Public-key signature scheme with reduced hardware trust

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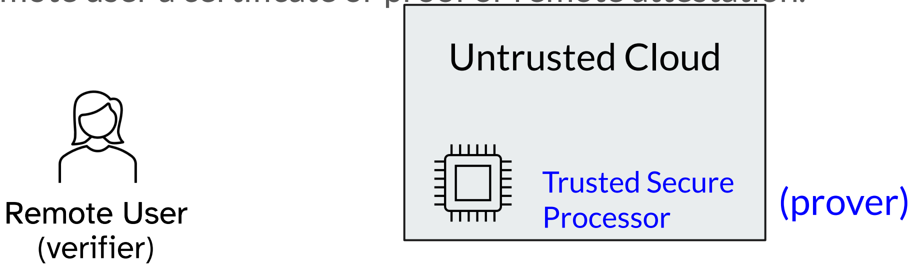
Remote Attestation

Setup:

A remote user wants to perform some sensitive computation on an untrusted computer in the cloud.

More Specifically:

- A "verifier" wants to verify that a "prover" is not compromised i.e. doesn't contains malicious code.
- The untrusted device sends the remote user a certificate or proof or remote attestation.



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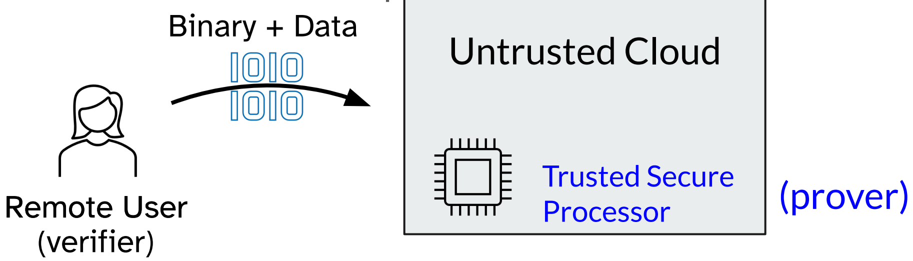

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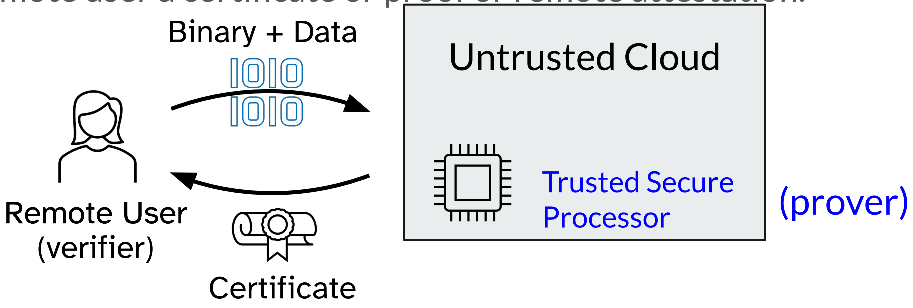

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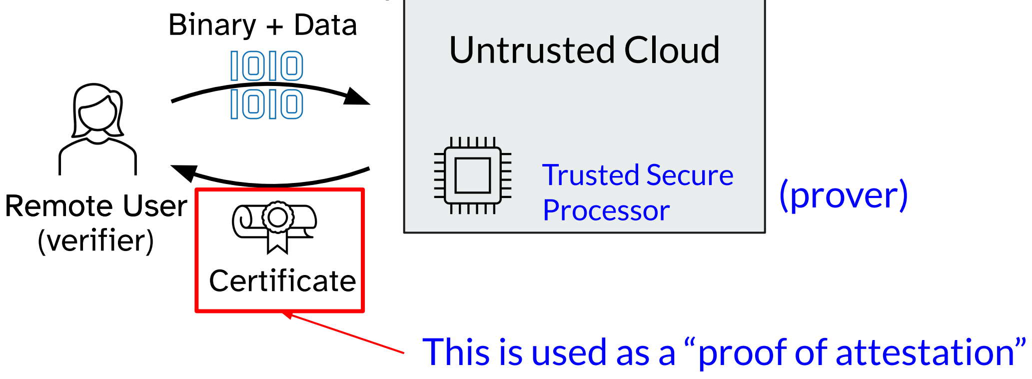

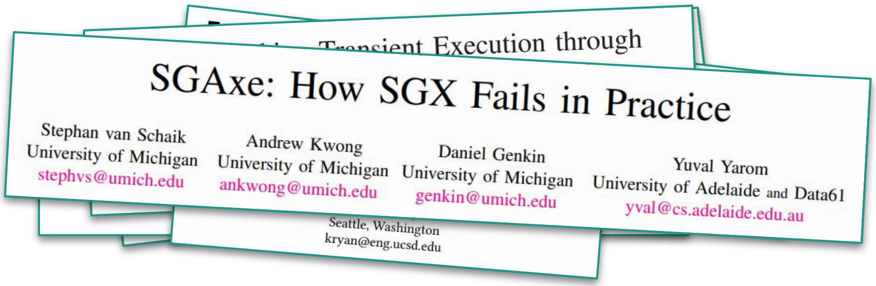
SGAxe: How SGX Fails in Practice

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- In recent years, the security of remote attestation schemes has been compromised.
- Most attacks target the hardware (microarchitectural side channels and transient execution attacks).
- These attacks steal the secret key used to **sign** the certificate.

Hardware Vulnerabilities and Side Channels

- Systems are **not secure** if an attacker can steal secret keys.
- The hardware resources (processors, memory etc...) are **shared between several programs**.
- One program might be able to exploit shared resources to spy on another and **steal secret keys**.

These are called side channels:

Real life example: **When you watch a movie on your computer and it freezes...**

... you can guess someone else in the house is using the internet connection!

Similarly, an attacker program can observe the ressources it shares with a victim and infer secrets!

The introduction of the Spectre (transient-execution attack) make these attacks even worse!

Conclusion: We need to change our trust assumptions on the hardware.

