Decentralized Multi-Client Functional Encryption

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Introduction

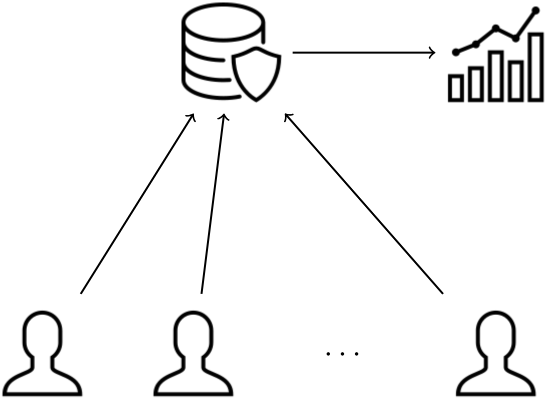
Definitions

Centralized scheme

Decentralized scheme

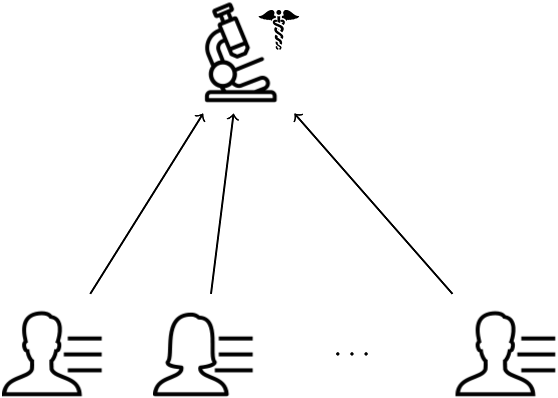
Context

Privacy and data analysis



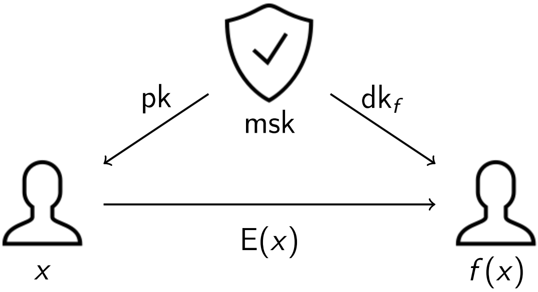
Context

Example: medical studies



Context

Functional Encryption (FE) [BSW11]:



IP-FE [ABDP15]: $f(\vec{x}) = \langle \vec{x}, \vec{y} \rangle$ for a given $\vec{y}$

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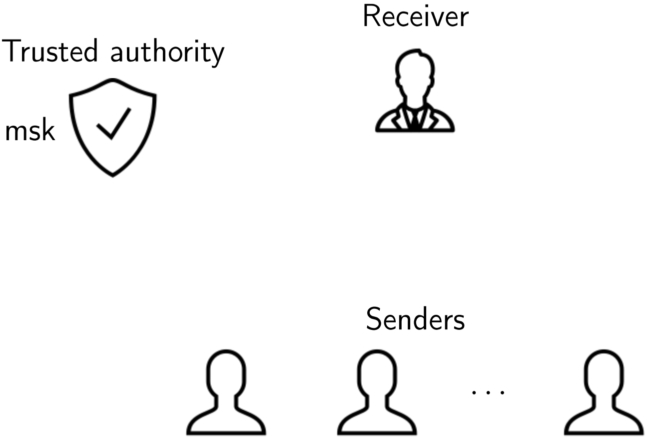
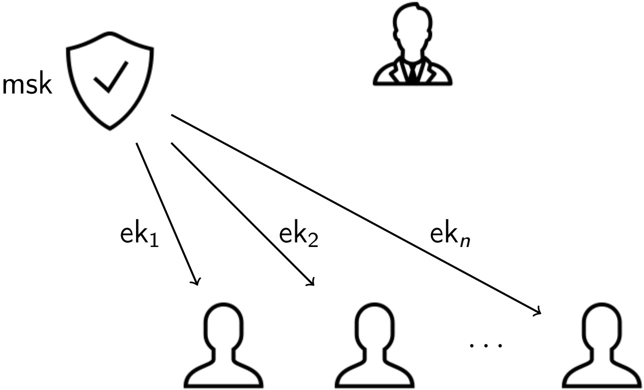
Description

