Deploying MPC in Open Finance: Challenges and Opportunities

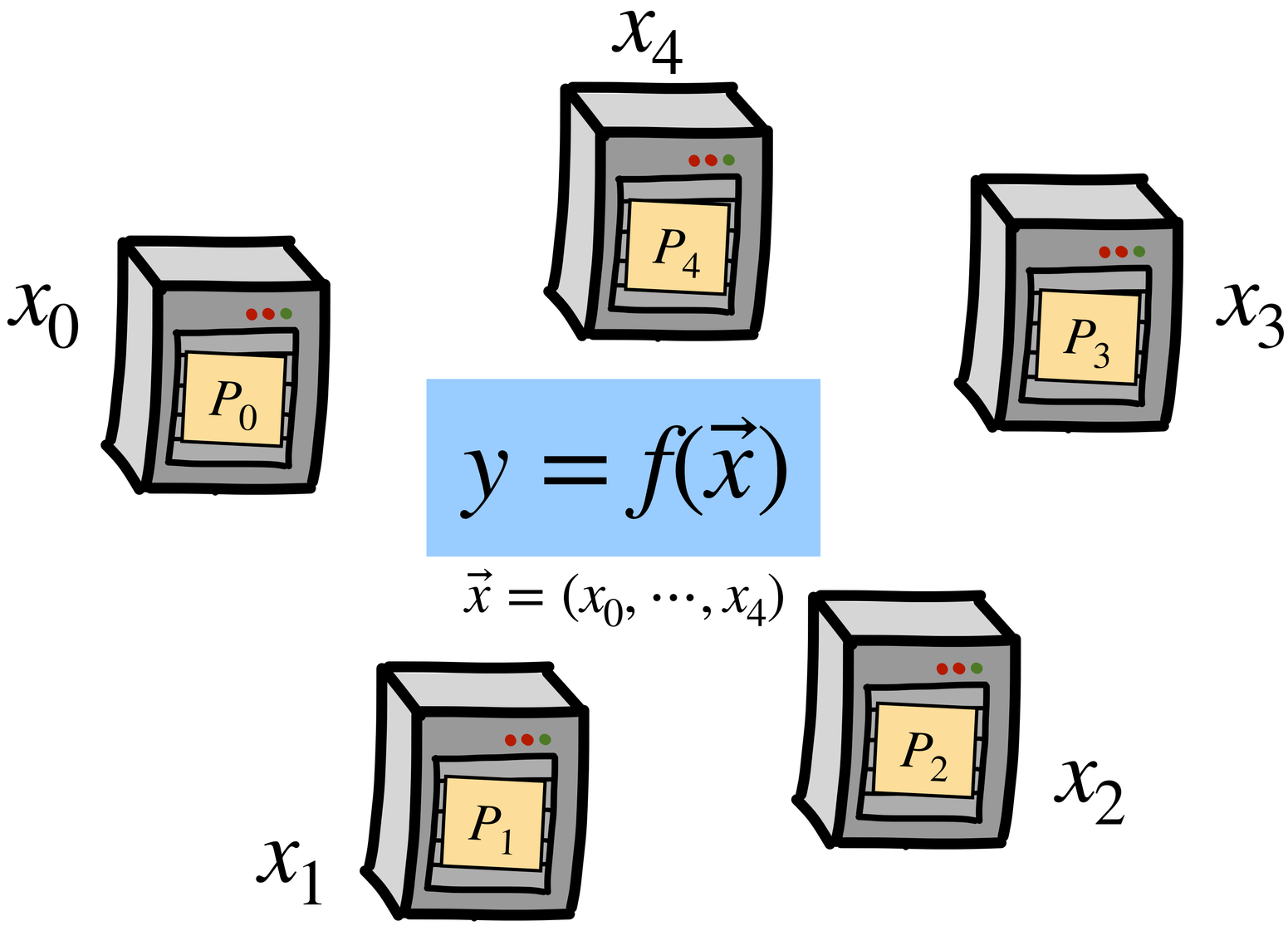
Nidhish Bhimrajka Yashvanth Kondi Daniel Noble Supreeth Varadarajan

S:L ENCE ABORATORIES

In this talk...

- Introduction to the Account Aggregator (AA) ecosystem, a regulator-driven Open Finance framework in India
- Identify gaps in trust and incentives in present ecosystem
- Propose an MPC-based solution which:
  - Mitigates data duplication concerns to reinstate trust
  - Facilitates fair compensation to balance incentives
- Discuss our design principle of drop-in replacement, and the technical challenges posed by integration with AA ecosystem

Secure Multiparty Computation (MPC)



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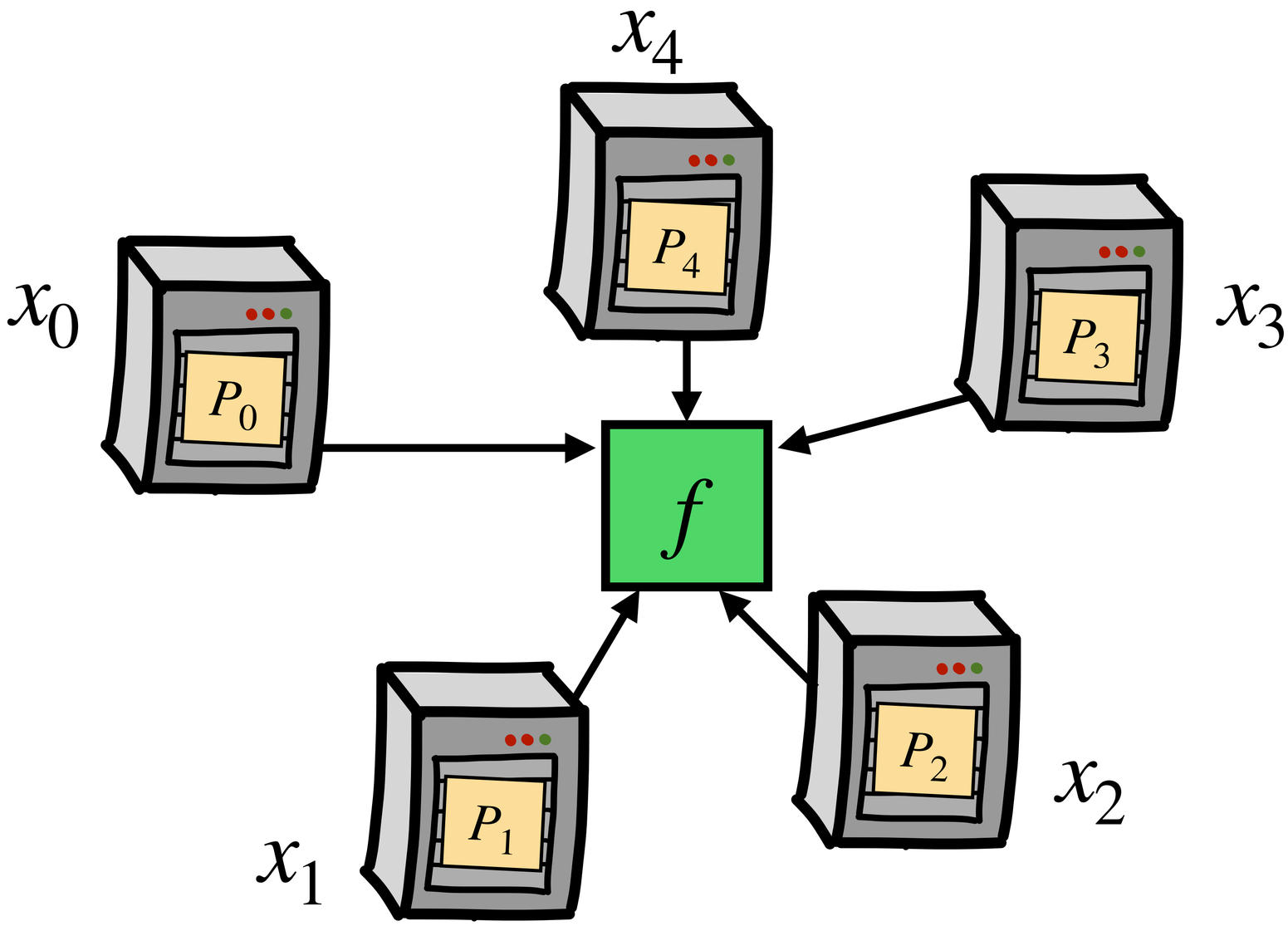

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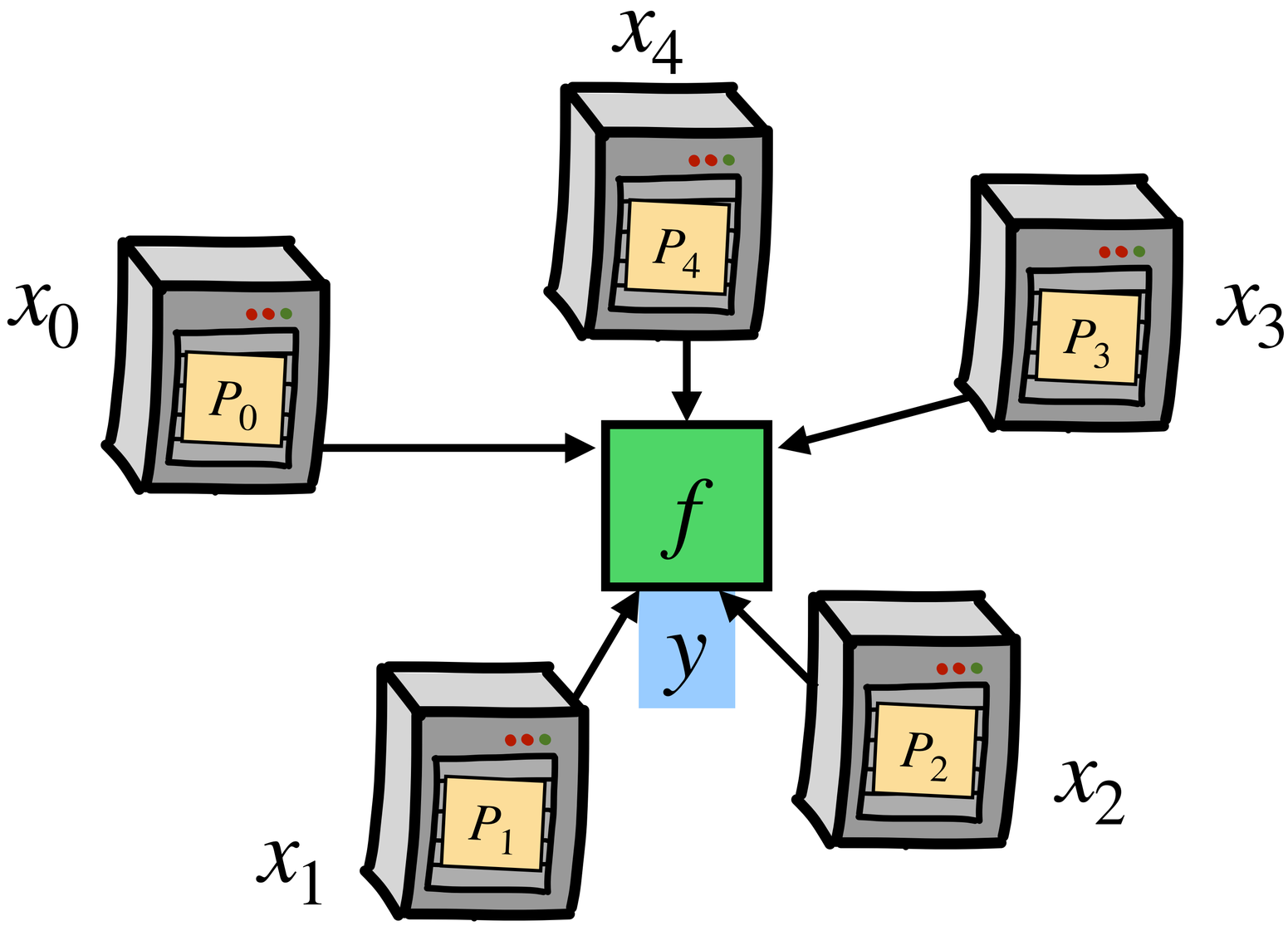

