TECHNISCHE UNIVERSITÄT DARMSTADT

Do You Need a Receipt? Anonymous Credential Revocation at Continental Scale via Private Record Certification

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CROSSING

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DFG Deutsche Forschungsgemeinschaft
German Research Foundation

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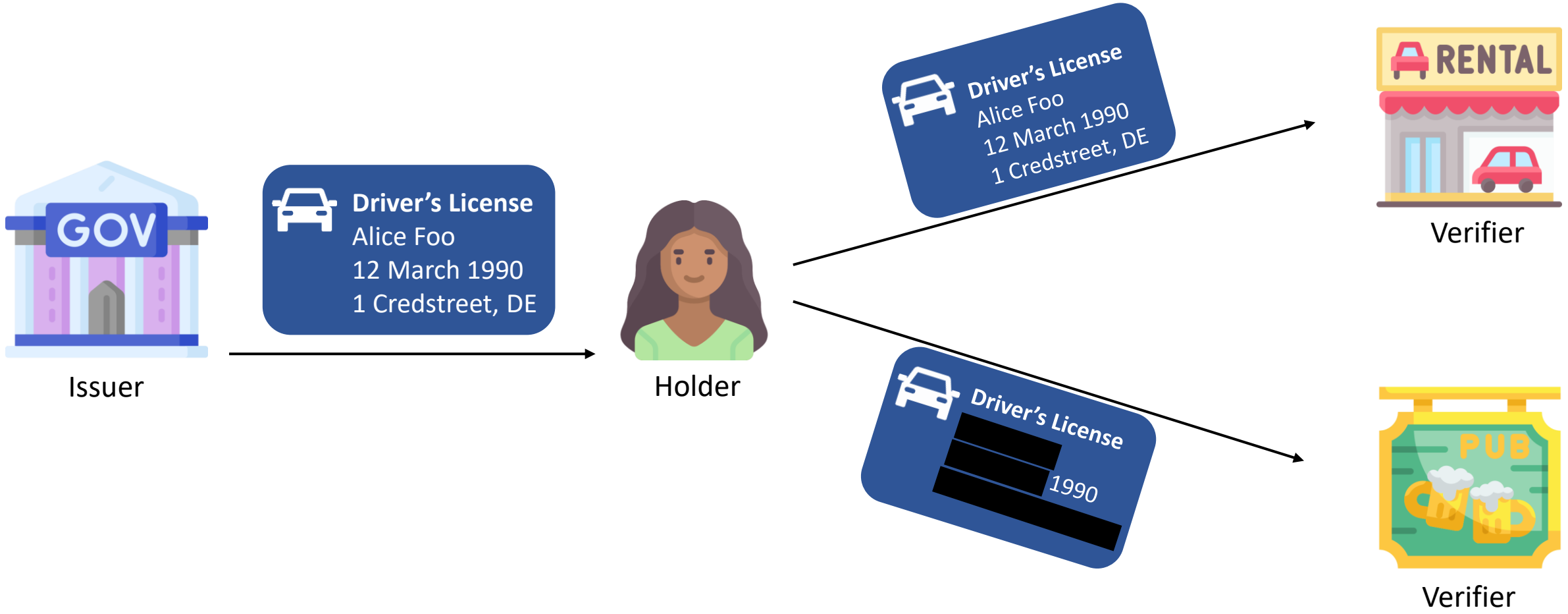
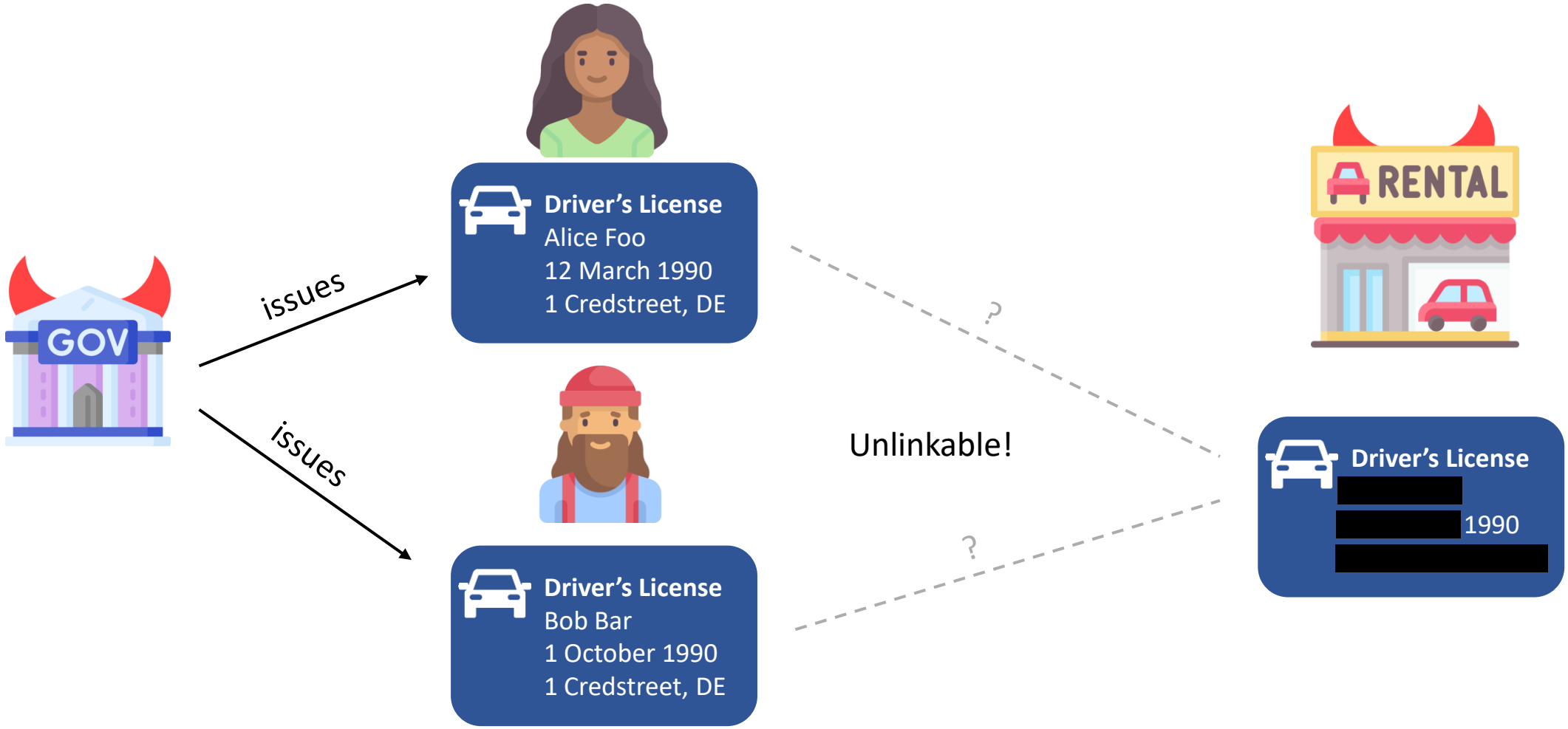
erc
European Research Council
Established by the European Commission