Involved parties:



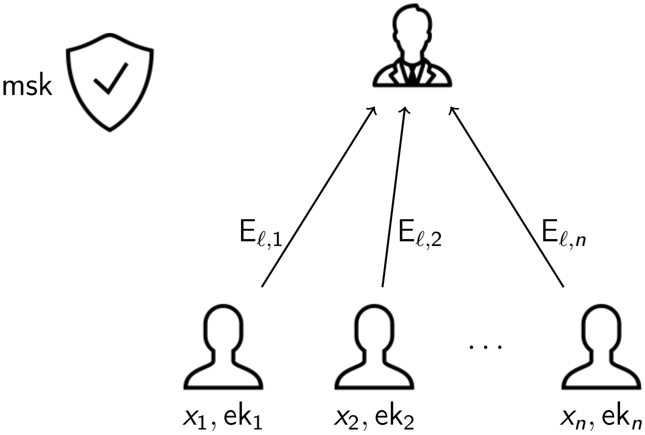
Description

SetUp: Sets msk, returns personal encryption keys ek_i



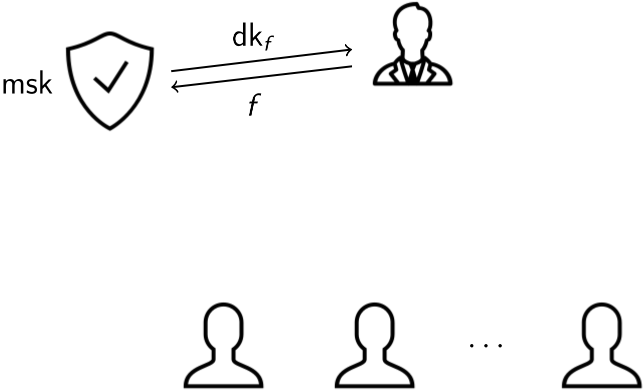
Description

Encrypt: Returns encrypted value $\mathsf{E}_{\ell,i}$



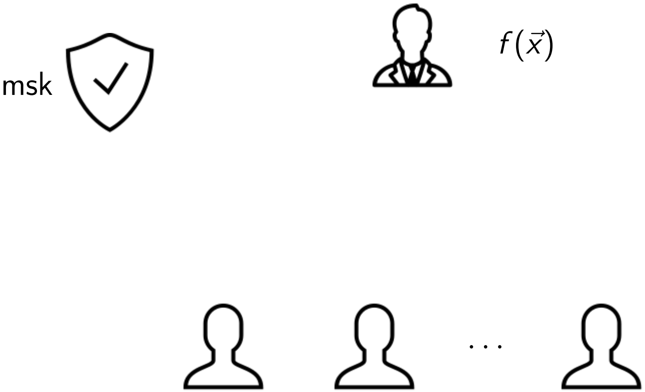
Description

DKeyGen: Given a function f, returns a decryption key dk_f



Description

Decrypt: Returns the value $f(\vec{x})$

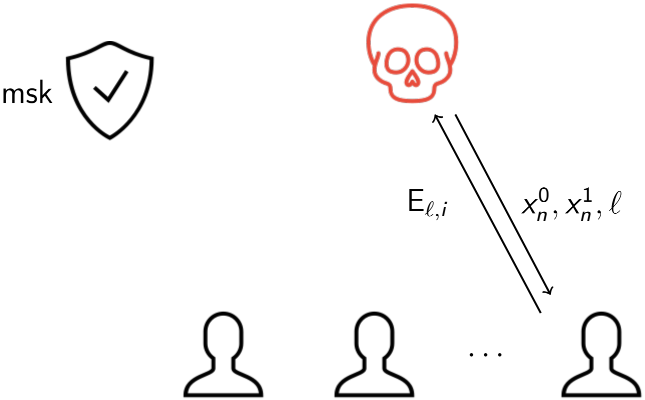


