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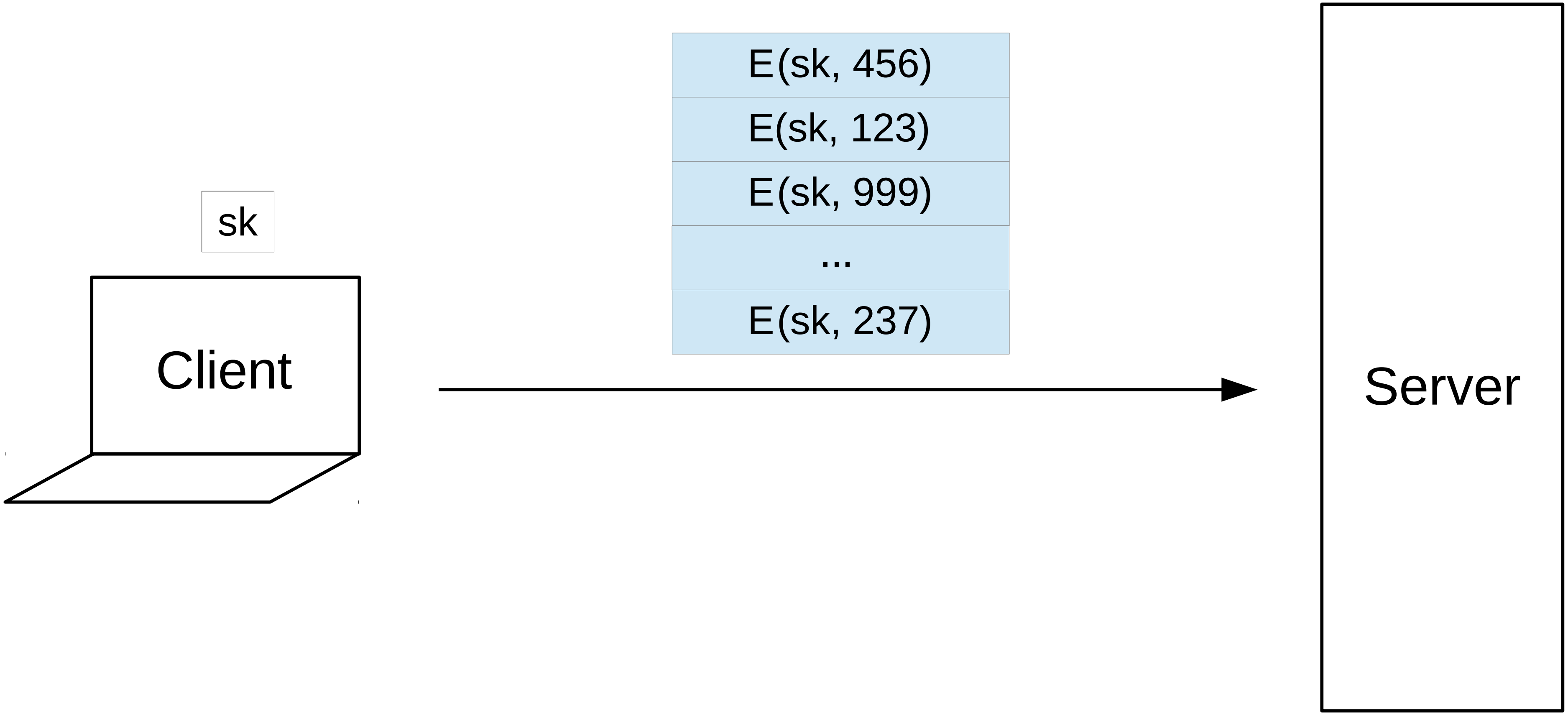

