Obfuscated Access and Search Patterns in Searchable Encryption

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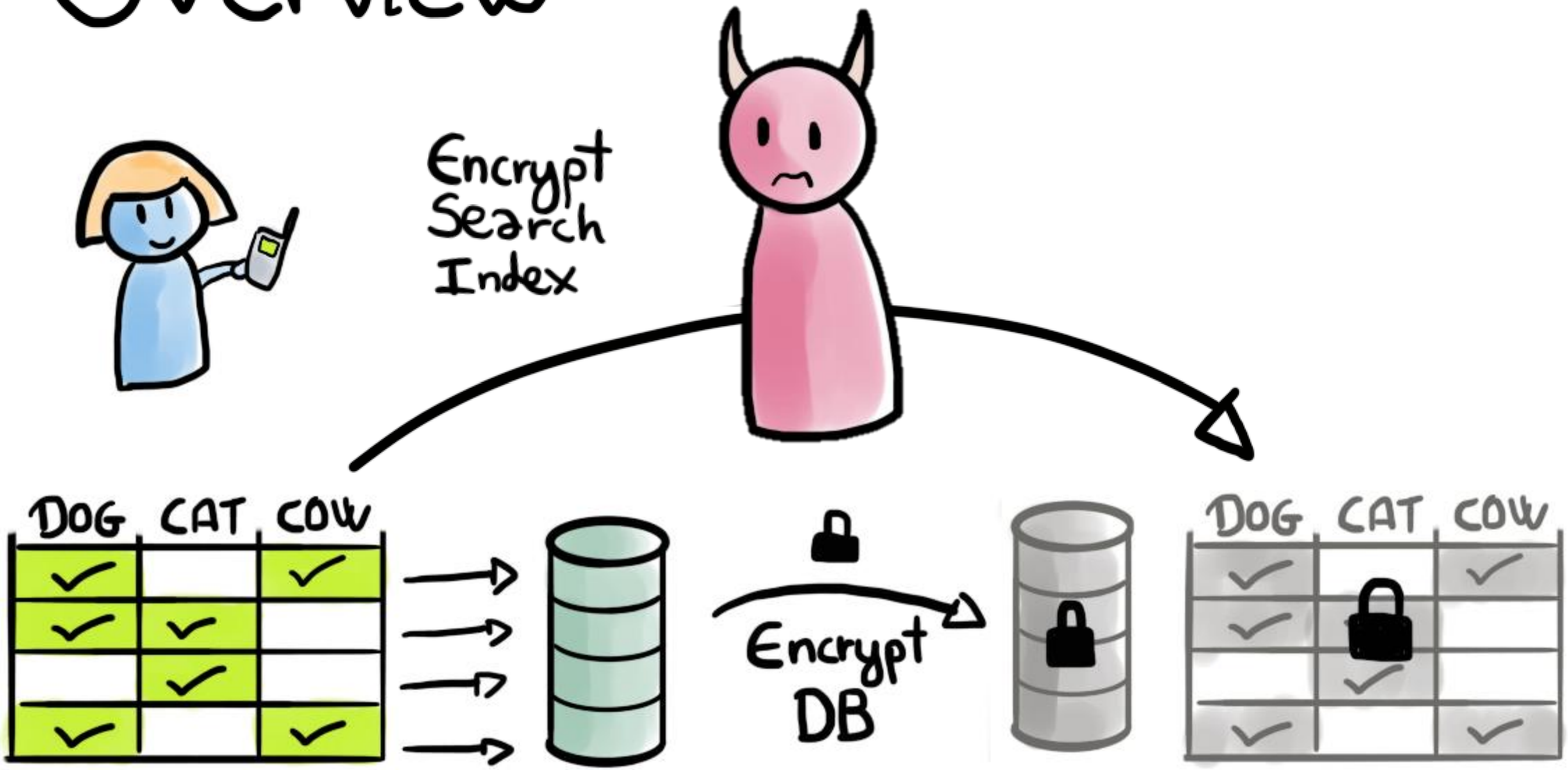
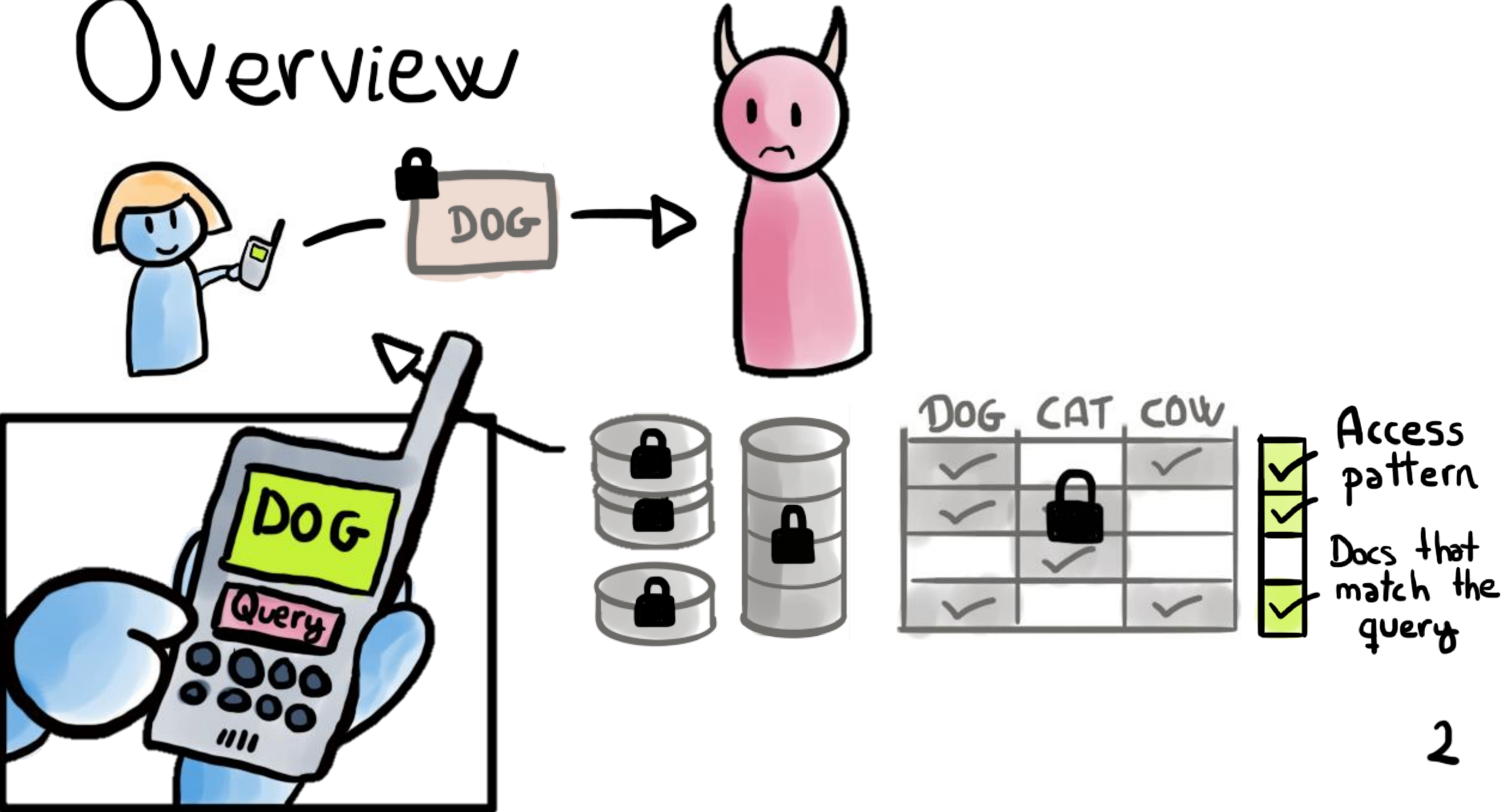
NDSS'21

