Decentralized Mnemonic

Backup System

PriFi Labs Inc.

If you do not own your private keys …

…you do not own your crypto assets!

Non custodial wallets

➡ The private keys are stored on your device

◉ Problem
What if your device gets lost or stolen?

✓ Solution
During setup, you were given a "secret recovery phrase"
a 12-word mnemonic phrase (BIP39 standard) that can be used as a backup or to import the wallet into another device

```
witch collapse practice feed shame open
despair creek road again ice least
```

How do I keep my wallet safe?

Backup your Secret Recovery Phrase

MetaMask requires that you store your Secret Recovery Phrase in a safe place. It is the only way to recover your funds should your device crash or your browser reset. We recommend you to write it down. The most common method is to write your 12-word phrase on a piece of paper and store it safely in a place where only you have access. **Note: if you lose your Secret Recovery Phrase, MetaMask can't help you recover your wallet.** Never give you Secret Recovery Phrase or your private key(s) to anyone or any site, unless you want them to have full control over your funds.

source: *Metamask FAQ*

Storing a piece of paper in a safe place is inconvenient

- Problem - Where do you store your paper?
  In your cash and credit card wallet? It could get lost or stolen
  In the house? It could burn down
  In a deposit box at the bank? Good but cumbersome

- ✓ Solution
  How about storing it on the blockchain directly?

- ➡ Decentralized Mnemonic Backup System
  to save a backup of any blockchain mnemonic to the Secret Network

Outline

Iteration 1: User Experience

Iteration 2: Security Hardening

Iteration 3: Improving Availability

Iteration 1

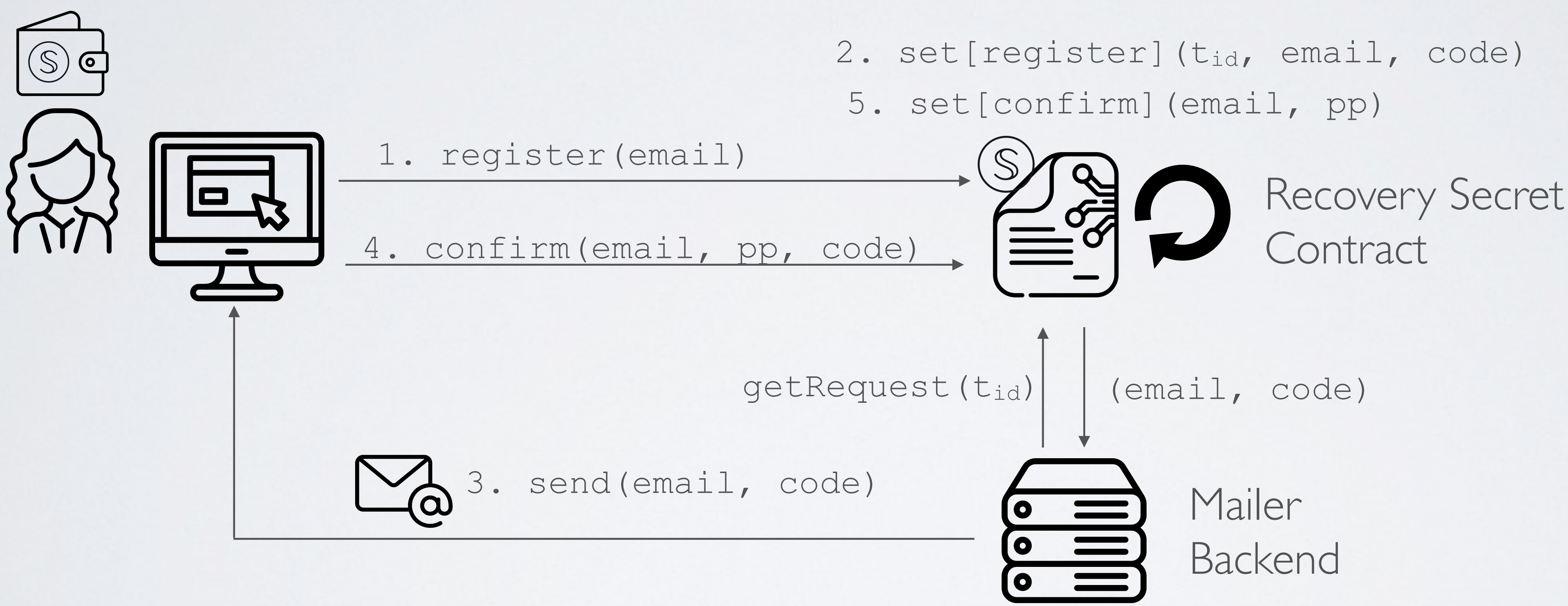
User Experience

Basics

1. **Backup** - Alice pushes her passphrase to the blockchain using her email and a throwaway wallet