Anonymous Credentials

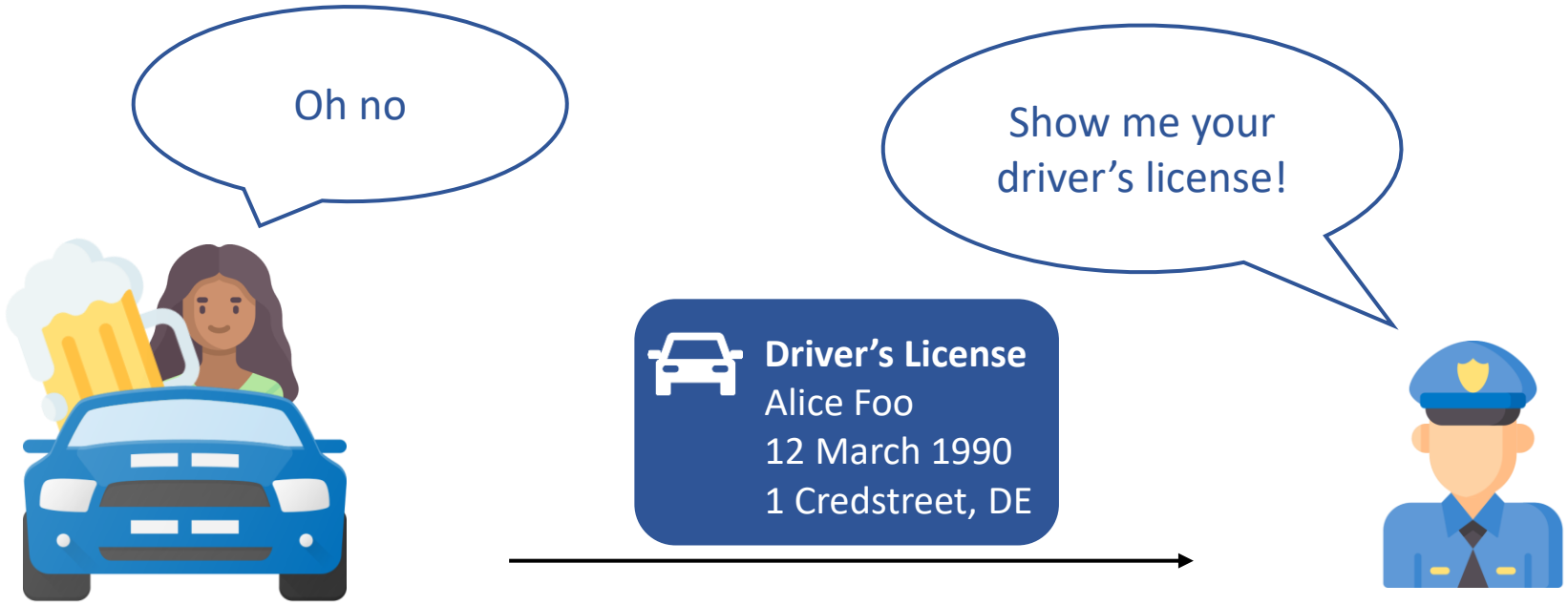


Anonymous Credentials - Unlinkability



How to invalidate a Credential?

How to invalidate a Credential?



Anonymous Credential Revocation



Revocation Authority







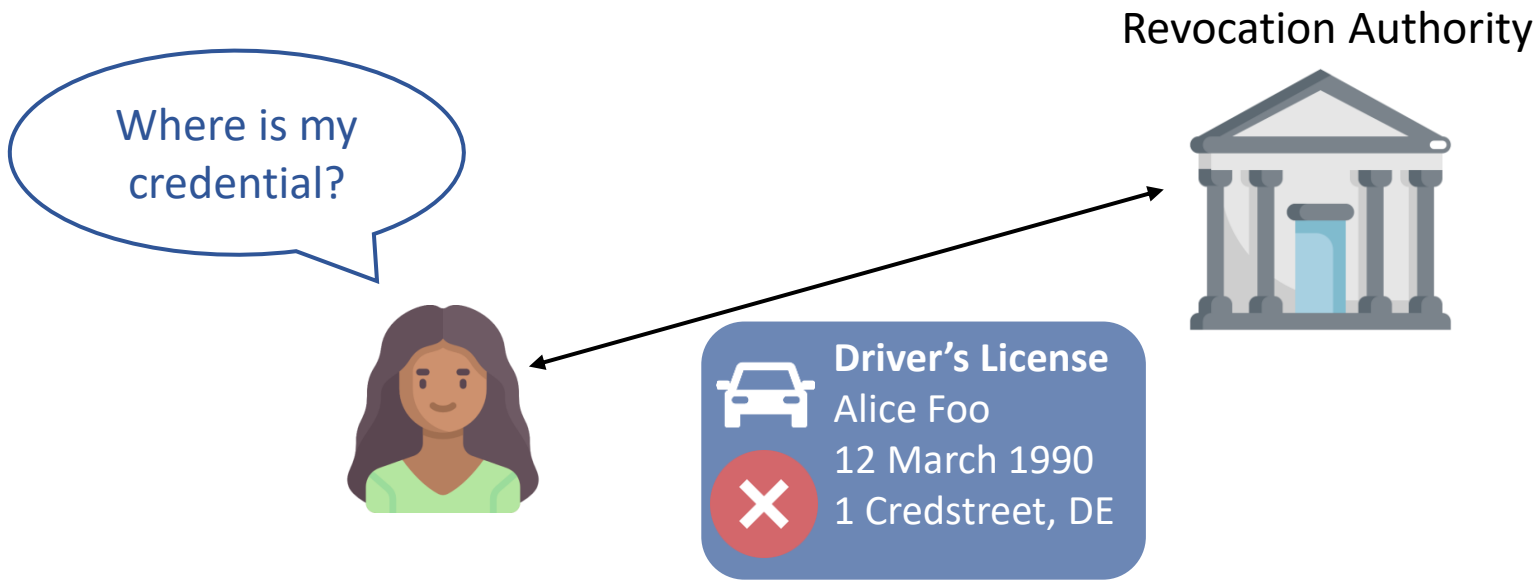
Anonymous Credential Revocation



Anonymous Credential Revocation



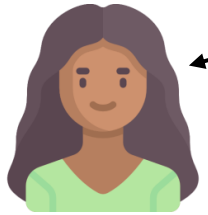
Anonymous Credential Revocation



Anonymous Credential Revocation

Revocation is time-critical!

Revocation Authority







Driver's License
Alice Foo
12 March 1990
1 Credstreet, DE

Driver's License
Alice Foo
12 March 1990
1 Credstreet, DE

Revocation Scheme Wishlist



Unlinkability



Instant Revocation



Scalability



Revocation Privacy

Ideal Revocation Scheme

Property	Unlinkability	Scalability	Instant Revocation	Revocation Privacy
Status List	✗	–	–	✗
Token-Based	–	–	✗	✗
Accumulator	✓	✗	–	✗
Ours	✓	✓	✓	✓

Naïve Approach



Revocation Authority

(sk, pk)

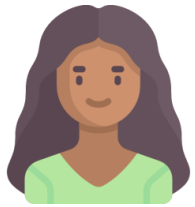


$=$

0
1
1
0
1

idx = 3

$\text{Sign}(sk, (3, \text{time}))$





Driver's License
idx = 3

Naïve Approach



Revocation Authority
(sk, pk)

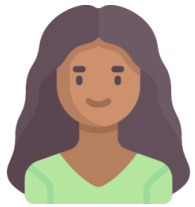


$=$

0
1
1
0
1

idx = 3

$\text{Sign}(sk, (3, \text{time}))$





Driver's License
idx = 3

No privacy!

Naïve Approach



Revocation Authority
(sk, pk)

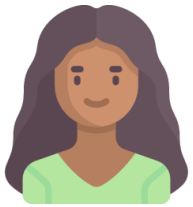


$=$

$\text{Sign}(sk, (1, \text{time}))$
$\perp$
$\text{Sign}(sk, (3, \text{time}))$
$\perp$
$\text{Sign}(sk, (5, \text{time}))$

idx = 3


[3]





Driver's License
idx = 3

Naïve Approach



Revocation Authority
(sk, pk)

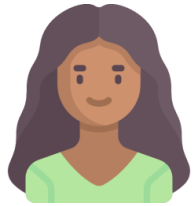
$=$

$\text{Sign}(sk, (1, \text{time}))$
$\perp$
$\text{Sign}(sk, (3, \text{time}))$
$\perp$
$\text{Sign}(sk, (5, \text{time}))$

Private Information Retrieval (PIR)

idx = 3

$[3]$



Driver's License
idx = 3

Naïve Approach

Property	Unlinkability	Scalability	Instant Revocation	Revocation Privacy
Naïve Approach V1	–	✗	–	✗



Revocation Authority
(sk, pk)

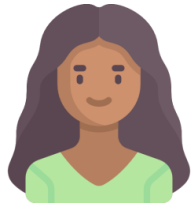
$=$

$\text{Sign}(sk, (1, \text{time}))$
$\perp$
$\text{Sign}(sk, (3, \text{time}))$
$\perp$
$\text{Sign}(sk, (5, \text{time}))$

Private Information Retrieval (PIR)

idx = 3

$[3]$



Driver's License
idx = 3

Naïve Approach



Revocation Authority
(sk, pk)



$=$

$\mathrm{Sign}(sk, co_1), co_1$
$\mathrm{Sign}(sk, co_2), co_2$
$\mathrm{Sign}(sk, co_3), co_3$
$\mathrm{Sign}(sk, co_4), co_4$
$\mathrm{Sign}(sk, co_5), co_5$

