A Symbolic Analysis of ECC-based Direct Anonymous Attestation

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Outline

Direct Anonymous Attestation

Contributions

Formal Analysis of ECC DAA

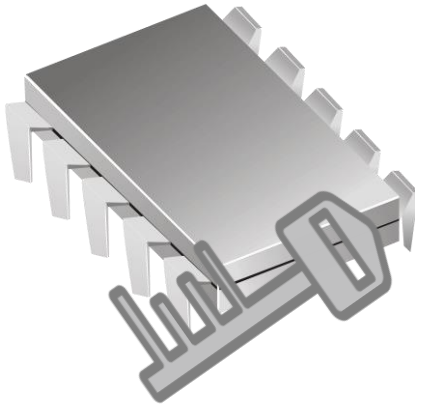
Summary

Direct Anonymous Attestation (DAA)

Anonymous Digital Signature scheme

- Strong but privacy-preserving authentication
- ISO/IEC 20008 2013

Hardware-backed attestation using TPMs



Properties of DAA

- User-controlled Anonymity
- User-controlled Traceability
  - Host controls whether signatures can be linked.

DAA Schemes

TPM 1.2 (RSA-based)

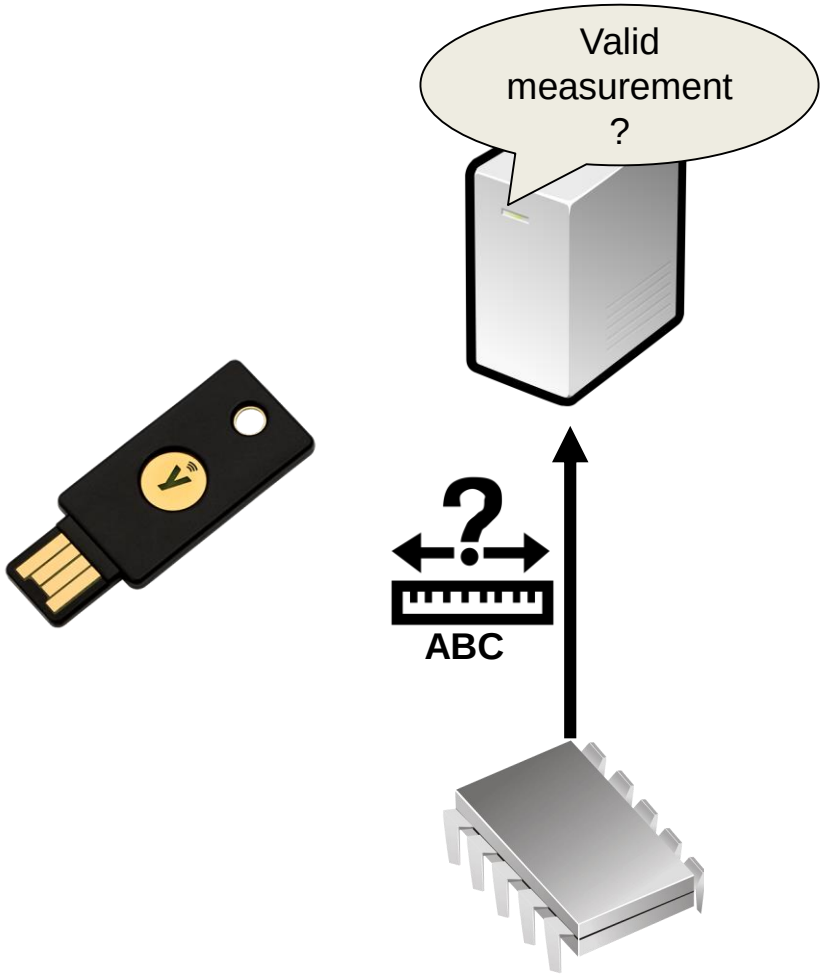
- ISO/IEC 20008-2 mechanism 2

TPM 2.0 (pairing-based)