Security model

Malicious adversary

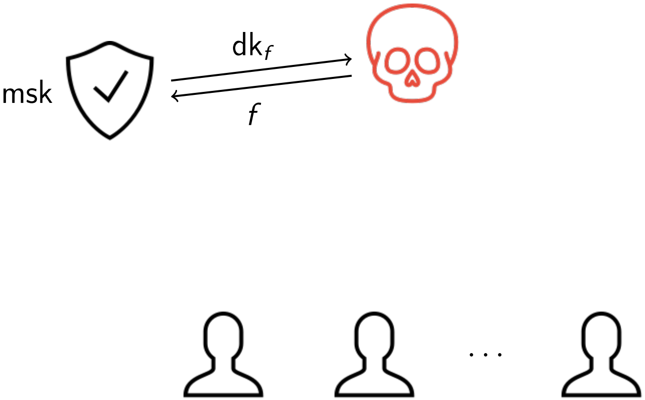
Security model

Encryption queries: QEncrypt$(i, (x_i^0, x_i^1), \ell)$



Security model

Decryption key queries: QDKeyGen(f)



Security model

Corruption of senders: QCorrupt(i)

Security model

Conditions of trivial win:

- $f(\vec{x}^0) \neq f(\vec{x}^1)$
- $x_i^0 \neq x_i^1$ for any corrupted sender i

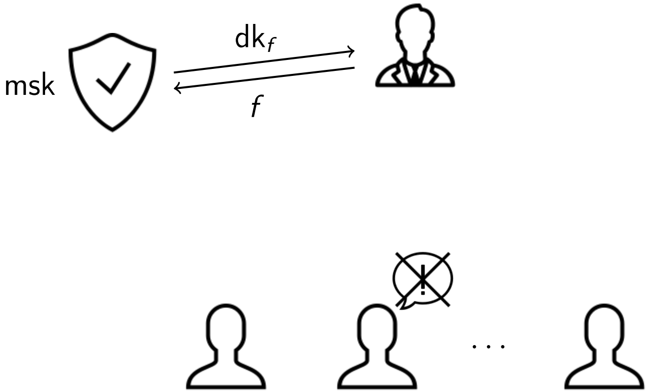
Security model

Variants:

- selective security
- static corruption

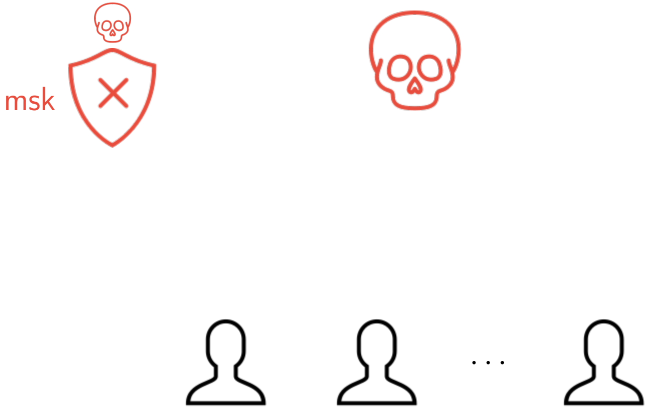
Why decentralization

No right management for senders



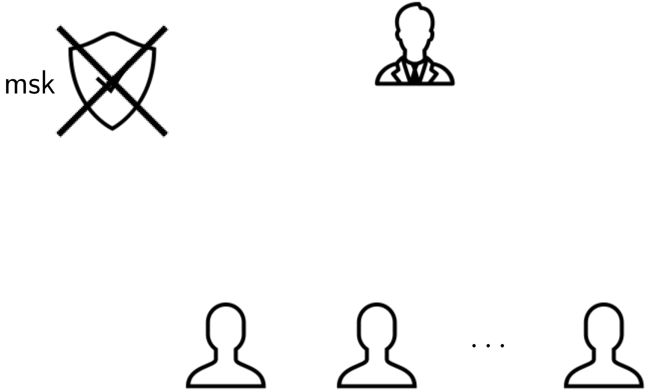
Why decentralization

Corruption of the authority



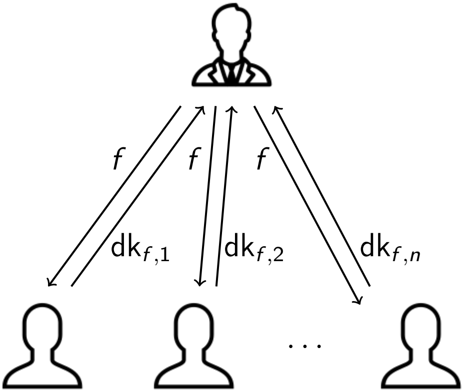
Why decentralization

Requires decentralization



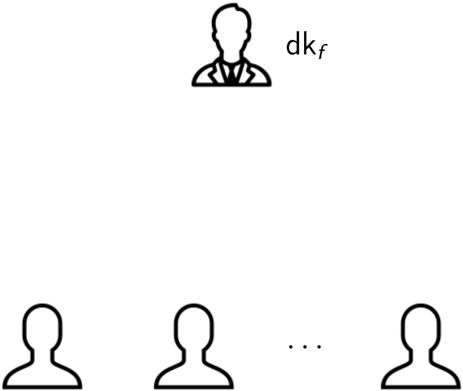
Impact on the definition

DKeyGenShare: returns a part $\mathsf{dk}_{f,i}$ of the future key dk_f



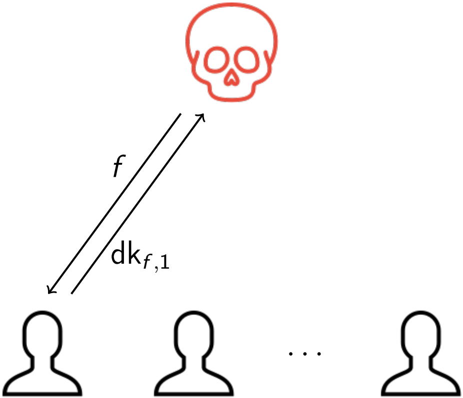
Impact on the definition

DKeyGenComb: Build the decryption key dk_f from $(\mathsf{dk}_{f,i})_i$



Impact on the security

Partial key queries: QDKeyGen(f, i)



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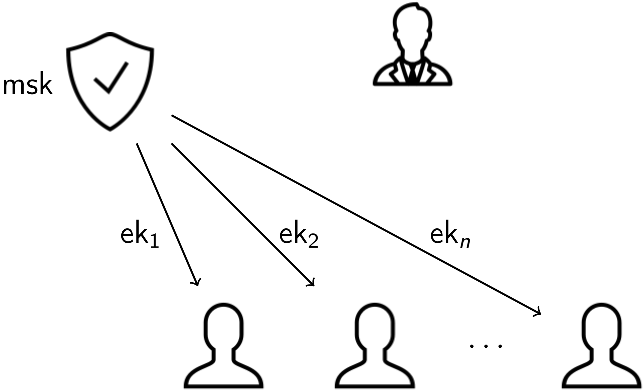
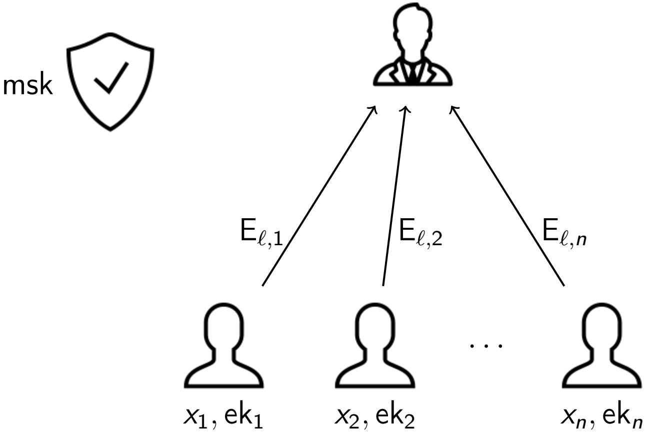
Description