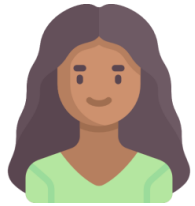


Private Information Retrieval (PIR)

idx = 3



$[3]$





Driver's License
idx = 3

r_i

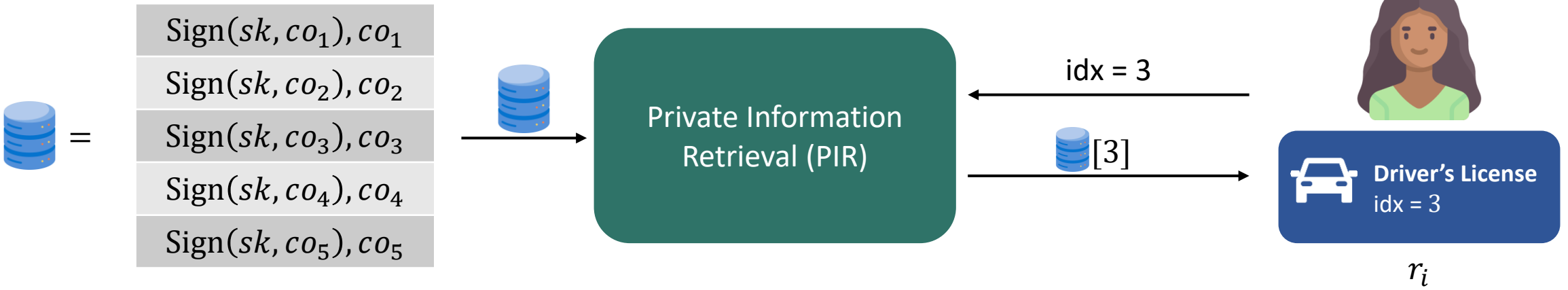
if i is revoked: $\mathrm{co_i} \leftarrow \mathrm{Commit}(\perp; r_i)$
valid: $\mathrm{co_i} \leftarrow \mathrm{Commit}(i, \mathrm{time}; r_i)$

Naïve Approach

Property	Unlinkability	Scalability	Instant Revocation	Revocation Privacy
Naïve Approach V2	✓	✗	–	✓



Revocation Authority
(sk, pk)

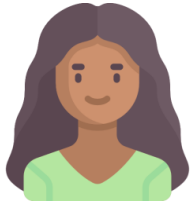


r_i

if i is revoked: $\mathrm{co_i} \leftarrow \mathrm{Commit}(\perp; r_i)$
valid: $\mathrm{co_i} \leftarrow \mathrm{Commit}(i, \mathrm{time}; r_i)$

Naïvely revoking Credentials

Driver's License
Alice Foo
12 March 1990
idx = 3



Holder



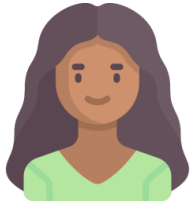
Revocation Authority



Verifier

Naïvely revoking Credentials

Driver's License
Alice Foo
12 March 1990
idx = 3



Holder



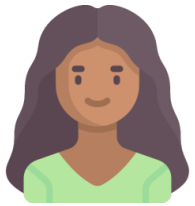
Revocation Authorities



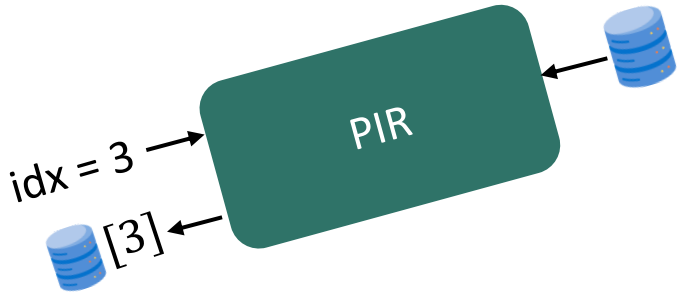
Verifier

Naïvely revoking Credentials





Holder



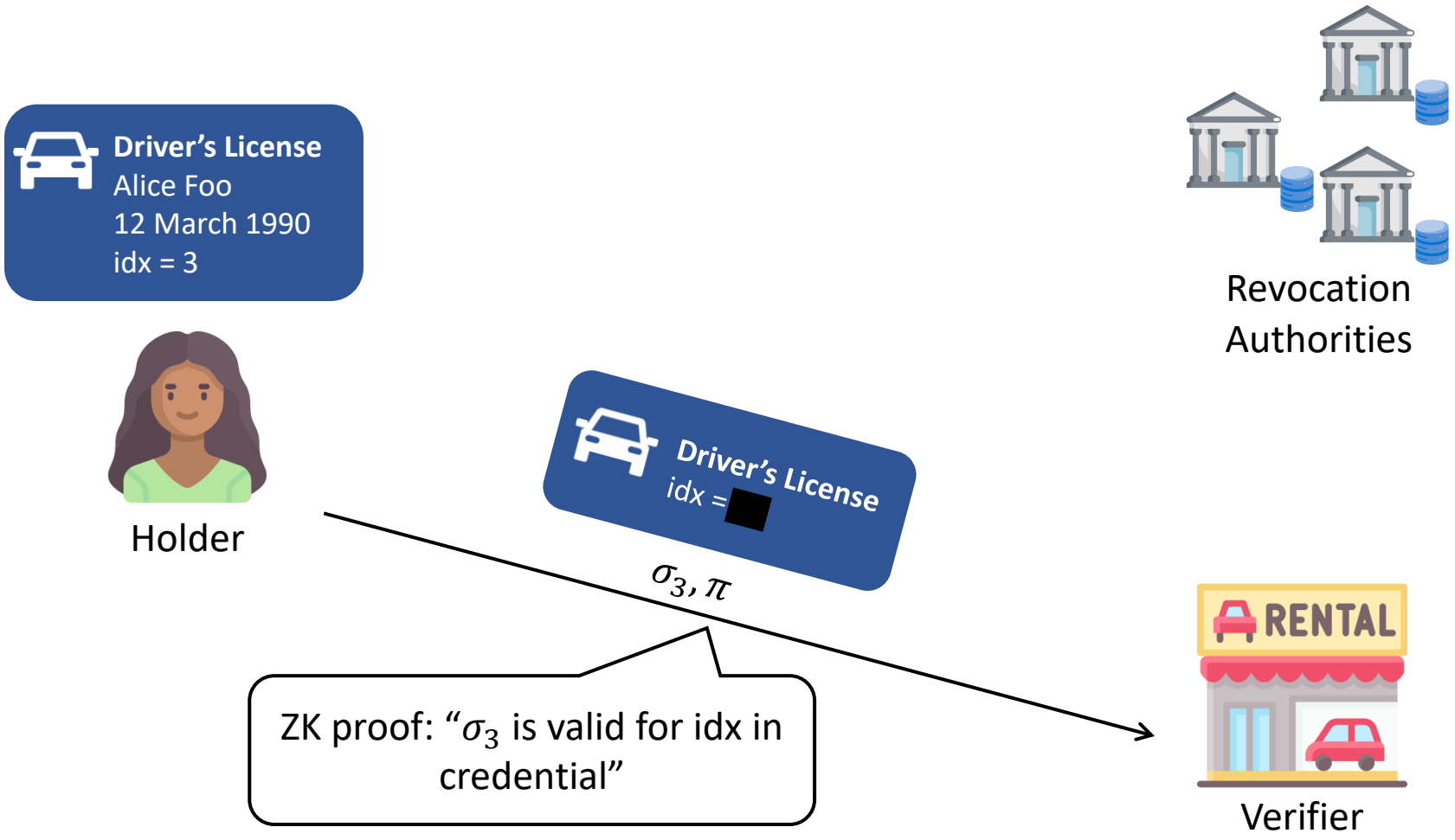


Revocation Authorities



Verifier

Naïvely revoking Credentials

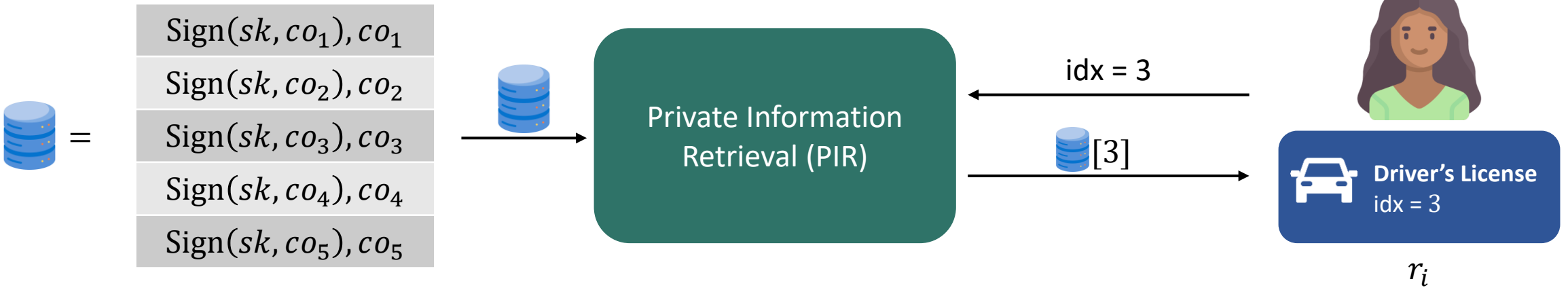


Naïve Approach

Property	Unlinkability	Scalability	Instant Revocation	Revocation Privacy
Naïve Approach V2	✓	✗	–	✓



Revocation Authorities



if i is revoked: $\text{co}_\text{i} \leftarrow \text{Commit}(\perp; r_i)$

valid: $\text{co}_\text{i} \leftarrow \text{Commit}(i, \text{time}; r_i)$

Naïve Approach



Revocation Authorities

Property	Unlinkability	Scalability	Instant Revocation	Revocation Privacy
Naïve Approach V2	✓	✗	–	✓

size: $96B \cdot 1$ billion $= 96\ GB$!