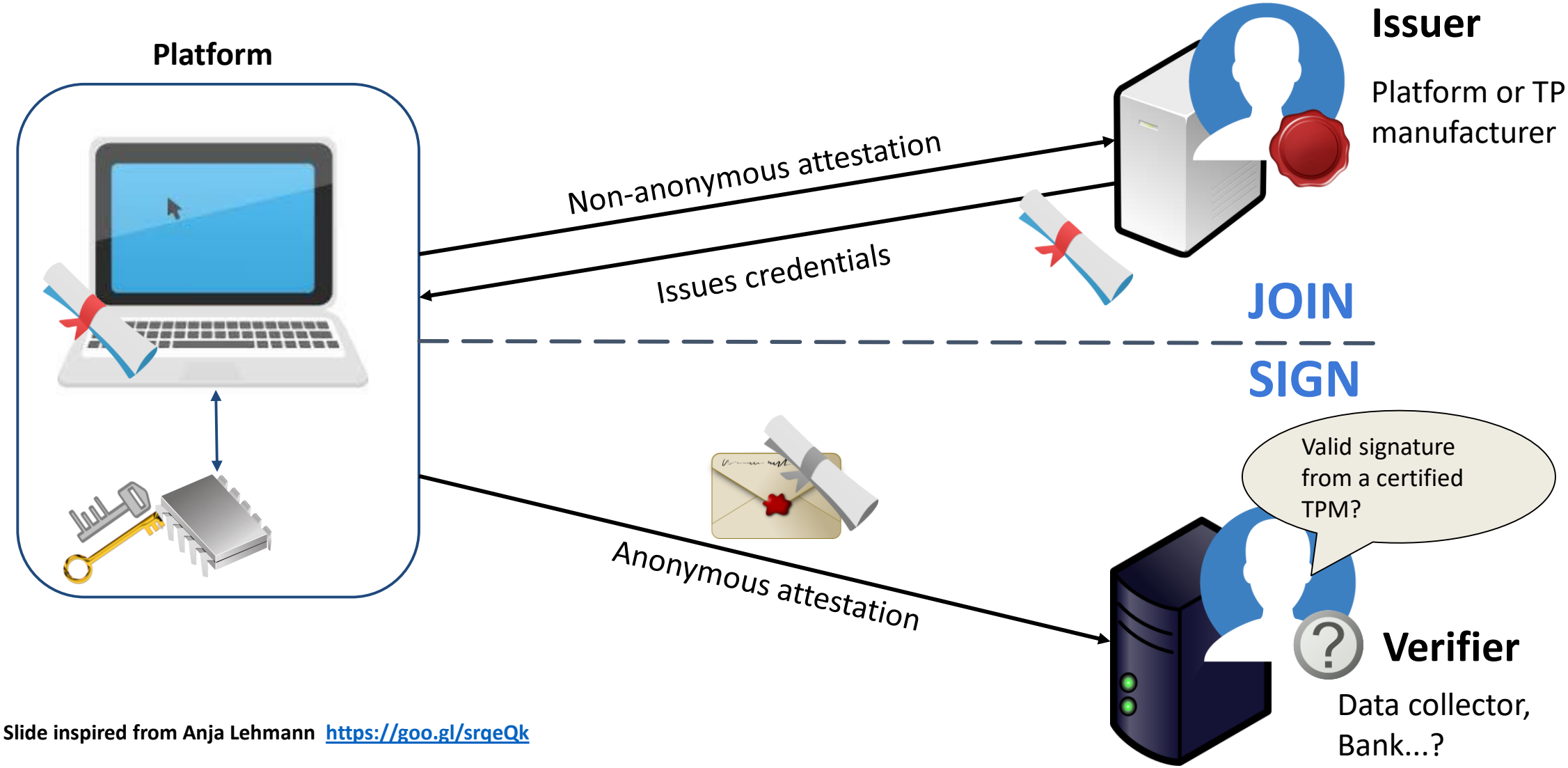
- ISO/IEC 20008-2 mechanism 4 & ISO/IEC 11889
- Smaller keys & signatures!
- Proposed for FIDO 2

Enhanced Privacy ID (EPID)

- Used by Intel SGX
- Improved revocation



Overview of DAA operations



* Slide inspired from Anja Lehmann https://goo.gl/srqeQk

Is ECC DAA secure?