SetUp(λ): $\mathsf{ek}_i \leftarrow \mathbb{Z}_p$, $\mathsf{msk} = (\mathsf{ek}_i)_i$, $\mathsf{pp} = (\mathbb{G}, \mathcal{H}$ onto $\mathbb{G})$



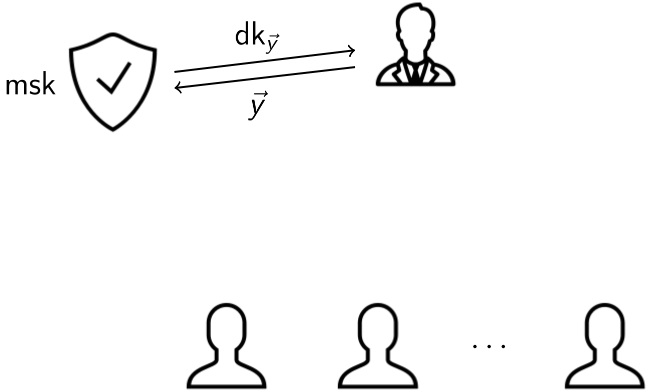
Description

Encrypt(ek_i,x_i,ℓ): $\mathsf{E}_{\ell,i} = \mathcal{H}(\ell)^{\mathsf{ek}_i} \cdot g^{x_i} \in \mathbb{G}$



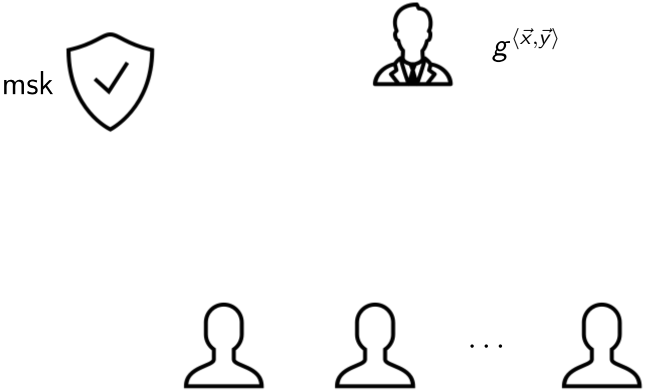
Description

DKeyGen(msk,$\vec{y}$): $\mathsf{dk}_{\vec{y}} = \langle \mathsf{msk}, \vec{y} \rangle = \langle (\mathsf{ek}_i)_i, \vec{y} \rangle \in \mathbb{Z}_p$



Description

Decrypt$(\mathsf{dk}_{\vec{y}}, \ell, \vec{\mathsf{E}}_\ell)$: $\prod_i \mathsf{E}_{\ell,i}^{y_i} \cdot \mathcal{H}(\ell)^{-\mathsf{dk}_{\vec{y}}}$



Description

Given $\mathsf{E}_{\ell,i} = \mathcal{H}(\ell)^{\mathsf{ek}_i} \cdot g^{x_i}$ and $\mathsf{dk}_{\vec{y}} = \langle \mathsf{msk}, \vec{y} \rangle$, the detail of the correctness is:

$$
\begin{aligned}
\alpha &= \prod_i \mathsf{E}_{\ell,i}^{y_i} \cdot \mathcal{H}(\ell)^{-\mathsf{dk}_{\vec{y}}} \\
&= \prod_i (\mathcal{H}(\ell)^{\mathsf{ek}_i} \cdot g^{x_i})^{y_i} \cdot \mathcal{H}(\ell)^{-\langle \mathsf{msk}, \vec{y} \rangle} \\
&= \mathcal{H}(\ell)^{\sum_i \mathsf{ek}_i y_i} \cdot g^{\sum_i x_i y_i} \cdot \mathcal{H}(\ell)^{-\langle \mathsf{msk}, \vec{y} \rangle} \\
&= g^{\langle \vec{x}, \vec{y} \rangle}
\end{aligned}
$$

