Traitor Tracing without Trusted Authority from Registered Functional Encryption

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Scenario: Group Messaging

- L users wish to broadcast messages to each other privately, such that:
  - Small ciphertext, e.g. sublinear in L [Efficiency]
  - No information about any message exchanged is revealed [CPA-Security]
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    → Allows to exclude traitor from the group
- Desired primitive: Traitor Tracing [CFN94]

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  - Authority: Generates public parameters (or master public key) + all users' secret keys
  - Encryptor: Encrypts w.r.t. master public key to all users
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- Key escrow problem: No security if authority is corrupt

Motivation

- This work:

Efficient traitor-tracing *without* a trusted authority

- Goals:
  - Remove trusted authority
  - Non-trivial, concrete efficiency (Ciphertext grows sublinear in number of users)
  - Security from simple and well-understood objects (e.g. not iO)

Our Contributions

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- Prototype implementation for our RTT (RPLBE)
- More applications of our RFEs

Related Works: Prior + Concurrent

- All prior schemes require trusted authority, except [Luo22]:
    - [Luo22]: No Setup + Relies on iO + Non-compact master public key + Non-deterministic decryption

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  - Removes trusted authority in IBE
- Concurrent works on RFE:
  - [DPY23] gets RLFE (with *non-transparent* setup) in GGM
  - [ZLZ+24] gets (very selective) RQFE and RLFE from variants of k-Lin, with *non-transparent* setup

Functional Encryption

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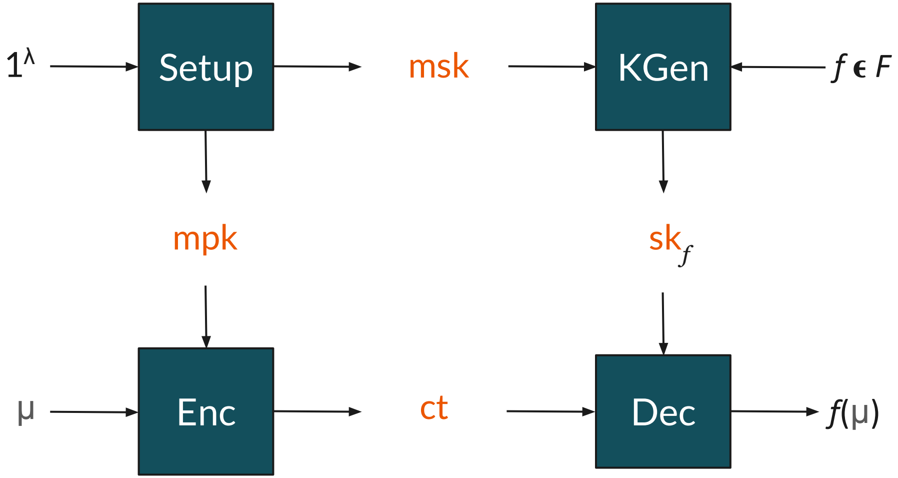
Traditionally



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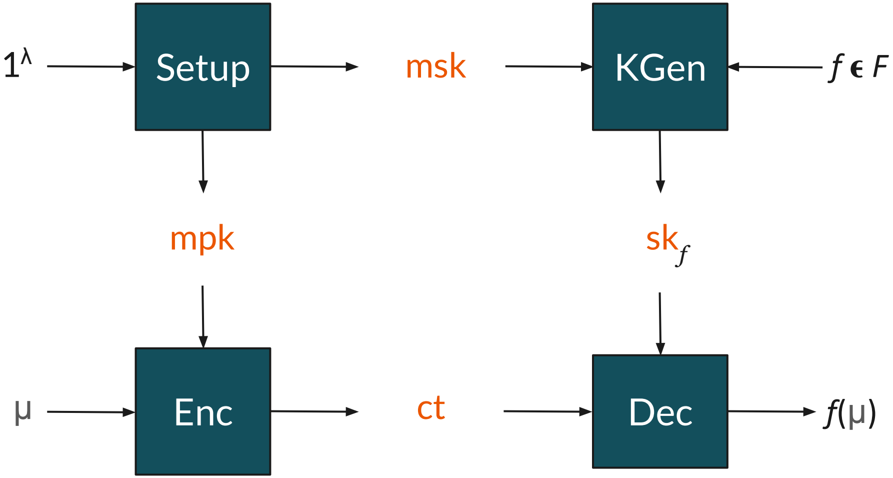