Digital Signatures

- Family of cryptographic algorithms used to prove the authenticity of a message.
- Some schemes use a key pair with a private key (to sign) and a public key (to verify the signature).

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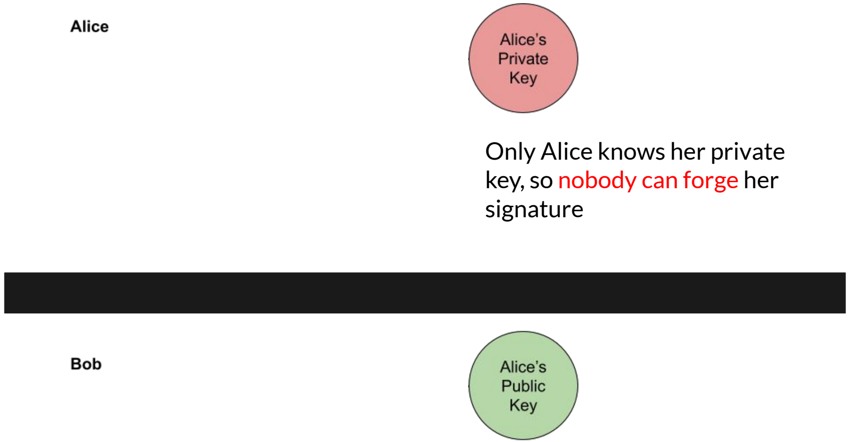

Only Alice knows her private key, so nobody can forge her signature

Everybody can see Alice's public key, so anyone can verify Alice's signature.

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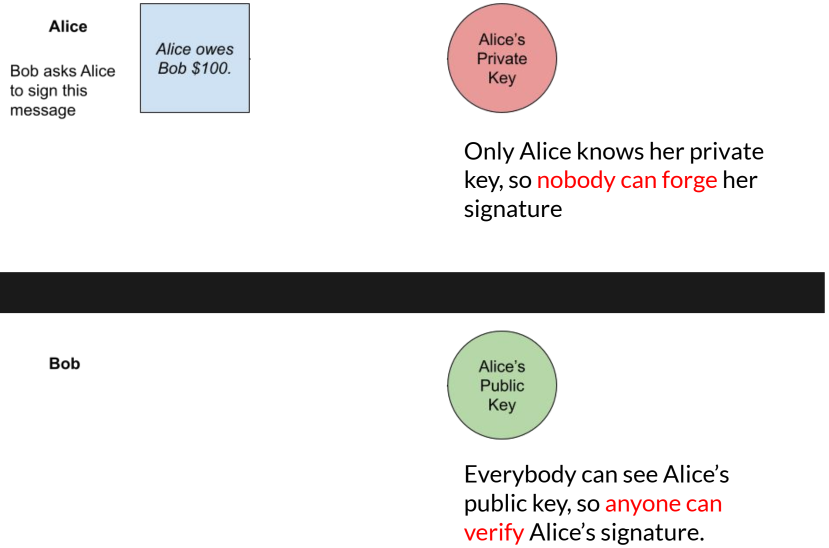

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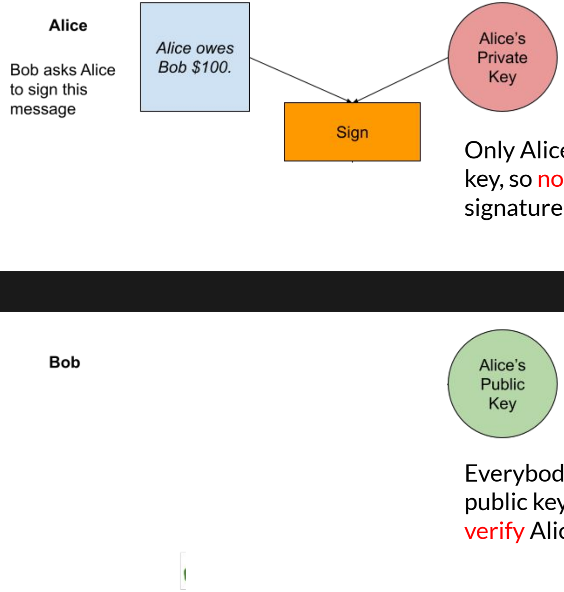

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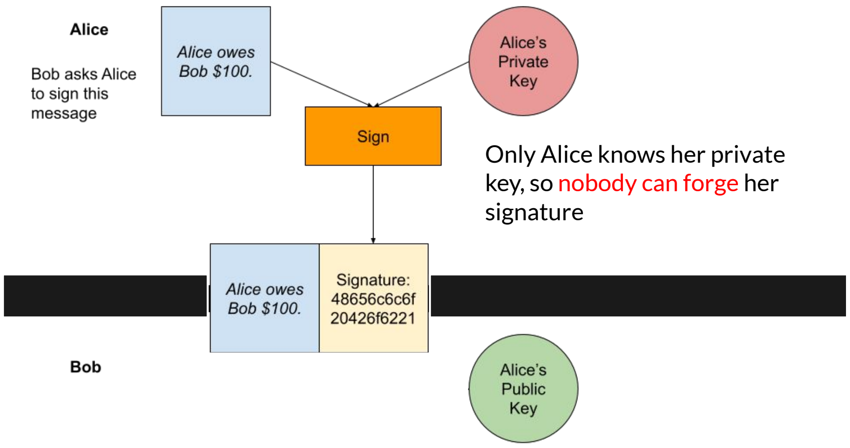

