Group Time-based One-time Passwords and its Application to Efficient Privacy-Preserving Proof of Location

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Overview

- **Background**

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- **Group Time-based One-Time Passwords (GTOTP)**

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- **Summary and Open Questions**

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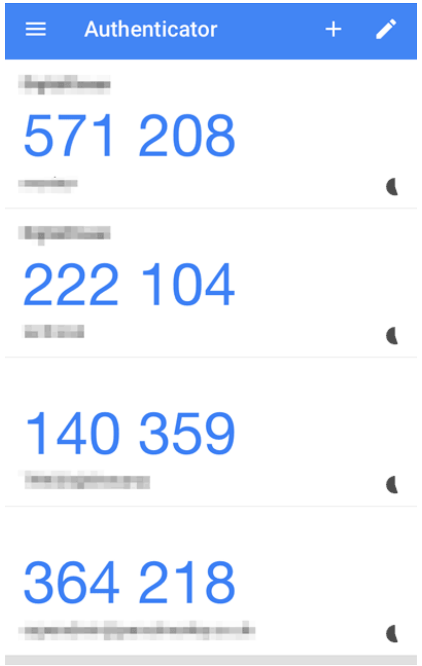
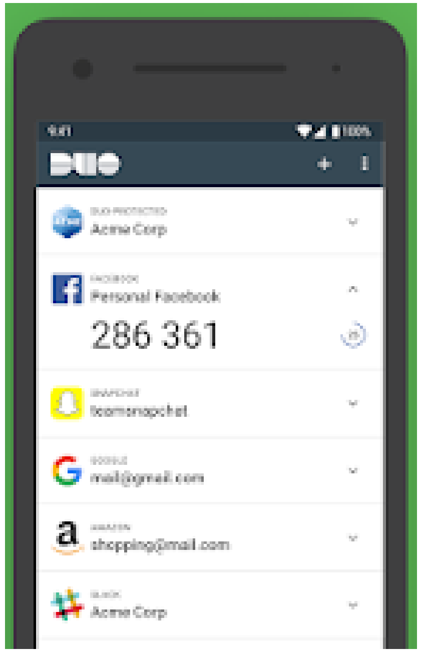
- TOTP as an authentication factor:
  - Lightweight: very efficient to generate
  - Easy to use





Time-based One-time Passwords (TOTP)

- Time-based One-time Passwords
- TOTP as an authentication factor:
  - Lightweight: very efficient to generate
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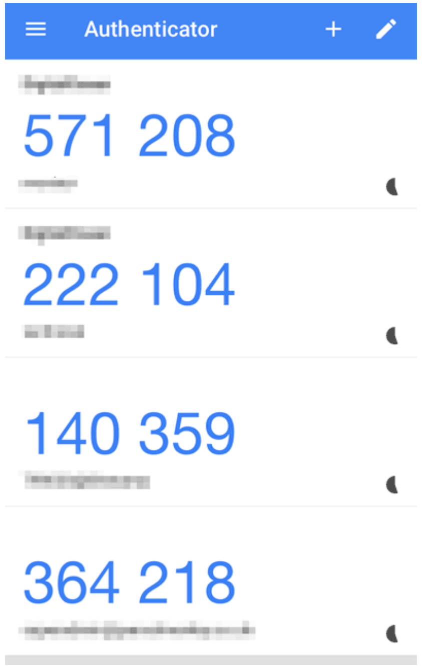
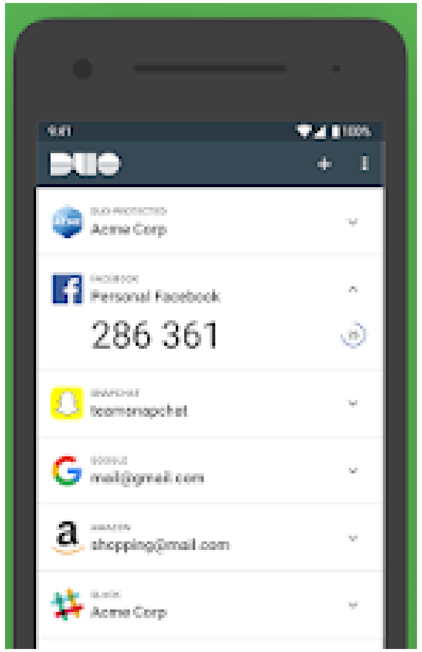
- TOTP can be realized using
  - Symmetric keys shared between the prover and the verifier
  - Asymmetric method: **hash-based** or digital signatures





Time-based One-time Passwords

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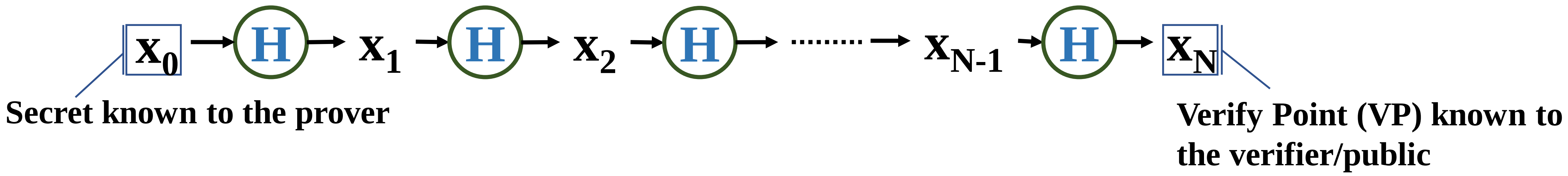