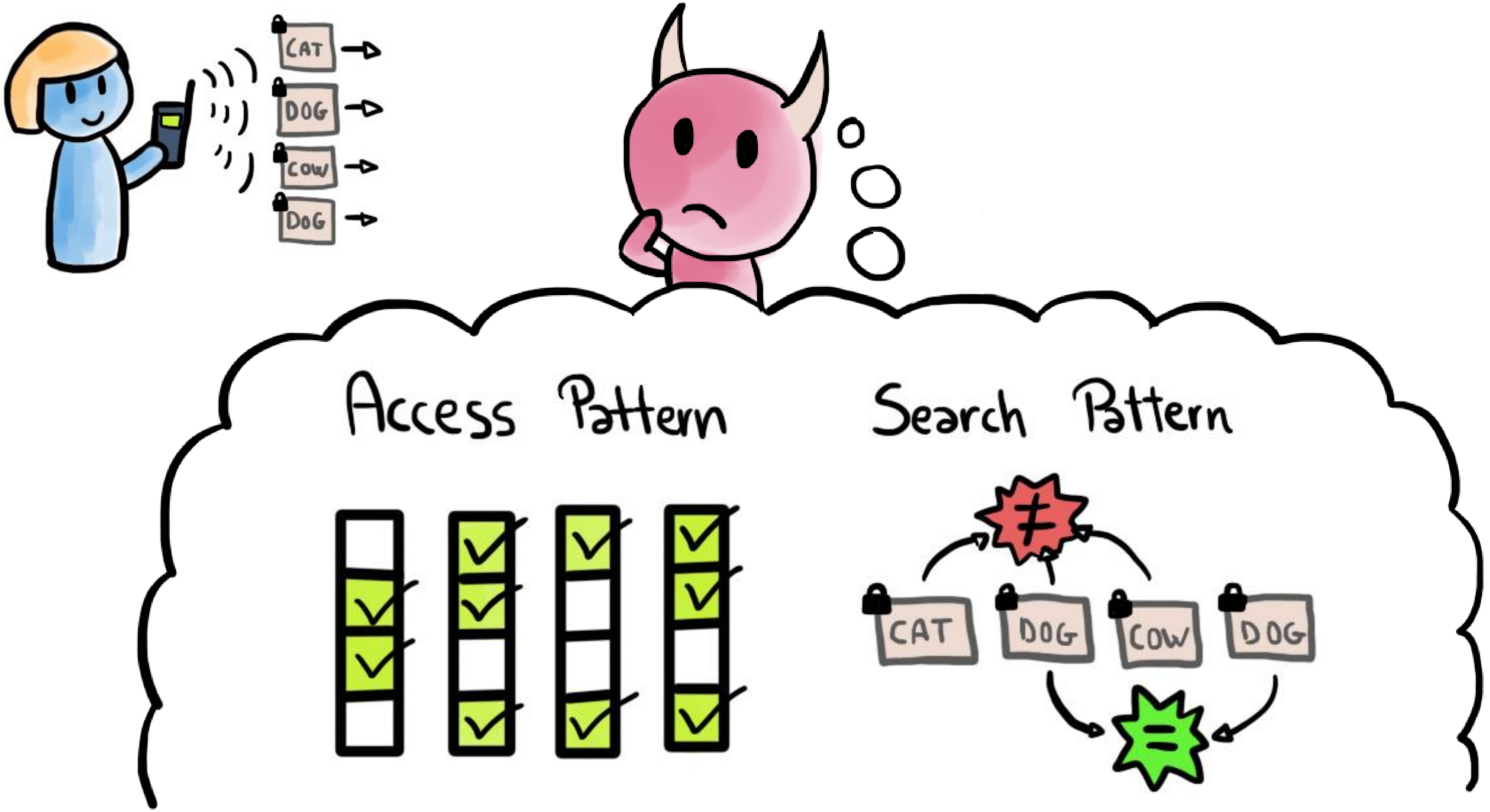
Overview



Overview

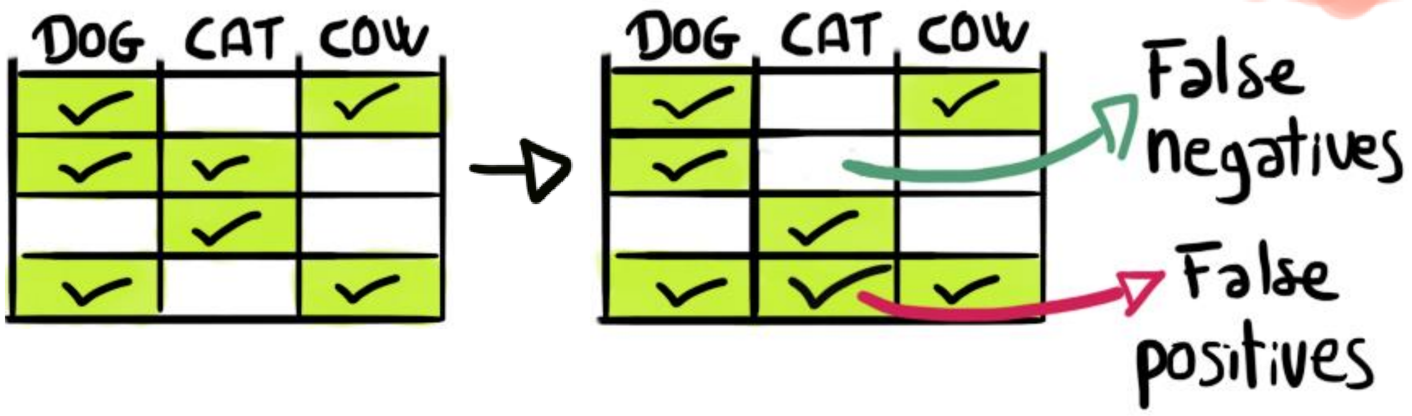

DOG
DOG
Query
DOG
CAT
COW
Access pattern
Docs that match the query

Overview


CAT
DOG
COW
DOG
Access Pattern
Search Pattern
≠
CAT
DOG
COW
DOG
=

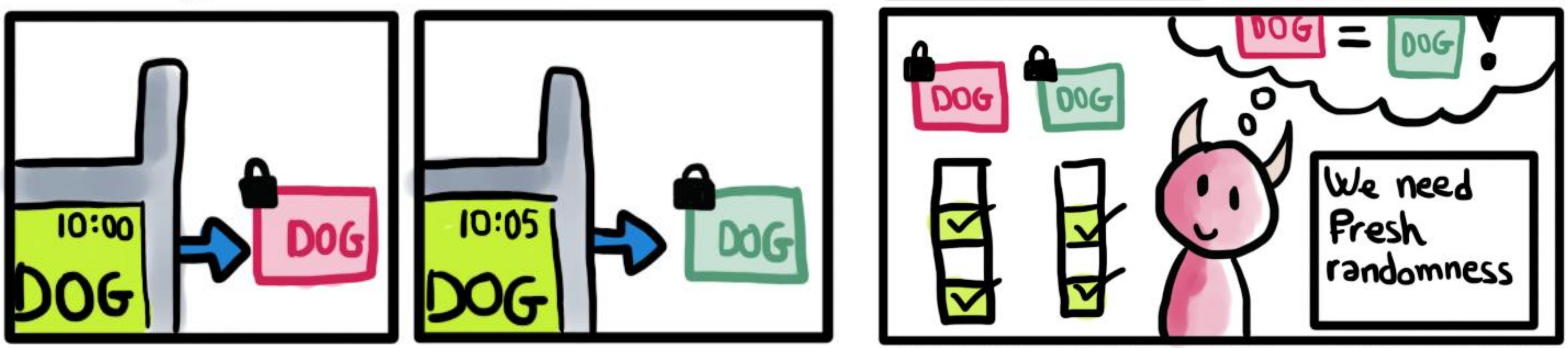
Hiding Access Pattern