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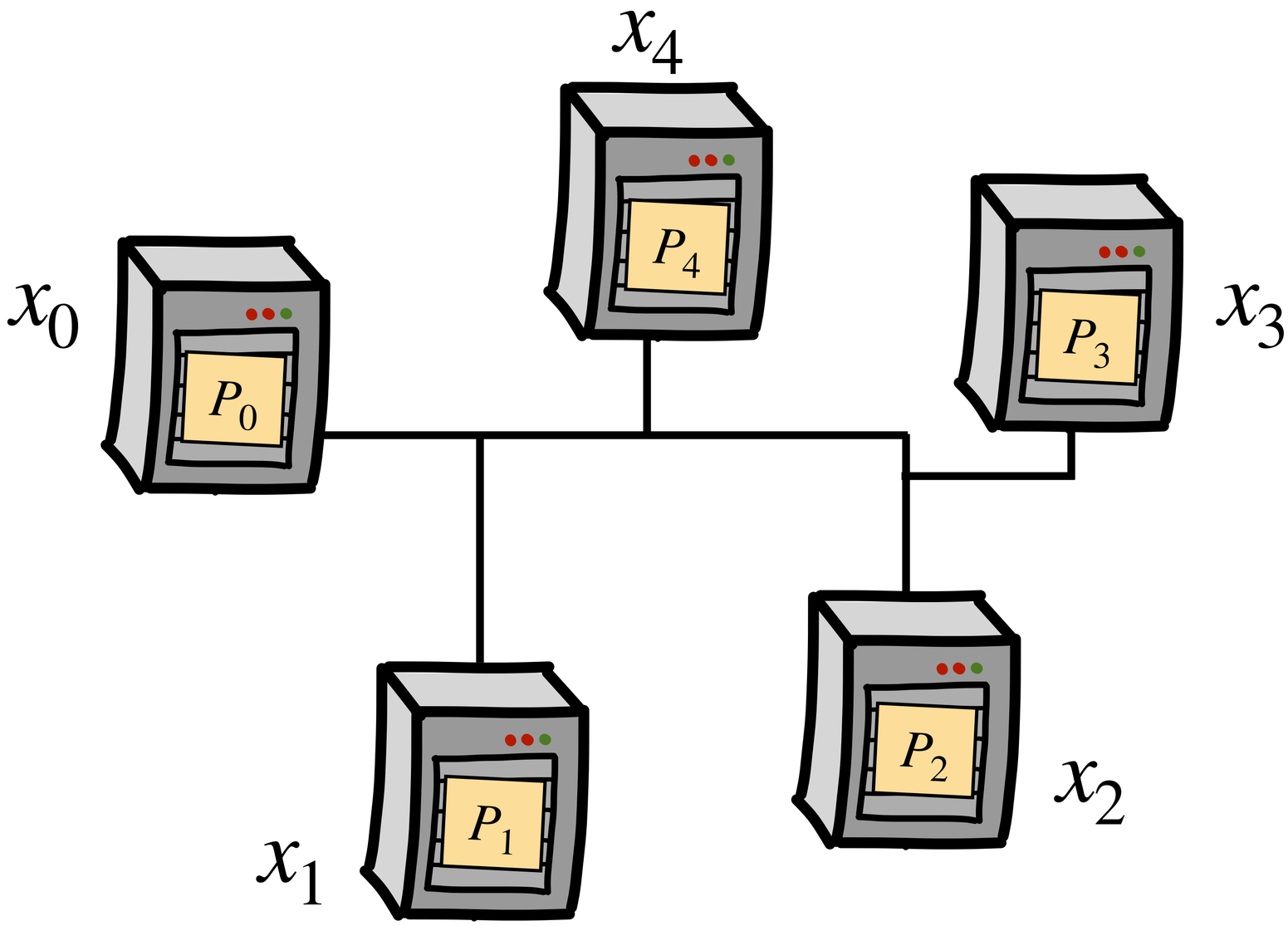

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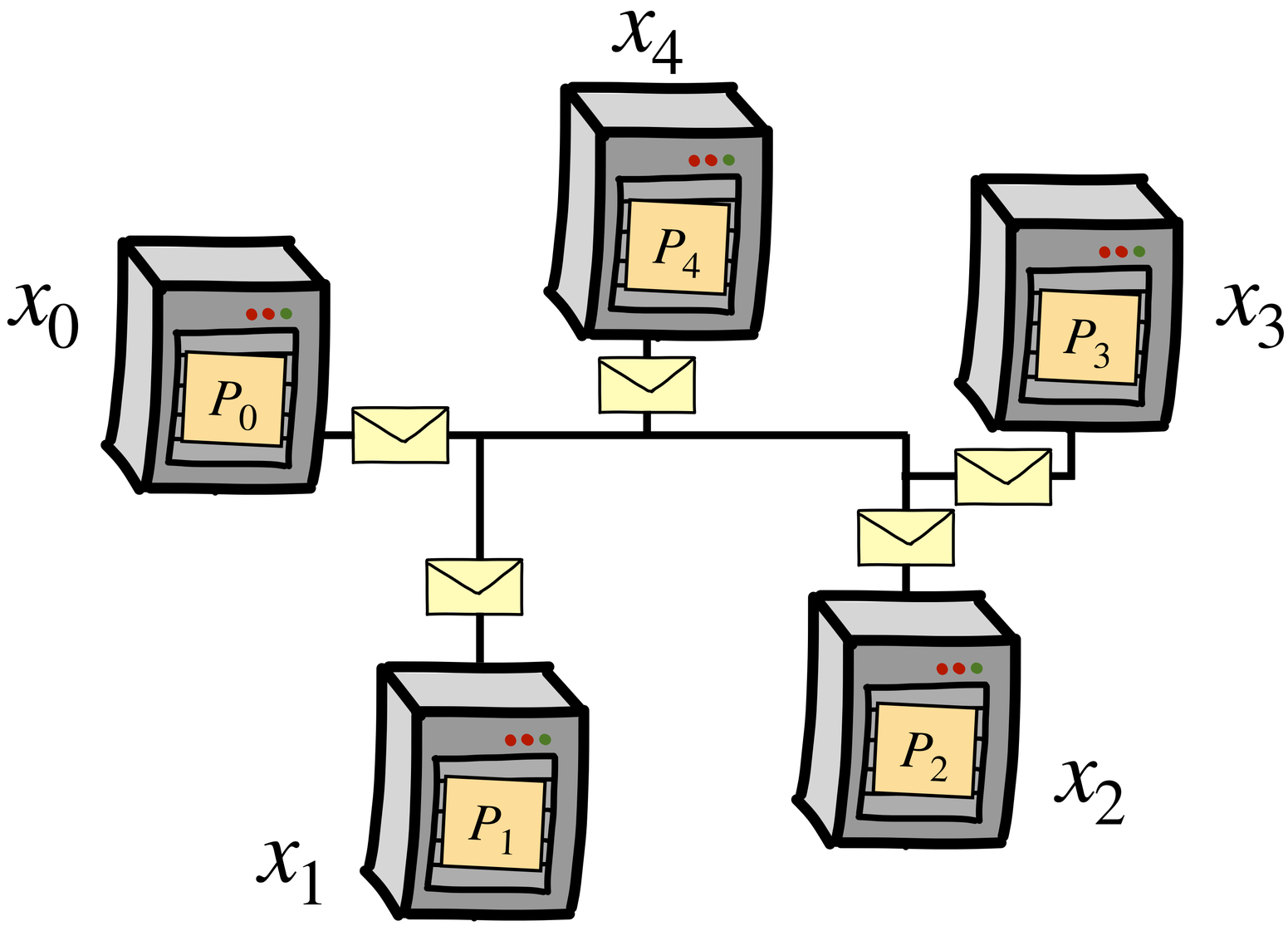

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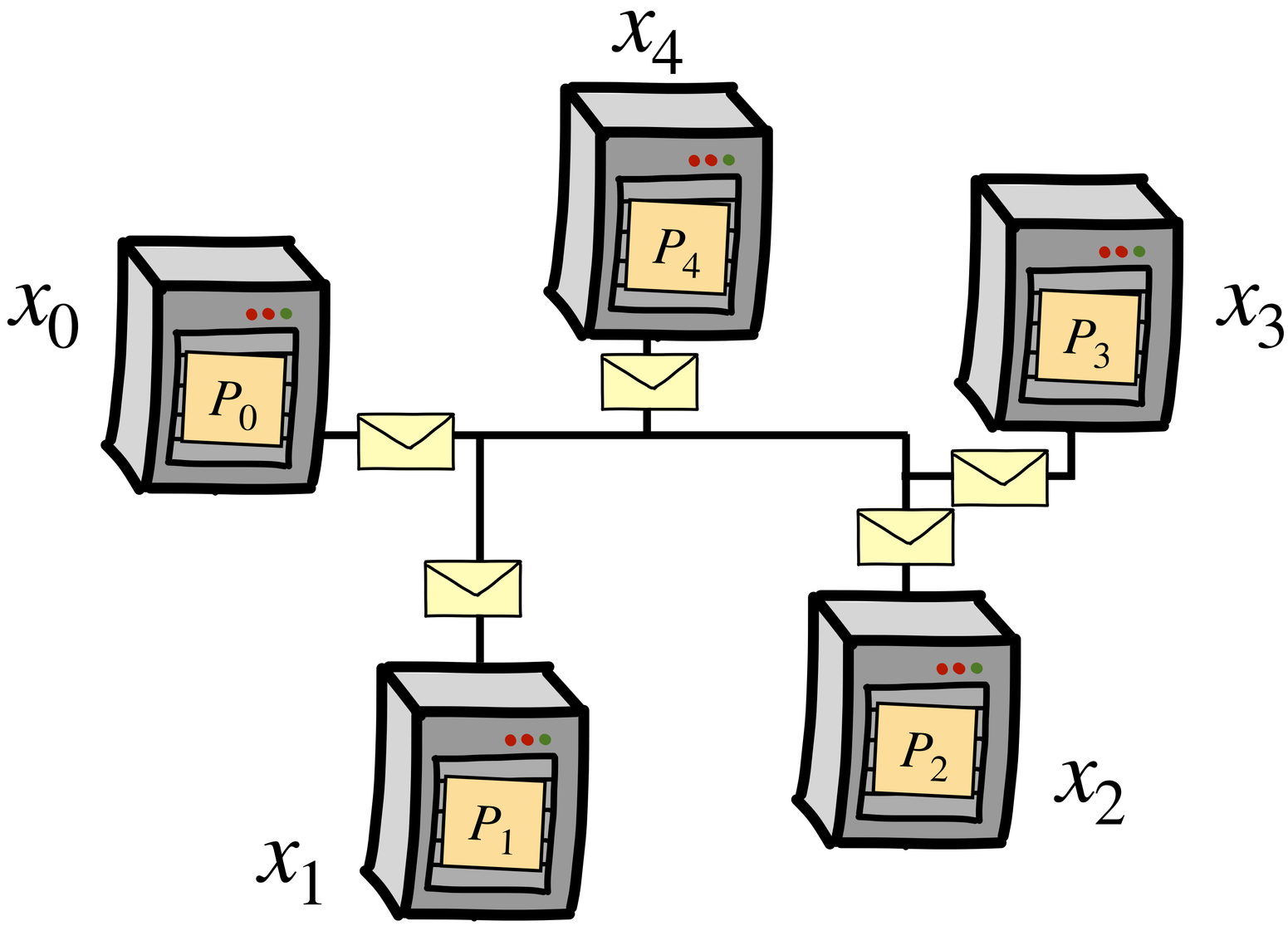

