Secure and Privacy-Preserving Car-Sharing Systems

Lukas Malina, Petr Dzurenda, Norbert Lovinger, Ijeoma Faustina Ekeh*, Raimundas Matulevičius*

Brno University of Technology, *University of Tartu
malina@vut.cz

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Motivation, Research Questions and Contributions

- Our work analyzes **Car-Sharing Systems** (CSS) and its security and privacy features.

- **RQ1**: What are security and privacy threats in CCS and which privacy-preserving techniques (PETs) can be suitable?
- **RQ2**: How to design a cryptographically secure car-sharing system that protects users' privacy and is practical for deployment on constrained devices and handheld devices?

- **Analysis** of legal aspects, PETs and threats in CSS.
- **Proposal** of privacy-preserving solution for CSS based on group signatures
- Security and performance **assessment** of the proposal.

Threats and Legal Issues

- General Data Protection Regulation (GDPR), California Consumer Privacy Act (CCPA), and Digital Service Act (DSA) increased the **transparency** of how user data are processed.
- CSS suffers by typical threats such as **man-in-the-middle attack**, **impersonation attack**, **data tampering attack**, **unauthorized access**, etc.
- More details in the paper.

PETs in CSS

- For CCS we detect these useful PETs:
  - **Data Anonymization Techniques** - e.g. masking vehicle license plates and user IDs in trip records, generalizing trip start/end locations, etc.
  - **Secure Multi-party Computation (SMPC)** - e.g. calculating the price per ride, average trip distance, and more, without revealing individual user data.
  - **Zero-Knowledge Proofs (ZKP)** - e.g. proving a user's valid driver's license without disclosing personal details.
  - **Group Signatures (GS)** - e.g. proving access to vehicles, holding valid access tokens (GS enable users to sign messages on behalf of group to preserve anonymity.)
- Our solution deploys Kim *at al.*'s group signature scheme from 2023 [3] (KSAP23).