CLRZ

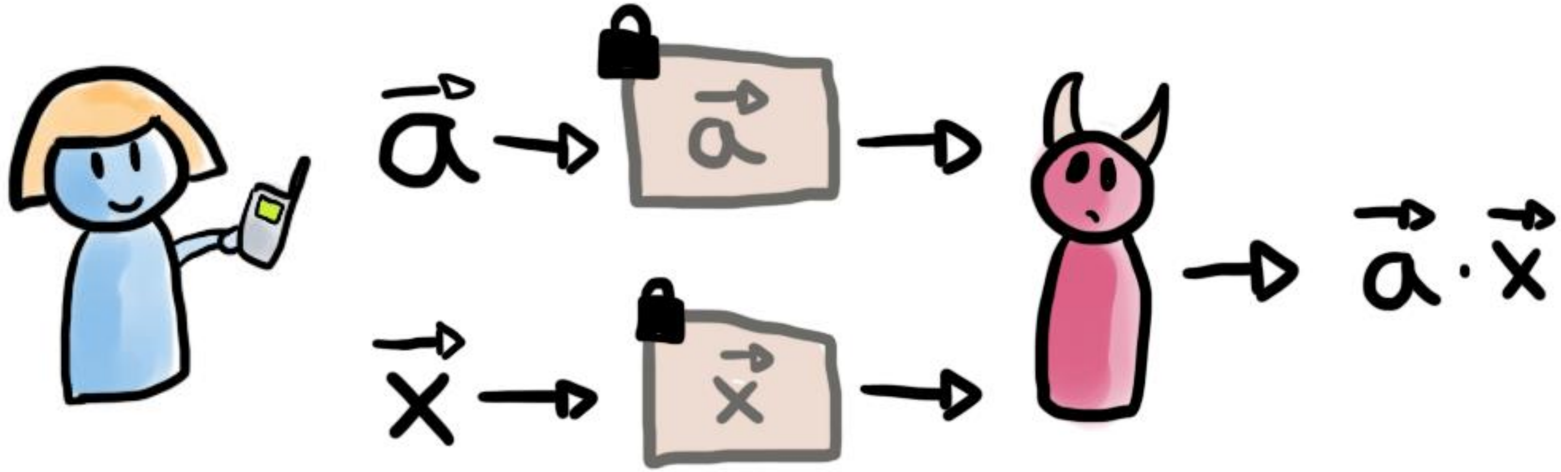


G. Chen, T.-H. Lai, M. K. Reiter, and Y. Zhang, "Differentially private access patterns for searchable symmetric encryption," in *IEEE INFOCOM 2018-IEEE Conference on Computer Communications*. IEEE, 2018, pp. 810–818.

Hiding Search Pattern?