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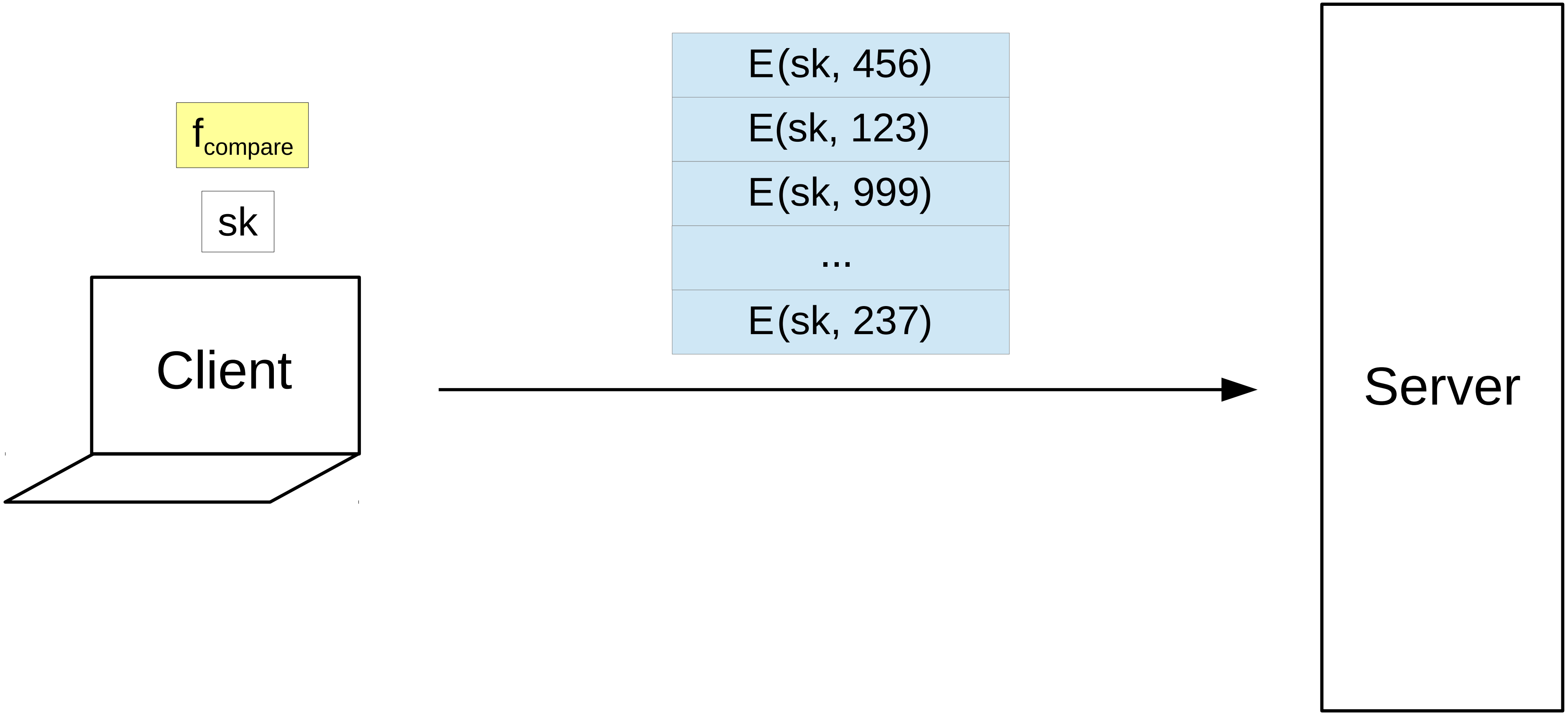