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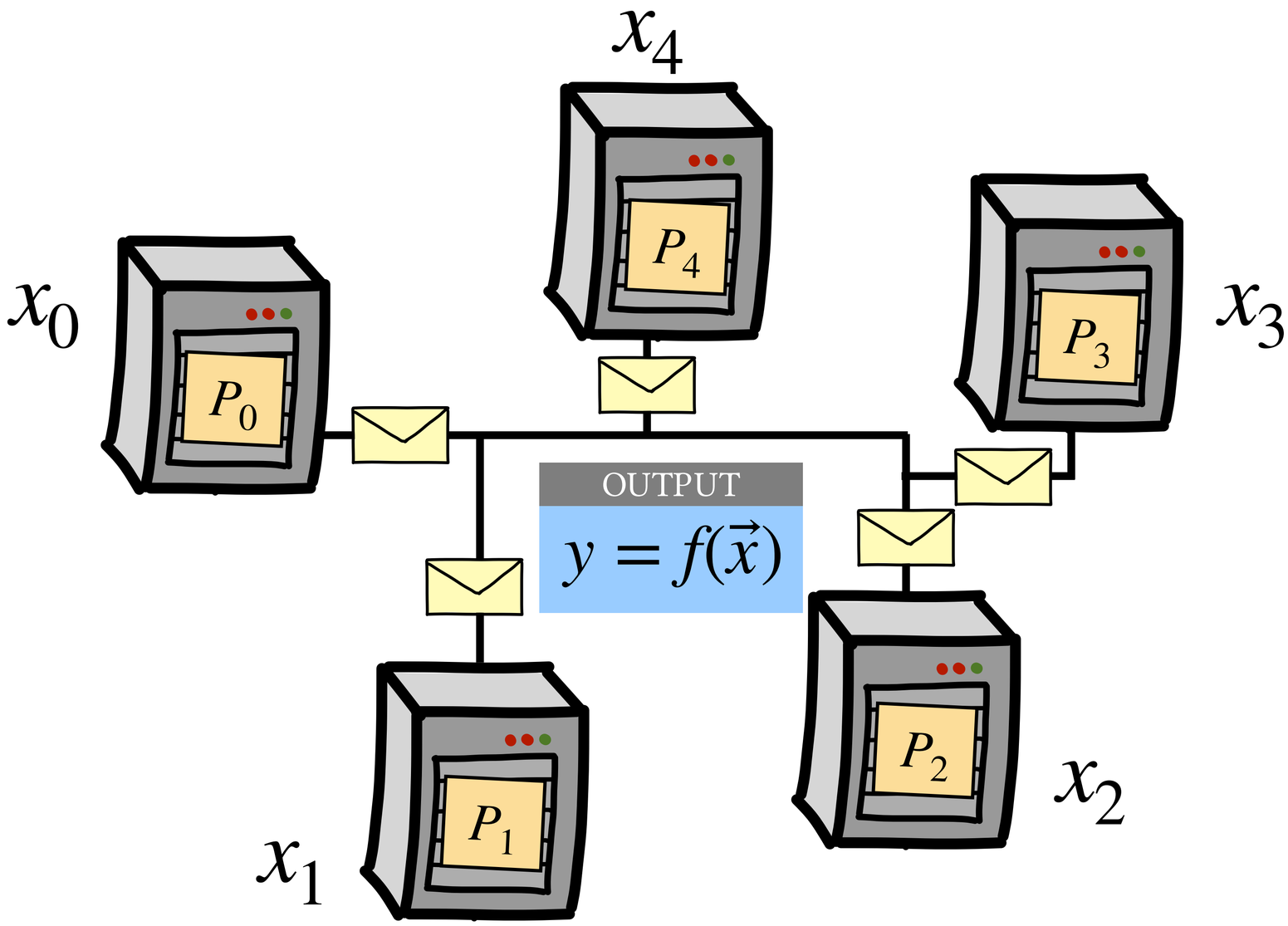


What is Open Finance?

- Open Finance frameworks enable people to securely mobilize personal financial data in order to avail of financial services
  eg. Proving financial health when applying for a loan, apartment rental, etc.

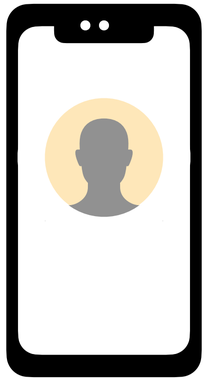
- Cryptographic protocols for provenance replace unverifiable physical documents, and heuristics such as screen scraping

- The Account Aggregator (AA) ecosystem in India is one such Open Finance framework, regulated by the central bank

Account Aggregator (AA)

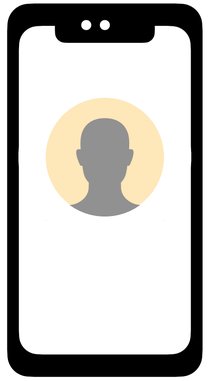
- Users consolidate their financial information across multiple regulated Financial Information Providers (FIPs)
- Upon user consent, the AA shares a curated view of finances to licensed Financial Information Users (FIUs)
  — who then provide financial services to the user
- According to Sahamati (regulated authority for AA), the AA ecosystem as of 2024 has over 80 million users, 155 FIPs, 475 FIUs
- However, issues persist: incentive gaps, and single points of failure

User / Data Principal



Financial Information Provider

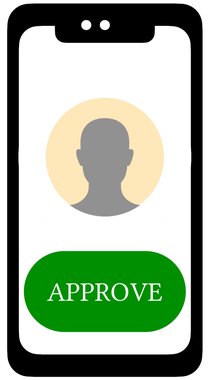
Financial Information User



FIP

Account Aggregator

FIU



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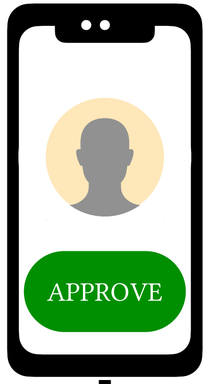
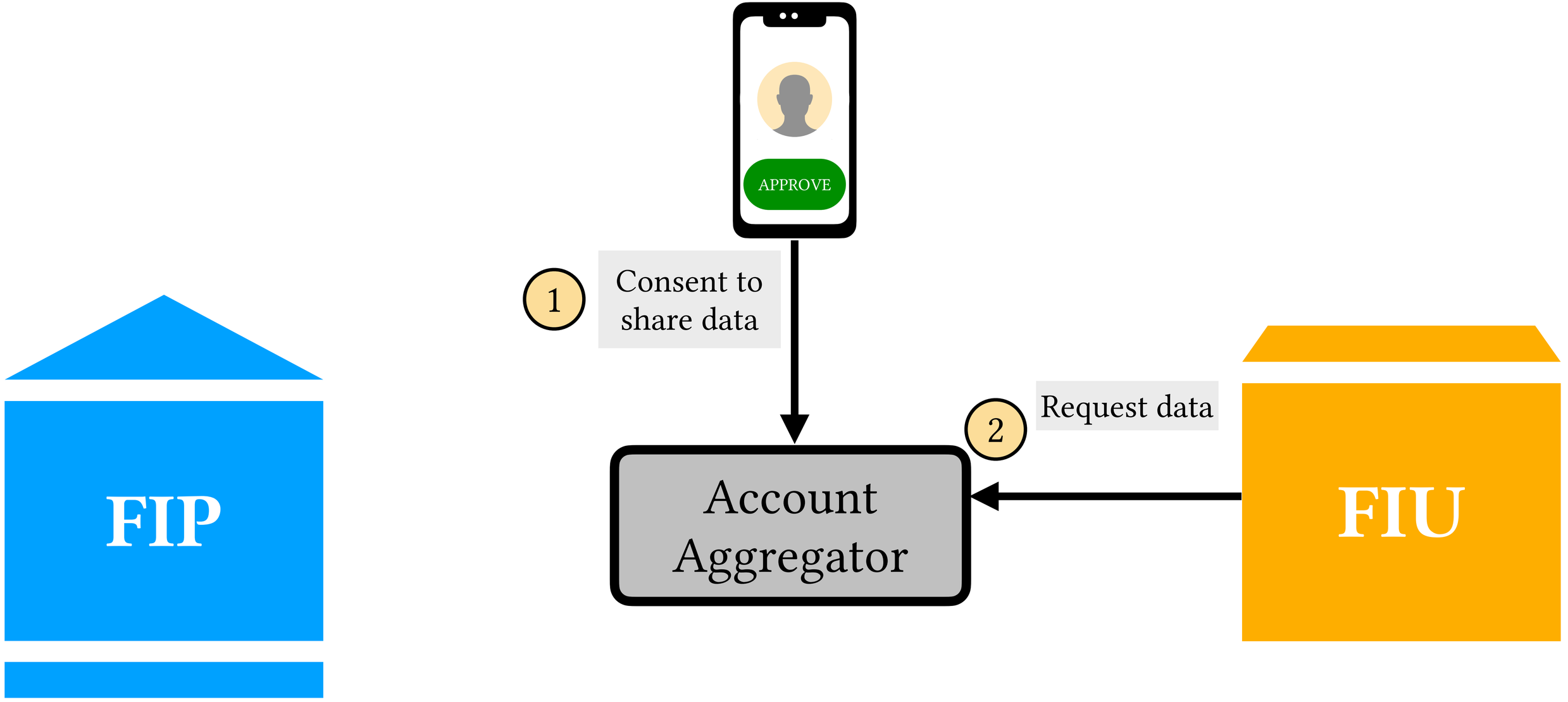
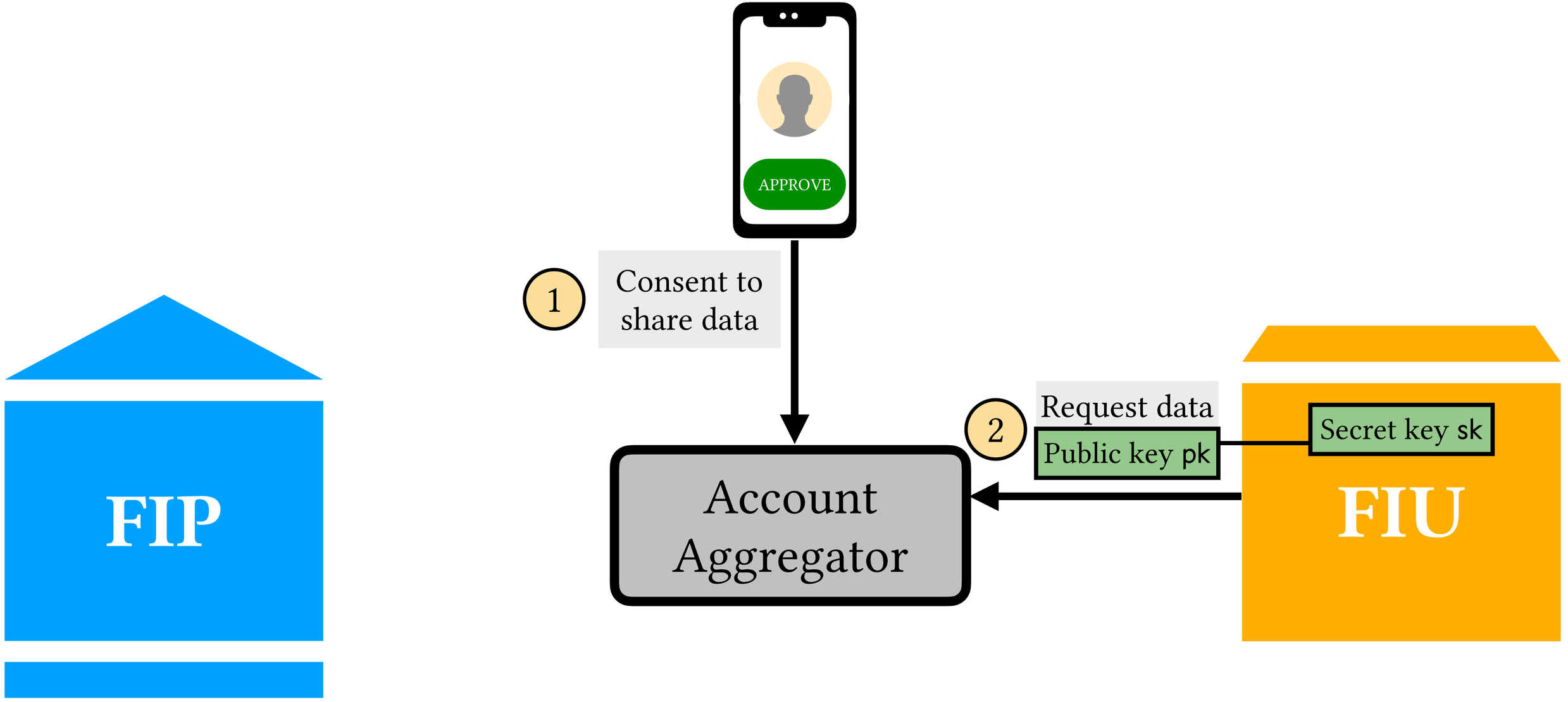