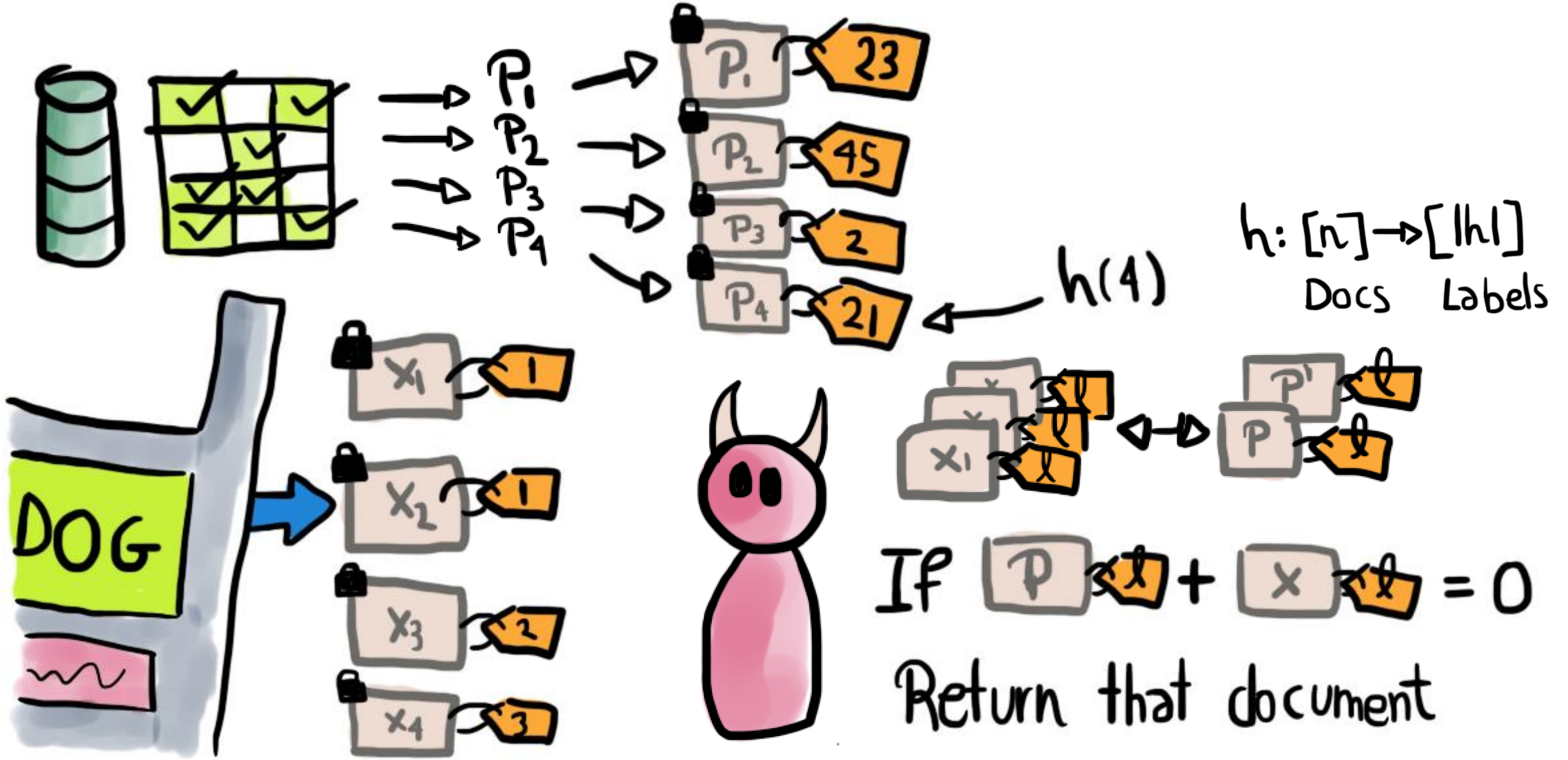
IPPE: Inner Product Predicate Encryption



$$P(x) = (x - r_1)(x - r_2)\cdots(x - r_d) = a_0 + a_1 x + a_2 x^2 + \cdots + a_d \cdot x^d = \vec{a} \cdot \vec{x}$$

$$\vec{x} = (x^0, x^1, x^2, \ldots)$$

OSSE: Obfuscated SSE



Polynomial Generation

$r_1 = (DOG \| \ell \| 5)$ ← There are 5 $(DOG\|\ell\|\cdots)$ already

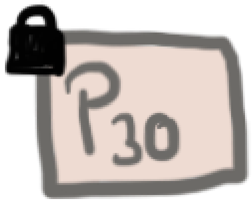
$r_2 = (COW \| \ell \| 0)$

$r_3 = (RAT \| \ell \| 1)$

$r_4 = (AAA \| \ell \| 0)$

$r_5 = (AAA \| \ell \| 0)$

$r_6 = (30 \| 0 \| -1)$



$D_{30} = \{DOG, COW, RAT\}$

$\ell = h(30)$

$S_{max} = \frac{\text{Max keywords}}{\text{per document}} = 5$

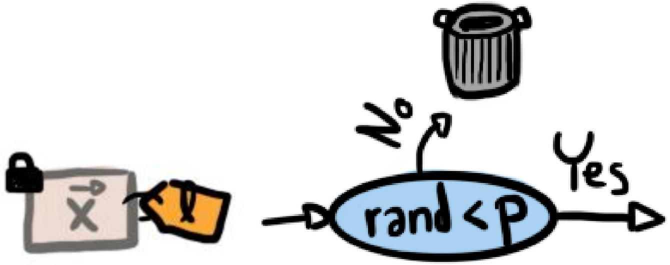
Token Generation

- **Find (database) with "DOG":**

For $\ell = 1 \rightarrow |h|$:

For $c = 0 \rightarrow c_{max}$:

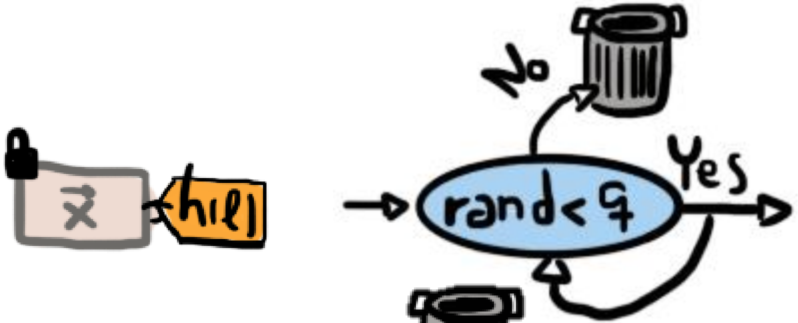
$x = (DOG \| \ell \| c) \rightarrow$

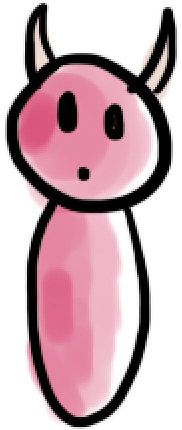


- **False positives:**

For $id = 1 \rightarrow n$:

$x = (id \| 0 \| -1) \rightarrow$

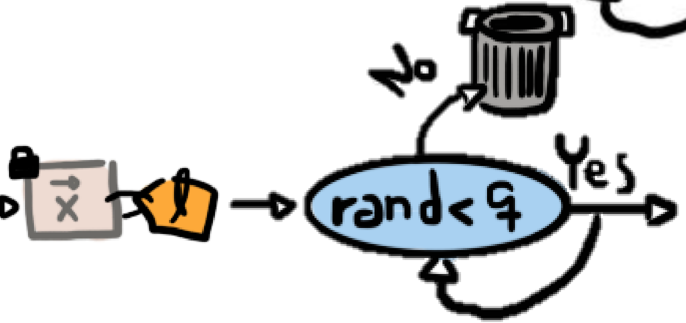




- **Non-matches:**

For $\ell = 1 \rightarrow |h|$:

$x = (AAA \| -1 \| 0) \rightarrow$



$r_1 = (DOG \| \ell \| 6)$

$r_2 = (COW \| \ell \| 0)$

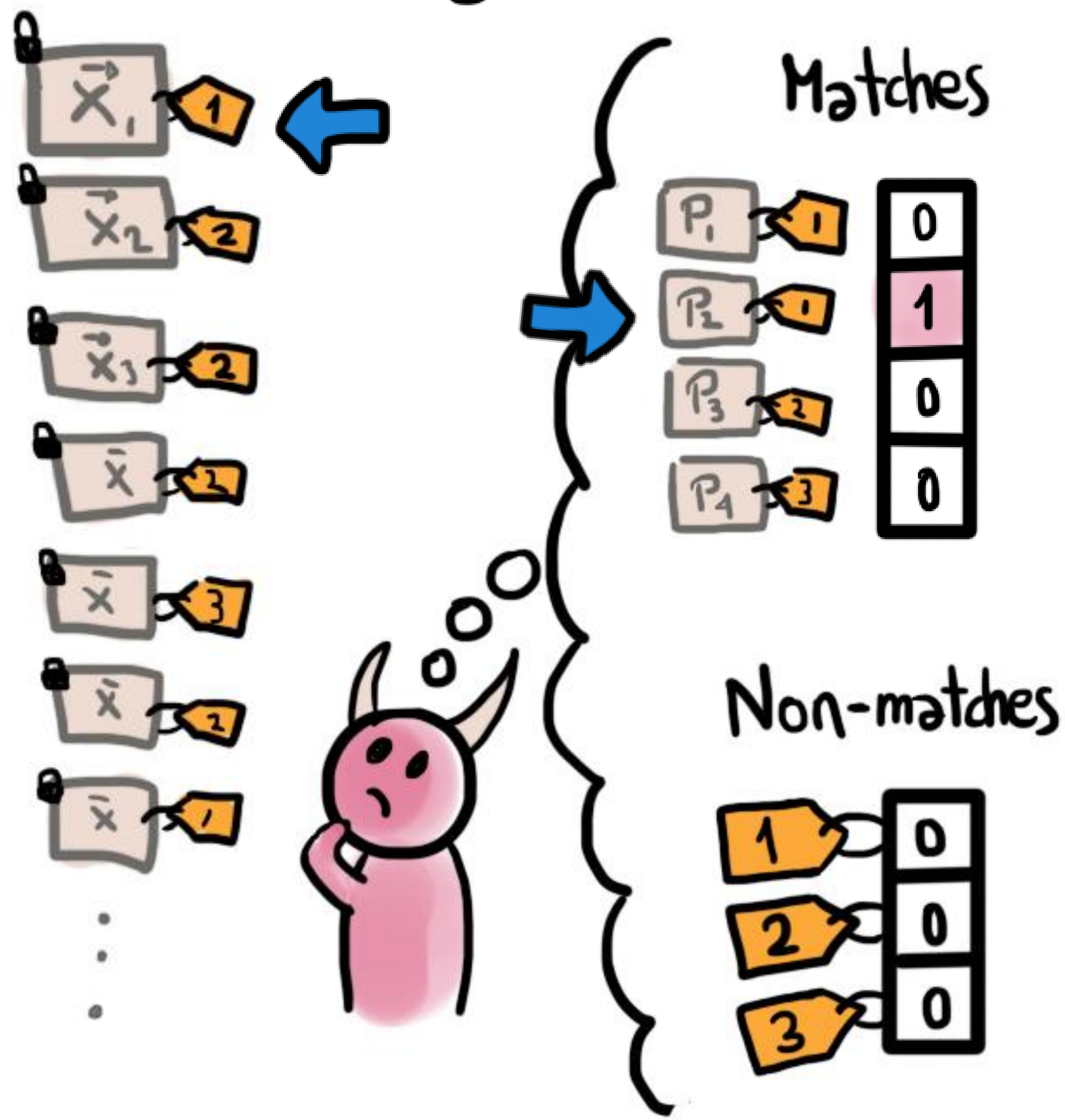
$r_3 = (RAT \| \ell \| 1)$

$r_4 = (AAA \| \ell \| 0)$

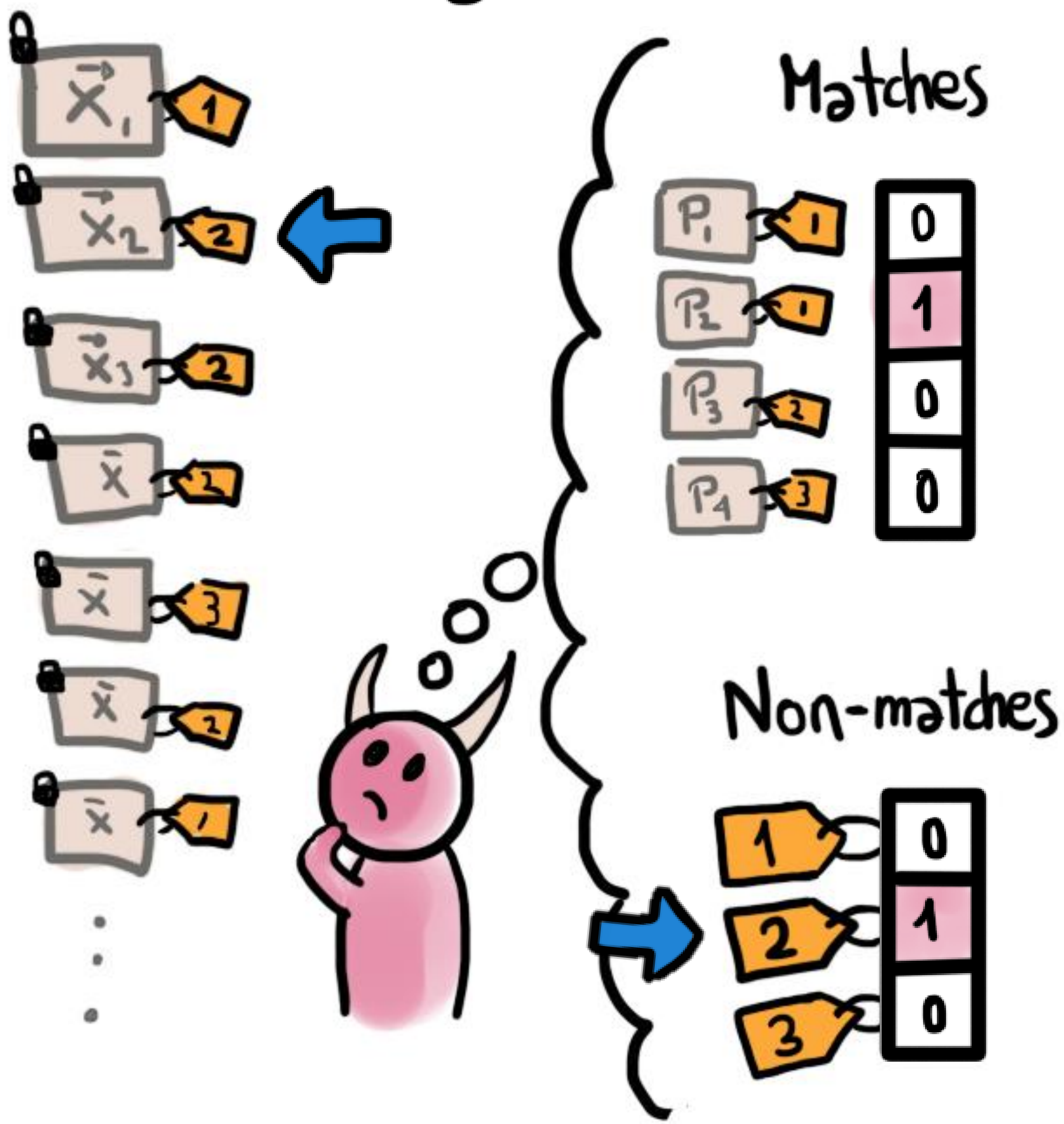