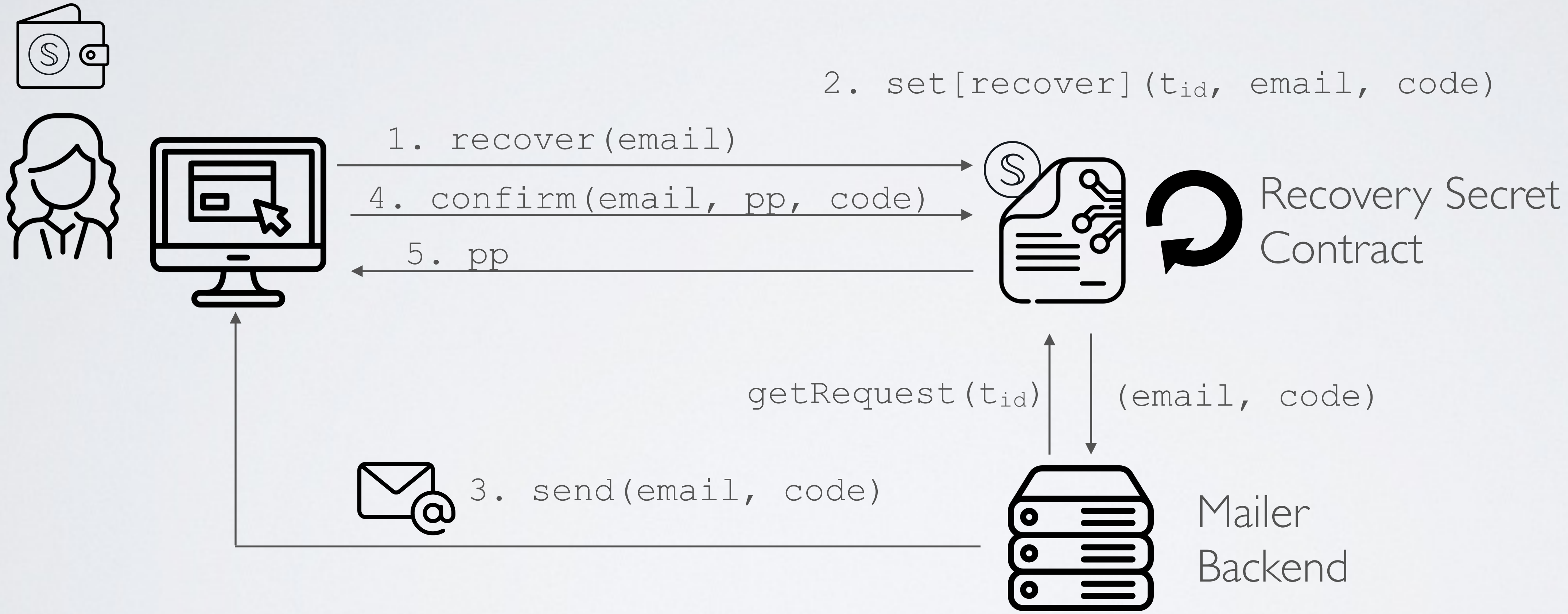
2. **Recovery** - Alice recovers her passphrase using her email and yet another throwaway secret wallet

Backup



2. set[register](tid, email, code)
5. set[confirm](email, pp)
1. register(email)
4. confirm(email, pp, code)
Recovery Secret Contract
getRequest(tid)
(email, code)
3. send(email, code)
Mailer Backend

Recovery



2. set[recover](t_id, email, code)
1. recover(email)
4. confirm(email, pp, code)
5. pp
Recovery Secret Contract
getRequest(t_id)
(email, code)
3. send(email, code)
Mailer Backend

Security Analysis

What if the attacker hacks Alice's account after registration?

- He/she could get the passphrase from the transaction history

What if the attacker hacks the mailer backend?

