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BETTER.

SESSION ID: CRYPT-W12

Post-Quantum EPID Signatures from Symmetric Primitives

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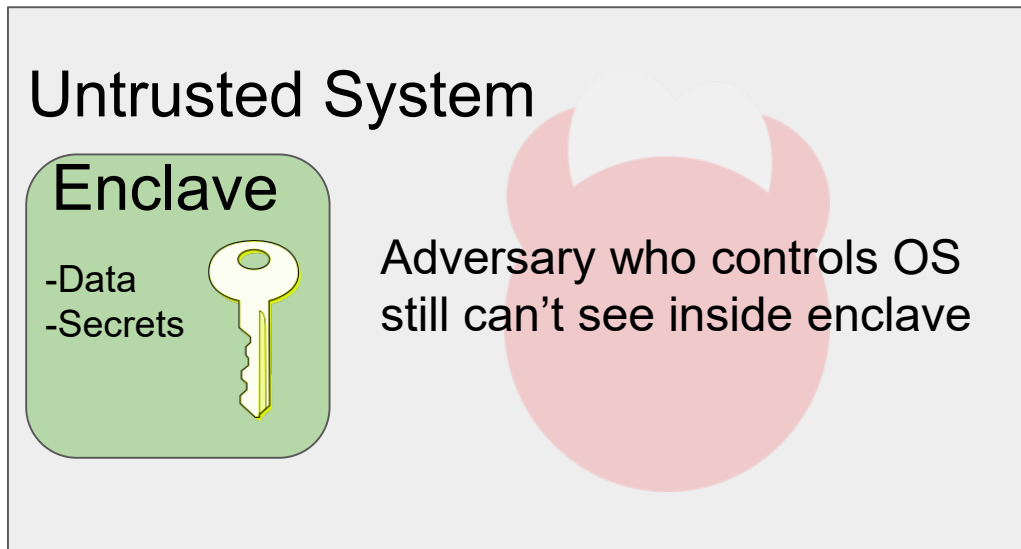
Ben Fisch

#RSAC

Hardware Enclaves

A trusted component in an untrusted system

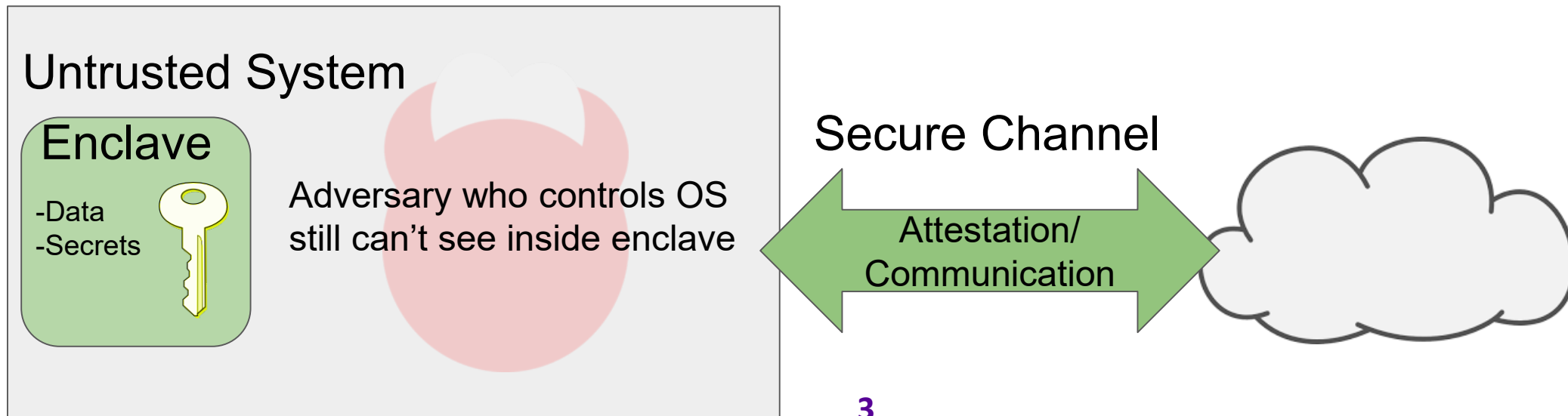
- Protected memory isolates enclave from compromised OS