Need proof that ECC DAA is secure

Challenge: Can we formally verify the security and privacy of ECC DAA?

The Tamarin Prover

- State-of-the-art symbolic security protocol analysis tool
- Successfully applied to TLS 1.3, 5G, eVoting, V2X, etc

Contributions

Formalization of ISO/IEC 20008-2

- First faithful automatable models of all ECC DAA operations
- Propose authentication goals for the JOIN operation and find a flaw
- Encode symbolic variants of goals from game-based security (secrecy, privacy)

Security Evaluation of ECC DAA

- Security goals
  - Authentication: does not hold when a single TPM is compromised
  - Secrecy: does not hold when a single TPM is compromised
  - Privacy: holds in the presence of an adversary
- Recommend and provably secure fix for the JOIN operation

What did we model?

Analysed ISO/IEC 20008-2 mechanism 4

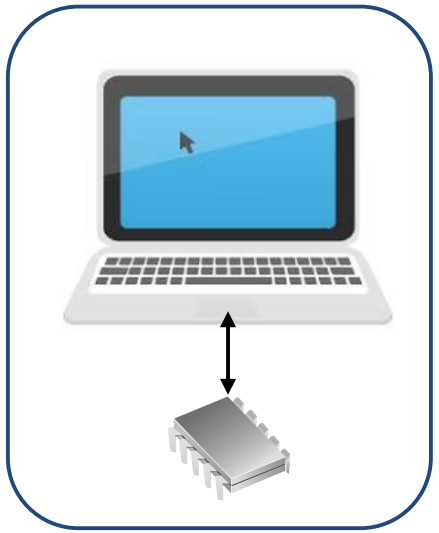
- "*a secure and authentic channel between the principal signer and Issuer*"
- The standard does not provide a way to establish the channel

Two additions

- Message Authentication Codes (MAC)
  - Chen, Page, Smart "*On the design and implementation of an efficient DAA scheme*".
- TPM Endorsement Keys
  - TPM Library – Part 1: Architecture

Restriction: Only consider a single Issuer

Challenges



Separation of Host and TPM

- Communicate over secure I/O in practice
- Restricted analysis to only consider unique 1:1 pairing