- During backup, he/she could upload an arbitrary passphrase
- During recovery, he/she could get the verification code and retrieve the passphrase

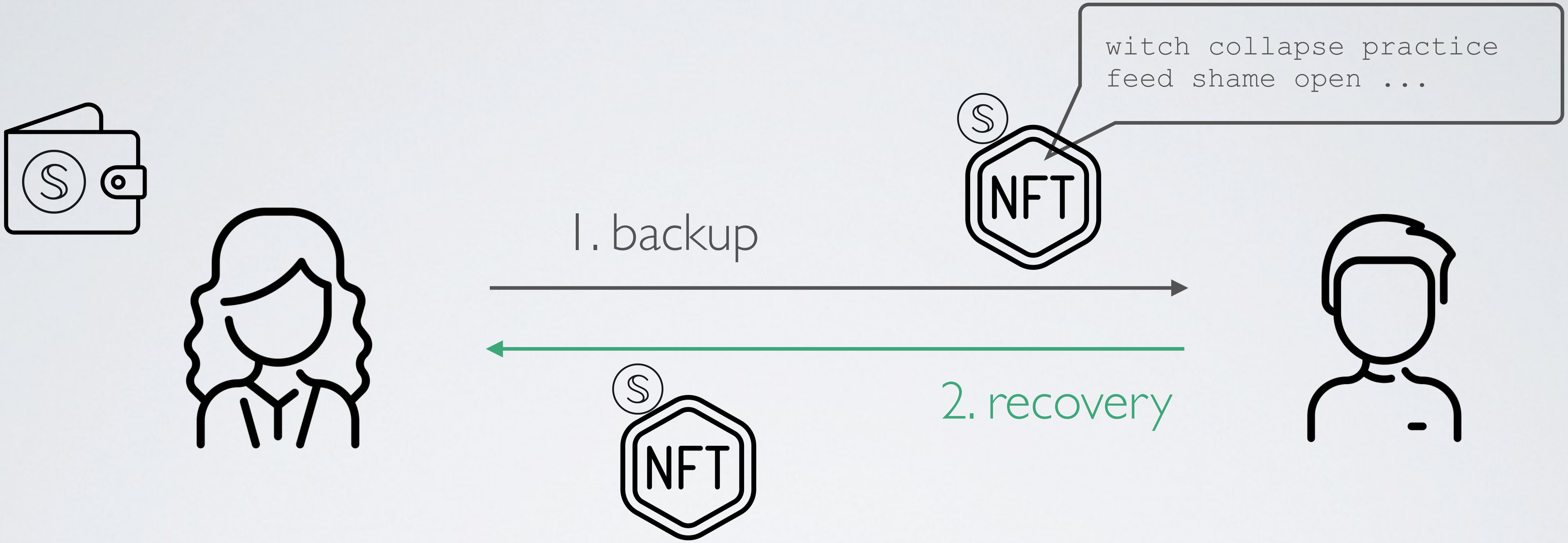
What if the attacker hacks the secret contract?

- **He/she will have access to all users' passphrases**

Iteration 2

Security Hardening

By leveraging Secret NFTs (Secret Network)



1. **Backup** - Alice creates a throwaway Secret wallet to mint an NFT (with the passphrase as private metadata) and send it to Bob

2. **Recovery** - Alice creates a new wallet and gets the NFT back to recover the passphrase

Protecting the passphrase

- Bob can get Alice passphrase when owning the NFT

✓ Solution
Encrypt the passphrase using an AES symmetric key and use store that key in the Recovery Secret Contract

Backup : $c = E_{AES}(k, m)$

Recovery : $m = D_{AES}(k, c)$

The problem of sending the key on the network

✓ Instead of sending the key directly, let's use a key agreement protocol between Alice and the Recovery Secret Contract

➡ ECDH (Elliptic-curve Diffie–Hellman)