$r_5 = (AAA \| \ell \| 0)$

$r_6 = (30 \| 0 \| -1)$

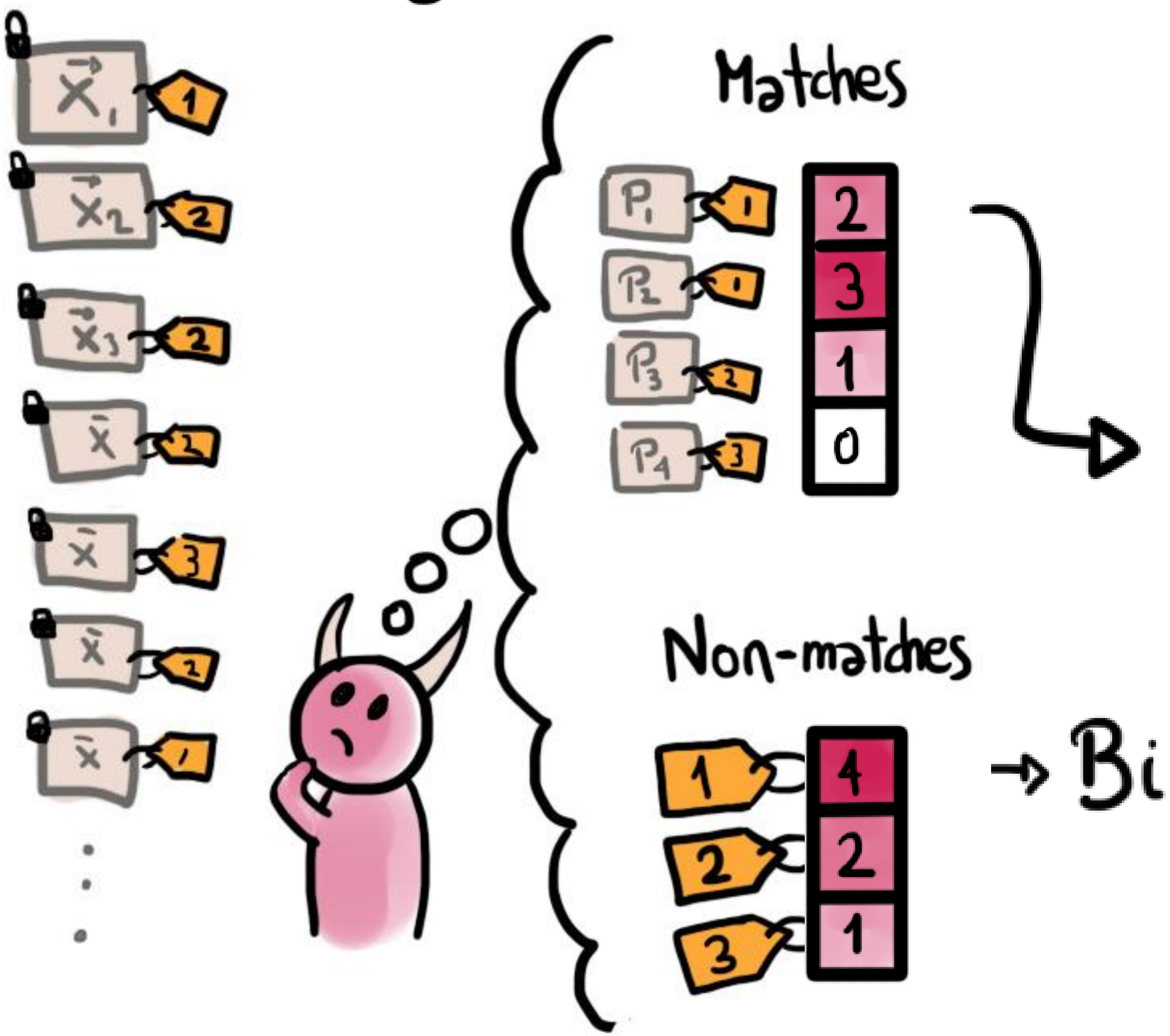
Adversary's View



Adversary's View



Adversary's View



$$\begin{cases} Ber(p) + Geo(1-q) & DOG \in D_1 \\ Geo(1-q) & DOG \notin D \end{cases}$$