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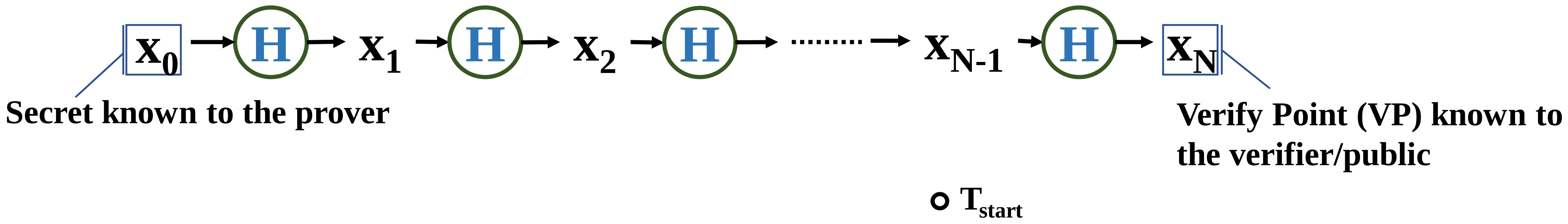

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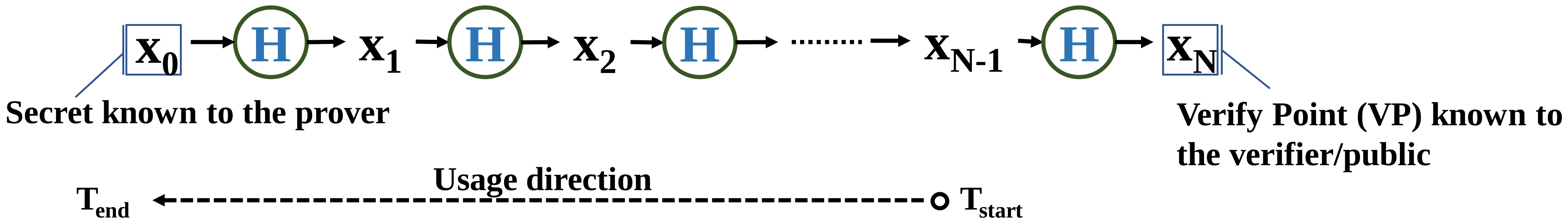

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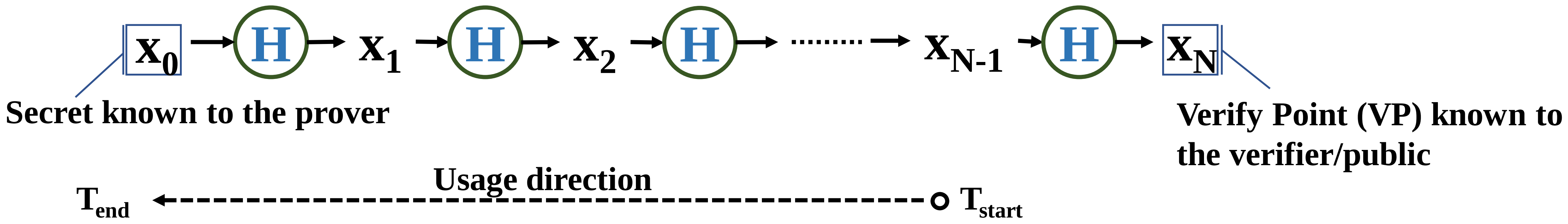

- One key pair per user (x_0, x_N)
  - Asymmetric: verifier compromise resilience
  - **No identity privacy:** each ***verify point*** x_N is associated with one prover, and the verifier knows the identity of the prover

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  - Not fit for resource-constrained devices or applications

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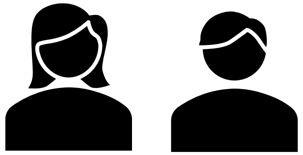
How to *efficiently* and *generically* transform a traditional (asymmetric) TOTP into a GTOTP scheme?

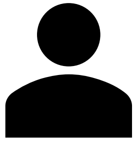
Group TOTP

Group Members (Provers)



Trusted Registration Authority (RA)

Verifier



Group TOTP

Group Members (Provers)

Trusted Registration Authority (RA)