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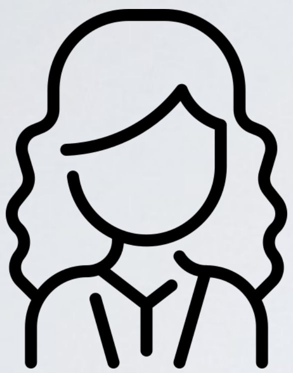
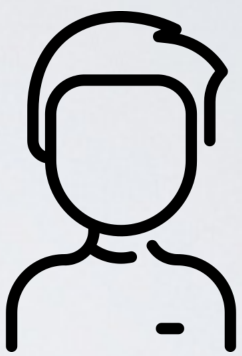
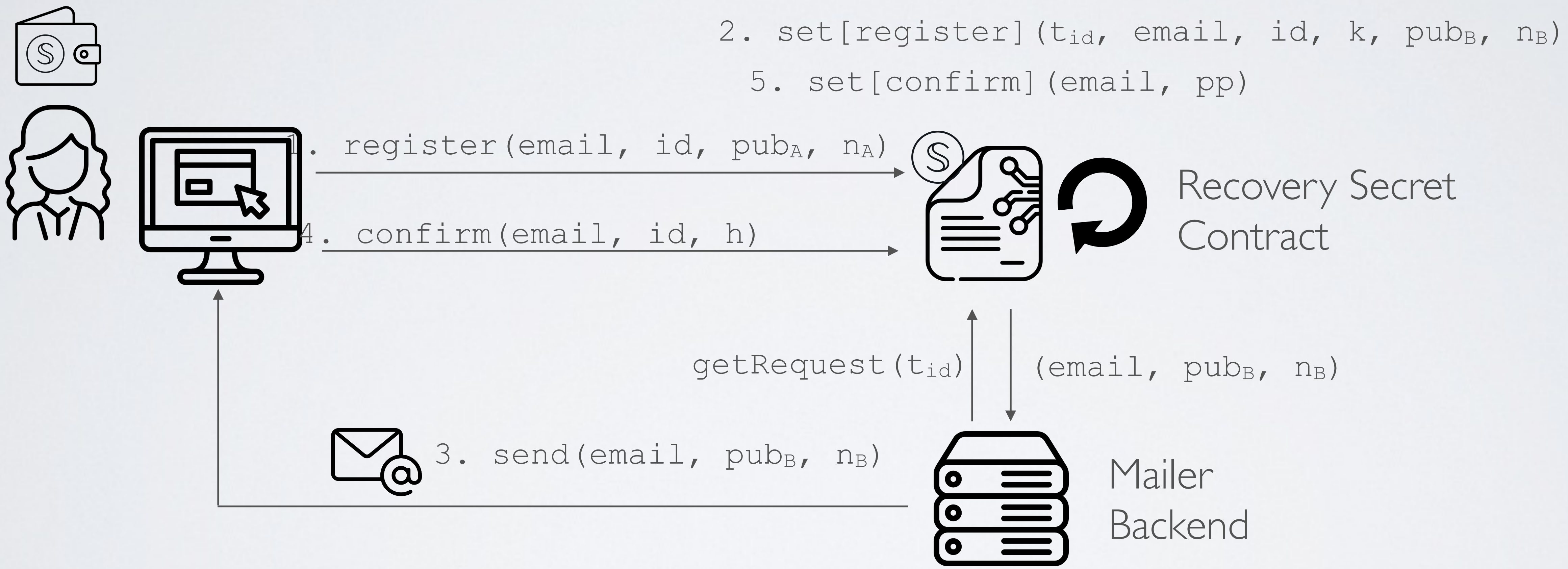