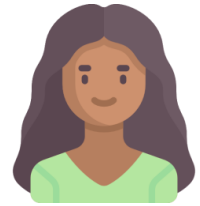
$=$

$\mathrm{Sign}(sk, co_1), co_1$
$\mathrm{Sign}(sk, co_2), co_2$
$\mathrm{Sign}(sk, co_3), co_3$
$\mathrm{Sign}(sk, co_4), co_4$
$\mathrm{Sign}(sk, co_5), co_5$

Private Information Retrieval (PIR)

idx = 3

[3]



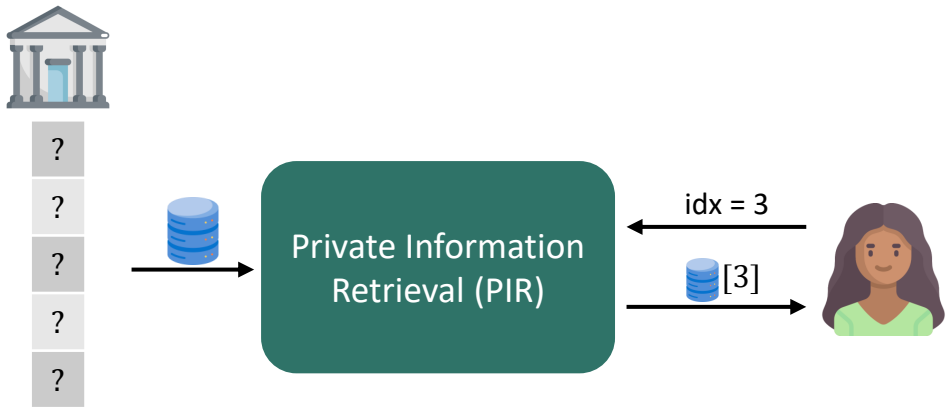
Driver's License
idx = 3

r_i

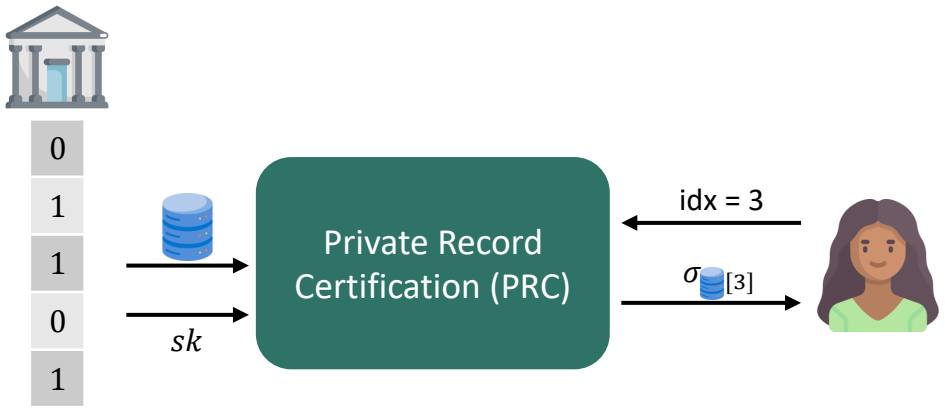
if i is revoked: $\mathrm{co_i} \leftarrow \mathrm{Commit}(\perp; r_i)$
valid: $\mathrm{co_i} \leftarrow \mathrm{Commit}(i, \mathrm{time}; r_i)$

Private Record Certification (PRC)

PIR



PRC



Naïve Approach



Revocation Authority
(sk, pk)

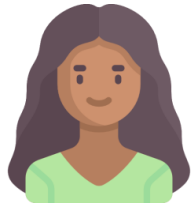
$=$

$\mathrm{Sign}(sk, co_1), co_1$
$\mathrm{Sign}(sk, co_2), co_2$
$\mathrm{Sign}(sk, co_3), co_3$
$\mathrm{Sign}(sk, co_4), co_4$
$\mathrm{Sign}(sk, co_5), co_5$

Private Information Retrieval (PIR)

idx = 3

$[3]$



Driver's License
idx = 3

r_i

PRC for Revocation



Revocation Authority

(sk, pk)

size: $1b \cdot 1$ billion $= 125\ MB$!

$=$

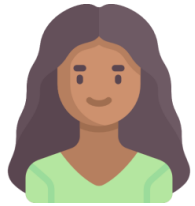
0
1
1
0
1

sk

Private Record Certification (PRC)

idx = 3

$\sigma_{[3]}$



Driver's License
idx = 3

PRC for Revocation



Revocation Authority

(sk, pk)



$=$

0
1
1
0
1

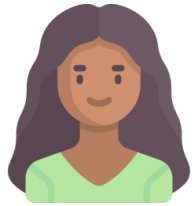


sk

Private Record Certification (PRC)