Verifier

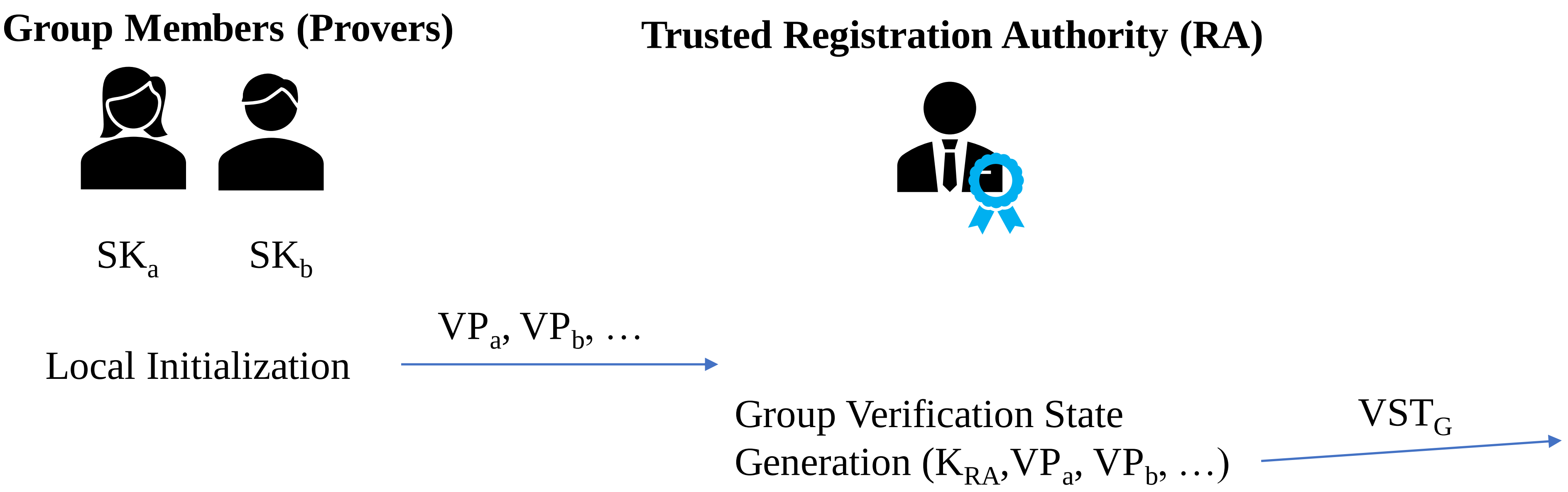
Local Initialization

VP_a, VP_b, …

Group TOTP

Group Members (Provers)
Trusted Registration Authority (RA)
Verifier
SK$_a$ SK$_b$
VP$_a$, VP$_b$, …
Local Initialization

Group TOTP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Trusted Registration Authority (RA)
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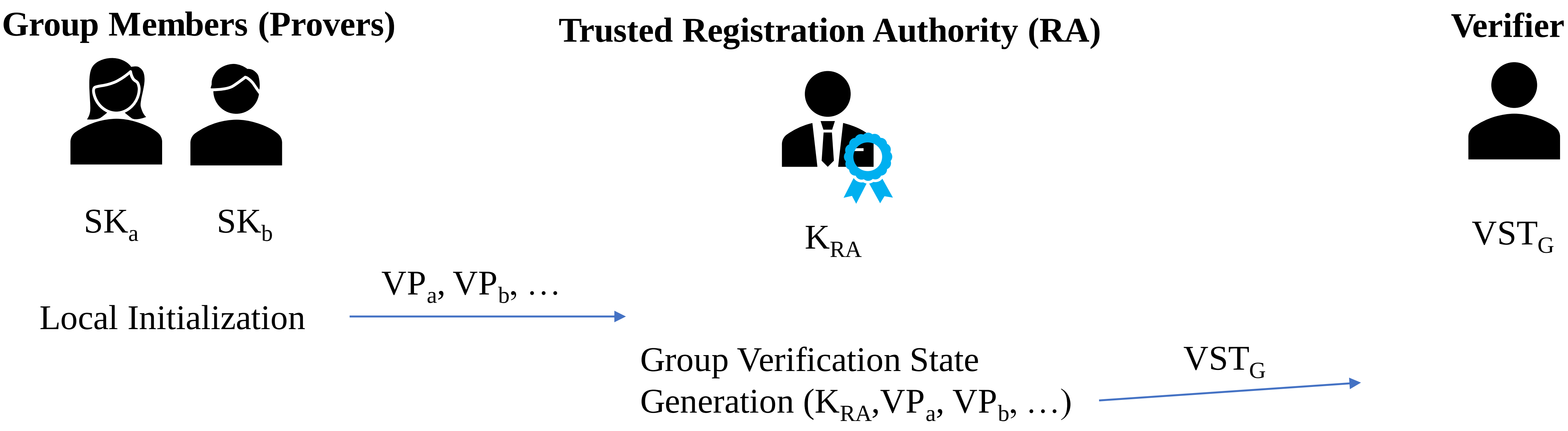
SK_a
SK_b
VP_a, VP_b, …
Local Initialization
Group Verification State Generation (K_{RA},VP_a, VP_b, …)
VST_G