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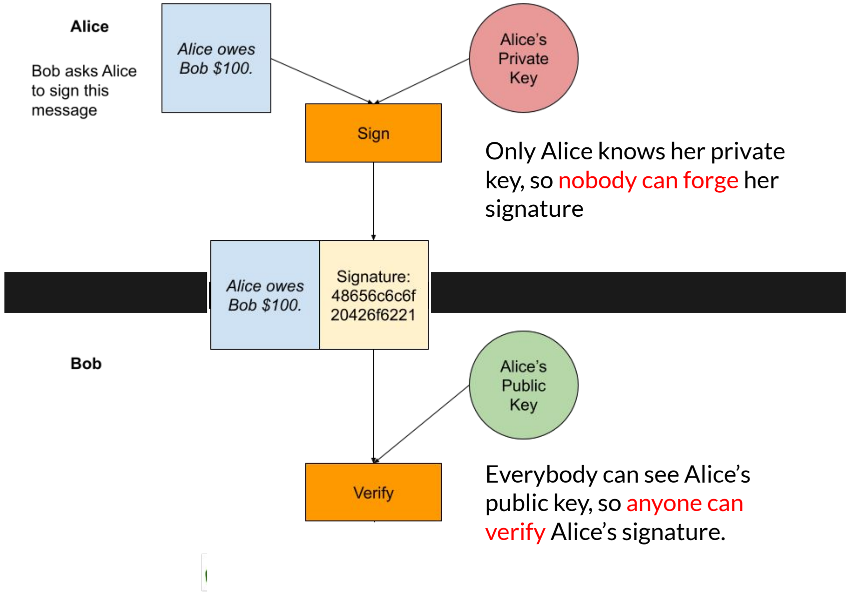

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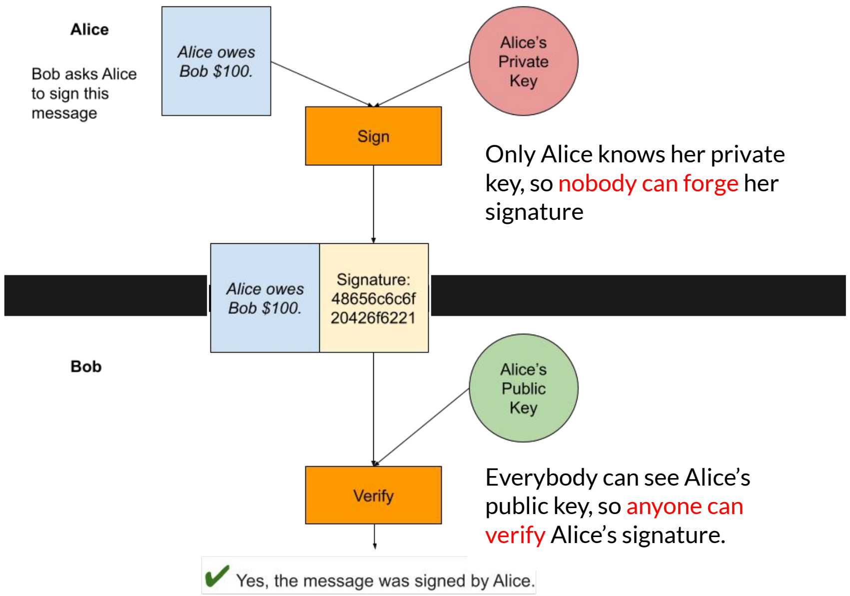
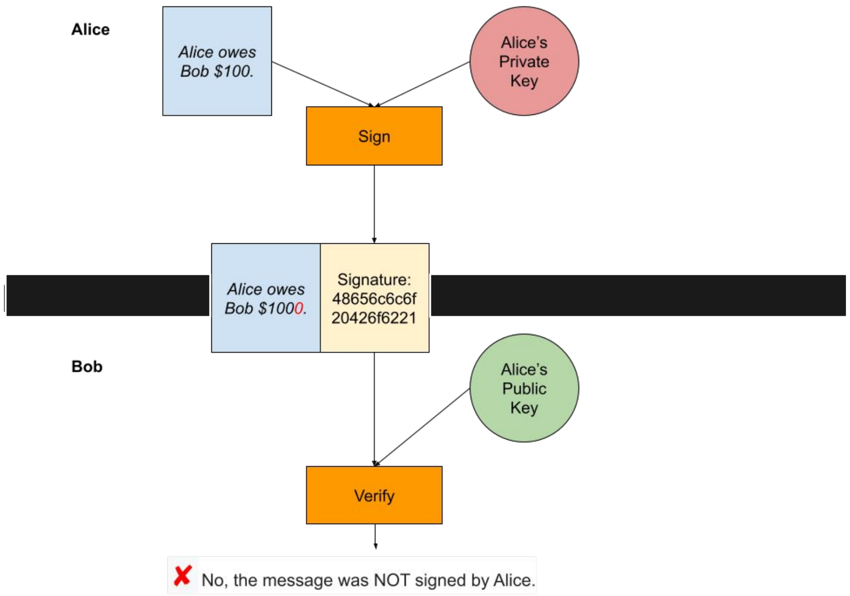


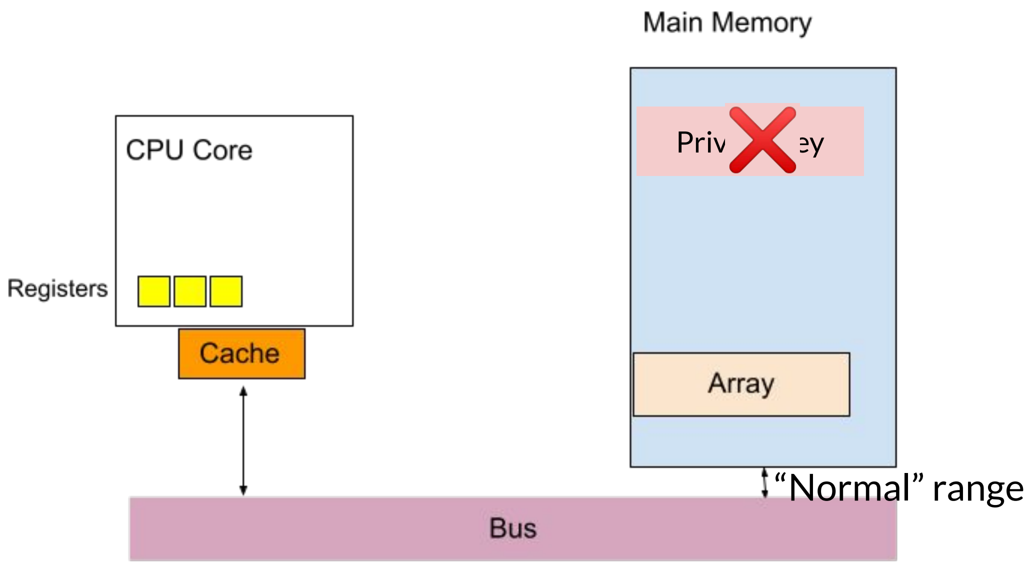
Digital Signatures: Forgery Detection

- What if Bob modified the message?