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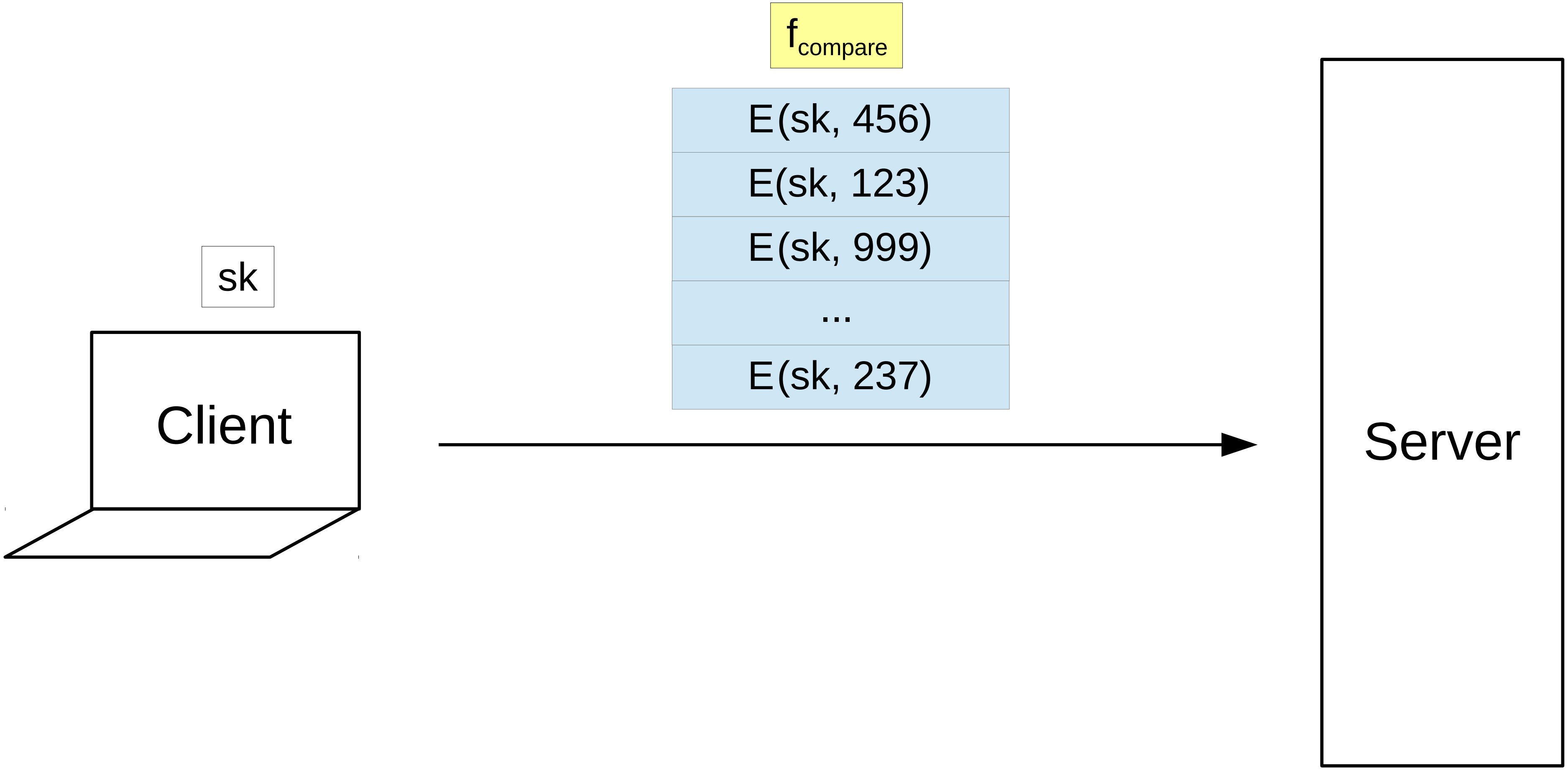