Group TOTP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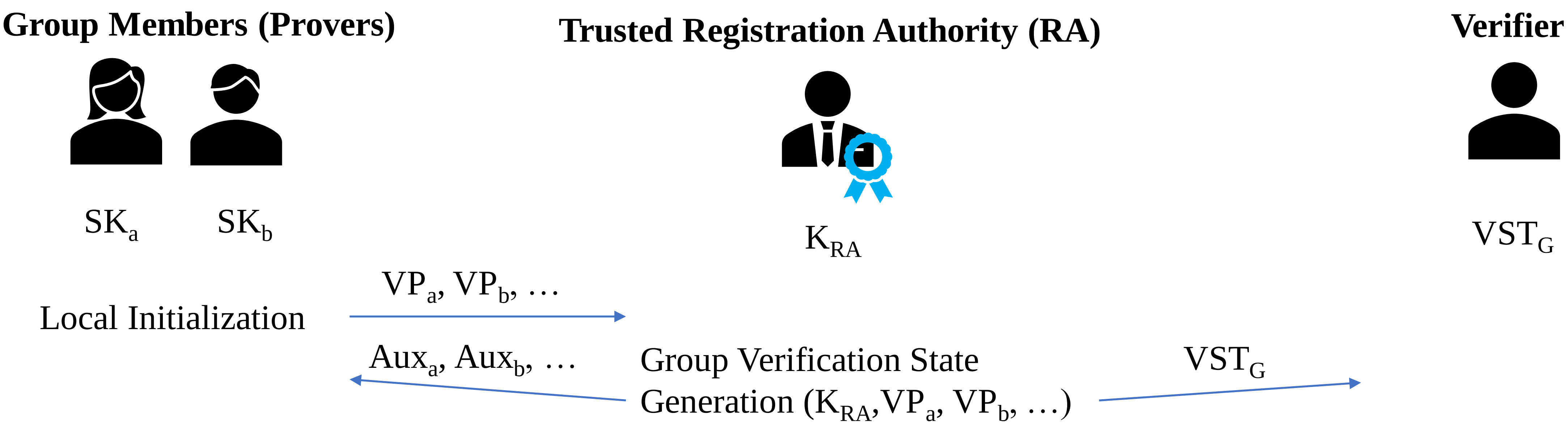
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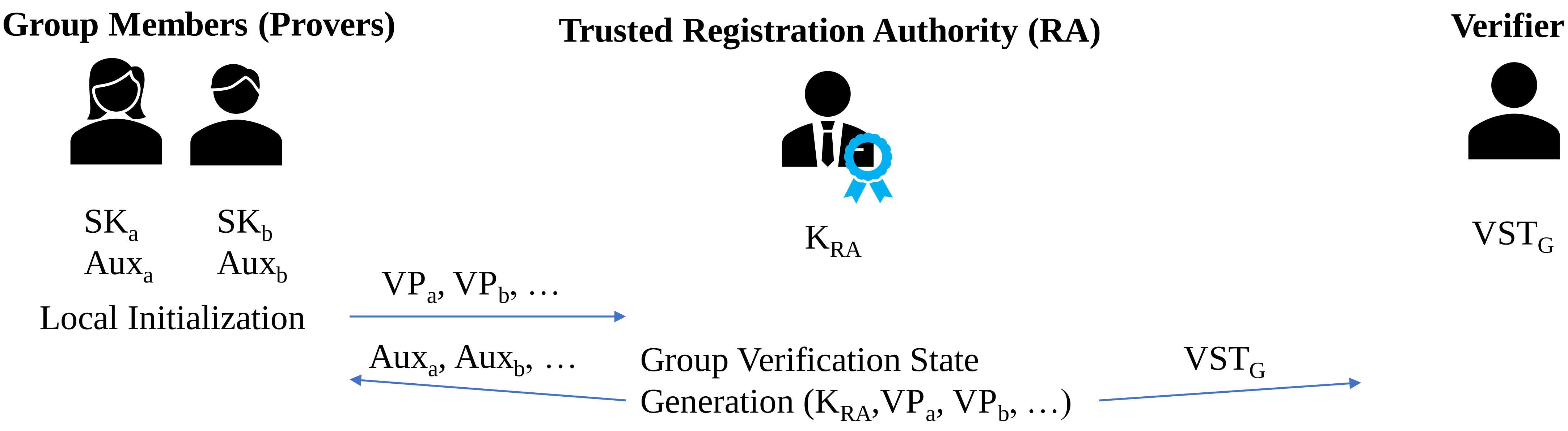
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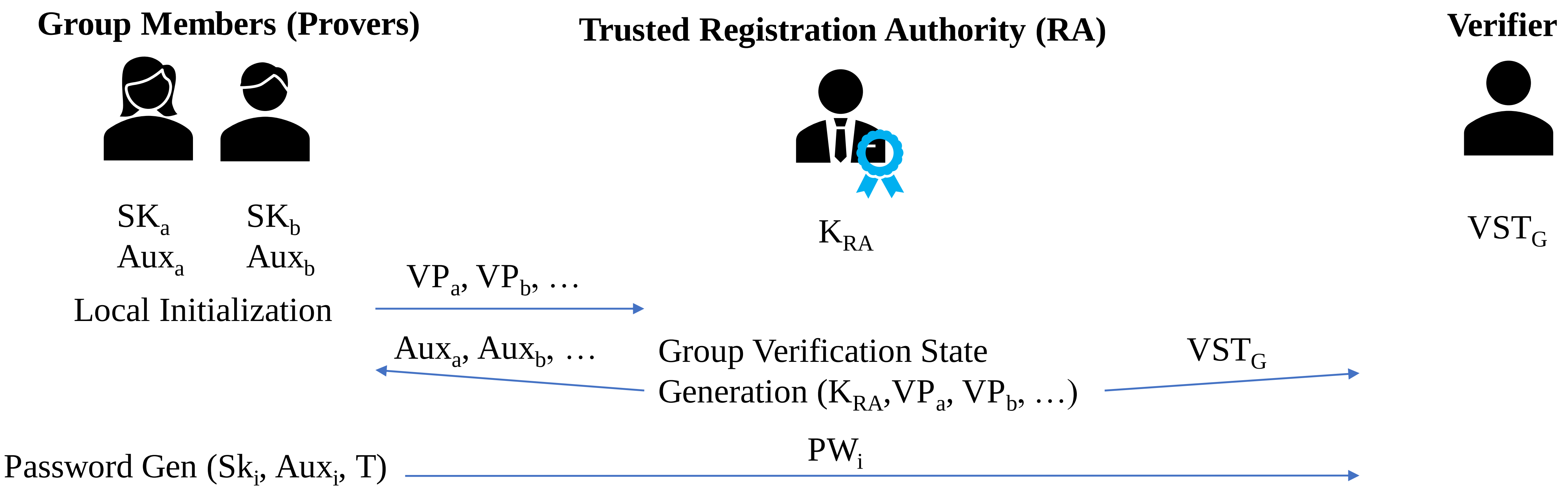
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PW$_i$