How to make digital signatures with minimal trust?

- Contribution I: Limit shared hardware resources
- Contribution II: Keep all secrets in the CPU registers



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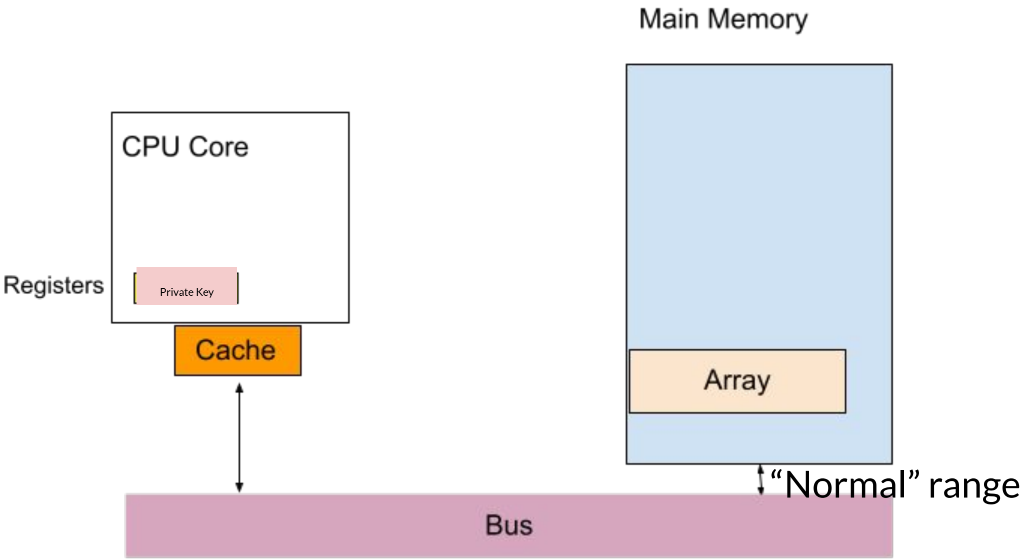
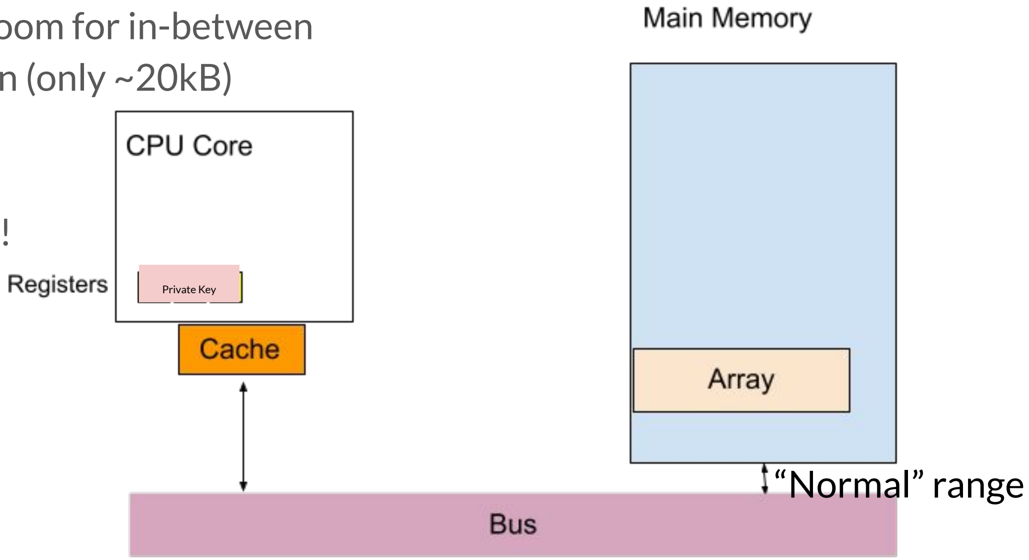


How to make digital signatures with minimal trust?

- Contribution I: Limit shared hardware resources
- Contribution II: Keep all secrets in the CPU registers
- Challenges
  - Very little room for in-between computation (only ~20kB)
- We need a lightweight signature scheme!



Digital Signature: Lamport Signature Scheme

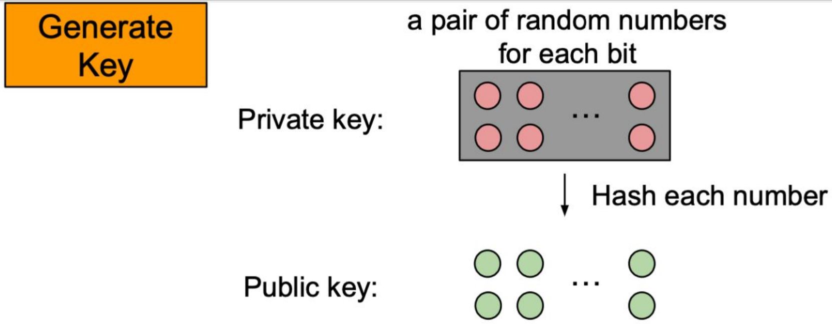
First Public Key Digital Signature Algorithm!

For each bit of the message to sign (256 bits):

We generate 2 random 128-bit number, one to encode 0 and one to encode 1.
0: 53285a2d862e7d9b13bbf416bb4a09e3 →
1:
These are one element of the private key.