Our Solution

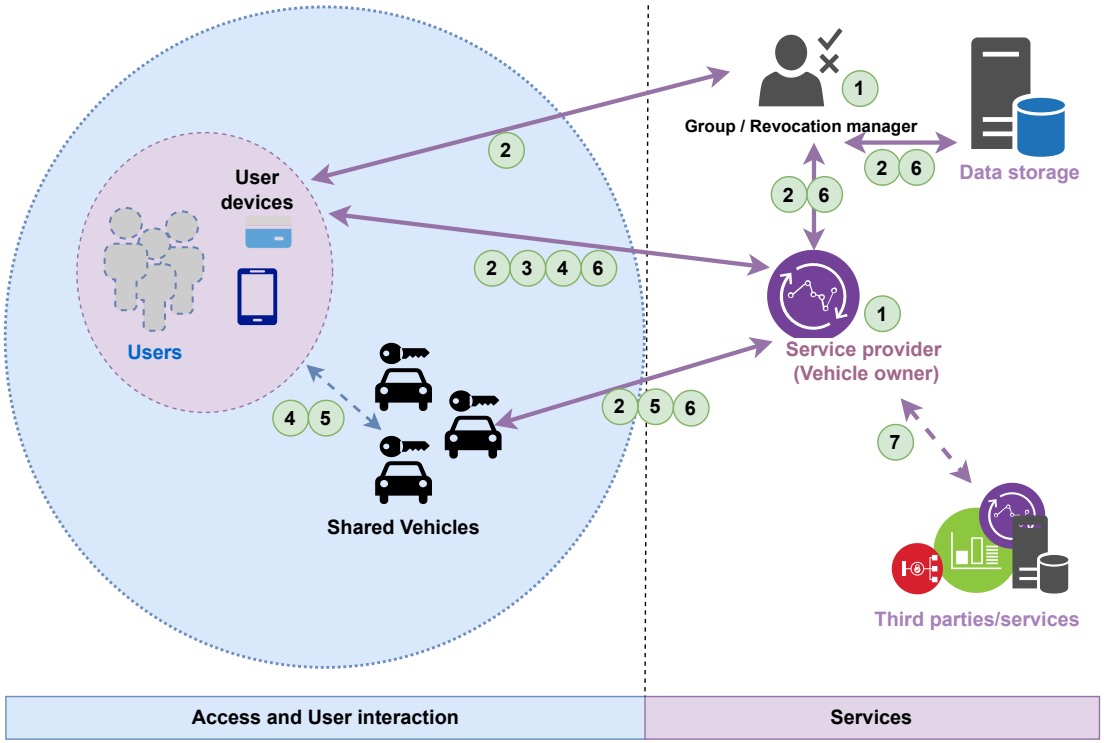