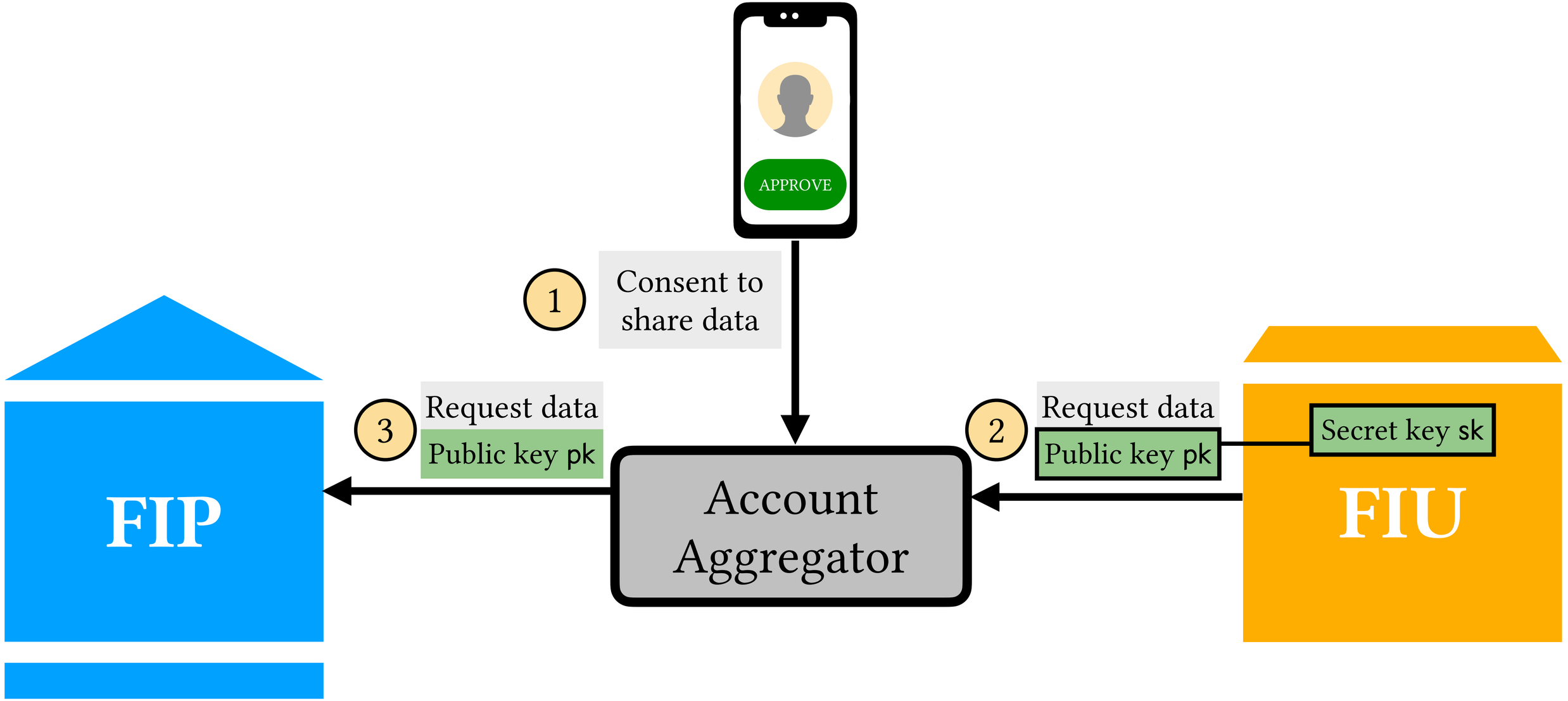
1

Consent to share data

Account Aggregator


APPROVE
1
Consent to share data
2
Request data
FIP
Account Aggregator
FIU


APPROVE
1
Consent to share data
FIP
Account Aggregator
2
Request data
Public key pk
Secret key sk
FIU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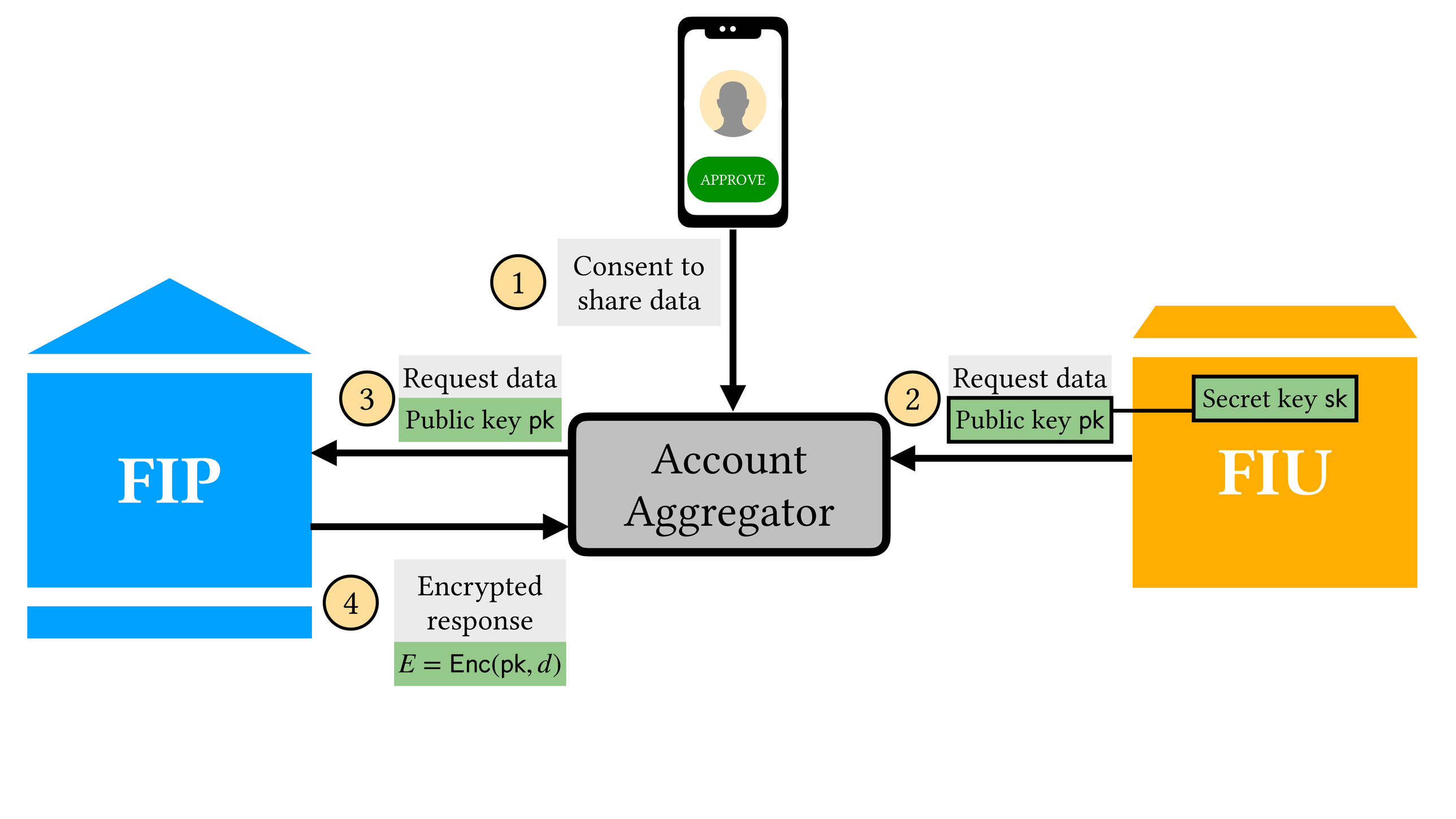
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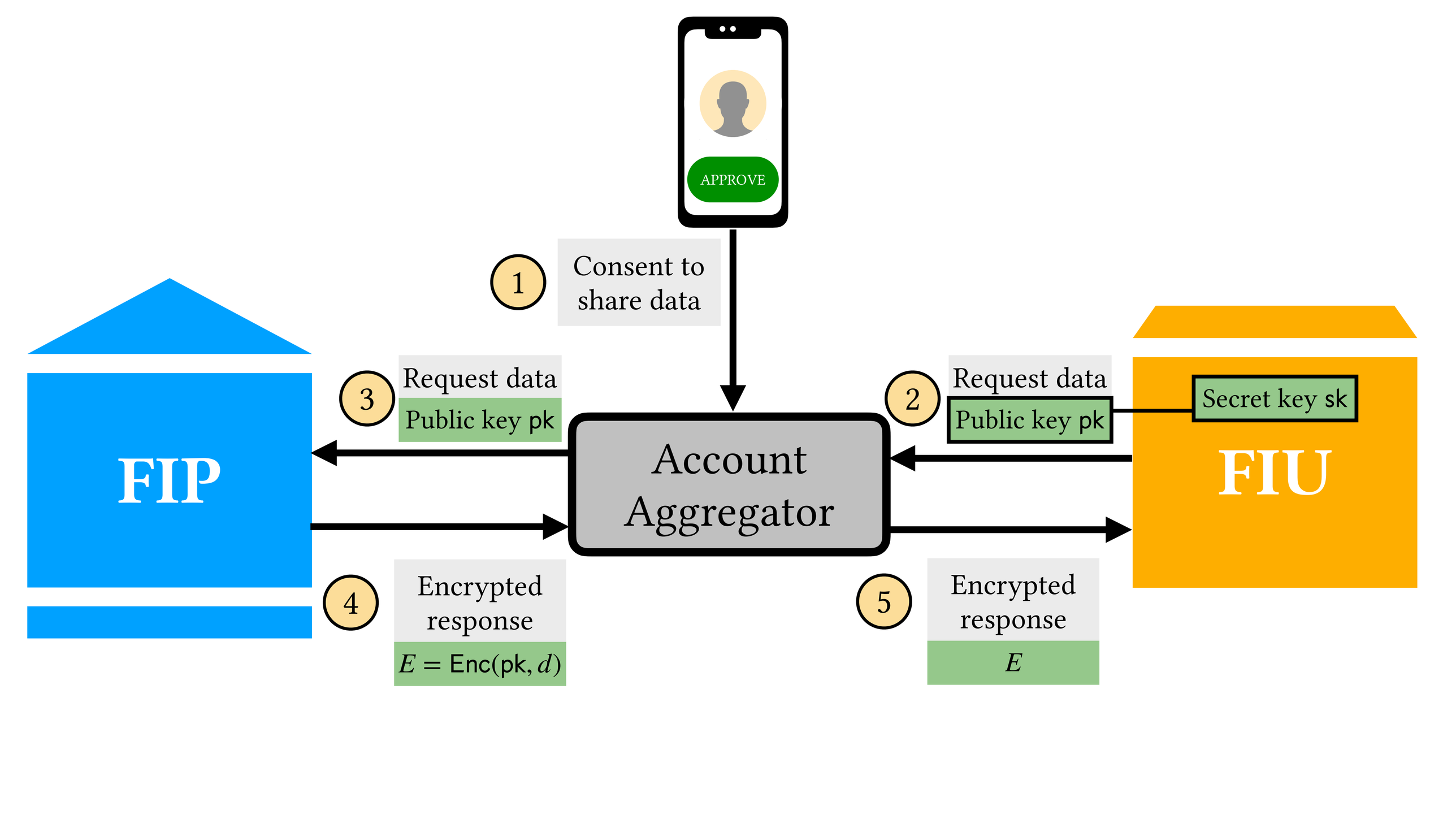
Account Aggregator
2
Request data
Public key pk
Secret key sk
FIU
4
Encrypted response
$E = \mathsf{Enc}(\mathsf{pk}, d)$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Secret key sk
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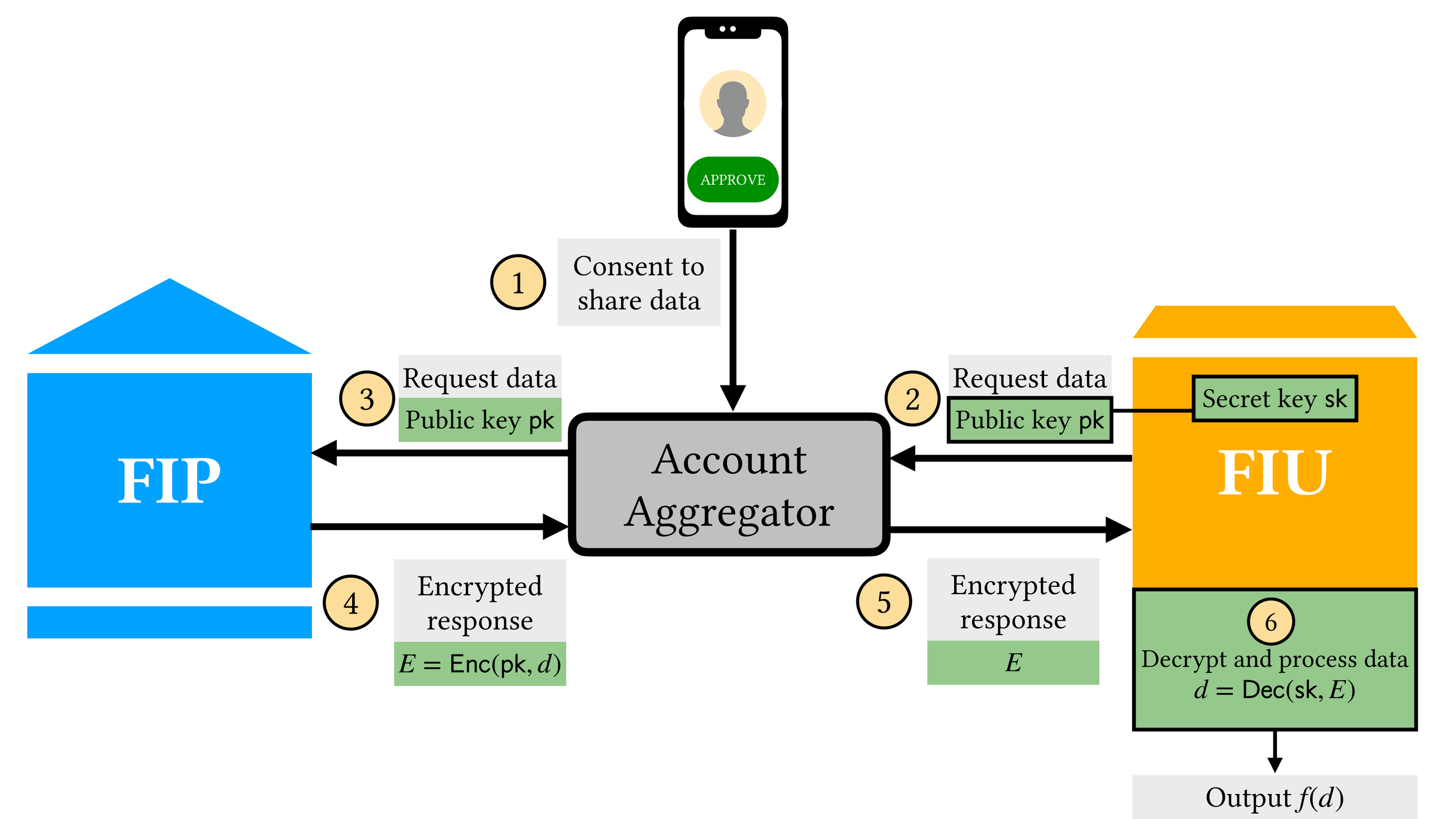
Encrypted response
$E = \mathsf{Enc}(\mathsf{pk}, d)$
5
Encrypted response
E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5
Encrypted response
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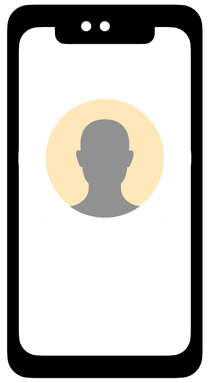
6
Decrypt and process data
$d = \mathsf{Dec}(\mathsf{sk}, E)$
Output $f(d)$