$f_{compare}$

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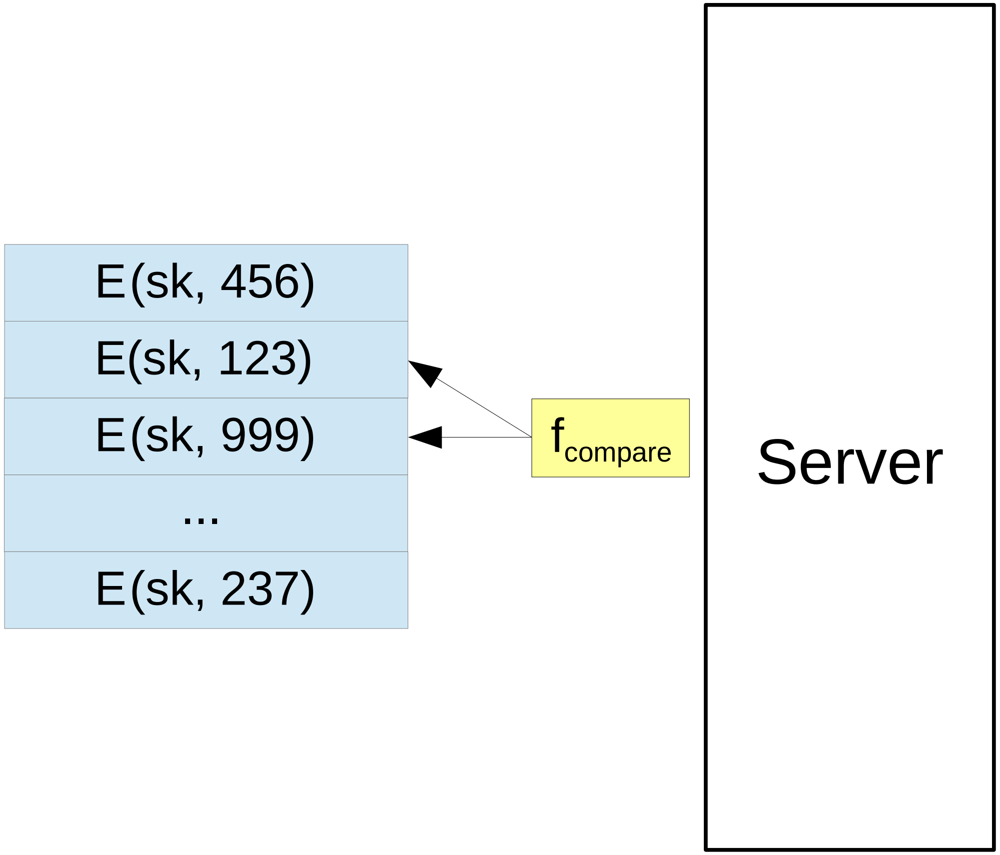

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- – To compare 16-bit numbers:
  we only need a 17-way multilinear map

Order-Revealing Encryption

Our results:

- Not order-preserving, but *order-revealing*
- No obfuscation
  - Inspired by obfuscation techniques
- To compare 16-bit numbers:
  we only need a 17-way multilinear map
- For k-bit numbers: O(k) ops in (k+1)-linear map

Order-Revealing Encryption

Our results:

– Prove construction in generic map model [BR'13]

Order-Revealing Encryption

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- Instances of Multi-Input Functional Encryption [GGJS'14] with a single secret key

Order-Revealing Encryption

<u>Our results:</u>

- Prove construction in generic map model [BR'13]
- Techniques extend to other functionalities; arity > 2
- Instances of Multi-Input Functional Encryption [GGJS'14] with a single secret key
- Not fast, but *implementable*!

Order-Revealing Encryption

Our results – main techniques:

- Each ciphertext is a sequence of matrices encoded in the exponent of an (asymmetric) multilinear map