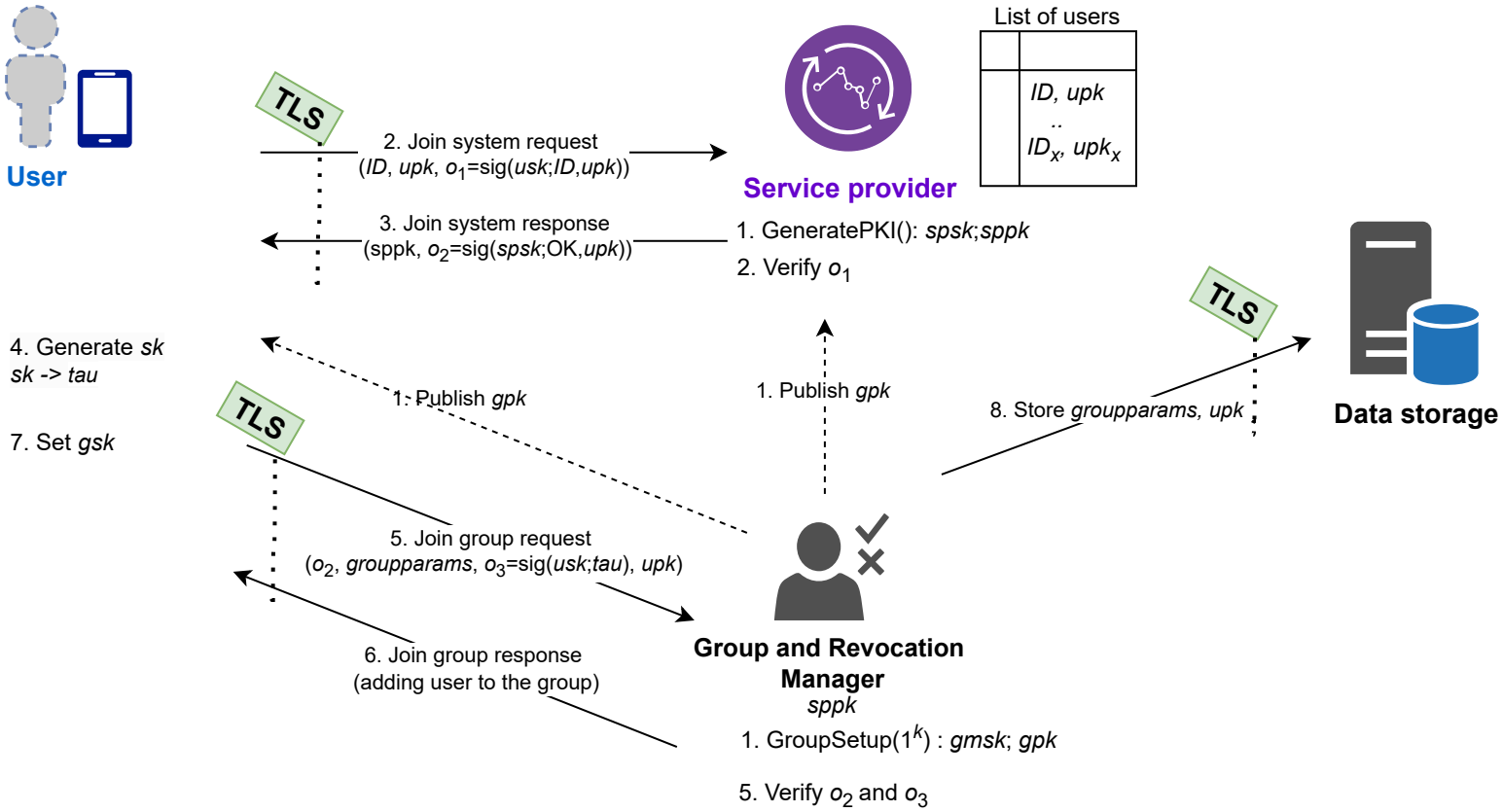
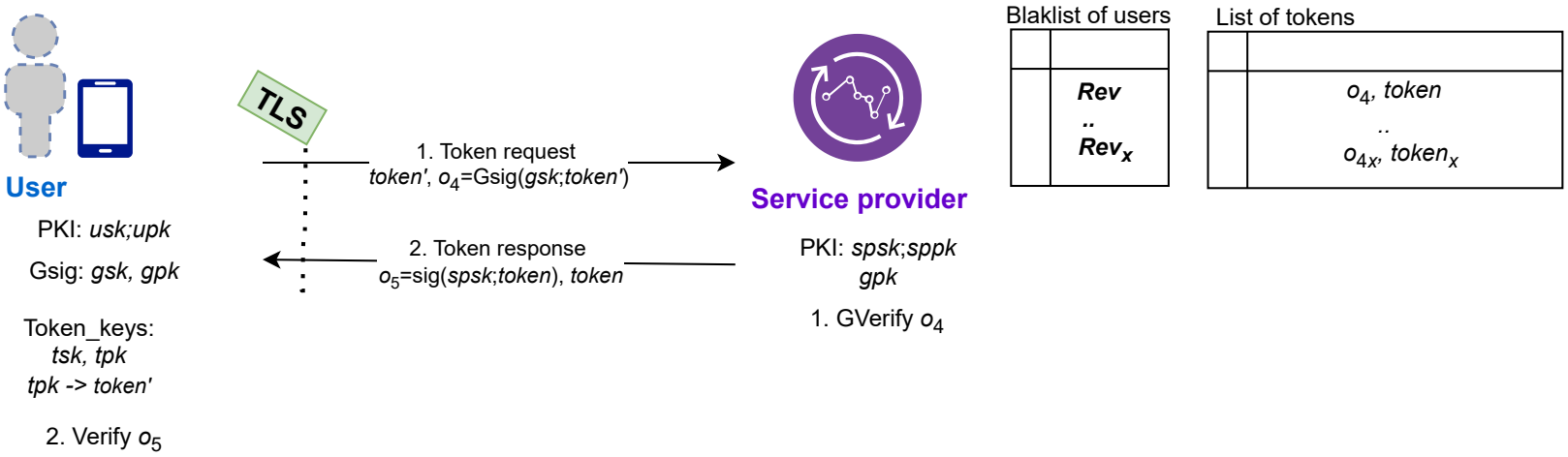