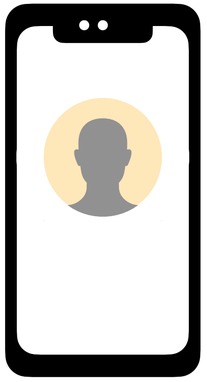
User device



Account Aggregator

Provides	Data d	Consent to mobilize d	Pipeline from consent→data	Services to user
Obtains	—	Services from FIU	Fees from FIU	Depends on business model

User device



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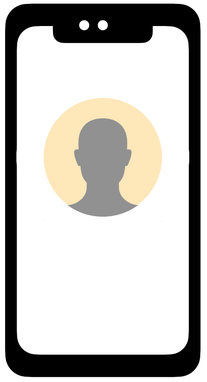
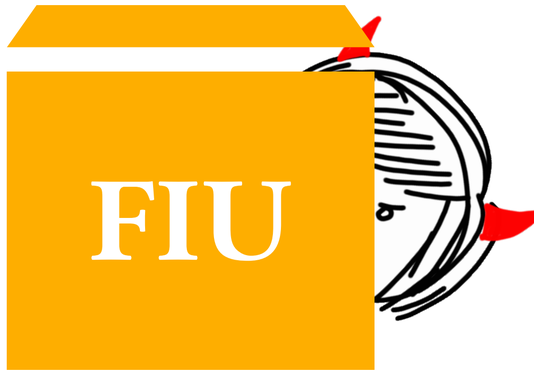


Account Aggregator



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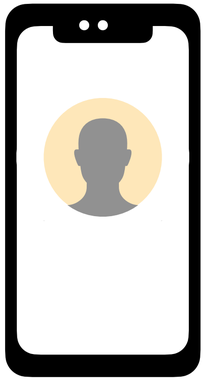
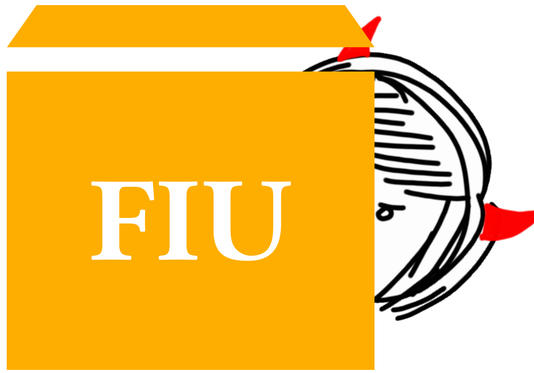


Account Aggregator



	FIP	User device	Account Aggregator	FIU
Provides	Data d	Consent to mobilize d	Pipeline from consent→data	Services to user
Obtains	—	Services from FIU	Fees from FIU	Depends on business model

Data theft

No consent

Lost fees

Data d

Unrestricted reuse

Implications of Exposing d to FIU

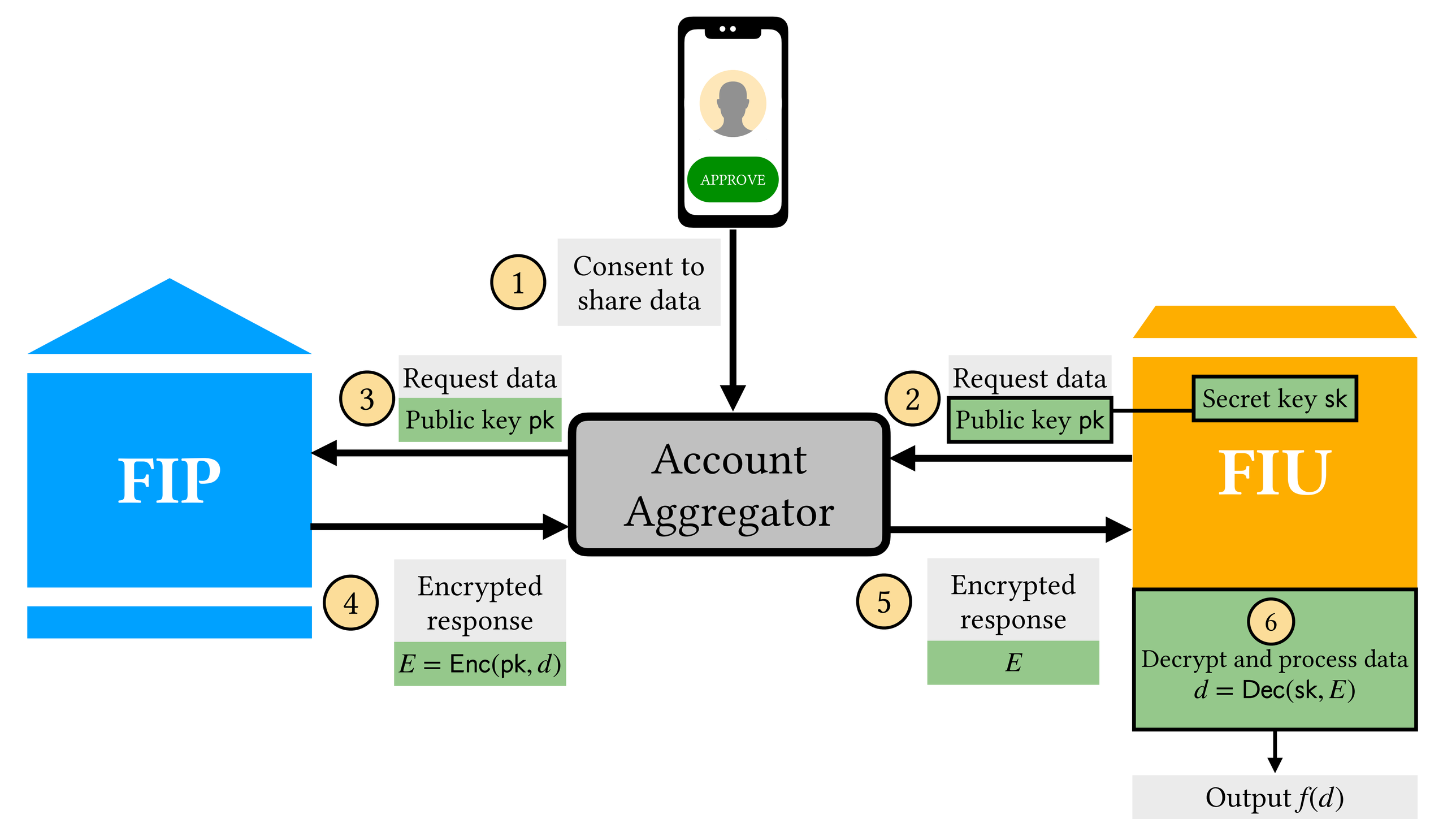
- Data breach or insider attack on FIU puts data in the wrong hands, affects the whole ecosystem