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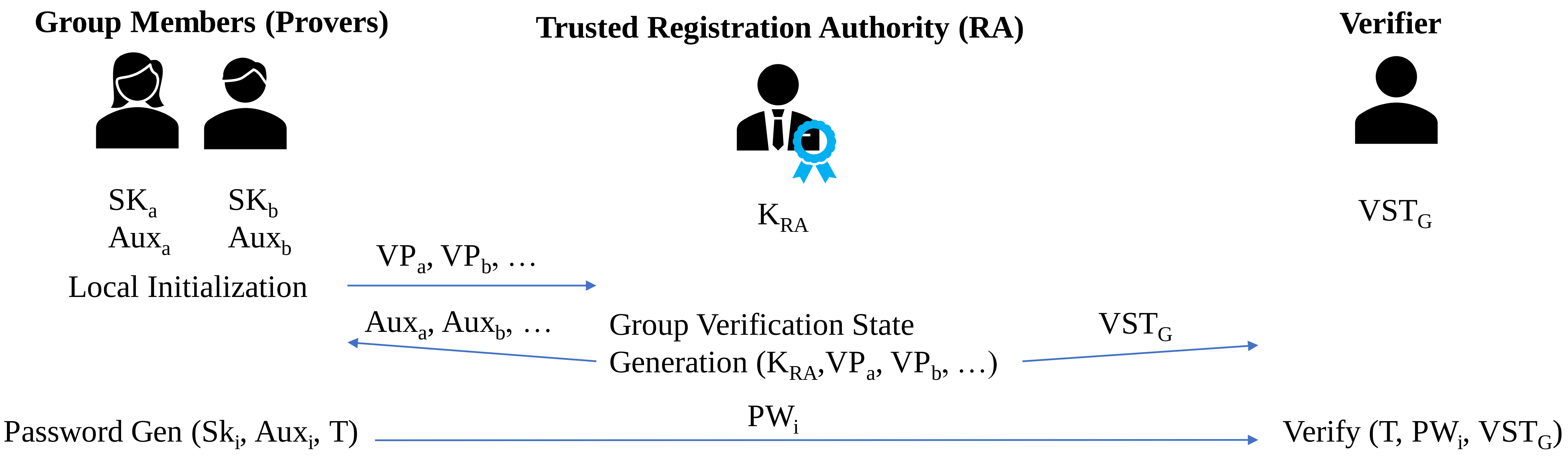

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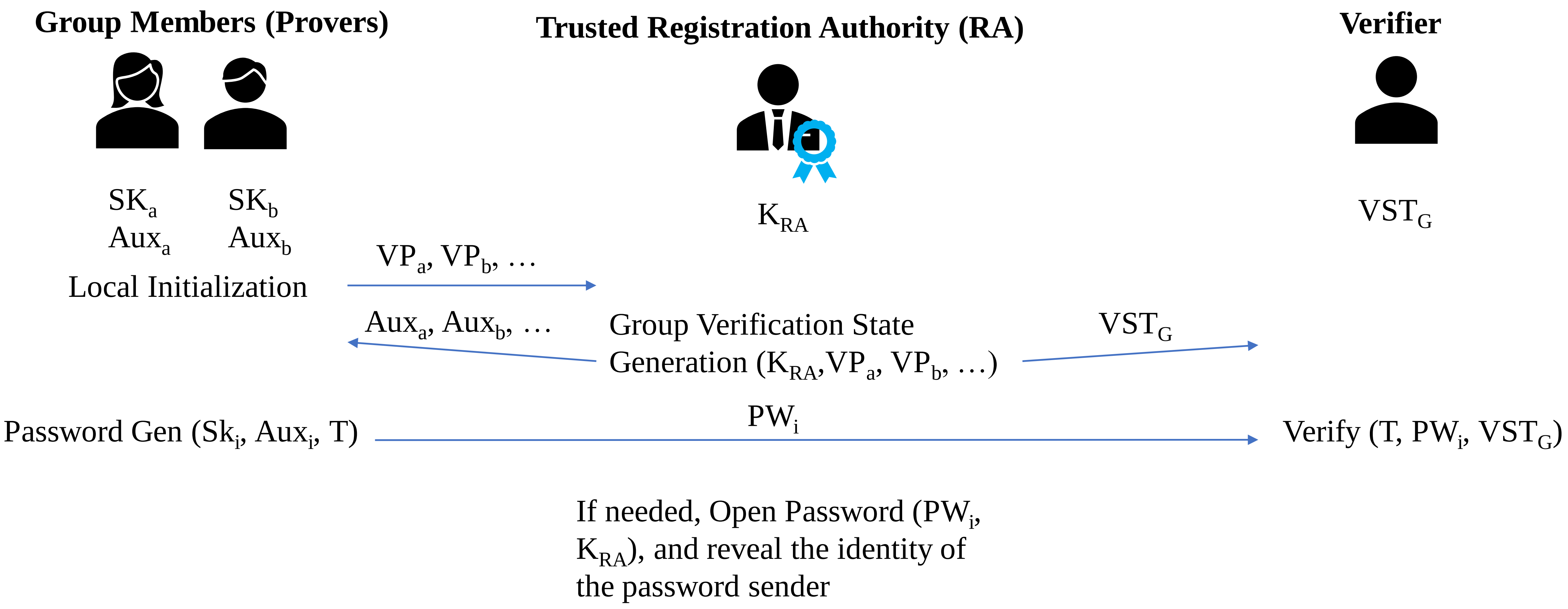