Figure: Entities and phases in our solution based on group signatures (KSAP23 scheme [3]).

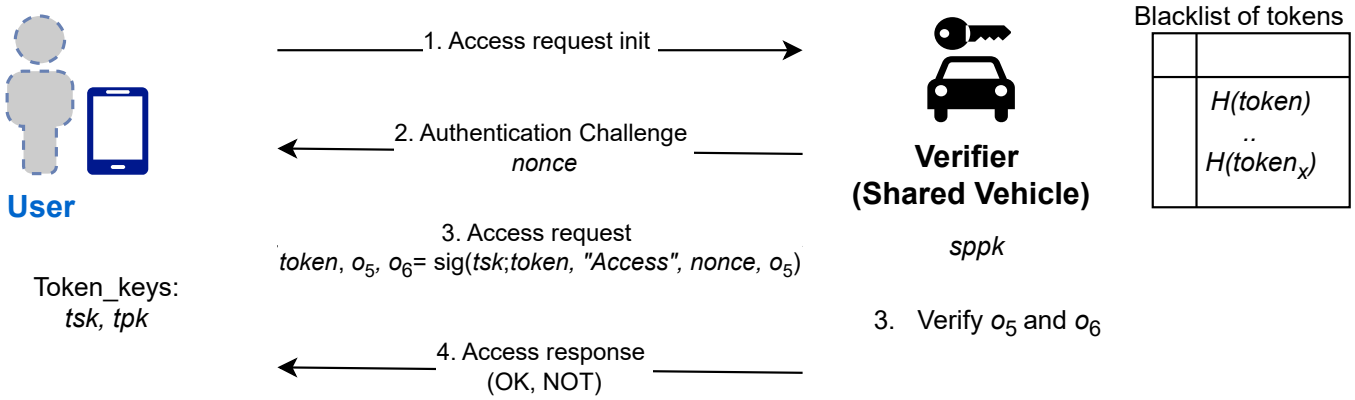
Solution Phases - Registration/Join



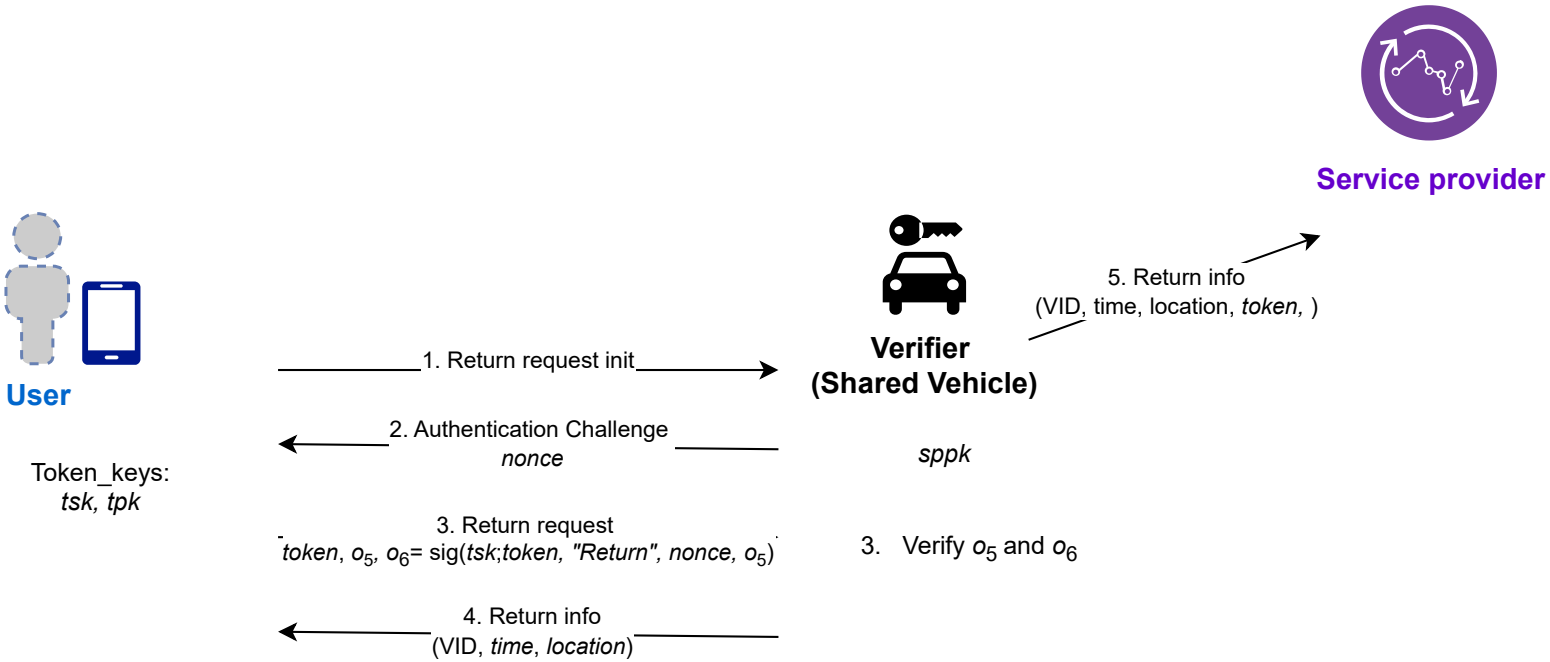
Solution Phases - Token Acquiring



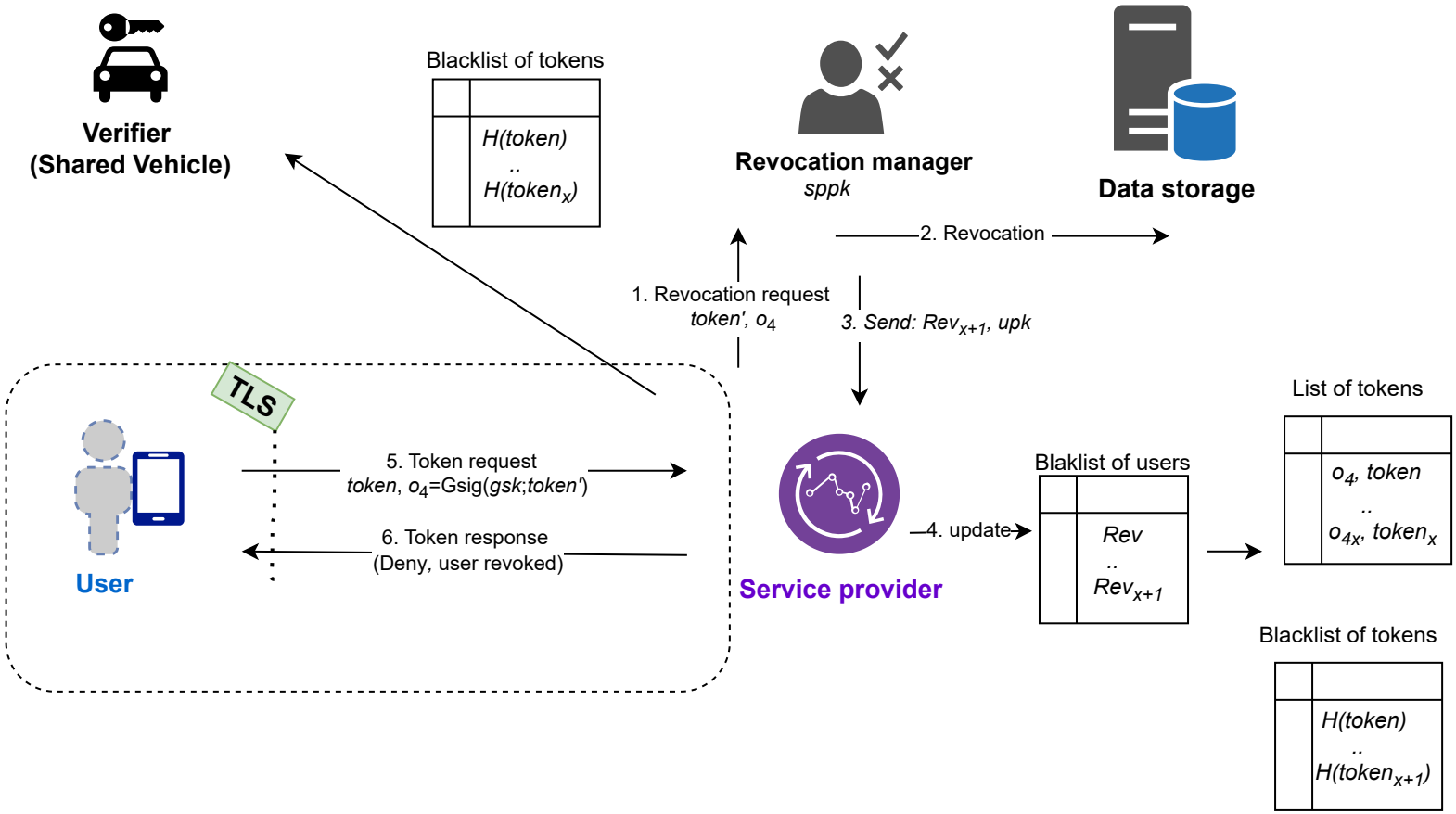
Solution Phases - Vehicle Access



Solution Phases - Vehicle Returning



Solution Phases - Revocation



Security Evaluation

The solution supports the following security properties (the full description is in the paper):

- **Soundness and completeness** - by phases, rules and group signatures (GS).
- **User anonymity** - by using GS.
- **User unlinkability** - by using GS.
- **Token unforgeability** - by using asymmetric cryptography - dig. signature (DS).
- **Token non-delegability** - by using DS.
- **Non-repudiation** - by using DS and GS.
- **Traceability** - by cooperation of GRM and SP, SP can detect the identity of malicious users.
- **Revocation** - by cooperation of GRM and SP. Blacklist of revoked users.

Performance Evaluation

Our solution deploys the group signature KSAP23 [3] that requires:

- for signing: 12 exponentiations in G_1,
- for verification: 3 pairings and 10 exponentiations in G_1,
- signature length: 5352 b (composed of 6 $|G_1|$ and 3 $|Z_p|$),
- KSAP23 scheme [3] allows efficient revocation but is less efficient than BBS04 [1].

Performance Comparison