We can generate an element of the public key by hashing.
0: H(53285a2d862e7d9b13bbf416bb4a09e3) = H( )
= c21c9b4aa082bdace250f85db5b6e1b8db1f0262cc5afe8dbb6b4d9e989e8758 →
1: H( ) =

Digital Signature: Lamport Signature Scheme



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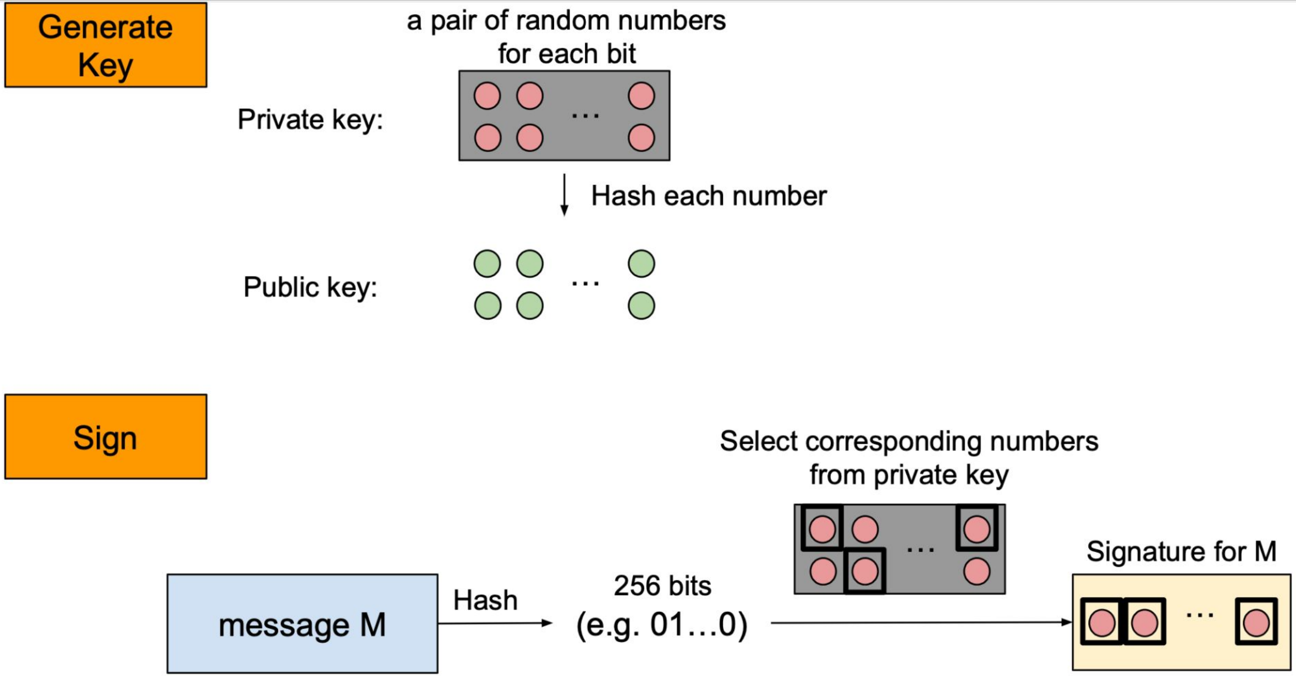

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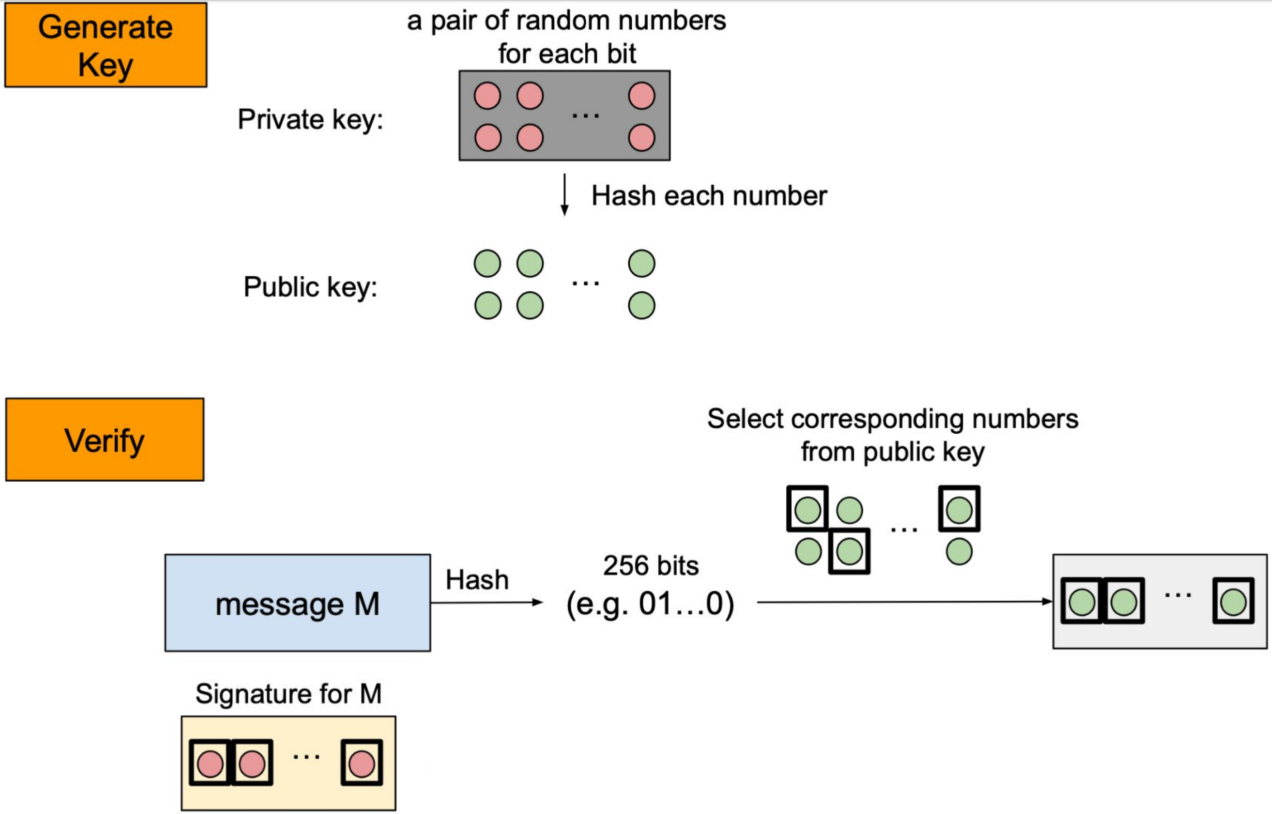