Zero Knowledge Proofs

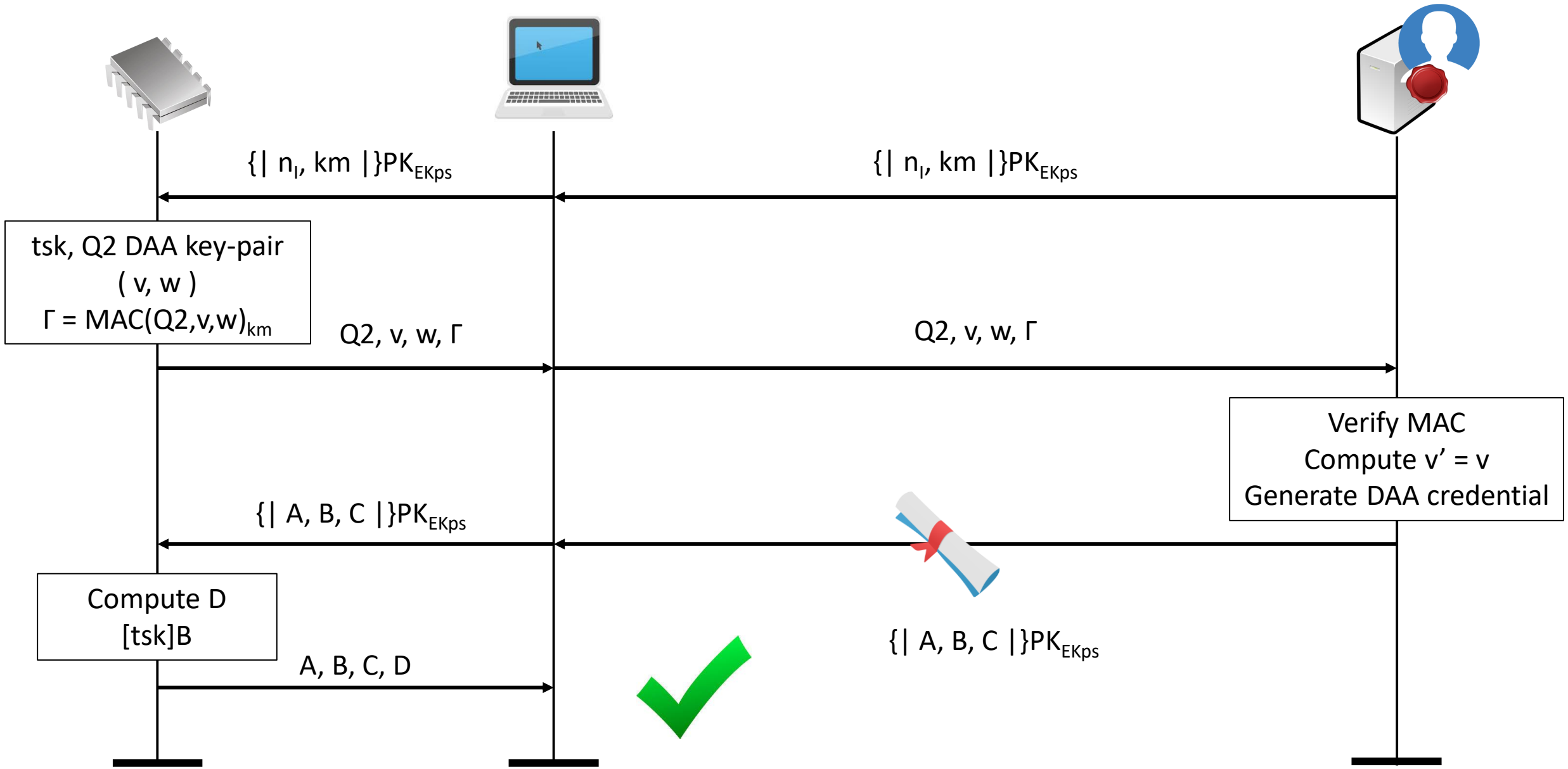
- Defined functions and equations to represent ZKPs symbolically