  - Users lose control over their personal financial information

  - FIPs affected on a macro level: loss of proprietary data

- Heuristic FIP solution: throttle response rate
  - Undermines ecosystem, and still leaks data anyway

- A compliance-by-design approach is needed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Account Aggregator
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Request data
Public key pk
Secret key sk
FIU
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Encrypted response
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Decrypt and process data
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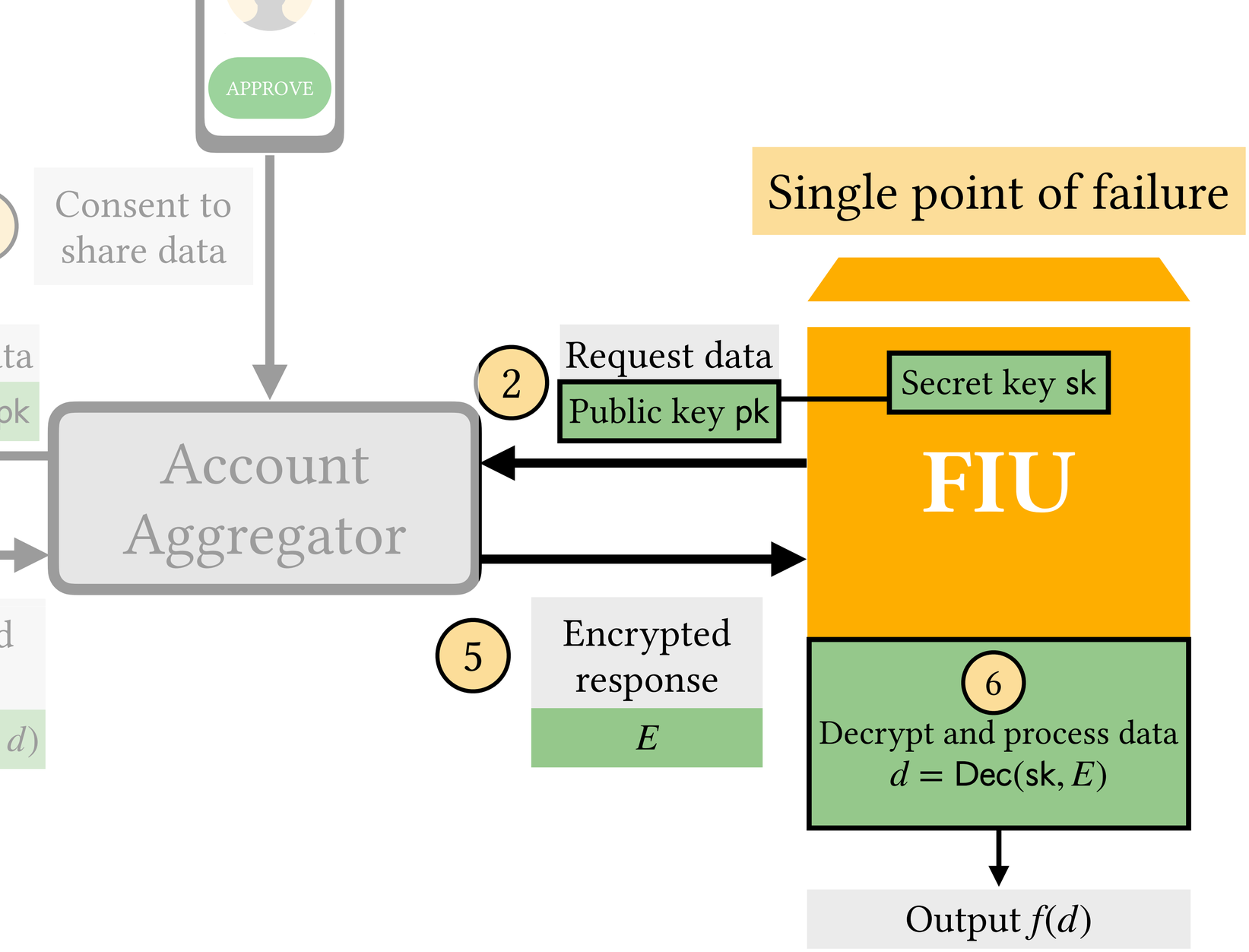
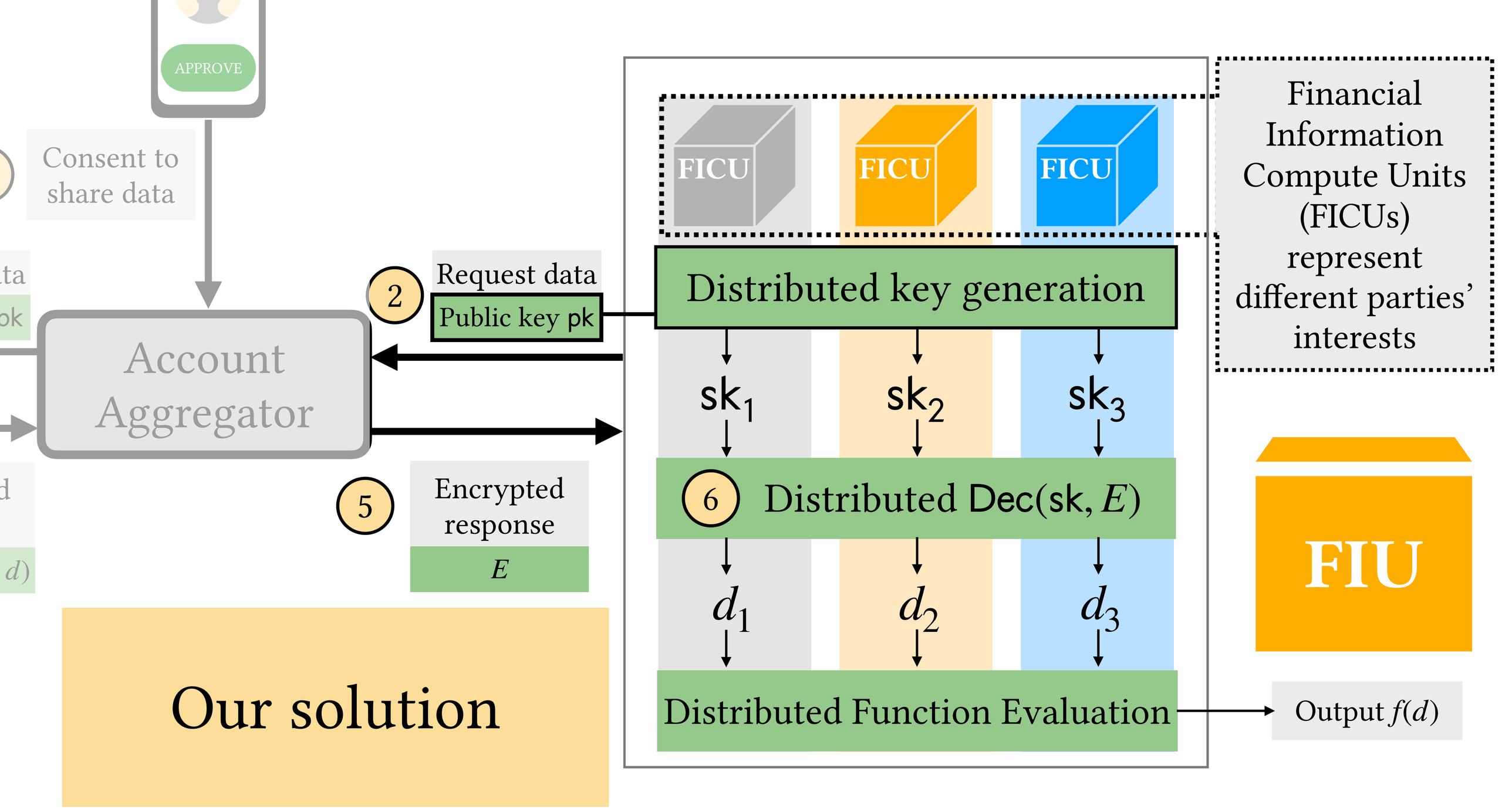
Output $f(d)$


APPROVE
Consent to share data
Account Aggregator
2
Request data
Public key pk
Single point of failure
Secret key sk
FIU
5
Encrypted response
E
6
Decrypt and process data
d = Dec(sk, E)
Output f(d)


APPROVE
Consent to share data
Account Aggregator
2
Request data
Public key pk
5
Encrypted response
E
FICU
FICU
FICU
Financial Information Compute Units (FICUs) represent different parties' interests
Distributed key generation
sk1
sk2
sk3
6
Distributed Dec(sk, E)
d1
d2
d3
Distributed Function Evaluation
Output f(d)
FIU
Our solution

The FICU Paradigm

- Three FICU nodes, with naturally non-colluding operators:
  - FIU, interested in utility of data
  - FIP (or proxy), interested in minimizing data exposure
  - Infrastructure provider, interested in credibility of the AA ecosystem
- **Duplication protection**. Data is secret shared, and accessible only via MPC
- **Fixes participation incentives**.
  Value of data $\propto$ quality and quantity of usage
  Fine-grained compensation model for FIPs

Technical Details

- MPC model: 3 parties, no colluding pairs (1 active corruption)
- Ideal functionality to realize:
    1. Generate pk and $[\mathsf{sk}]$
    2. Obtain $\mathsf{ct} = \mathsf{Enc}(\mathsf{pk}, d)$ from AA
    3. Compute $[d] = \mathsf{Dec}([\mathsf{sk}], \mathsf{ct})$
    4. Operate on $[d]$ as required

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Threshold decryption

-Well studied problem

-Simple solution: tweak Enc to directly encrypt secret shares

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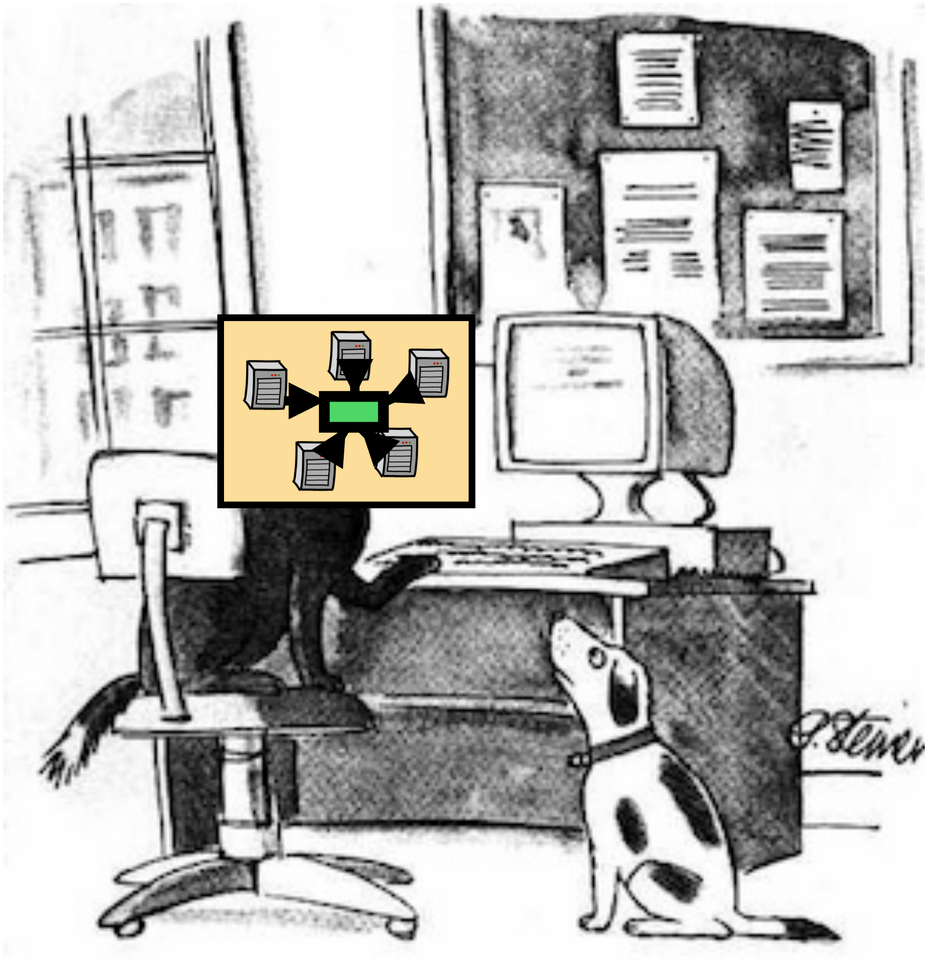
Standards set externally; can't be changed