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VST_G
Password Gen (Sk_i, Aux_i, T)
PW_i
Verify (T, PW_i, VST_G)
If needed, Open Password (PW_i, K_{RA}), and reveal the identity of the password sender

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- **Anonymity**: adversary cannot distinguish one group member's password from another's

Detailed Construction of VST_G Generation

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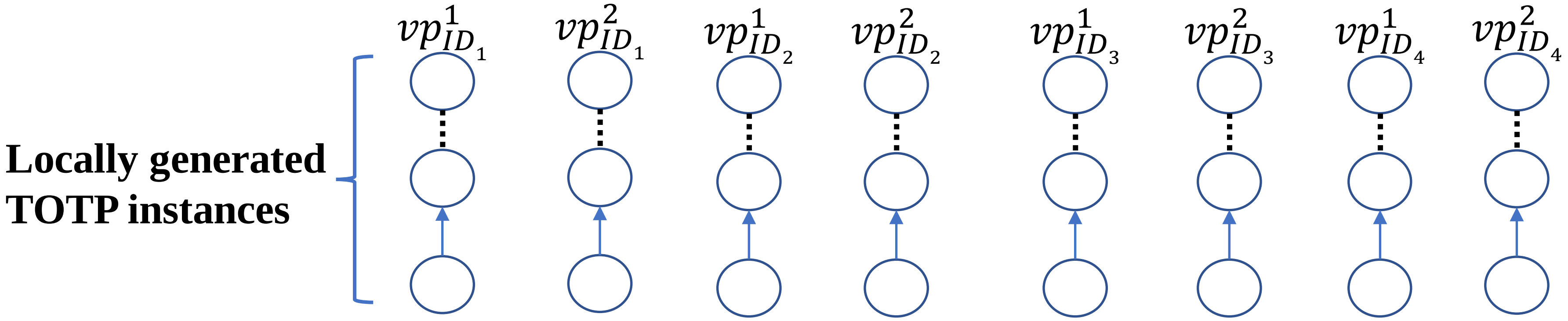
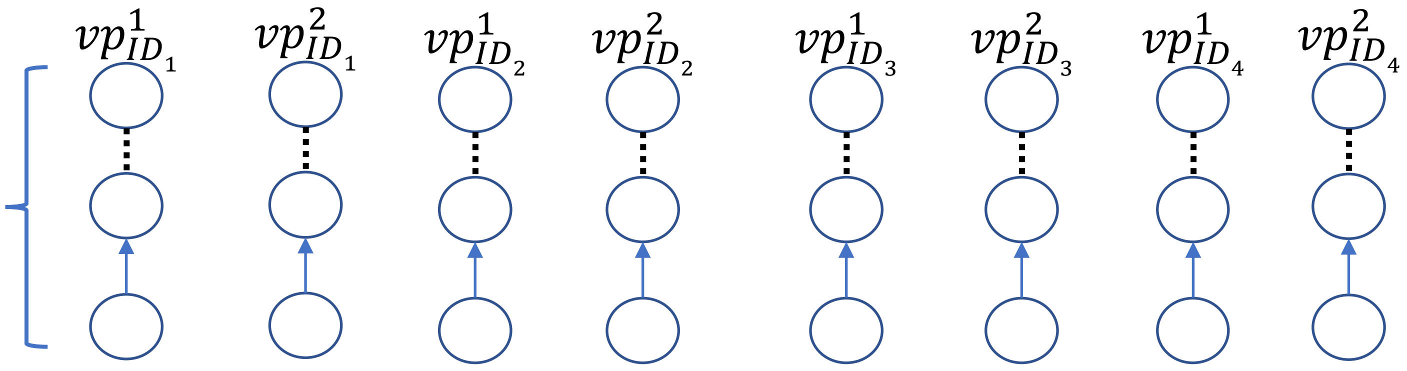


Detailed Construction of VST_G Generation

$$C^{i}_{\mathsf{ID}_j} = \mathsf{ASE.Enc}(k_{\mathrm{RA}}, \mathsf{ID}_j)$$
$$\hat{vp}^{i}_{\mathsf{ID}_j} := \mathsf{H}_1(vp^{i}_{\mathsf{ID}_j} || C^{i}_{\mathsf{ID}_j} || i)$$