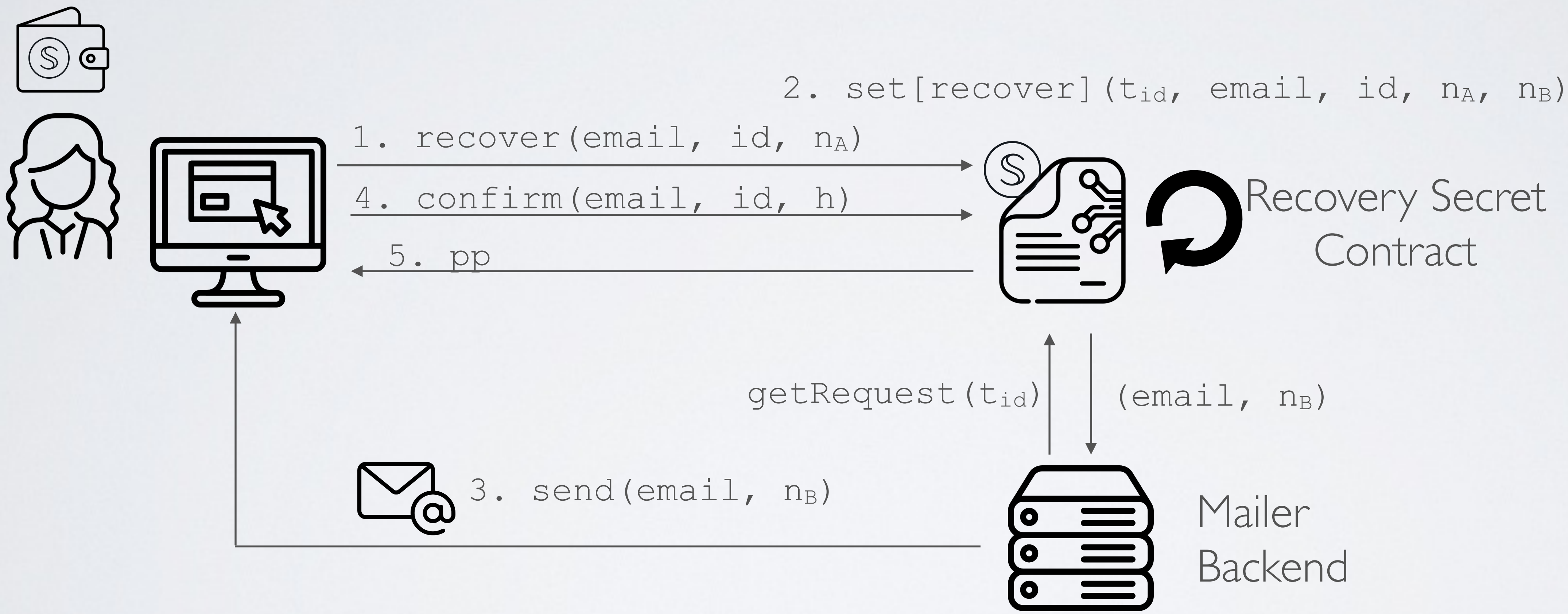
1. generates (Sec_A, Pub_A)	$\xrightarrow{n,\ Pub_A}$	1. generates (Sec_B, Pub_B)
		2. calculates s = ECDH(Sec_B, Pub_B, Pub_A)
	$\xleftarrow[Pub_B]{}$	
2. calculates s = ECDH(Sec_A, Pub_A, Pub_B)		3. calculates k = PBKDF2(s, n)
3. calculates k = PBKDF2(s, n)		

Backup



2. set[register](t_id, email, id, k, pub_B, n_B)
5. set[confirm](email, pp)
1. register(email, id, pub_A, n_A)
4. confirm(email, id, h)
Recovery Secret Contract
getRequest(t_id)
(email, pub_B, n_B)
3. send(email, pub_B, n_B)
Mailer Backend

Recovery



2. set[recover](t_id, email, id, n_A, n_B)
1. recover(email, id, n_A)
4. confirm(email, id, h)
5. pp
Recovery Secret Contract
getRequest(t_id)
(email, n_B)
3. send(email, n_B)
Mailer Backend

Security Analysis

What if the attacker hacks Alice's account after registration?

✓ He/she cannot recover the key from the transaction history

What if the attacker hacks the mailer backend?

✓ He/she could retrieve the key with the verification code but will not be able to get the passphrase without locating the NFT

What if the attacker hacks the secret contract?

✓ He/she could get all users' keys but will not be able to get any passphrase without locating each corresponding NFT