Then solve the discrete logarithm of α

Security

- adaptive ciphertext queries
- adaptive corruption queries

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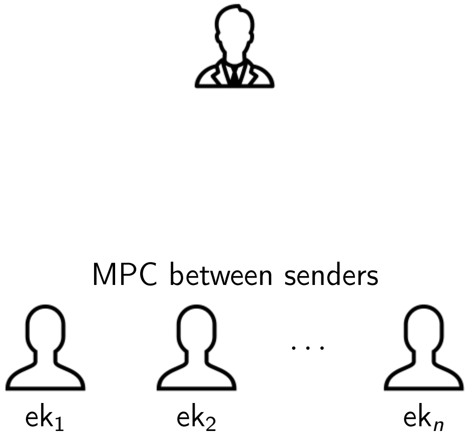
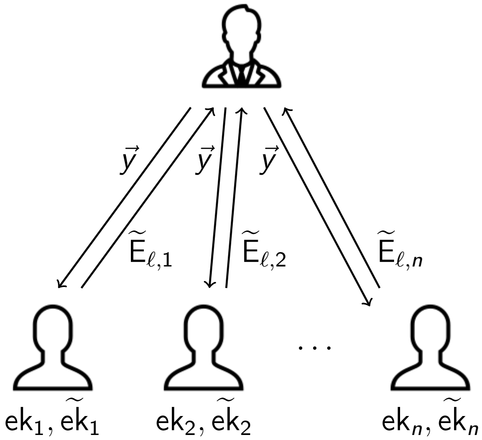
Idea

Problem: interactions for DKeyGen



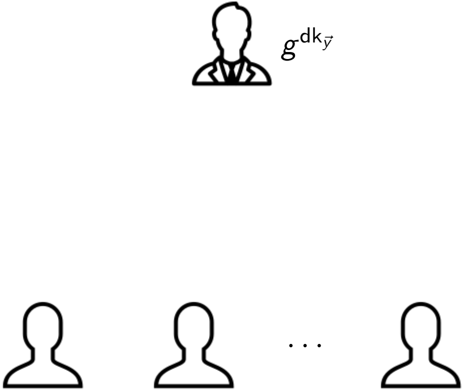
Idea

Solution: $\widetilde{\text{MCFE}}$ to build $\mathsf{dk}_{\vec{y}} = \langle (\mathsf{ek}_i y_i)_i, \vec{1} \rangle$



Idea

Specific problem: key as group element instead of scalar



Idea

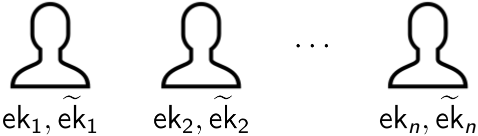
Specific solution: pairings

- message related MCFE in $\mathbb{G}_1$
- key related $\widetilde{\text{MCFE}}$ in $\mathbb{G}_2$

Description

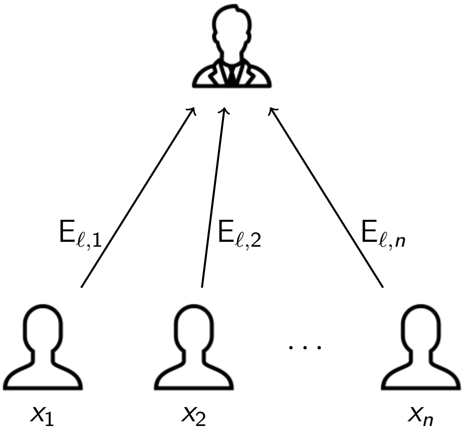
SetUp(λ): $\mathsf{ek}_i, \widetilde{\mathsf{ek}}_i \leftarrow \mathbb{Z}_p, \mathsf{sk}_i = (\mathsf{ek}_i, \widetilde{\mathsf{ek}}_i)$,
$\mathsf{pp} = (\mathbb{G}_1, \mathcal{H}_1, \mathbb{G}_2, \mathcal{H}_2, \mathbb{G}_T, e, \widetilde{\mathsf{dk}} = \sum_i \widetilde{\mathsf{ek}}_i)$