idx = 3

$\sigma_{[3]}$



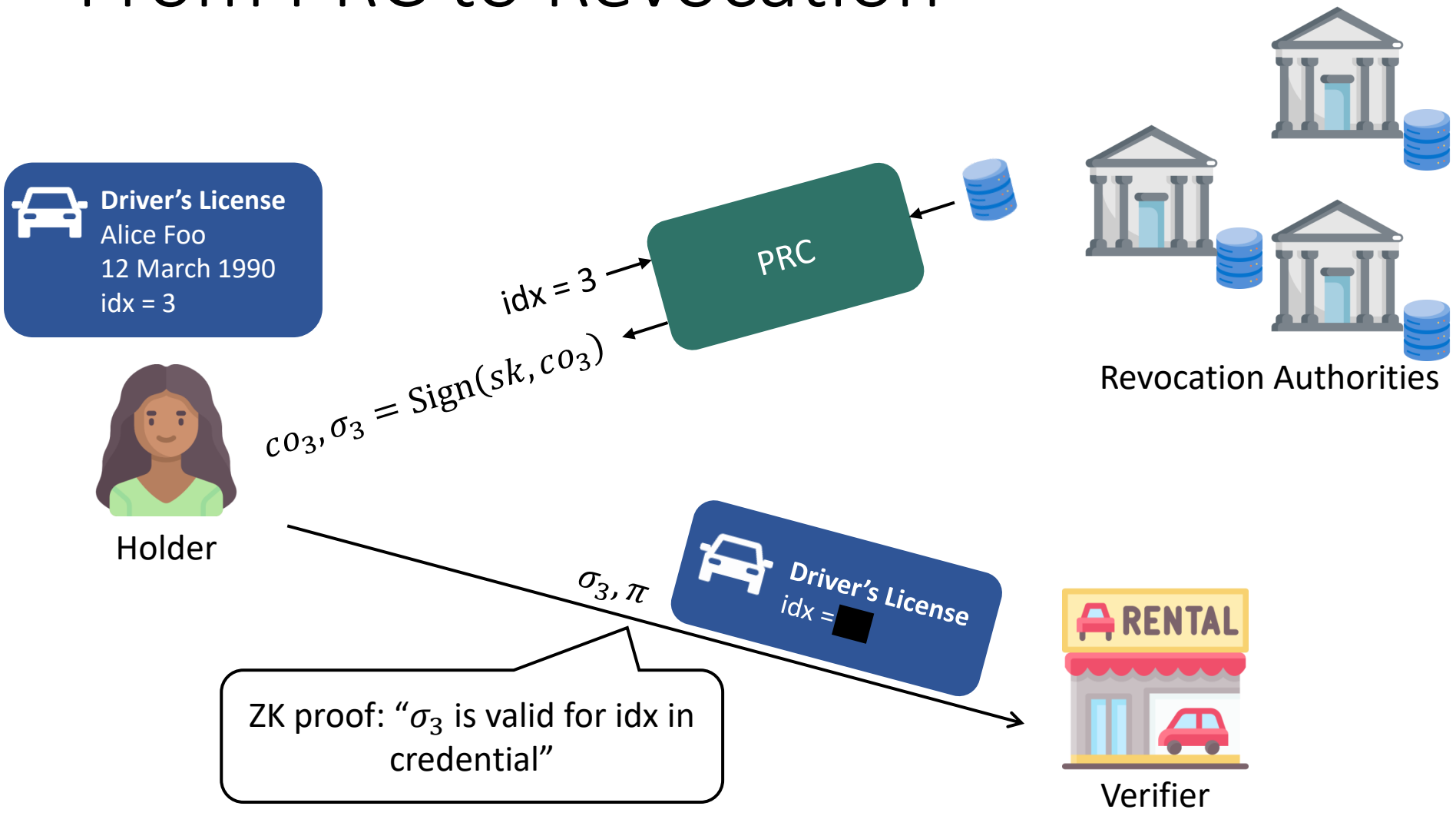


Driver's License
idx = 3

r_i

Design this to be $(\text{Sign}(sk, co_3), co_3)$

From PRC to Revocation



Ingredients 



Secure MPC





Secret Sharing

here: GMW



Commitment Scheme

here: Pedersen

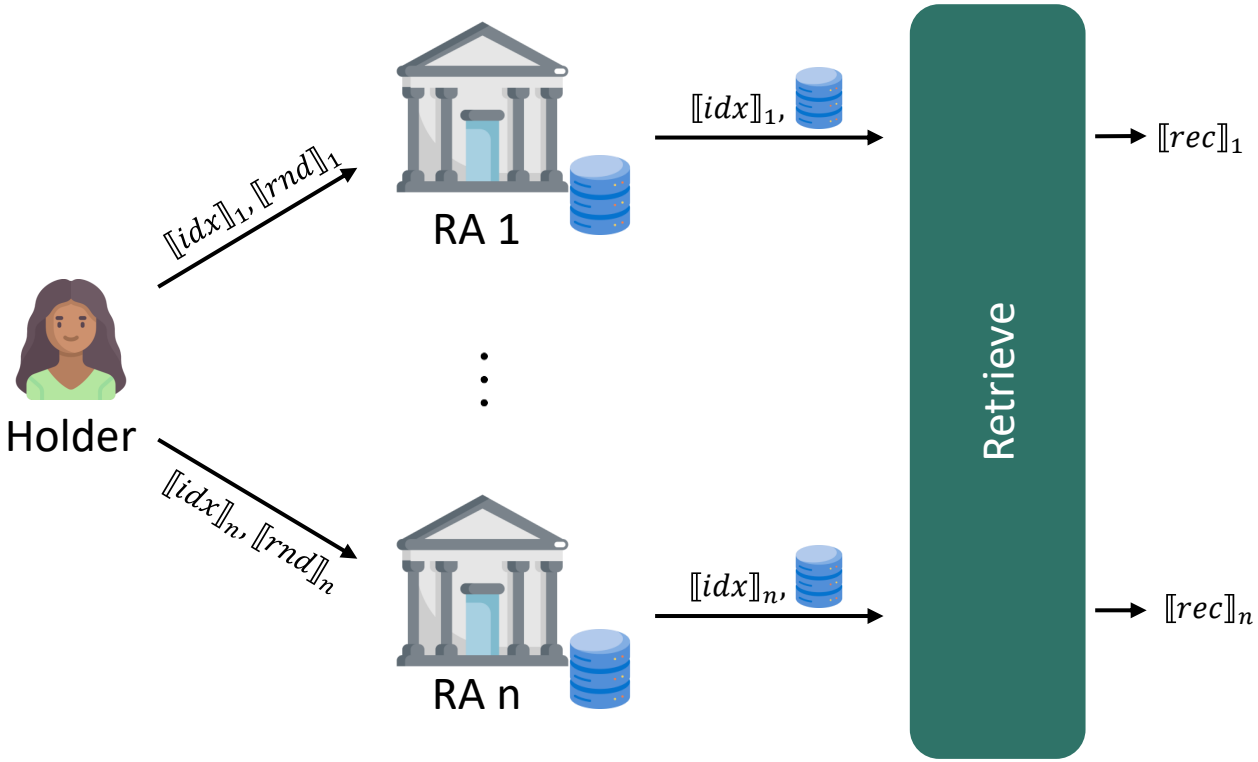


Threshold Signature

here: Threshold EdDSA

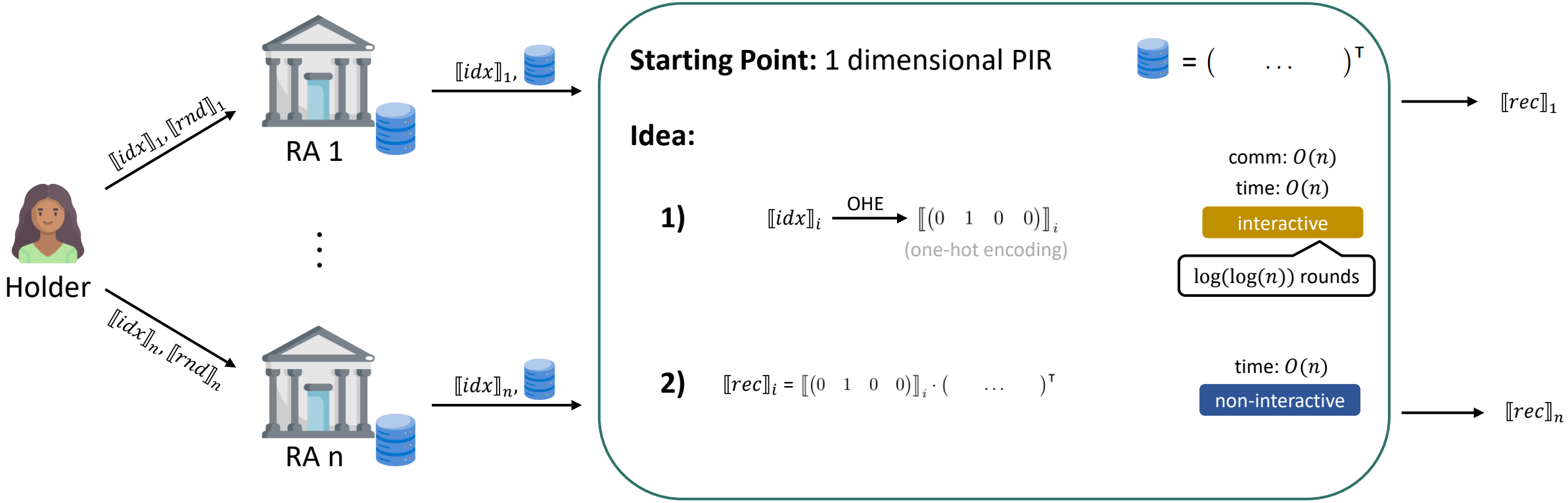
Constructing PRC

$[\![\cdot]\!]$	secret share