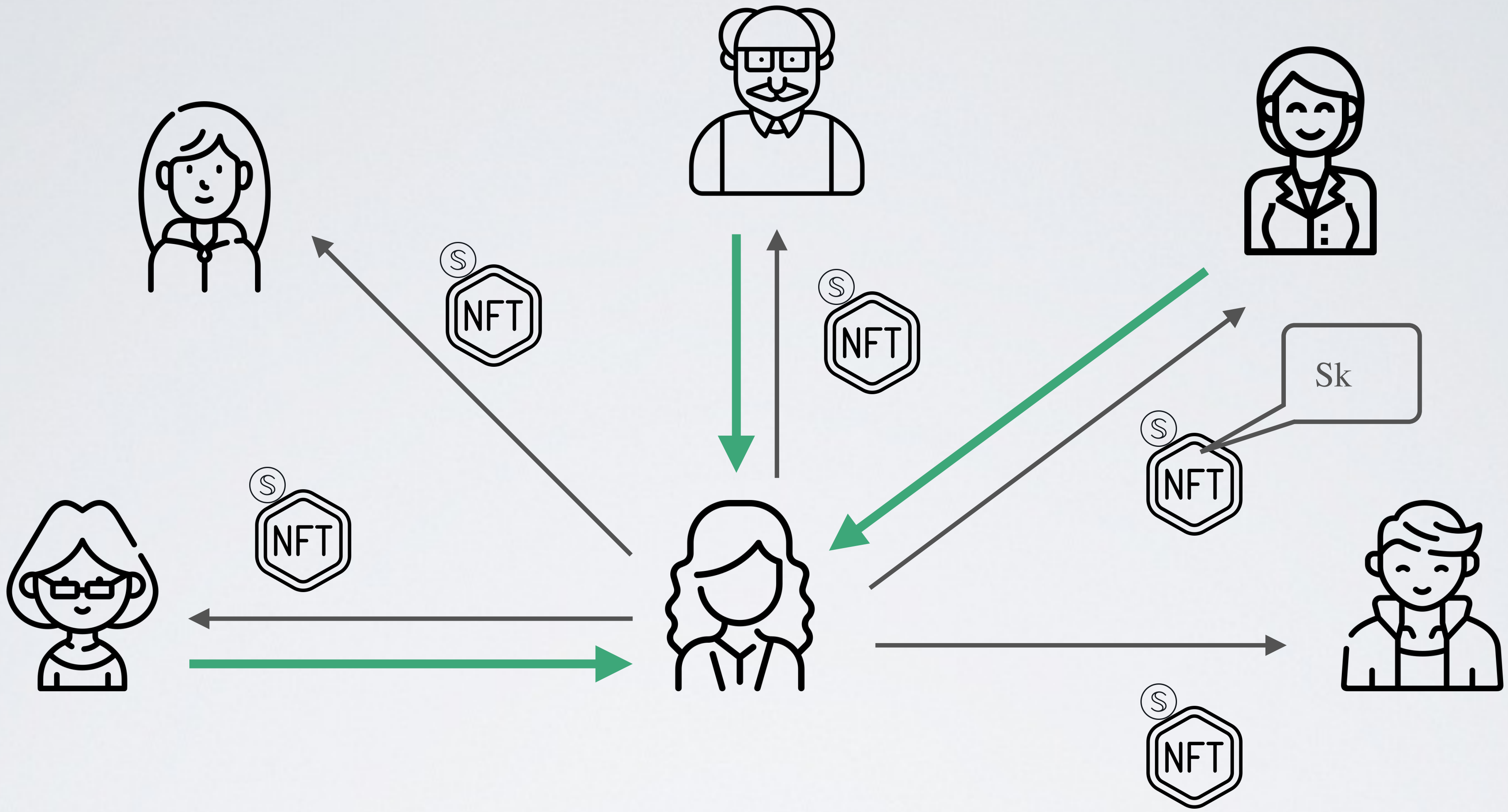
Yet another problem

- What if Bob cannot return the NFT back to Alice when needed

Iteration 3

Improving Reliability

By using Shamir's Secret Sharing scheme (SSS)



1. **Backup** - Alice splits the passphrase **m** into **i** secret shares with j threshold