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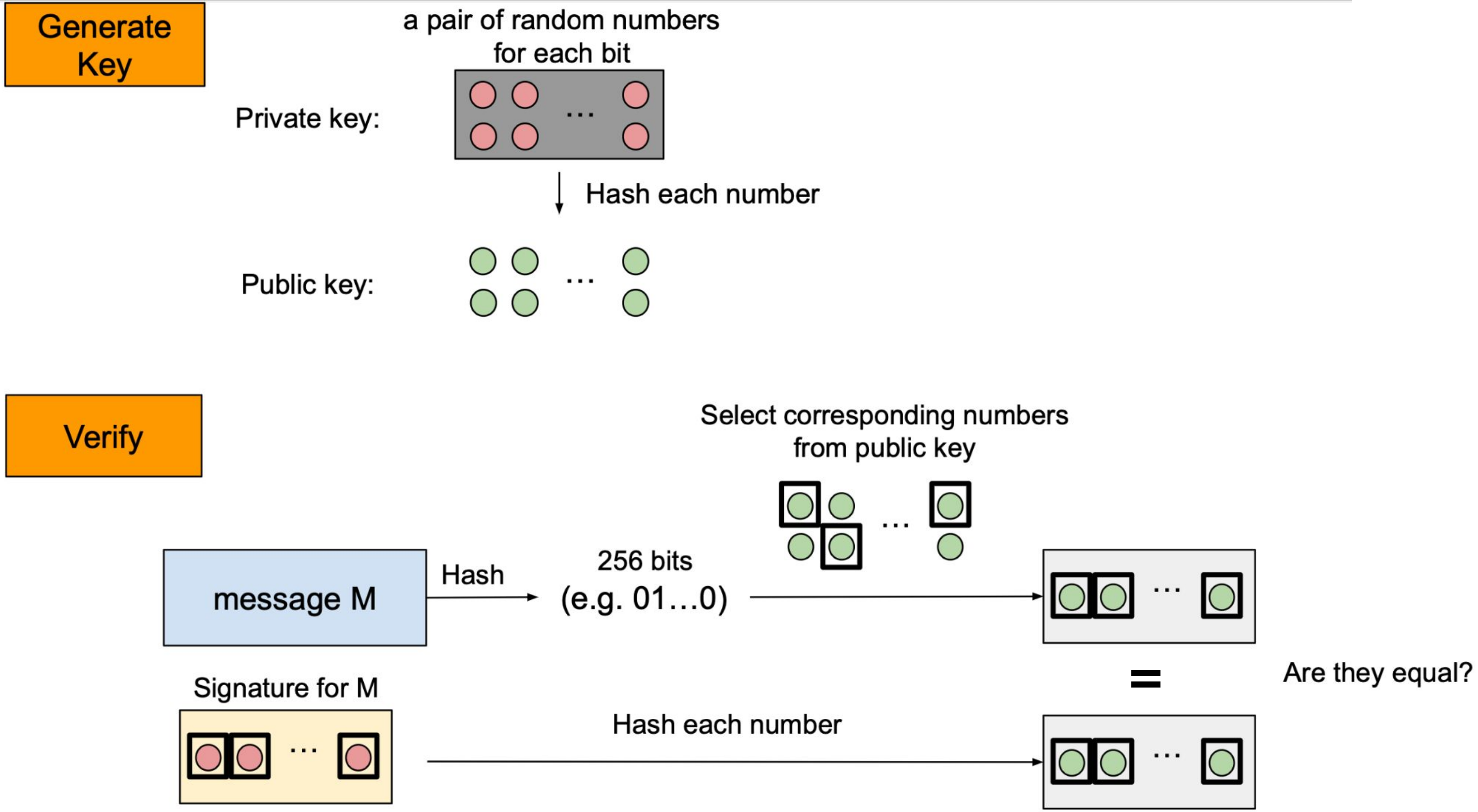


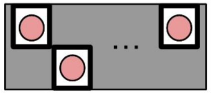
Limitations of Lamport

One Time Usage: **a private key may only be used once**!!

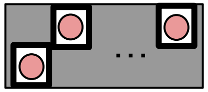
Each signature reveal part of the key ->

an attacker could sign new unseen messages by reconstructing the key!