idx	index
rnd	randomness
rec	record value



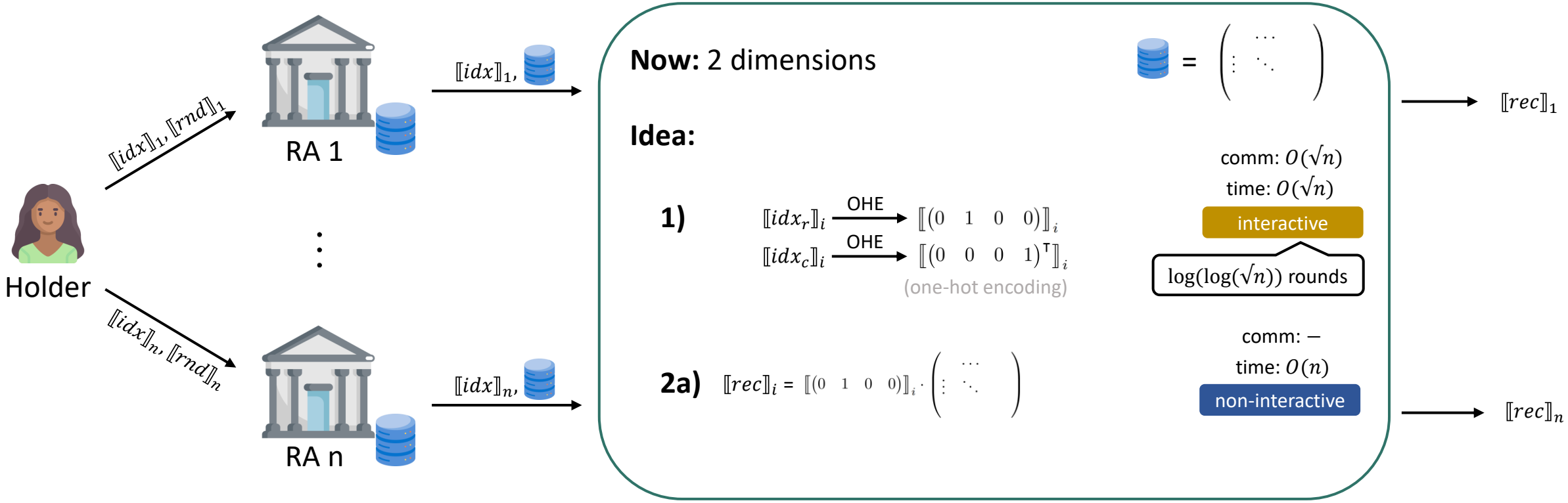
Constructing PRC

$[\![\cdot]\!]$	secret share
idx	index
rnd	randomness
rec	record value



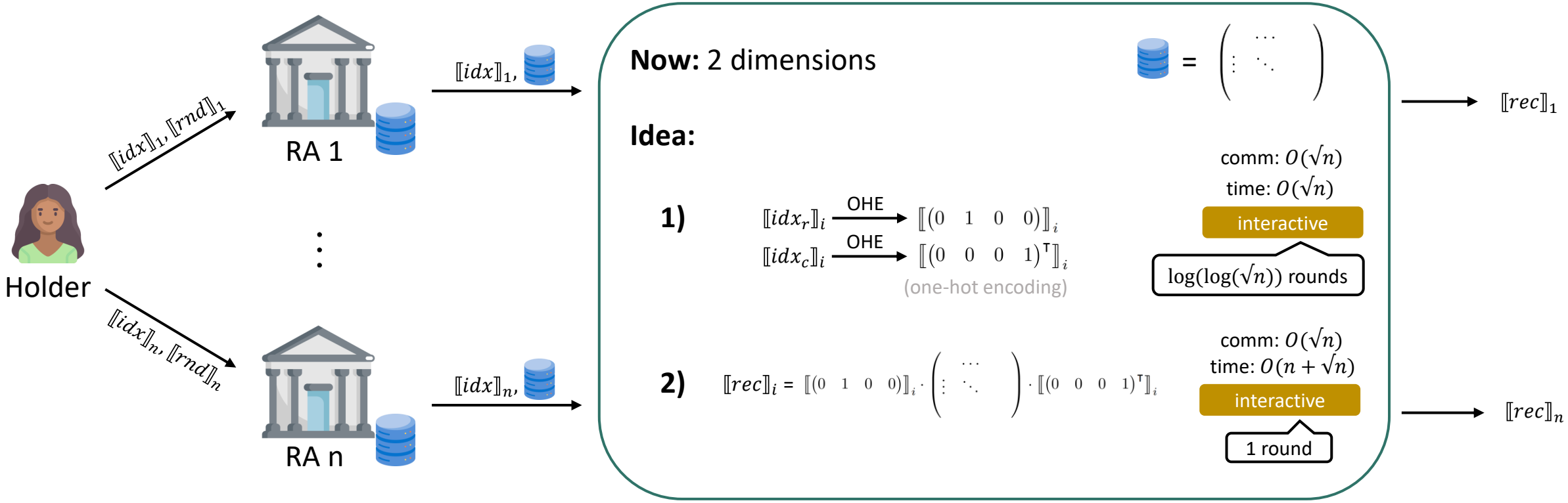
Constructing PRC

$[\![\cdot]\!]$	secret share
idx	index
rnd	randomness
rec	record value



Constructing PRC

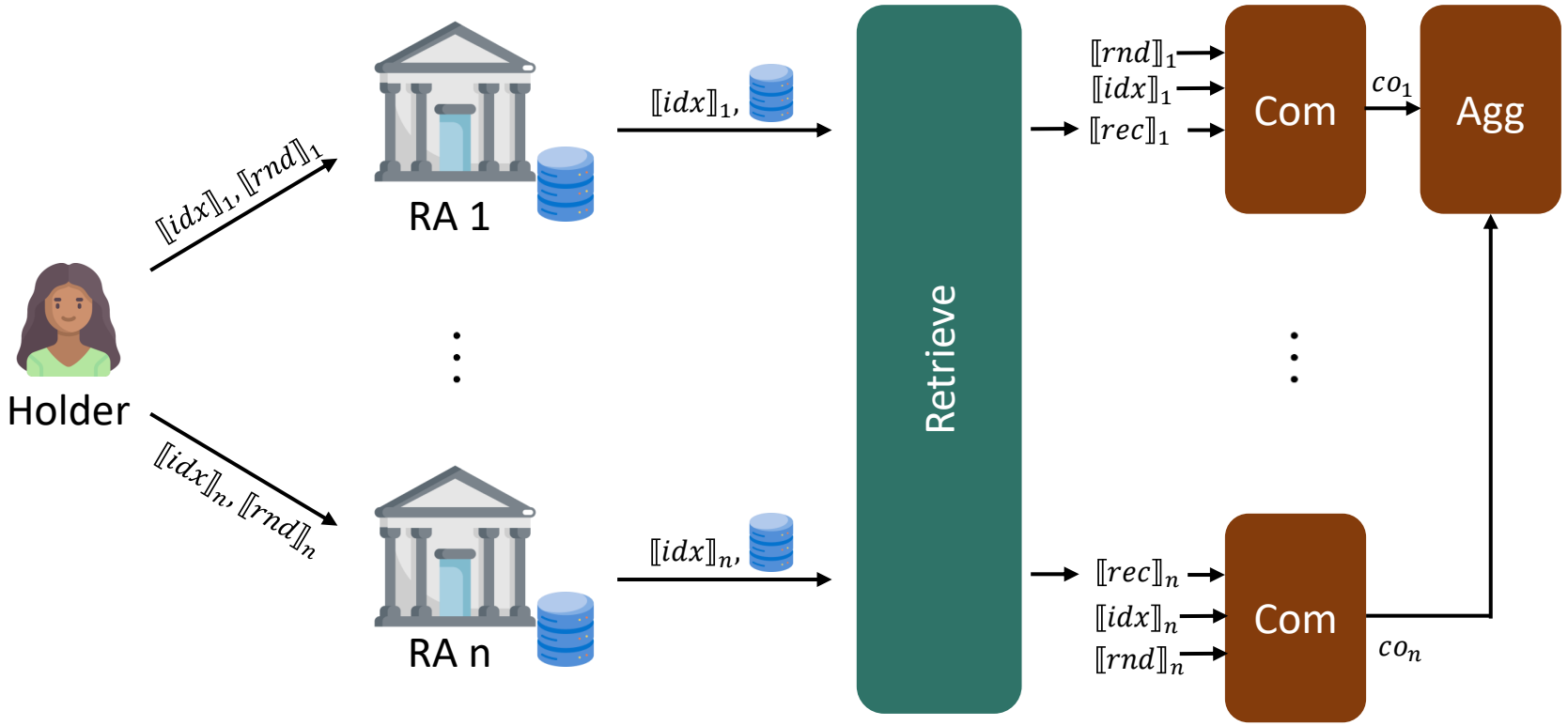
$[\![\cdot]\!]$	secret share
idx	index
rnd	randomness
rec	record value