MPC-agnostic Context

Peter Steiner,
The New Yorker
July 5, 1993 issue

"On the internet, nobody knows you're a dog"

MPC-agnostic Context



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"On the internet, nobody knows you're RUNNING MPC

Our Approach

- **Guiding principle**: Protocol specs are set agnostic to MPC, unrealistic to wait for MPC-friendly standards
- We design our solution to be a drop-in replacement for FIU, for integration with AA ecosystem as it exists *today*
- Two protocol design challenges:
  - $\mathsf{Dec}([\mathsf{sk}], \mathsf{ct})$ is a difficult function to handle in MPC
  - FIP (via AA) delivers data d as an XML file
    $\Rightarrow [d]$ must be **parsed** before running any queries

Dec([sk], ct) in MPC

Decryption involves two steps:

1. Establish shared key $K = \mathsf{SHA}(g^{\mathsf{sk} \cdot r})$

2. Use key K to evaluate AES in GCM mode

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Boolean circuit

Elliptic curve group ops

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Along the lines of
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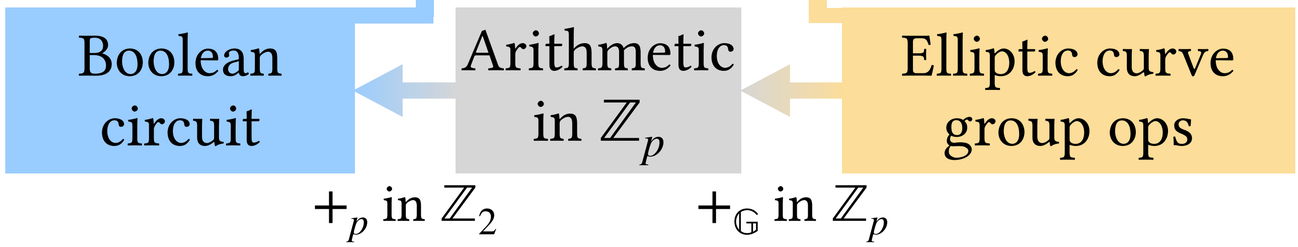

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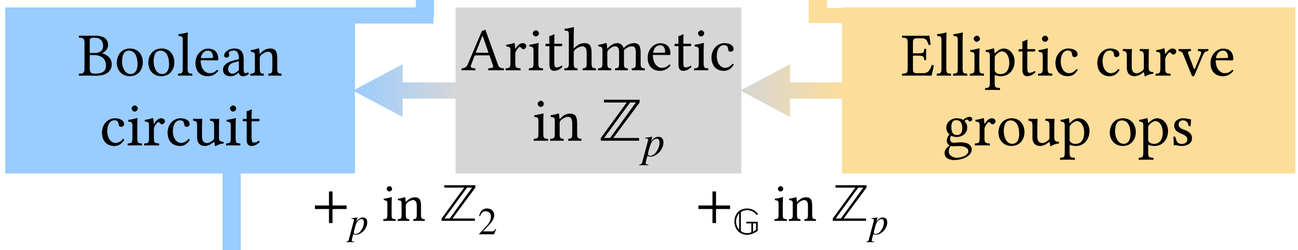

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Arithmetic in $\mathbb{Z}_p$

Elliptic curve group ops

$+_p$ in $\mathbb{Z}_2$

$+_{\mathbb{G}}$ in $\mathbb{Z}_p$

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Which general Boolean MPC paradigm?	
Garbled Circuits $O(1)$ rounds 100s bits/gate	"Secret-sharing" $O(\text{depth})$ rounds few bits/gate

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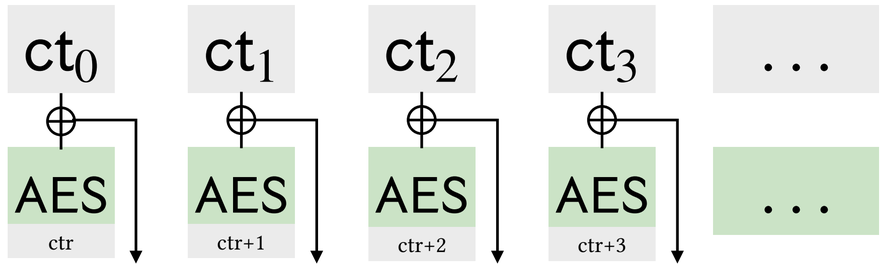
AES invocations in parallel



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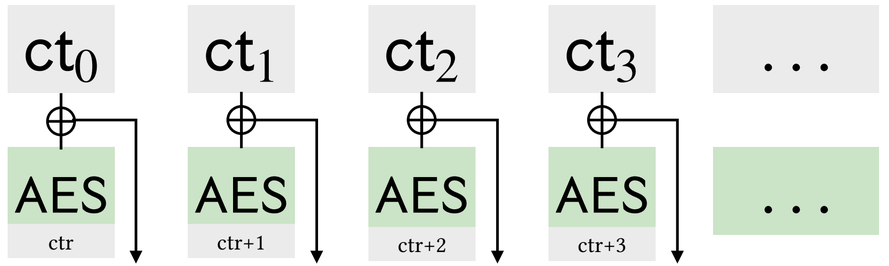

Circuit depth independent of |ct|

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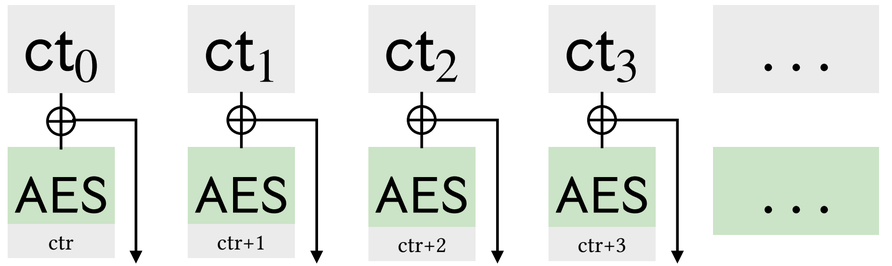
Wins for $|\mathsf{ct}| >$ few KB



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Why is Parsing Challenging?

- Plaintext is a bank statement that consists of a list of transactions, provided in XML format

```
<Transactions>
    ⋮
  <Transaction id="S1842" amt="54.2" nar="UPI/ZMTO" ts="13:22" >
    ⋮
</Transactions>
```

Why is Parsing Challenging?

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- Plaintext parsing: identify delimiters, cast into structure

```
<Transaction|id="S1842" |amt="54.2" |nar="UPI/ZMTO"|ts="13:22" >
```

```
transaction_struct  tr = {string id, int amt, string nar, time_t ts}
```

Why is Parsing Challenging?

- Plaintext is a bank statement that consists of a list of transactions, provided in XML format
- Plaintext parsing: identify delimiters, cast into structure
- What about parsing in secret shared form?

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

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XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

Step 1: identify delimiters

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<Transaction XXXXXXXX XXXXXXXXXX XXXXXXXXXXXXX XXXXXXXXXX>

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<Transaction XXXXXXXX XXXXXXXXXX XXXXXXXXXXXXX XXXXXXXXXX>

Leakage!

Step 1: identify delimiters

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10 chars

<Transaction XXXXXXXX XXXXXXXXXX XXXXXXXXXXXXX XXXXXXXXXX>

Leakage!

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10 chars

<Transaction XXXXXXXX XXXXXXXXXX XXXXXXXXXXXXX XXXXXXXXXX>

Leakage!

Step 1: identify delimiters

amt="54.2"
10 chars

vs.

amt="104.3"
11 chars

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<Transaction XXXXXXXX XXXXXXXXXX XXXXXXXXXXXXXX XXXXXXXXXX>

10 chars

Leakage!

Step 1: identify delimiters

✓

amt="54.2"

10 chars

vs.

✗

amt="104.3"

11 chars

Secure Parsing

- Ideal situation: each entry is “padded” to a fixed max length
- Our approach is to securely derive this padding

<Transaction|id=“S1842” |amt=“54.2” |nar=“UPI/ZMTO”|ts=“13:22” >

Secure Parsing

- Ideal situation: each entry is “padded” to a fixed max length
- Our approach is to securely derive this padding

```
id=S1842  amt=54.2  nar=UPI/ZMTO ts=13:22
```

Secure Parsing

- Ideal situation: each entry is “padded” to a fixed max length
- Our approach is to securely derive this padding

```
id = S1842
amt= 54.2
nar= UPI/ZMTO
ts= 13:22
```

Secure Parsing

- Ideal situation: each entry is “padded” to a fixed max length
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```
id = S1842
amt= 54.2
nar= UPI/ZMTO
ts= 13:22
```

Secure Parsing

- Ideal situation: each entry is “padded” to a fixed max length
- Our approach is to securely derive this padding

```
 id  S 1 8 4 2
amt  5 4 . 2
nar  U P I / Z M T O
 ts  1 3 : 2 2
```

Secure Parsing

- Ideal situation: each entry is “padded” to a fixed max length
- Our approach is to securely derive this padding

id	S	1	8	4	2				
amt	5	4	.	2					
nar	U	P	I	/	Z	M	T	O	
ts	1	3	:	2	2				

Max row length = 10

Secure Parsing

- Ideal situation: each entry is “padded” to a fixed max length
- Our approach is to securely derive this padding

id	S	1	8	4	2	#	#	#	#	#
amt	5	4	.	2	#	#	#	#	#	#
nar	U	P	I	/	Z	M	T	O	#	#
ts	1	3	:	2	2	#	#	#	#	#

Max row length = 10

Secure Parsing

- Ideal situation: each entry is “padded” to a fixed max length
- Our approach is to securely derive this padding

id	S	1	8	4	2	#	#	#	#	#
amt	5	4	.	2	#	#	#	#	#	#
nar	U	P	I	/	Z	M	T	O	#	#
ts	1	3	:	2	2	#	#	#	#	#

Max row length = 10

Max string length = 40

Actual string length = 22

Padding chars = 18

Secure Parsing

- Ideal situation: each entry is “padded” to a fixed max length
- Our approach is to securely derive this padding