Security (Informally) : $\left[\, \mathrm{mpk}\,, \{\, \mathrm{sk}_f \,\}, \mathrm{ct}(\mu_0)\,, \{\, \mathrm{sk}_f \,\} \,\right] \approx \left[\, \mathrm{mpk}\,, \{\, \mathrm{sk}_f \,\}, \mathrm{ct}(\mu_1)\,, \{\, \mathrm{sk}_f \,\} \,\right]$ provided $f(\mu_0) = f(\mu_1)$

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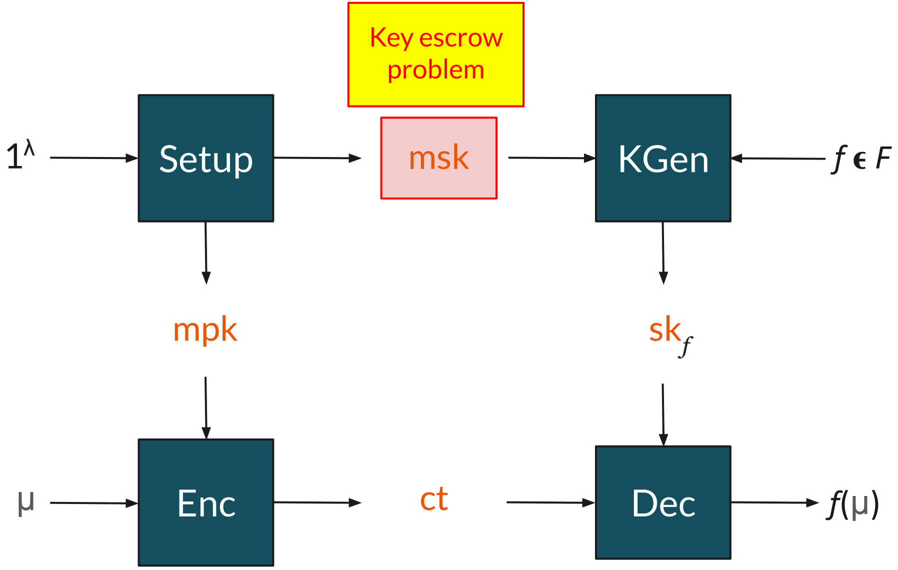
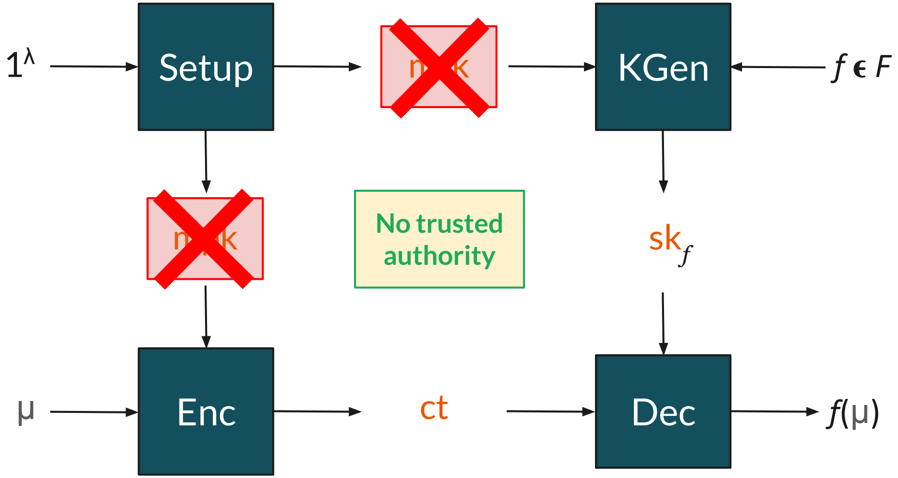