Constructing PRC

$[\![\cdot]\!]$	secret share
idx	index
rnd	randomness
rec	record value

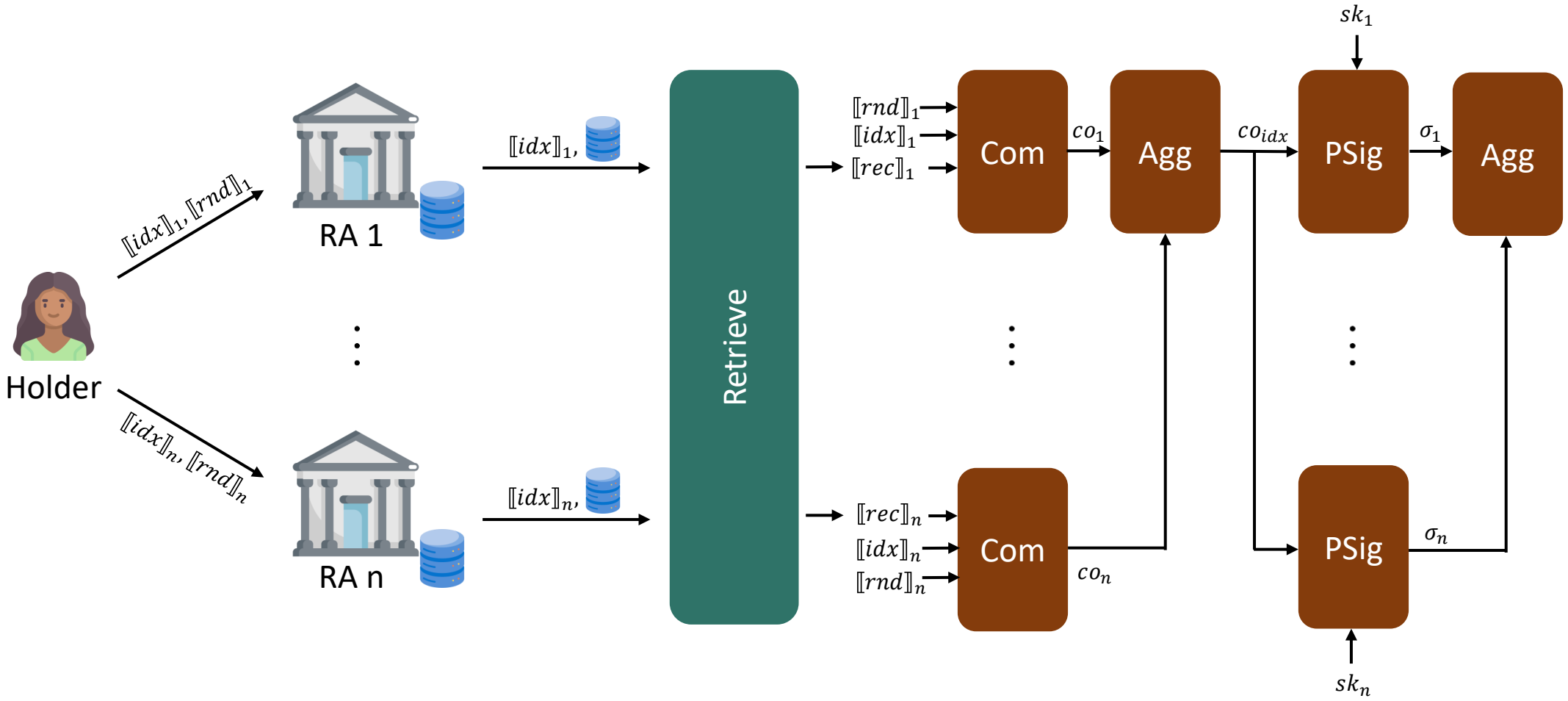
co	commitment



Constructing PRC

$[\![\cdot]\!]$	secret share
idx	index
rnd	randomness
rec	record value

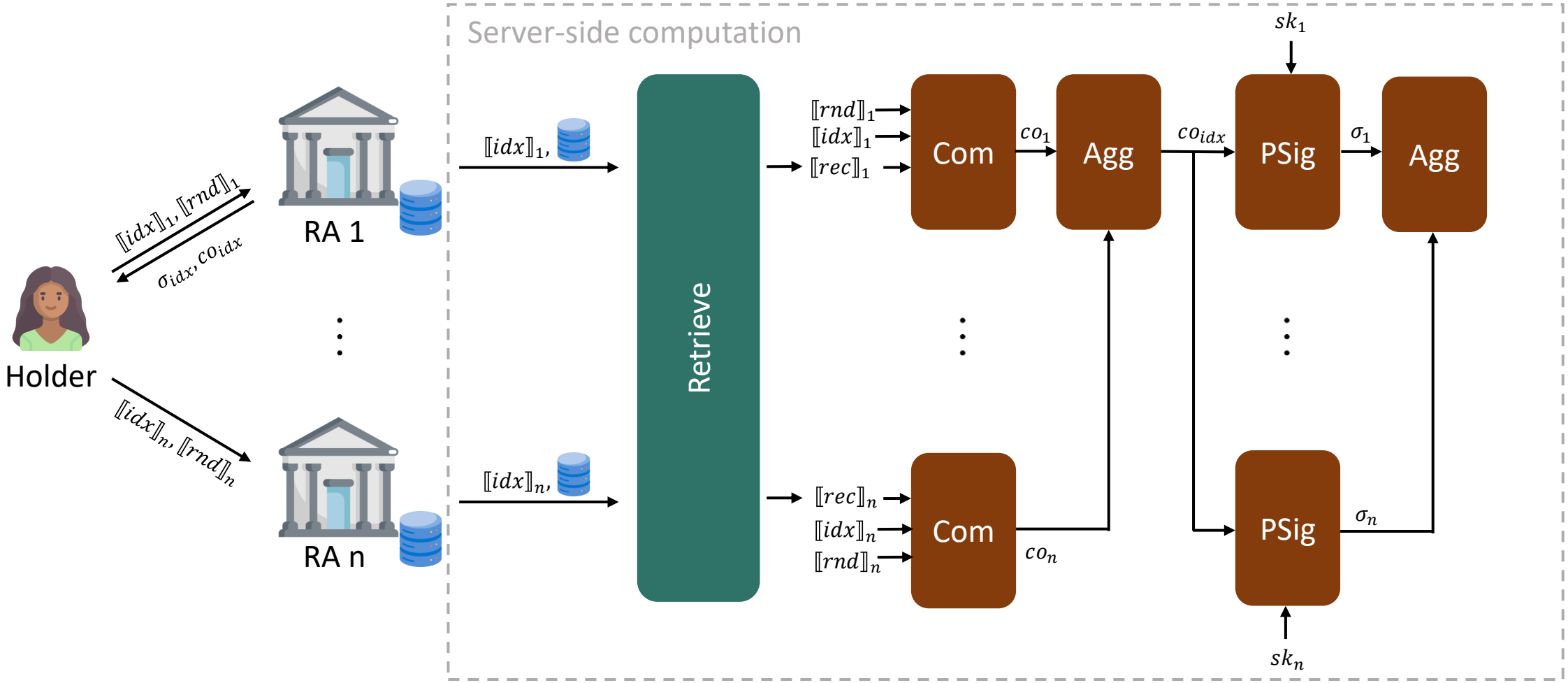
co	commitment
sk	signing key
σ	signature