Msg 1



Msg 2



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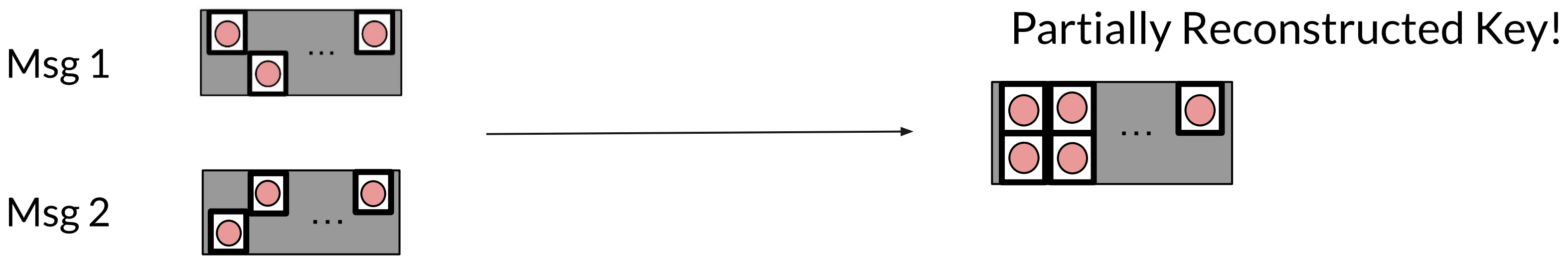
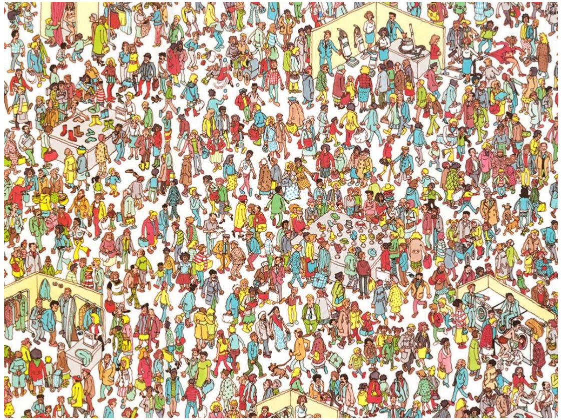
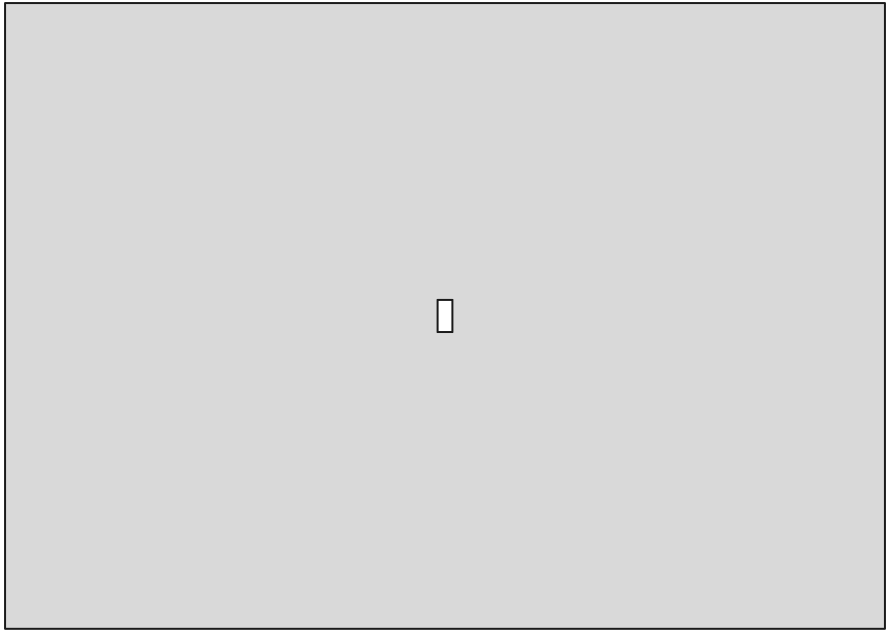


Zero Knowledge Proof-of-Knowledge

- Can we "sign" a message without revealing any of the private key values?
- Prove that we know the value of a secret "s" without revealing the secret.
- Example: Where's Waldo?

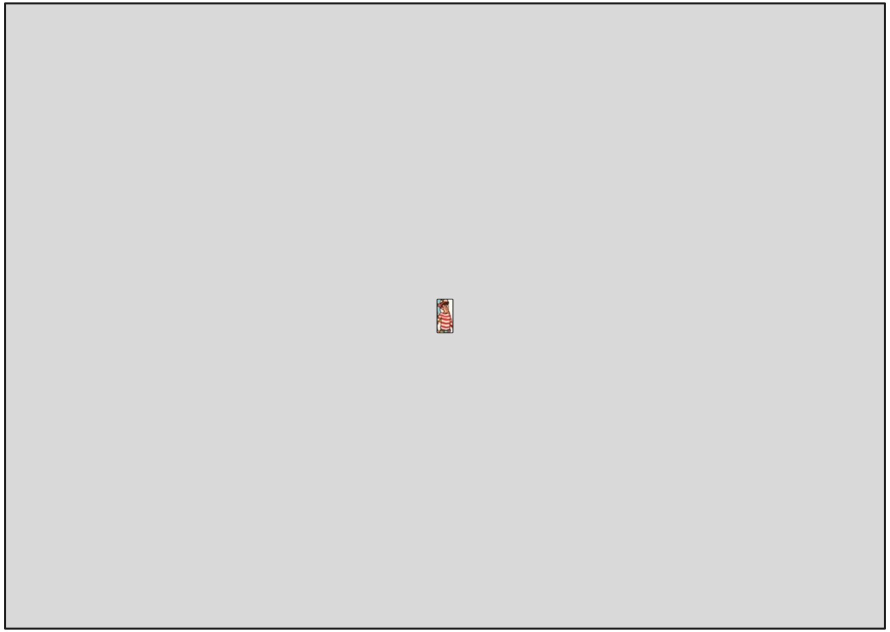


We have a blank canvas with a hole.



We have a blank canvas with a hole.

We position the picture behind the canvas so Waldo can be seen through the hole!