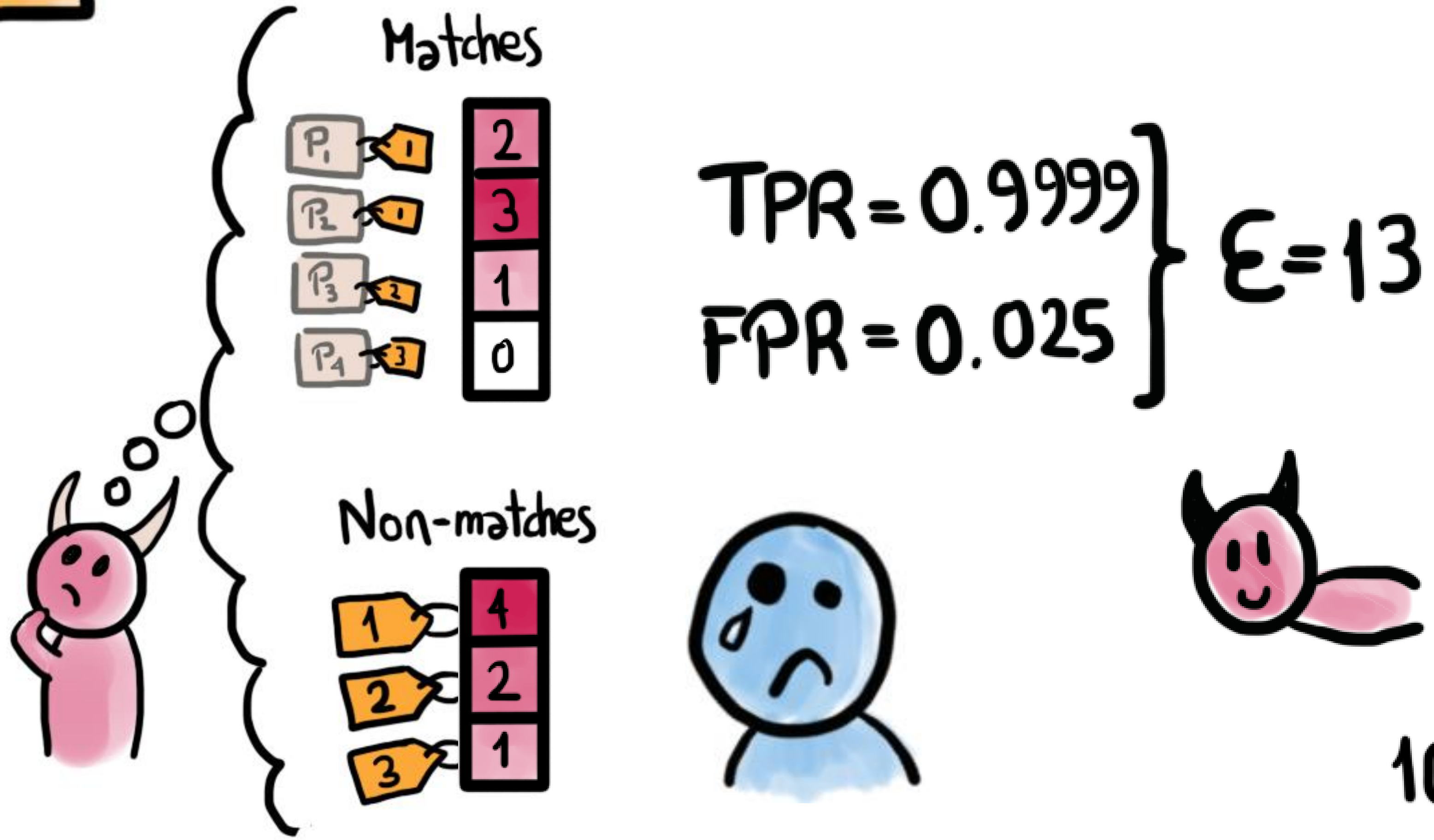
$$\rightarrow Bi(g_1, p) + Geo(1-q)$$

Security

We prove it holds by IPPE security

Differential Privacy

$$\varepsilon = \ln\left(\frac{TPR}{FPR} \cdot \frac{1-FPR}{1-TPR}\right)$$



Complexity Analysis

- Communication overhead (Zipf)

  $COMM = O(\log n_{keywords})$

  1 round

- Computational complexity

  $COMP < n \cdot (C_{max} + 1)$

- Client Storage: 

TWORAM (ORAM)

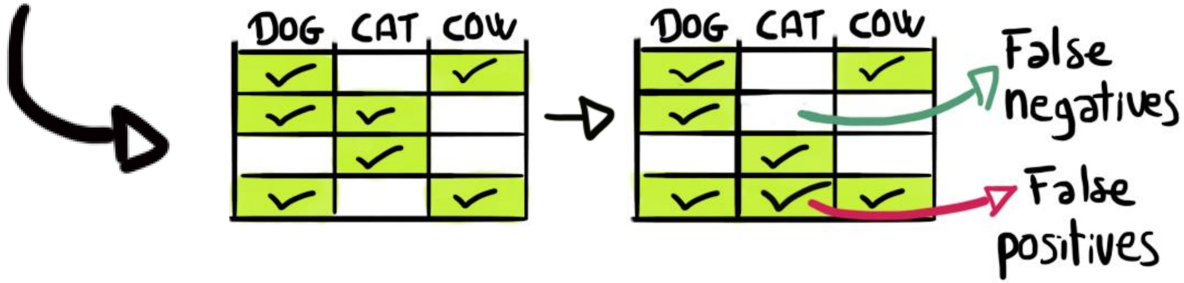
$O(\log n \cdot \log\log n)$

4 rounds at least

$O(\log^2 n)$ storage 

Evaluation:

- CLRZ vs. OSSE



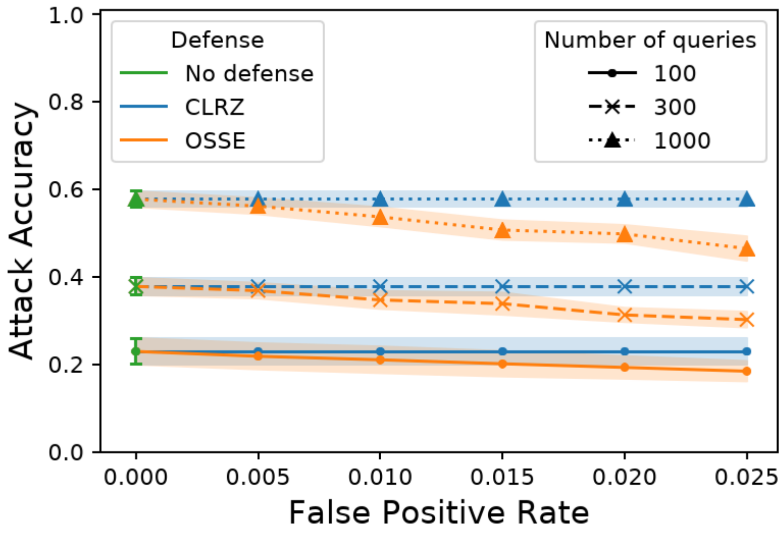
- Four different query recovery attacks
- Enron dataset
- We adapt the attacks against the defenses