No security if msk gets leaked

Registered Functional Encryption

Formalized in [FFM⁺23, DP23]



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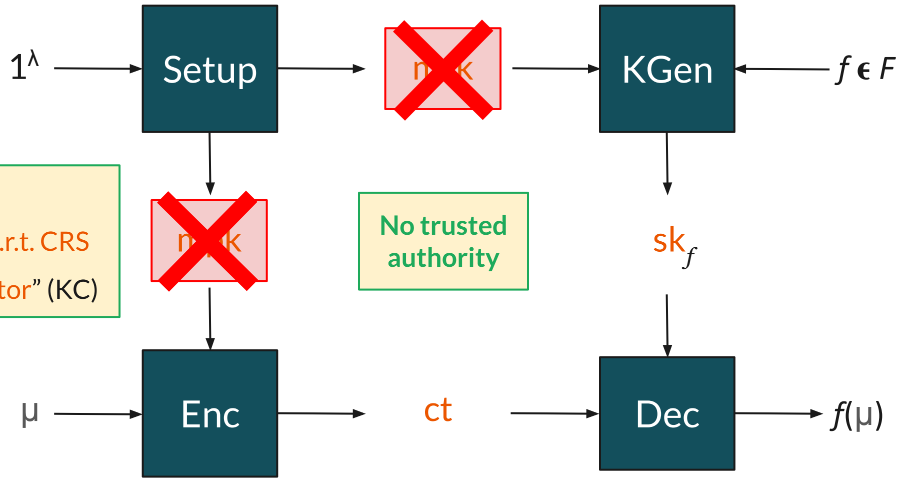

No trusted authority

Setup computes a CRS

User samples its own key-pair (pk, sk) w.r.t. CRS

Users "registers" (pk, *f*) with a "Key Curator" (KC)

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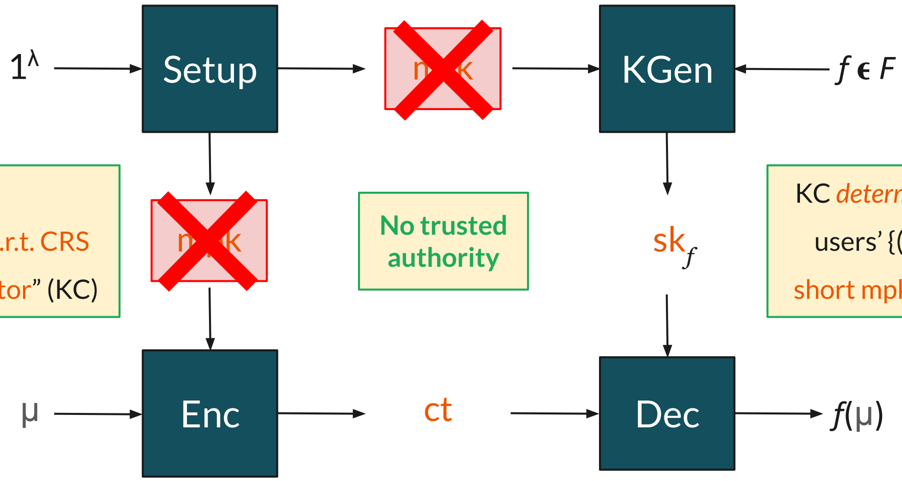