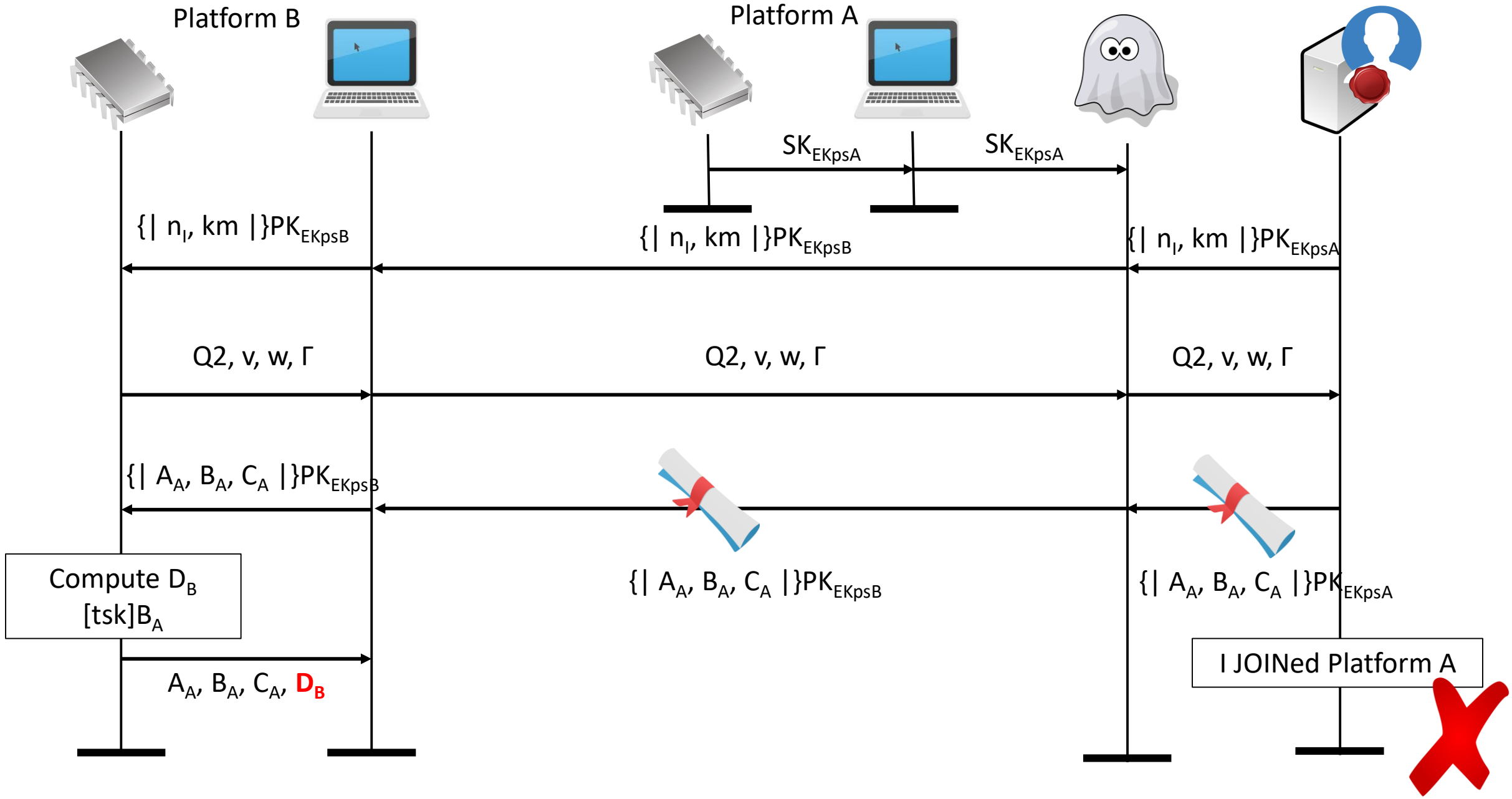
Proof Strategies

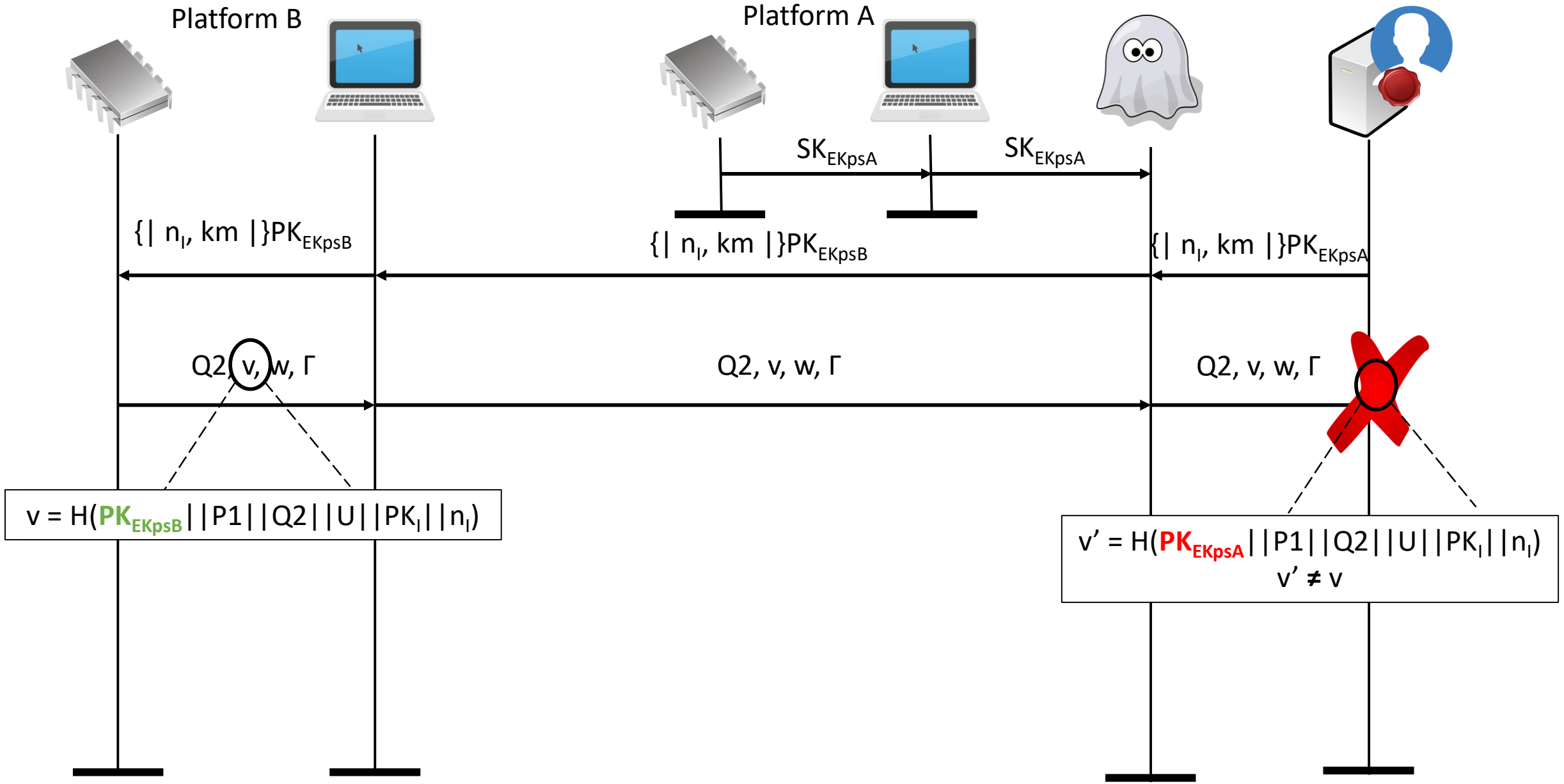
- Guided proof required for unlinkability, codified and automated in an Oracle
- All other lemmas automated using default heuristics

Security and Privacy Properties

Goal	Lemma	Model A	Model B
G1	functional_correctness_group_verification	✓	✓
G2	functional_correctness	✓	✓
G3	functional_correctness_dishonest_send	✓	✓
G4	aliveness	✓	✓
G5	weak_agreement_any_reveal	✓	✓
G6	weak_agreement	×	×
G7	ni_agreement_any_reveal	✓	✓
G8	ni_agreement	×	×
G9	i_agreement	×	×
G10	secrecy_cre	×	×
G11	can_be_deanonymised	✓	✓
G12	user_controlled_independent_link_tokens	✓	n/a
G13	user_controlled_linkability	n/a	✓
Goal	**Observational Equivalence**	**Model C**	
G14	unlinkability	✓	