Results

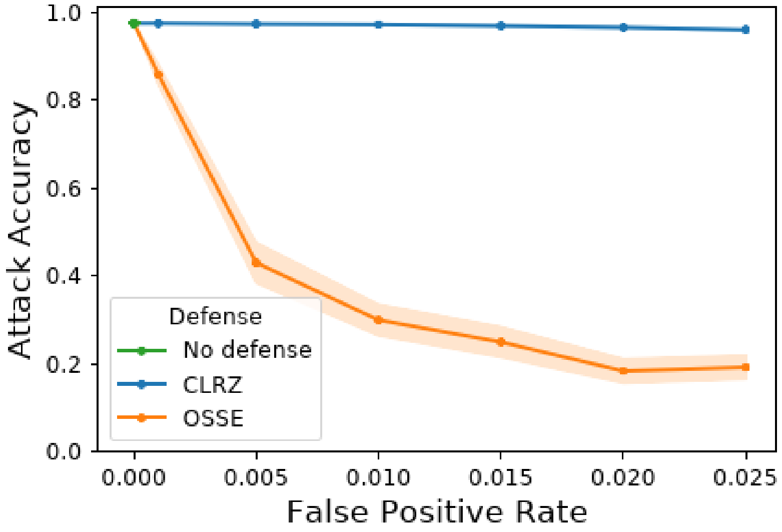
CLRZ

OSSE

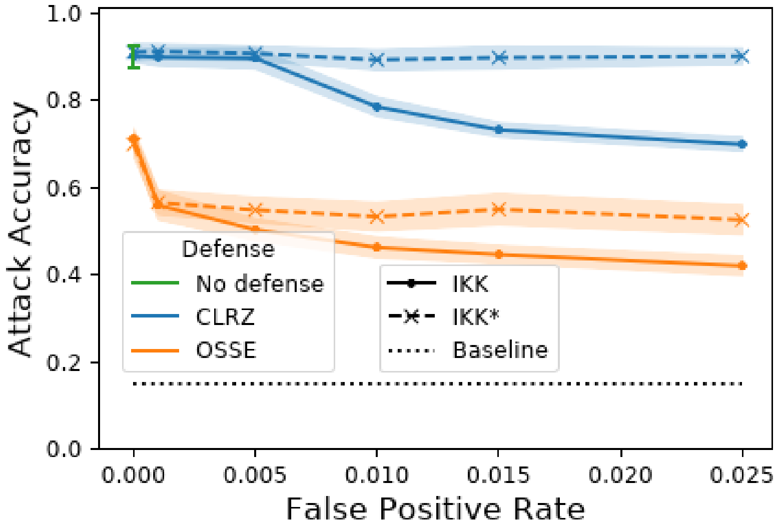
Liu et al.



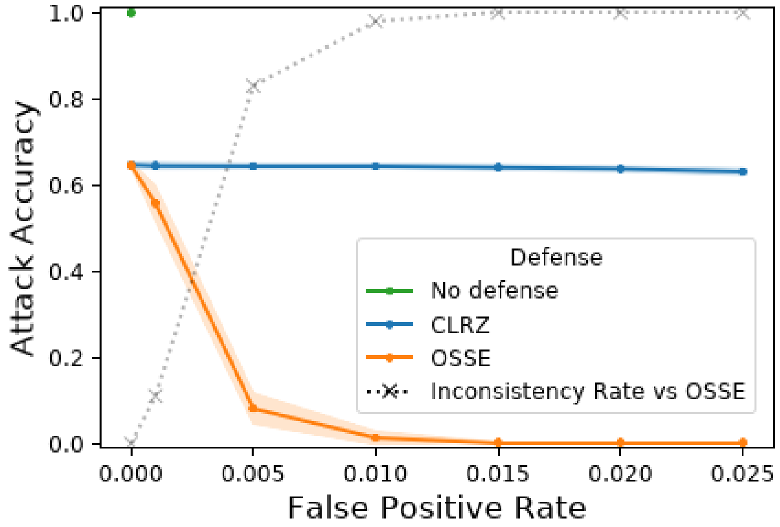
Pouliot & Wright



Islam et al.



Cash et al.



Conclusions

- Hiding search pattern is challenging but very effective against attacks!

- OSSE: SSE using IPPE

High computation

# cores	BuildIndex (min)	Trapdoor (s)	Search (min)
4	272.5	580.7	1099.1
8	136.3	290.5	549.6
16	68.2	145.3	274.8
32	34.1	72.8	137.4
64	17.1	36.4	68.7
128	8.5	18.2	34.4
160	6.9	14.7	27.5

TABLE V: Running Times

CLRZ=200 ms

Conclusions

- Hiding search pattern is challenging but very effective against attacks!

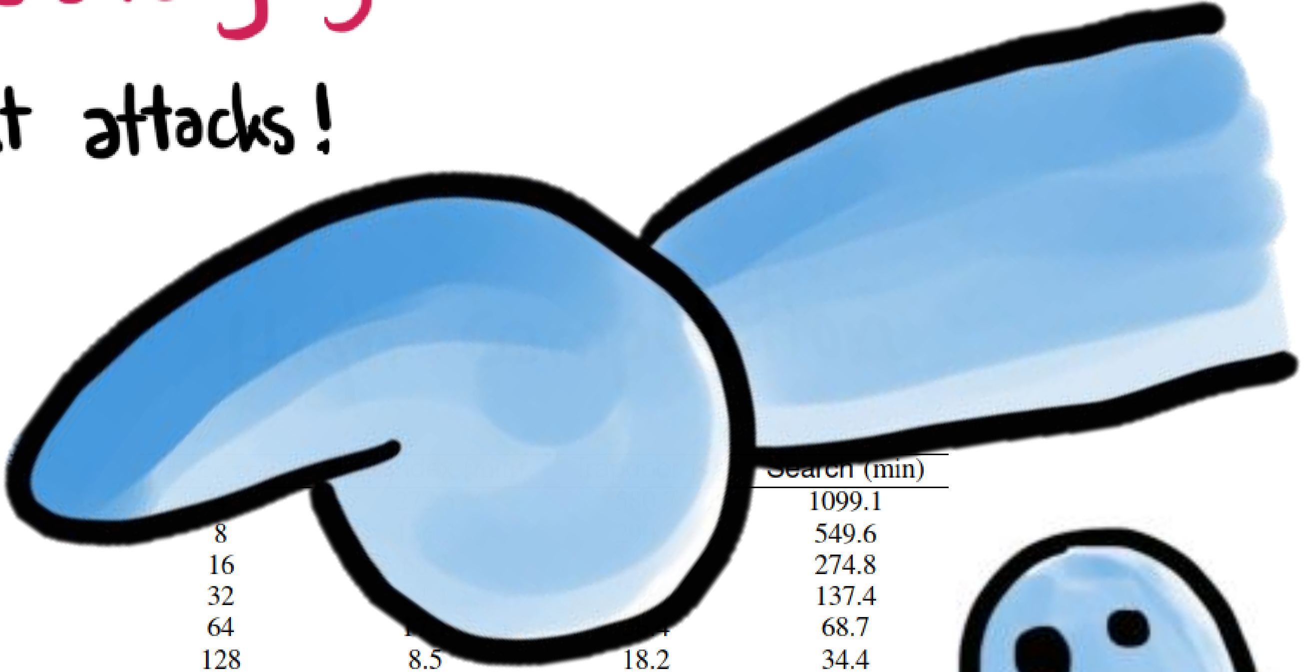
- OSSE: SSE using IPPE

1 comm round!

No client storage!

Better asymp. Comm than ORAM

Hides search pattern!



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Thanks!

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