Locally generated TOTP instances



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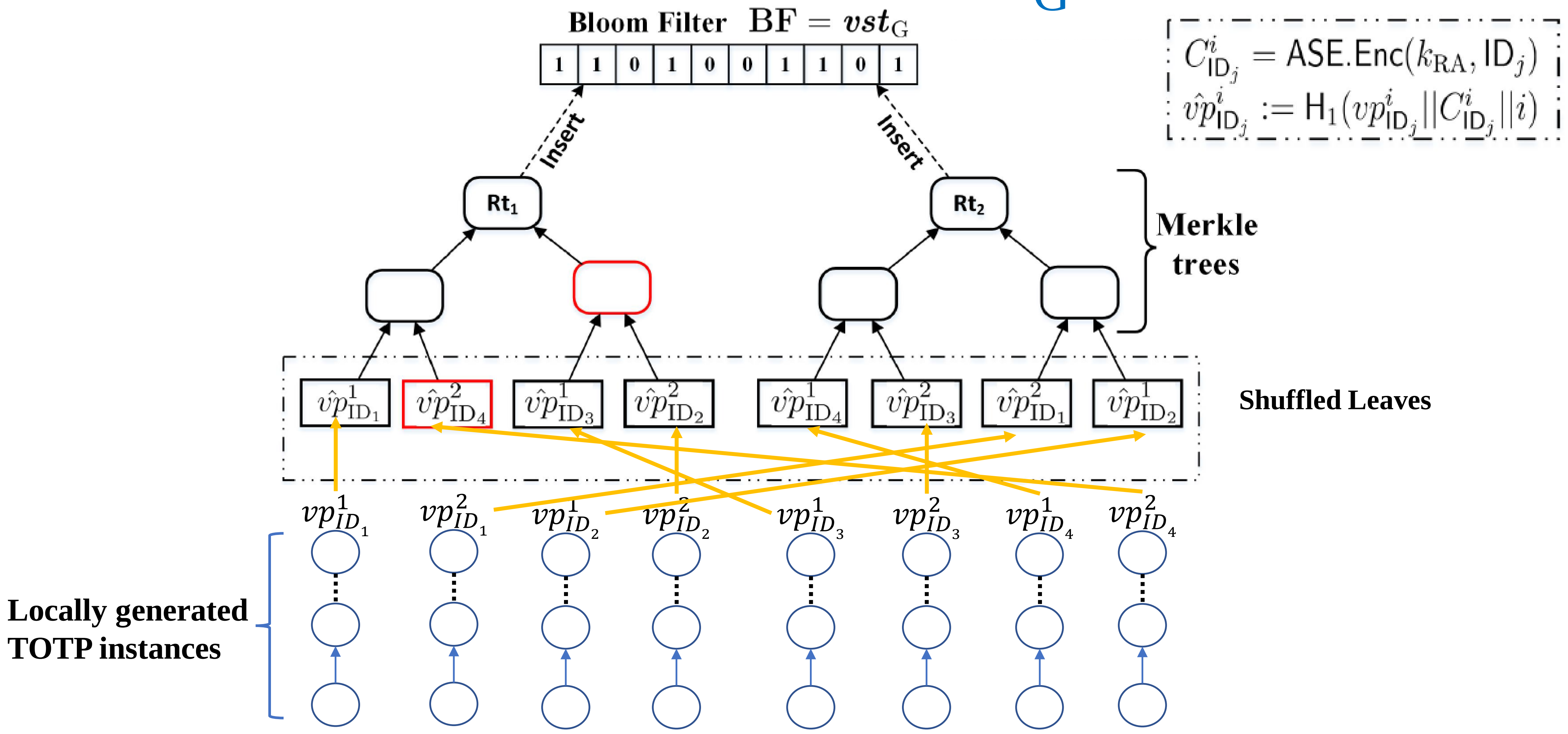
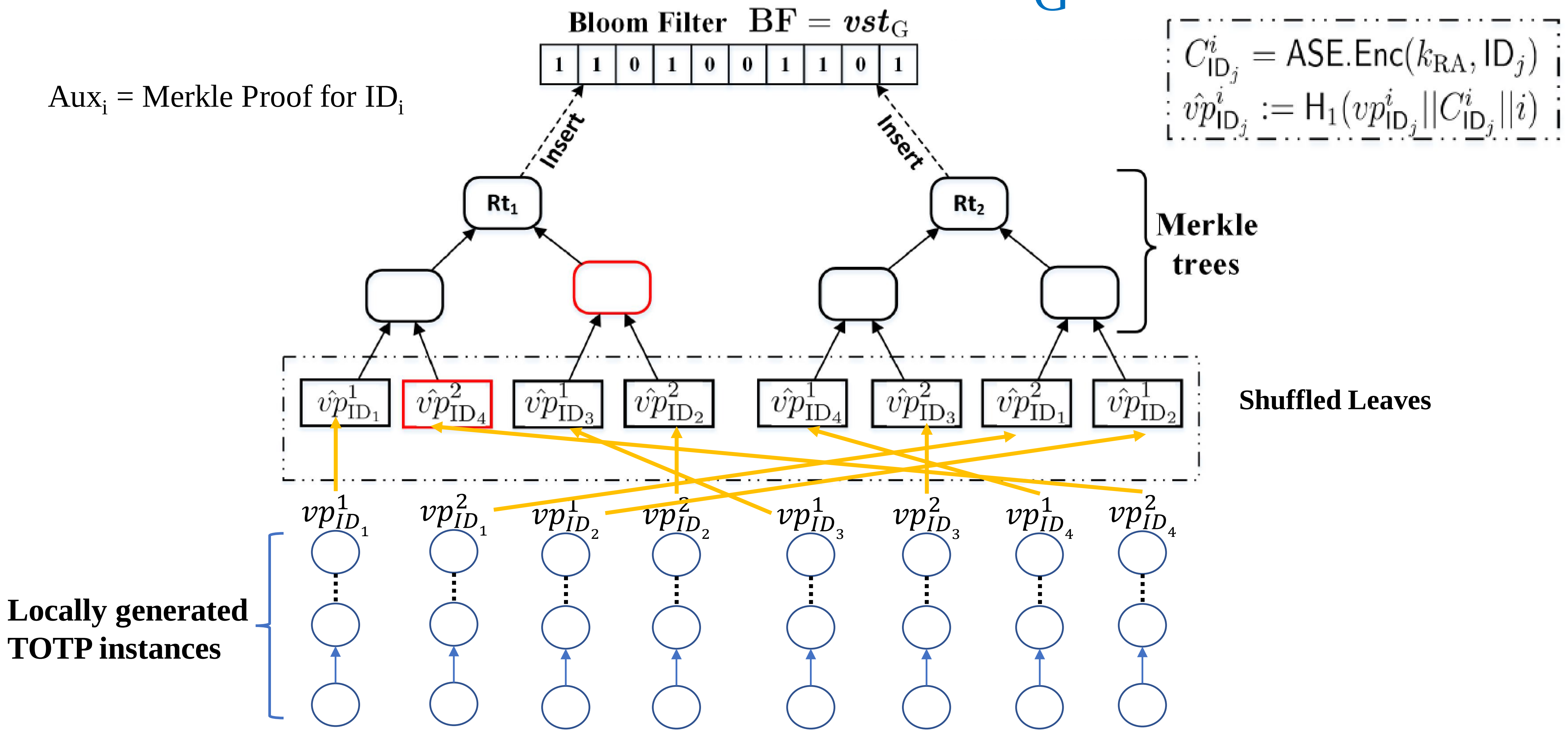