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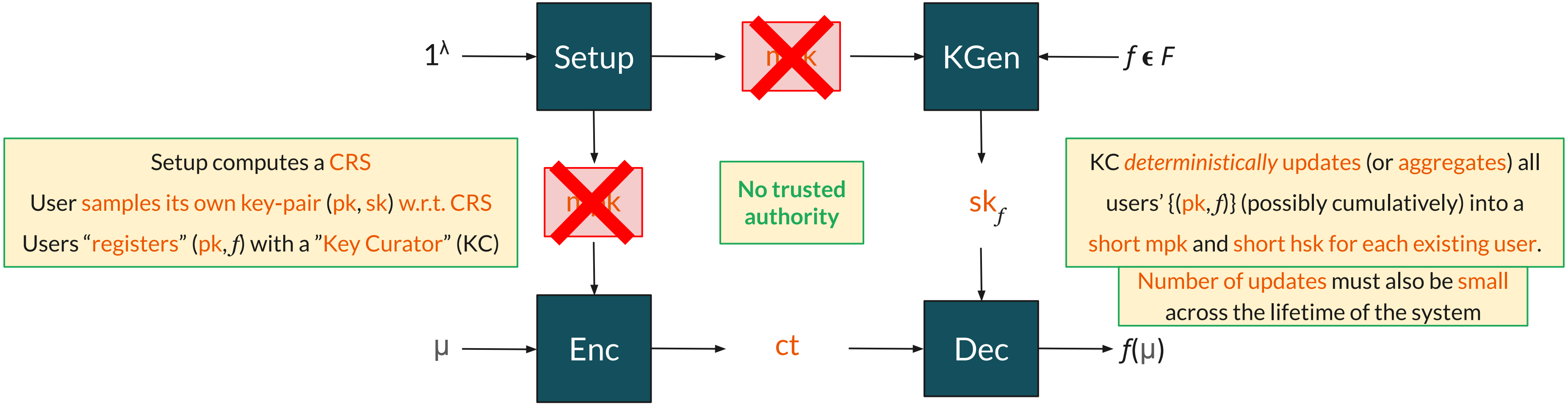

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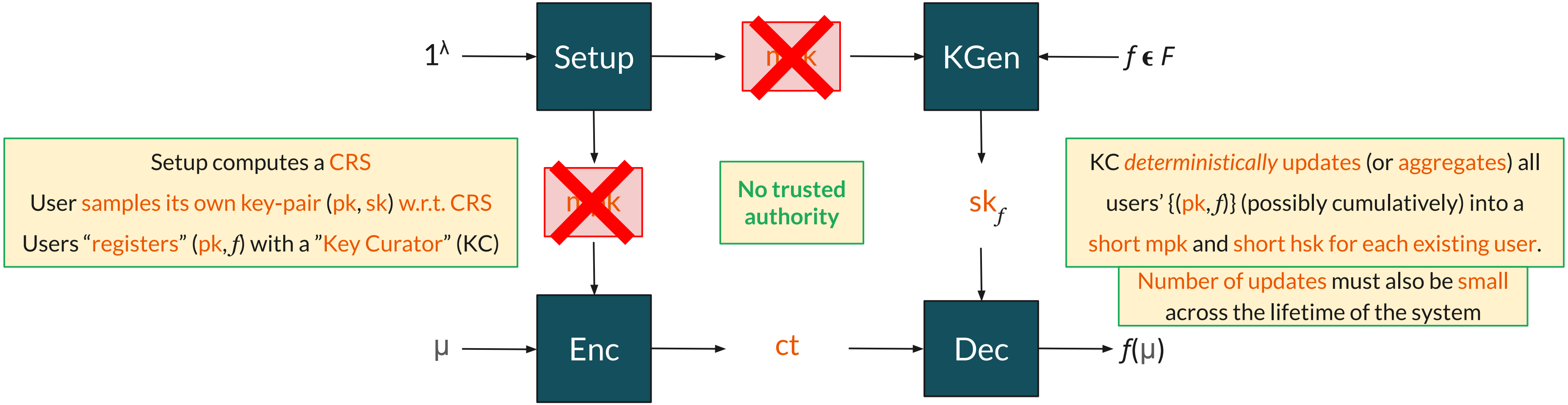

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Security (Informally) : Similar to FE , except now registered keys can be generated maliciously

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Secret keys from independent instances can be publicly combined into a secret key for the global instance.