MPC between senders



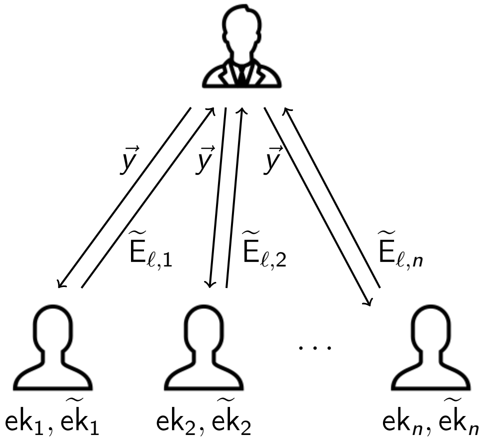
Description

Encrypt(ek_i,x_i,ℓ): $\mathsf{E}_{\ell,i} = \mathcal{H}_1(\ell)^{\mathsf{ek}_i} \cdot g_1^{x_i} \in \mathbb{G}_1$



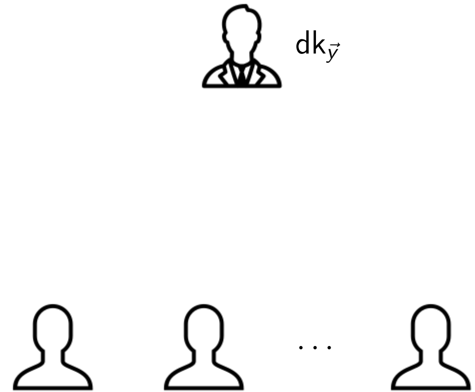
Description

DKeyGenShare(sk_i,$\vec{y}$): $\widetilde{\mathsf{E}}_{\ell,i} = \mathcal{H}_2(\vec{y})^{\widetilde{\mathsf{ek}}_i} \cdot g_2^{\mathsf{ek}_i y_i} \in \mathbb{G}_2$



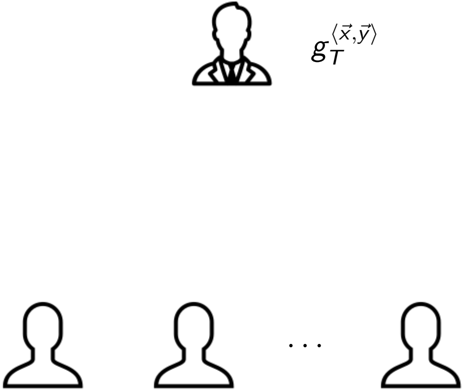
Description

$$\mathsf{DKeyGenComb}((\widetilde{\mathsf{E}}_{\ell,i})_i, \vec{y}):\ \mathsf{dk}_{\vec{y}} = \sum_i \mathsf{dk}_{\vec{y},i} \cdot \mathcal{H}_2(\vec{y})^{-\widetilde{\mathsf{dk}}} = g_2^{\sum_i \mathsf{ek}_i y_i} \in \mathbb{G}_2$$



Description

Decrypt$(\mathsf{dk}_{\vec{y}}, \ell, \vec{\mathsf{E}}_\ell)$: $e(\prod_i \mathsf{E}_{\ell,i}^{y_i}, g_2) \cdot e(\mathcal{H}_1(\ell), -\mathsf{dk}_{\vec{y}})$



Security

- adaptive ciphertext queries
- static corruption queries

Conclusion

In this paper we saw:

- MCFE primitive and scheme
- Security supporting corruptions
- Decentralization

Open questions:

- Security
- Number size
- Other function families

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Thank you !