Constructing PRC

$[\![\cdot]\!]$	secret share
idx	index
rnd	randomness
rec	record value

co	commitment
sk	signing key
σ	signature



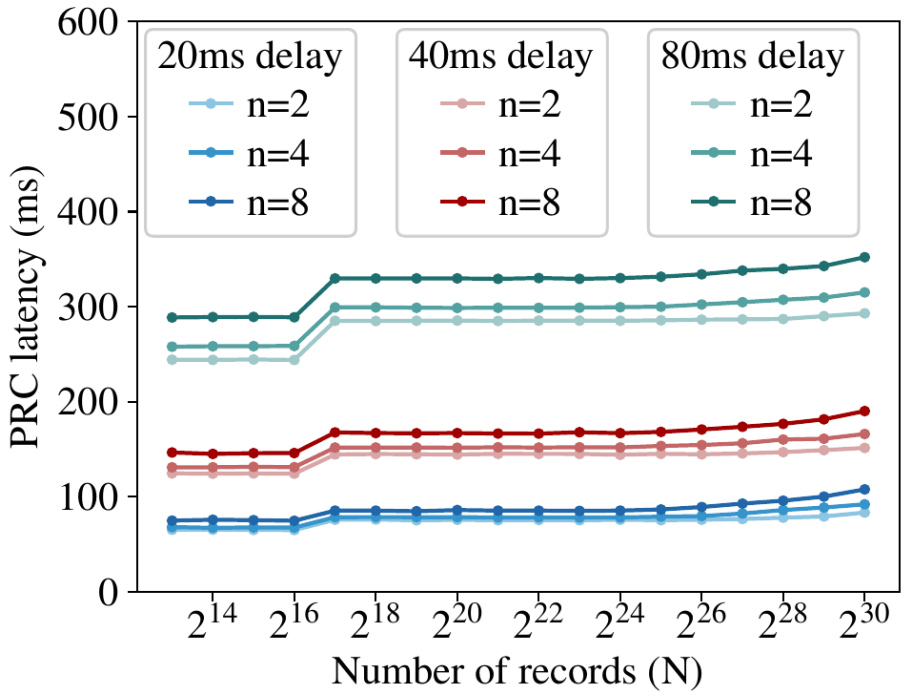
Evaluation

> 1 billion
credentials supported

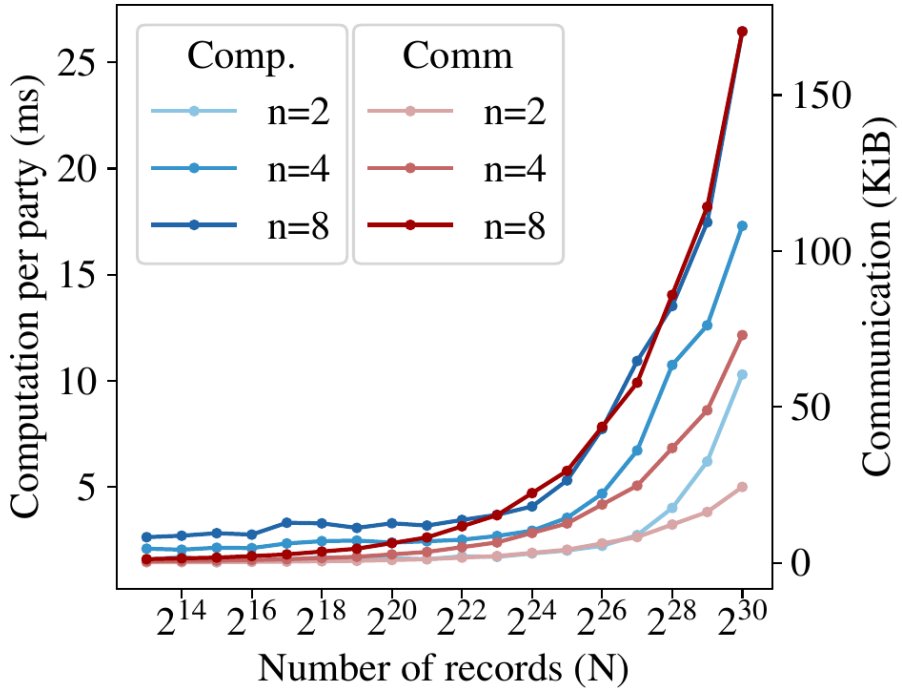
< 400ms
query latency

< 25ms
server compute per query

Latency

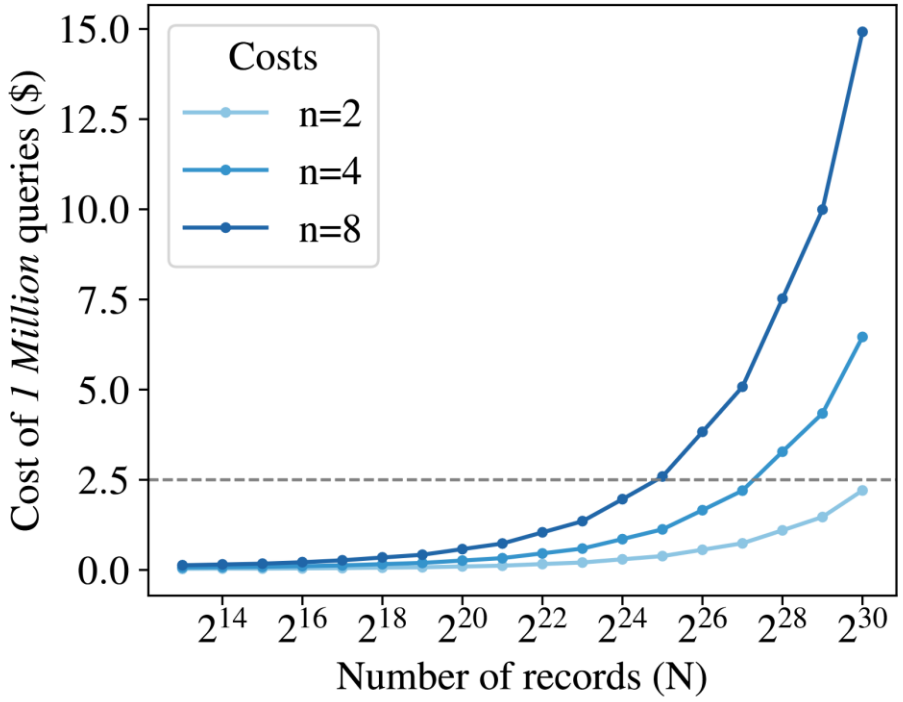


Computation & Communication



Evaluation

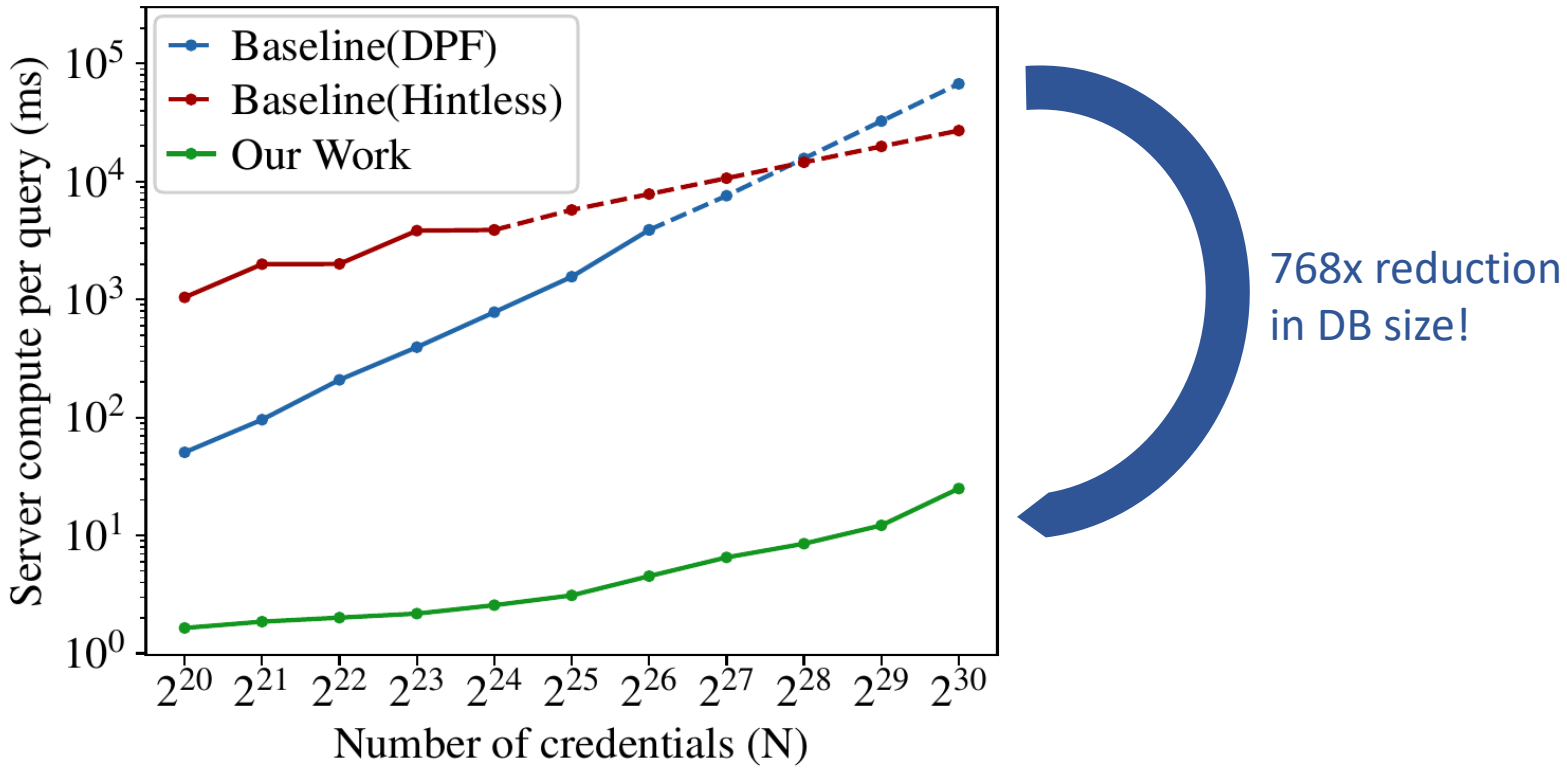
Cost



< $2.50

cost per server
for 1M queries

Comparison with Naïve PIR Approach



= = results extrapolated because code did not run for this DB size

Thank you for your attention!