```
id  S 1 8 4 2 # # # # #
amt 5 4 . 2 # # # # # #
nar U P I / Z M T O # #
ts  1 3 : 2 2 # # # # #
```

Max string length = 40

Actual string length = 22

Padding chars = 18

Max row length = 10

Secure Parsing

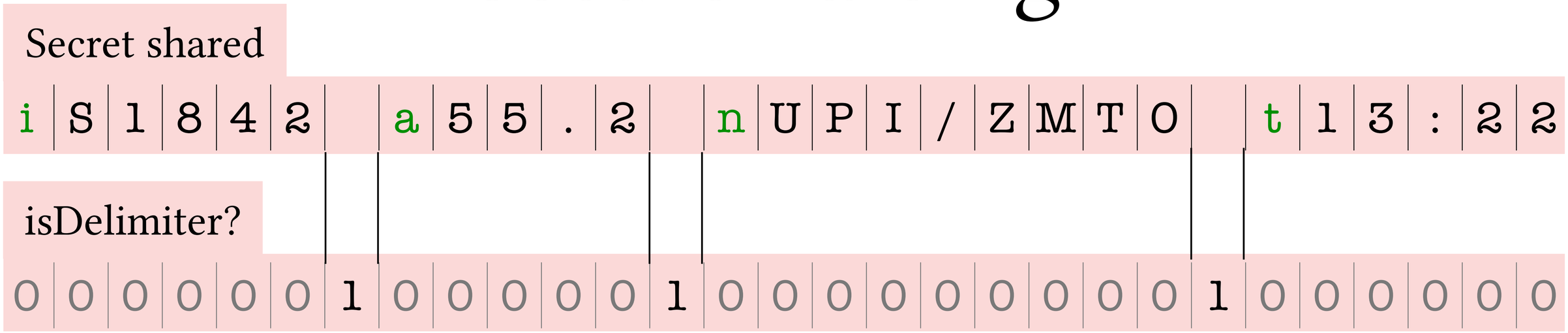
i S 1 8 4 2 a 5 4 . 2 n U P I / Z M T O t 1 3 : 2 2

Secure Parsing

Secret shared

i	S	1	8	4	2		a	5	5	.	2		n	U	P	I	/	Z	M	T	O		t	1	3	:	2	2

Secure Parsing



Secure Parsing

Secret shared

i	S	l	8	4	2		a	5	5	.	2		n	U	P	I	/	Z	M	T	O		t	l	3	:	2	2

isDelimiter?

0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

relative_index (distance from last delimiter-1)

0	1	2	3	4	5	-1	0	1	2	3	4	-1	0	1	2	3	4	5	6	7	8	-1	0	1	2	3	4	5

Secure Parsing

Secret shared

i	S	1	8	4	2		a	5	5	.	2		n	U	P	I	/	Z	M	T	O		t	1	3	:	2	2
0	1	2	3	4	5	-1	0	1	2	3	4	-1	0	1	2	3	4	5	6	7	8	-1	0	1	2	3	4	5

relative_index (distance from last delimiter-1)

Secure Parsing

Secret shared

i	S	1	8	4	2		a	5	5	.	2		n	U	P	I	/	Z	M	T	O		t	1	3	:	2	2
0	1	2	3	4	5	-1	0	1	2	3	4	-1	0	1	2	3	4	5	6	7	8	-1	0	1	2	3	4	5

relative_index (distance from last delimiter-1)

Post padding, absolute_index = (max_row_len × last_delim_index) + relative_index

0	1	2	3	4	5	-	10	11	12	13	14	-	20	21	22	23	24	25	26	27	28	-	30	31	32	33	34	35

Secure Parsing

Secret shared

i	S	1	8	4	2		a	5	5	.	2		n	U	P	I	/	Z	M	T	O		t	1	3	:	2	2

Post padding, absolute_index = (max_row_len × last_delim_index) + relative_index

0	1	2	3	4	5	-	10	11	12	13	14	-	20	21	22	23	24	25	26	27	28	-	30	31	32	33	34	35

Secure Parsing

Secret shared

i	S	1	8	4	2		a	5	5	.	2		n	U	P	I	/	Z	M	T	O		t	1	3	:	2	2

Post padding, absolute_index = (max_row_len × last_delim_index) + relative_index

0	1	2	3	4	5	-	10	11	12	13	14	-	20	21	22	23	24	25	26	27	28	-	30	31	32	33	34	35

Public Pad array

id	#	#	#	#	#	#	#	#	#	#
amt	#	#	#	#	#	#	#	#	#	#
nar	#	#	#	#	#	#	#	#	#	#
ts	#	#	#	#	#	#	#	#	#	#

Secure Parsing

Secret shared

i	S	1	8	4	2		a	5	5	.	2		n	U	P	I	/	Z	M	T	O		t	1	3	:	2	2
0	1	2	3	4	5	-	10	11	12	13	14	-	20	21	22	23	24	25	26	27	28	-	30	31	32	33	34	35

Post padding, absolute_index = (max_row_len × last_delim_index) + relative_index

Public Pad array

Actual requirement (secret)

id						#	#	#	#	#
amt					#	#	#	#	#	#
nar									#	#
ts						#	#	#	#	#

Secure Parsing

Secret shared

i	S	1	8	4	2		a	5	5	.	2		n	U	P	I	/	Z	M	T	O		t	1	3	:	2	2
0	1	2	3	4	5	-	10	11	12	13	14	-	20	21	22	23	24	25	26	27	28	-	30	31	32	33	34	35

Post padding, absolute_index = (max_row_len × last_delim_index) + relative_index

Public Pad array

Actual requirement (secret)

isPadRequired?

id						1	1	1	1	1
amt					1	1	1	1	1	1
nar									1	1
ts						1	1	1	1	1

Secure Parsing

Secret shared

i	S	1	8	4	2		a	5	5	.	2		n	U	P	I	/	Z	M	T	O		t	1	3	:	2	2

Post padding, absolute_index = (max_row_len × last_delim_index) + relative_index

0	1	2	3	4	5	-	10	11	12	13	14	-	20	21	22	23	24	25	26	27	28	-	30	31	32	33	34	35

Public Pad array

Actual requirement (secret)

absolute_index of required pads

id						6	7	8	9	10
amt					15	16	17	18	19	20
nar									29	30
ts						36	37	38	39	40

Secure Parsing

Secret shared

i	S	1	8	4	2		a	5	5	.	2		n	U	P	I	/	Z	M	T	O		t	1	3	:	2	2

Post padding, absolute_index = (max_row_len × last_delim_index) + relative_index

0	1	2	3	4	5	-	10	11	12	13	14	-	20	21	22	23	24	25	26	27	28	-	30	31	32	33	34	35

absolute_index of required pads

6	7	8	9	10	15	16	17	18	19	20	29	30	36	37	38	39	40
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#

Public Pad array

Two arrays with secret shared *absolute* indices of values within target array

Secure merge yields the desired final result

Secure Parsing

Secret shared

i	S	1	8	4	2		a	5	5	.	2		n	U	P	I	/	Z	M	T	O		t	1	3	:	2	2

Post padding, absolute_index = (max_row_len × last_delim_index) + relative_index

0	1	2	3	4	5	-	10	11	12	13	14	-	20	21	22	23	24	25	26	27	28	-	30	31	32	33	34	35

absolute_index of required pads

6	7	8	9	10	15	16	17	18	19	20	29	30	36	37	38	39	40
#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#	#

Public Pad array

Two arrays with secret shared *absolute* indices of values within target array

Secure merge yields the desired final result

Secure Parsing

	1	2	3	4	5	6	7	8	9	10
id	S	1	8	4	2	#	#	#	#	#

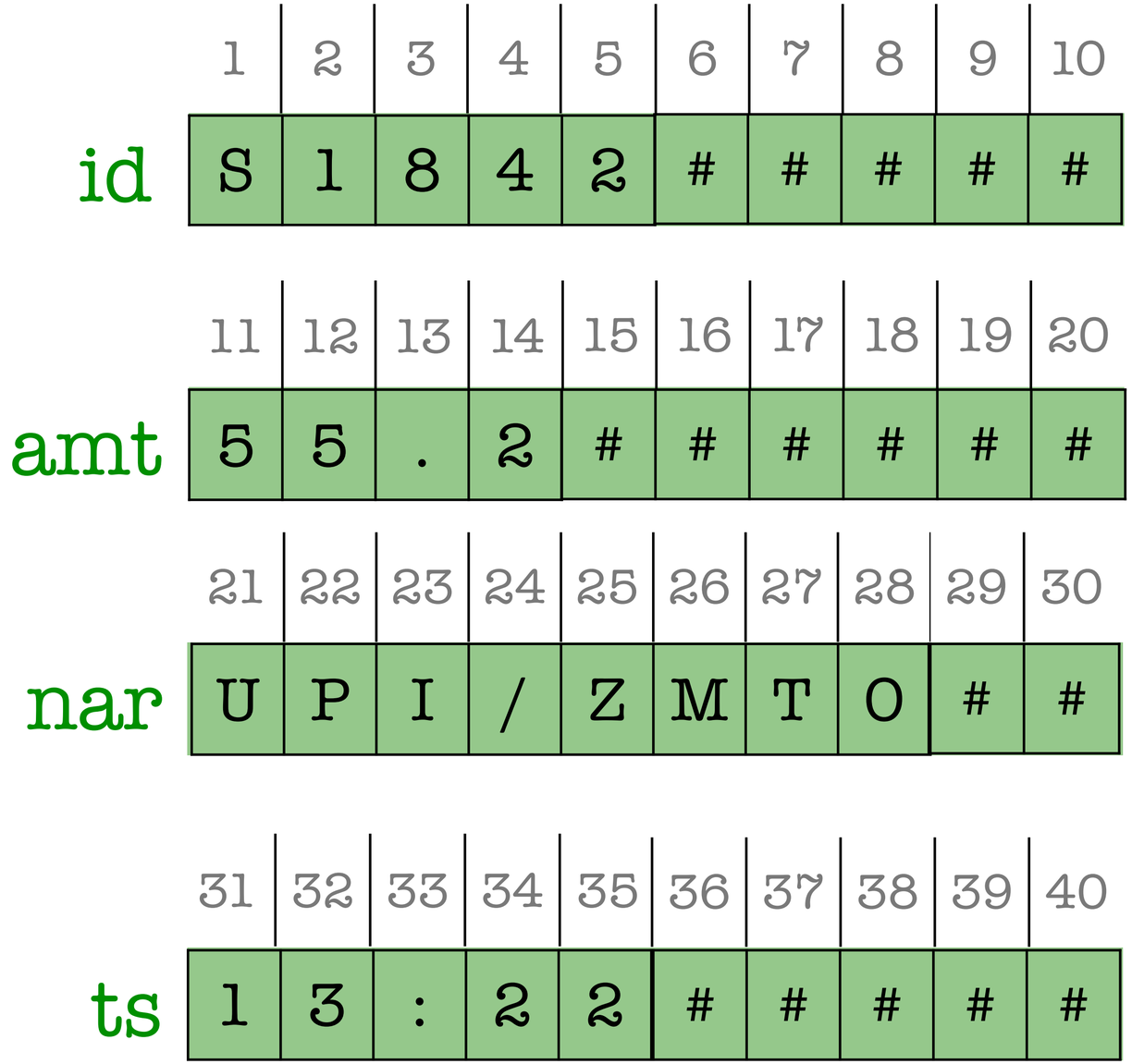
	11	12	13	14	15	16	17	18	19	20
amt	5	5	.	2	#	#	#	#	#	#

	21	22	23	24	25	26	27	28	29	30
nar	U	P	I	/	Z	M	T	O	#	#

	31	32	33	34	35	36	37	38	39	40
ts	1	3	:	2	2	#	#	#	#	#

Secure merge yields the desired final result

Secure Parsing



Secure merge yields the desired final result

Efficiency / Practicalities

- Rough cost profile:
  - Per character: constant number of additions, comparisons, share conversions
  - Constant number of shuffles (simple custom protocol)
  - Overall round complexity independent of file size
- Currently the most expensive component in our integration with the AA ecosystem

Efficiency / Practicalities

- End-to-end: Order of minutes to process a small encrypted bank statement, obtained via actual API
- Plenty of scope to improve the protocol and implementation
- Pilot deployment with partners:

SahamatiNet

Infrastructure provided by Sahamati

fold

Financial Information User (FIU)

Finfactor

Technology Service Provider

Conclusion

- Open Finance frameworks are increasingly popular worldwide
  - eg. India's regulator-driven Account Aggregator (AA) ecosystem

- We propose an MPC-based solution to close gaps in incentives and trust
  - Duplication protection from rogue data fiduciaries (AA: FIUs)
  - Fair compensation model for data custodians (AA: FIPs)

- Design principle: drop-in replacement for immediate use

- Coming soon: full specs on eprint, report on pilot deployment

Thanks!

silencelaboratories.com/open-banking