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- Given “master secret key homomorphic” QFE, define RQFE “global” master public key:

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- Each user also publishes helper information to help others decrypt their own share

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- Each user i misses msk for exactly the i-th function f_i, which is known to itself

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- We provide multiple transformations for security against maliciously registered keys
  - NIZK: prove well-formedness of keys
  - Leverage random oracle on our RQFE: Setup remains transparent
  - Modify RQFE scheme (without random oracle, loses transparent Setup)

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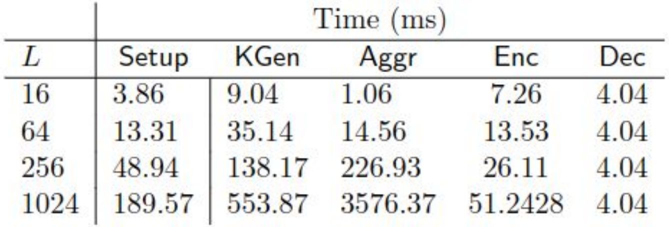
- We formalize the full chain of transformations in the registered setting

  Main observation: Weak RQFE suffices

Implementation: Registered PLBE

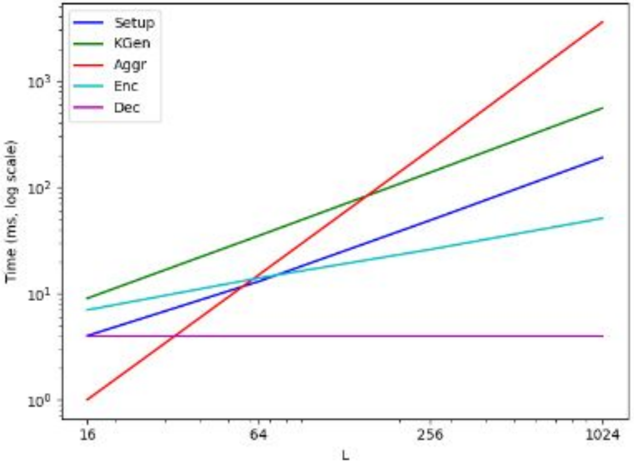
- Sizes for L = 1024:
  crs: 135KB, mpk: 6.6KB, ciphertext: 6.7KB
  pk: 102.5KB, sk: 97B, hsk: 194B

- Runtimes on PC:
  (AMD Ryzen 5 5600X, 3.7GHz CPU, 32GB of RAM)



	Time (ms)				
L	Setup	KGen	Aggr	Enc	Dec
16	3.86	9.04	1.06	7.26	4.04
64	13.31	35.14	14.56	13.53	4.04
256	48.94	138.17	226.93	26.11	4.04
1024	189.57	553.87	3576.37	51.2428	4.04

Table 4: Runtimes of our RPLBE algorithms for different L.



Other Application: Registered Threshold Encryption

- Registered Threshold Encryption (RTE):
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- RLFE → RTE: idea – Shamir's secret-sharing + linear function evaluation (in group exponent)

- t-out-of-L threshold:
  - User i runs RFE.KGen for a linear function $(1, i, \ldots, i^{t-1})$
  - Encrypt message μ: random degree t-1 polynomial P with P(0) = μ
  - RFE decryption : ensures user i learns P(i) (and nothing more)
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RLFE → RTE

RQFE → RTE
(*transparent setup*)

Summary

- New Model: Registered Traitor Tracing (RTT)
- Concretely efficient (weak) RQFE + Transformation to RTT with *transparent* setup
- Prototype implementation
- (More) Applications from our work:
    - RLFE → RTT with bounded collusion
    - RLFE → Single-key RFE for circuits
    - RTE from RLFE and RQFE (with *transparent* setup)

Summary

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- Concretely efficient (weak) RQFE + Transformation to RTT with *transparent* setup
- Prototype implementation
- (More) Applications from our work:
    - RLFE → RTT with bounded collusion
    - RLFE → Single-key RFE for circuits
    - RTE from RLFE and RQFE (with *transparent* setup)

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Thanks!