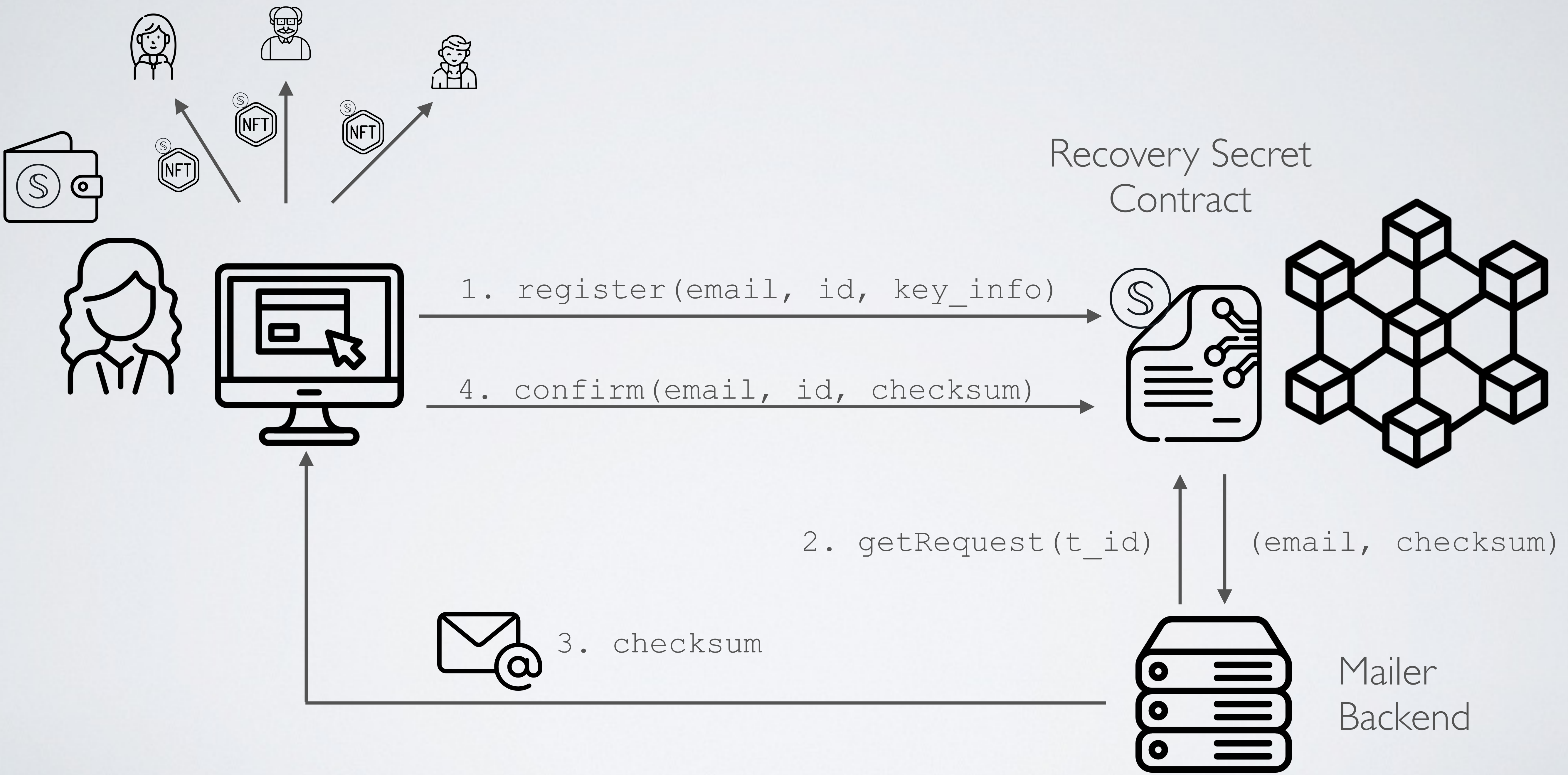
$$(s_1, \ldots, s_n) = E_{SSS}(E_{AES}(k, m), i, j)$$

2. **Recovery** - Alice needs only k shares back (threshold) to regenerate the passphrase

$$m = D_{AES}(k, D_{SSS}(s_1, \ldots, s_k))$$

Full Protocol

Backup


NFT
NFT
NFT
Recovery Secret Contract
1. register(email, id, key_info)
4. confirm(email, id, checksum)
2. getRequest(t_id)
(email, checksum)
3. checksum
Mailer Backend

Backup (detailed)

1. email, id, m, i, j (inputs)
2. generates (sec_A, pub_A) and n_A

3. register $_{tid, bid}$(email, id, pub_A, n_A) →

4. generates (sec_B, pub_B) and n_B
5. calculates $s = ECDH(sec_B, pub_B, pub_A)$
6. calculates $k = PBKDF2(s, n_{1A} + n_B)$
7. store register(email, id, k, t_{id}, b_{id}, pub_B, n_B)