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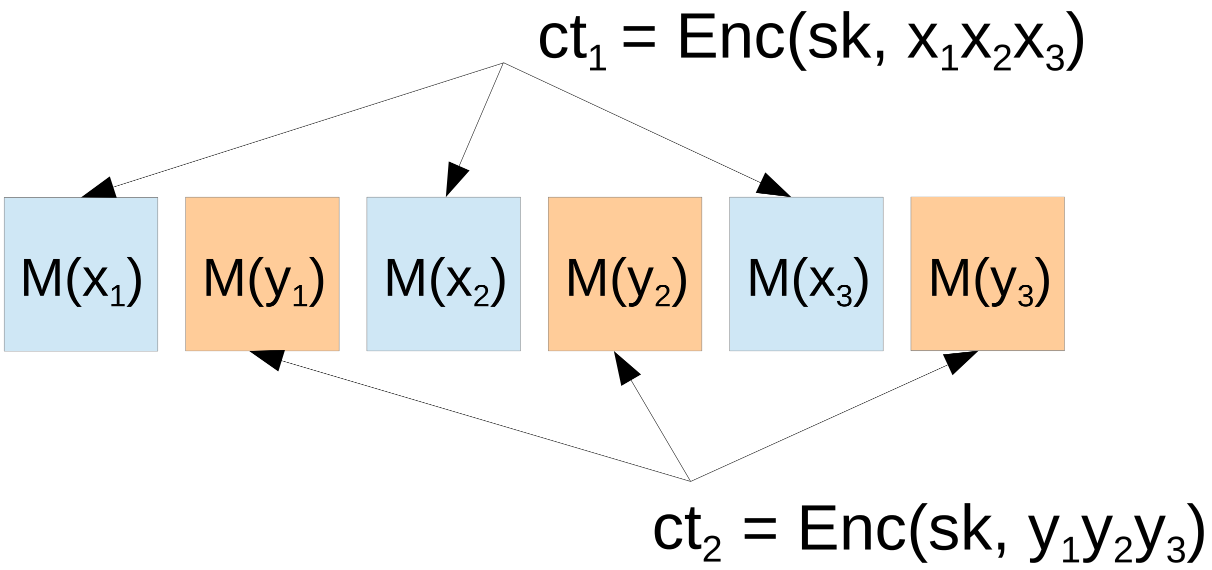

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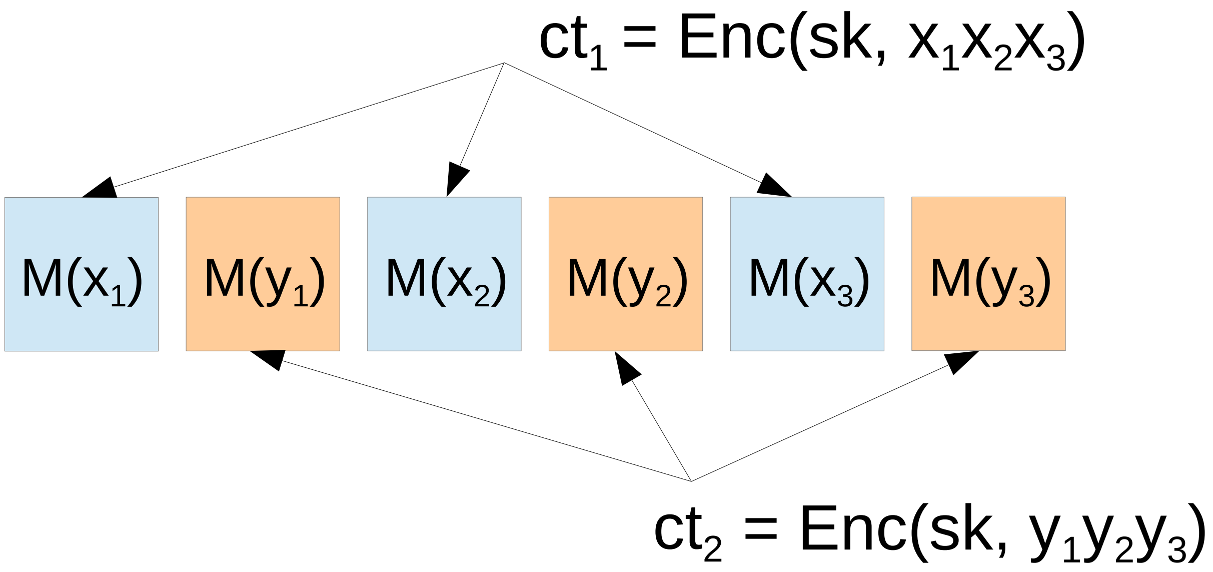

ct_1 = Enc(sk, $x_1x_2x_3$)

$M(x_1)$ $M(y_1)$ $M(x_2)$ $M(y_2)$ $M(x_3)$ $M(y_3)$

ct_2 = Enc(sk, $y_1y_2y_3$)

- To enforce consistency: *exclusive partition families* generalize straddling sets [BGK+'13]

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