{| n_I, km |}PK_{EKps}
{| n_I, km |}PK_{EKps}
tsk, Q2 DAA key-pair
(v, w)
Γ = $MAC(Q2,v,w)_{km}$
Q2, v, w, Γ
Q2, v, w, Γ
Verify MAC
Compute v' = v
Generate DAA credential
{| A, B, C |}PK_{EKps}
{| A, B, C |}PK_{EKps}
Compute D
[tsk]B
A, B, C, D


Platform B
Platform A
SK_{EKpsA}
SK_{EKpsA}
{| n_I, km |}PK_{EKpsB}
{| n_I, km |}PK_{EKpsB}
{| n_I, km |}PK_{EKpsA}
Q2, v, w, Γ
Q2, v, w, Γ
Q2, v, w, Γ
{| A_A, B_A, C_A |}PK_{EKpsB}
{| A_A, B_A, C_A |}PK_{EKpsB}
{| A_A, B_A, C_A |}PK_{EKpsA}
Compute D_B
[tsk]B_A
A_A, B_A, C_A, D_B
I JOINed Platform A


Platform B
Platform A
SK_{EKpsA}
SK_{EKpsA}
$\{|\ n_I, km\ |\}PK_{EKpsB}$
$\{|\ n_I, km\ |\}PK_{EKpsB}$
$\{|\ n_I, km\ |\}PK_{EKpsA}$
Q2, v, w, Γ
Q2, v, w, Γ
Q2, v, w, Γ
$v = H(PK_{EKpsB}||P1||Q2||U||PK_I||n_I)$
$v' = H(PK_{EKpsA}||P1||Q2||U||PK_I||n_I)$
$v' \neq v$

Summary

Discovered a flaw in the JOIN operation + proposed a fix

The security of a DAA should not rely on integrity of all TPMs

Fine-grained analysis of ECC DAA

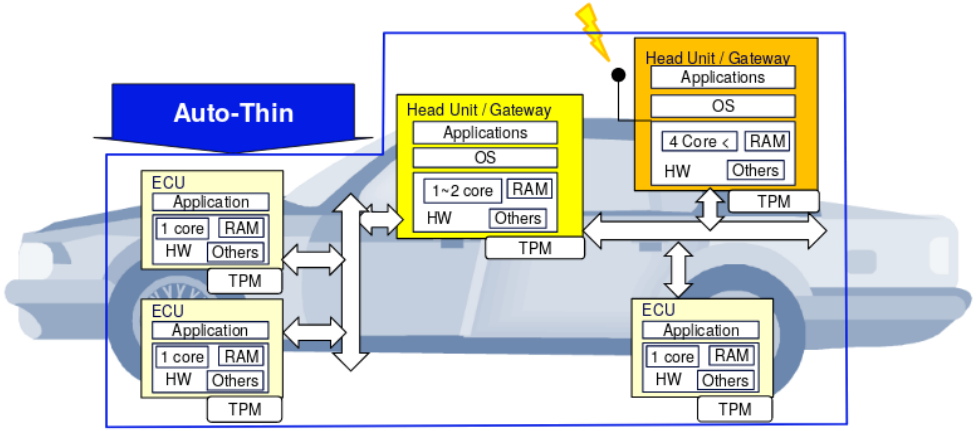
- Capture implementation detail including TPM command calls
- Allow adversary control over secure I/O between TPM and Host

@sudo_jorden

A DAA Scheme for V2X

Use-case targeting V2X communication using DAA

- V2X requires authentication and privacy
- State-of-the-art: Public Key Infrastructure



TCG Automotive-thin profile for TPMs in vehicles

Vehicle credentials (pseudonyms) can be created, signed, and verified using DAA

"Privacy-Enhanced Capabilities for VANETS Using Direct Anonymous Attestation."
In *2017 IEEE Vehicular Networking Conference, VNC 2017*