Phase:	This work	PRESTvO (Groza *et al.* [2])
Registration / Setting	3 Sig/Ver	7 IdSig/IdVer
Acquiring / Delegation	1 Sig/Ver + 1 Gsig/Gver	2 Gsig/Gver + 2 IdSig/IdVer
Access / Execute	1 Sig/Ver	(1 Gsig/Gver or 1 IdSig/IdVer) + 1 IdSig/IdVer
Return	1 Sig/Ver	not proposed
Revocation	1 GS Revocation	not described

Conclusion

- We presented main legislative, security and privacy issues and threats in car-sharing services.
- We proposed the efficient and practical privacy-preserving security solution for car-sharing systems.
- The solution allows instant revocation and requires less operations (compared with related solution PRESTvO).
- Future Work - focus on a beta implementation and field tests on real vehicles.

Thank you!

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malina@vut.cz

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BRNO UNIVERSITY OF TECHNOLOGY

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References


Boneh, D., Boyen, X., and Shacham, H.
Short group signatures.
In *Crypto* (2004), vol. 3152, Springer, pp. 41–55.


Groza, B., Andreica, T., Berdich, A., Murvay, P.-S., and Gurban, E. H.
Prestvo: Privacy enabled smartphone based access to vehicle on-board units.
IEEE Access 8 (2020), 119105–119122.


Kim, H., Sanders, O., Abdalla, M., and Park, J. H.
Practical dynamic group signatures without knowledge extractors.
Designs, Codes and Cryptography 91, 3 (2023), 853–893.