8. getTx $_{qry}$ (t_{id}) →

9. assert mailer query and $b_{id} + t < current_{id}$

10. (email, pub_B, n_B) ←

11. (pub_B, n_B) ←

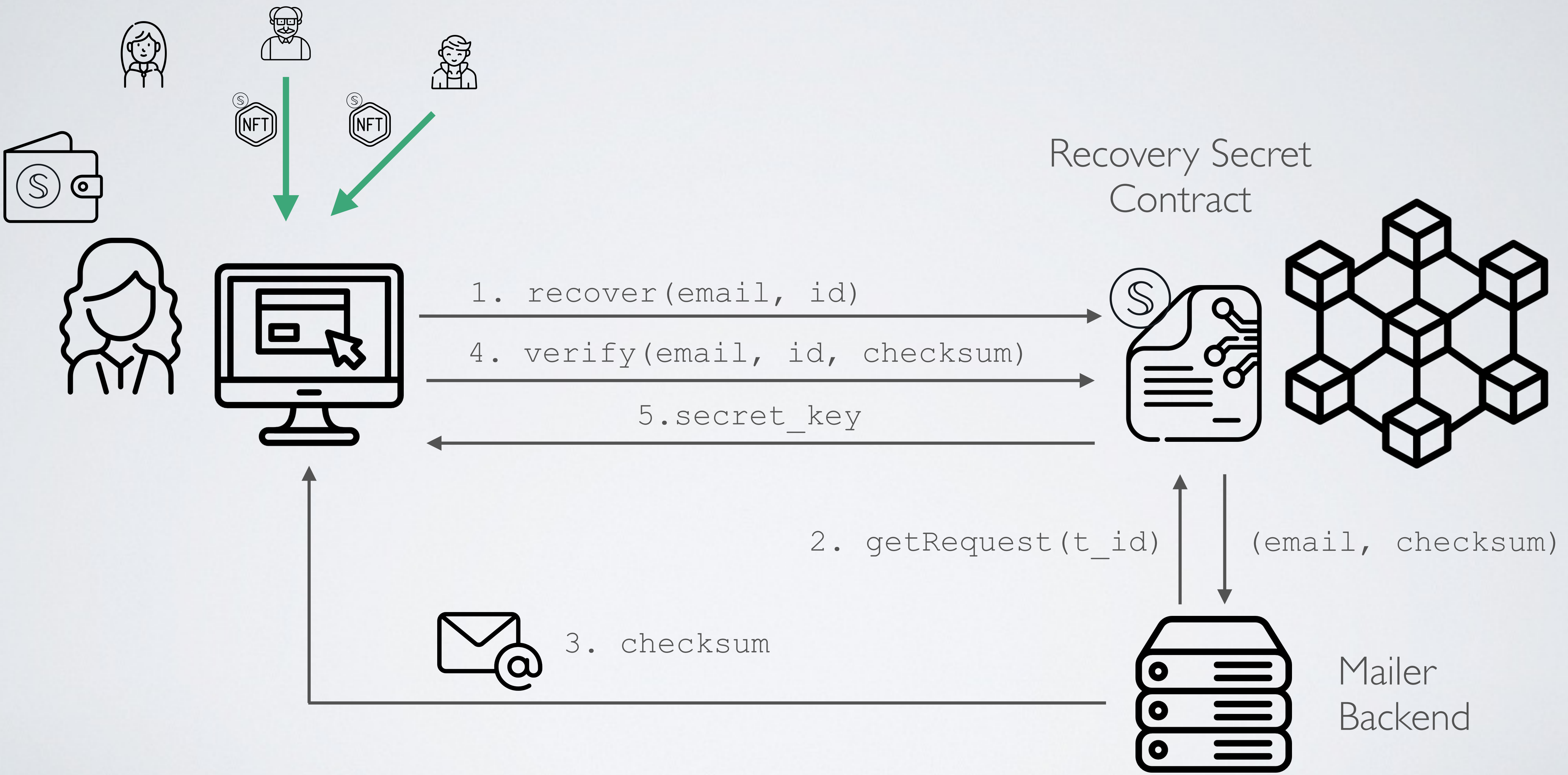
12. calculates $s = ECDH(sec_A, pub_A, pub_B)$
13. calculates $k = PBKDF2(s, n_A + n_B)$
14. calculates $h = HMAC(k, email + id)$

15. confirm $_{tid', bid'}$(email, id, h) →

16. assert $b_{id} + t < current_{id}$
17. calculates $h' = HMAC(k, email + id)$
18. assert $h == h'$
19. store confirm(email, id, k)

20. calculates $(s_1, \ldots., s_n) = E_{SSS}(id + E_{AES}(k, m), i, j)$
21. for each s_k, generates secret NFT

Recovery



NFT
NFT
Recovery Secret Contract
1. recover(email, id)
4. verify(email, id, checksum)
5.secret_key
2. getRequest(t_id)
(email, checksum)
3. checksum
Mailer Backend

Recovery (detailed)

1. email, $(s_1, \ldots., s_j)$ (inputs)
2. calculates id + c = $D_{SSS}(s_1, \ldots., s_j)$
3. generates n_A

4. recover $_{tid, bid}$(email, id, n_A)

5. assert confirm(email, id, k)
6. generates n_B
7. store recover(t_{id}, b_{id}, email, id, k, n_A, n_B)

8. getTx $_{qry}$ (t_{id})

9. assert mailer query and $b_{id} + t < current_{id}$

10. (email, n_B)

11. n_B

12. calculates h = HASH(n_A+ n_B)

13. verify $_{qry}$(email, id, h)

14. assert $b_{id} + t < current_{id}$
15. calculates h' = HASH($n_A + n_B$)
16. assert h == h'

17. k

18. calculates m = D_{AES}(k, c)