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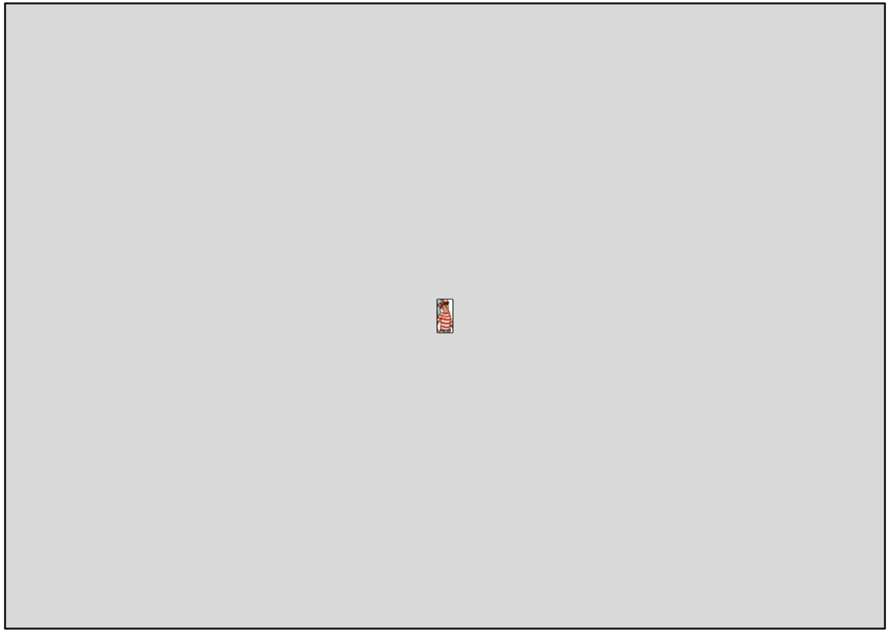
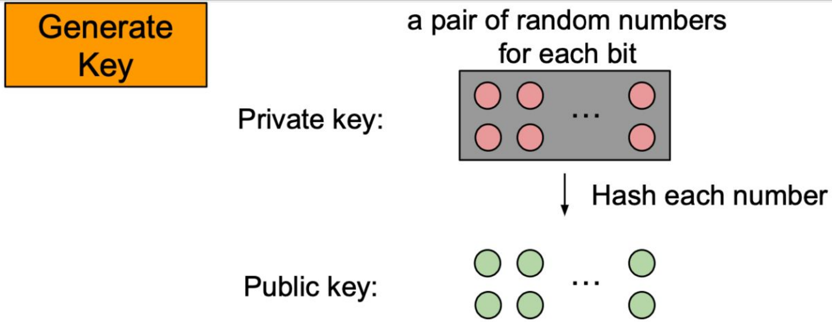
Someone can verify that we know where Waldo is, but we are not revealing Waldo’s exact location.

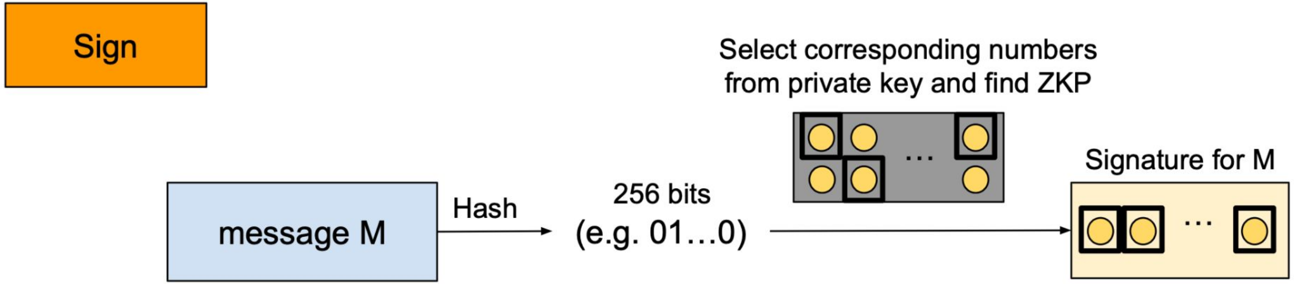


Digital Signature: Lamport Signature Scheme + Zero Knowledge



For each bit of the message, we want to prove we know such that H( ) = , but without revealing the value of .

We can use zero-knowledge proof of that! (represented with)

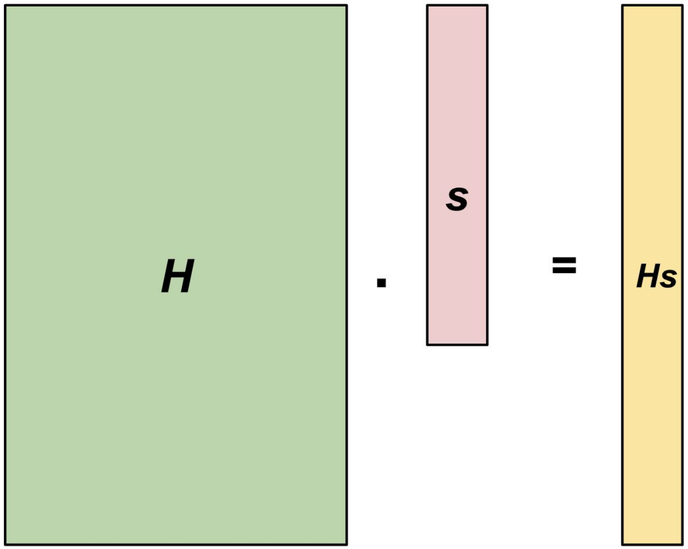


Assumptions we are considering for Zero-Knowledge Proof Scheme

- Discrete Logarithm & Schnorr
- Rabin one-way-function & square root modulo N
- Dual of Learning Parity with Noise (dual-LPN) & Stern ZKP

Dual of Learning Parity with Noise (dual-LPN)

- Assumption that given (H, Hs), it is “hard” to find s, where
  - H is an (n x m) bit matrix
  - s is a m-length random bit vector with hamming weight m/10 (sparse)



Stern's ZKP

- Prover picks y, a m-length random bit vector, and a permutation σ of size m
  - Commitment 1: σ || Hy
  - Commitment 2: σ (y)
  - Commitment 3: σ(y $\oplus$ s)
- Verifier picks a random bit b in {0, 1, 2}, and Prover opens the commitments as follows:
  - If b = 0, it opens commitment to σ (y) by giving (y and σ)
  - If b = 1, it opens (y $\oplus$ s)
  - If b = 2, it opens σ(y) and σ(s)
- Verifier verifies that
  - If b = 0, it verifies commitments (1), (2)
  - If b = 1, it verifies (1), (3) and that H*(y $\oplus$ s) $\oplus$ H*(s) = H(y)
  - If b = 2, it verifies (2), (3) and that σ(s) has correct hamming weight

Next Steps

- Designing our signature scheme
- Implementing the signature scheme
- Performance evaluation if the signature scheme is fast enough

Acknowledgements

Our mentors

Jules Drean

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Thank you!