Detailed Construction of VST_G Generation

Aux_i = Merkle Proof for ID_i



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- **Additional Building blocks:**
  - Commitment Scheme
  - Privacy-Preserving Location Proximity (PPLP) Scheme

Privacy-Preserving Proof of Location

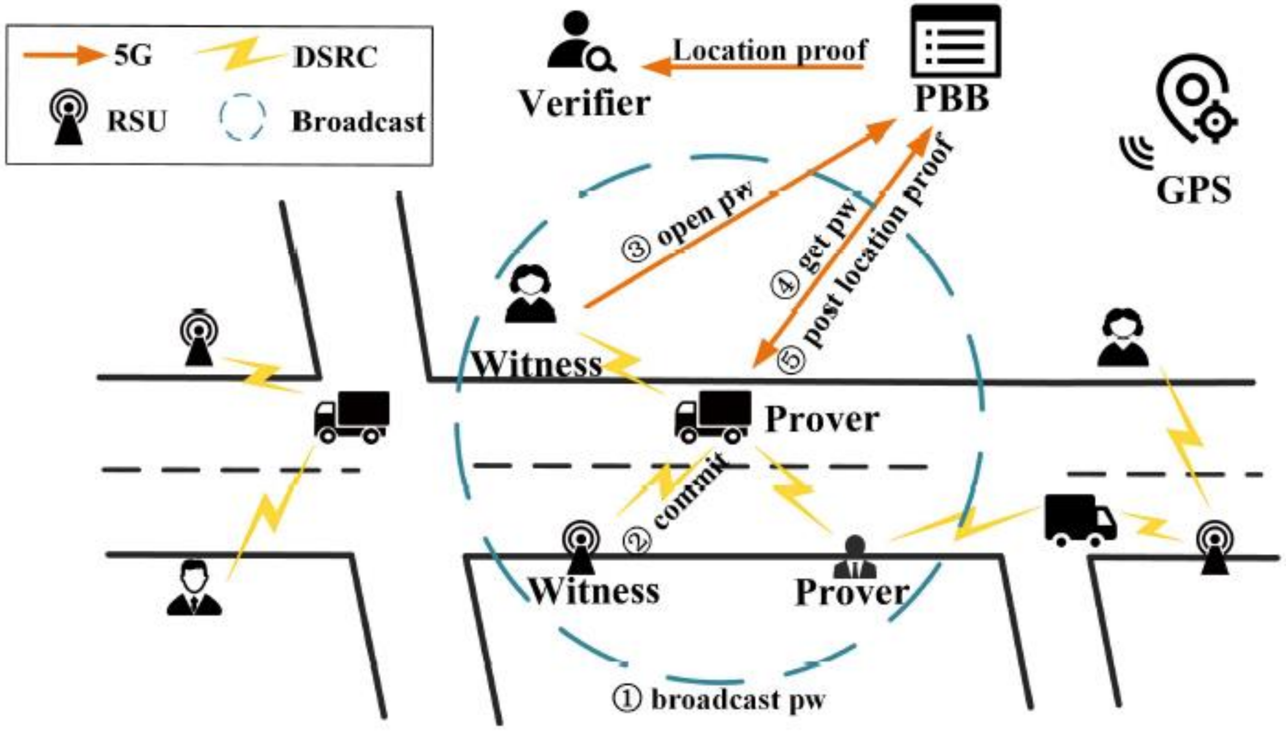
① A prover broadcasts its GTOTP password and privacy-preserving location proximity (PPLP) request to nearby witnesses via a short-range communication channel.

② Witnesses who can testify for the prover will respond with both message and location commitments regarding the PPLP responses.

③ Witnesses and prover exchange the password for verifying the message commitment.

④ The prover finally assembles the location proof based on the gathered proofs and publishes it to Public Ledger.

⑤ The verifier can obtain the location proof from either the Public Ledger or the prover.



Performance Evaluation

- Prover/witness: RPi3
- Verifier: PC with i7 CPU and 2GB RAM
- More detailed breakdown analysis in the paper

M	Computation time (s)				PfSize (KB)
	PfGen			Verify	
	Prover	Witness	Total	Verifier	
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10	0.237/0.276	0.089/0.098	0.326/0.347	0.0011	2.17
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- Open question:
  - Dynamic group management