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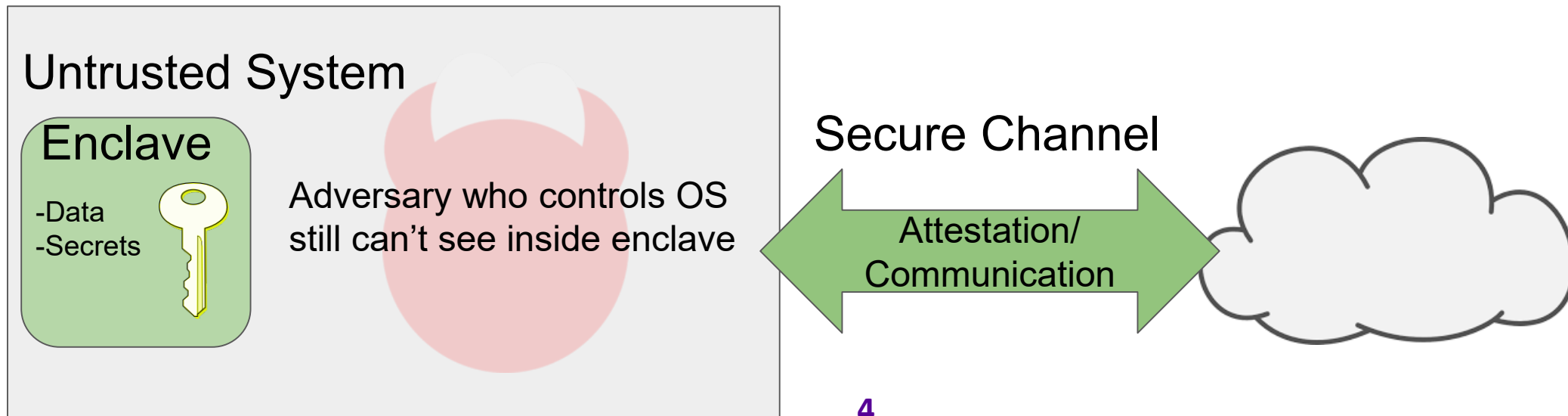
- Protected memory isolates enclave from compromised OS
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Hardware Enclaves

A trusted component in an untrusted system

- Protected memory isolates enclave from compromised OS
- Proves authenticity via a process called *attestation*
 - Is it “post-quantum” secure?





EPID Signatures [BL09]

Group signature-like primitive that provides two properties:

1. Signatures from any member of a group are indistinguishable from each other
2. Users can have their credentials revoked either by a blacklisted key or a blacklisted signature

Intel's EPID signature scheme relies on pairings and is not post-quantum secure

EPID Signatures [BL09]

$sk_i, cert_i \leftarrow \text{Join}(\dots)$ - interactive protocol between group member and manager to join group

$\sigma \leftarrow \text{Sign}(gpk, sk_i, cert_i, m, \text{SIG-RL})$ - any user who has joined can sign a message anonymously as a group member

$1/0 \leftarrow \text{Verify}(gpk, m, \text{KEY-RL}, \text{SIG-RL}, \sigma)$ - signatures only verify if signed by a valid, unrevoked group member

$\text{KEY-RL}' \leftarrow \text{RevokeKey}(\text{KEY-RL}, sk_i)$ - revoke a group member by key

$\text{SIG-RL}' \leftarrow \text{RevokeSig}(\text{SIG-RL}, \sigma)$ - revoke a group member by signature

Security properties: **Anonymity** and **Unforgeability**

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Security properties: **Anonymity** and **Unforgeability**

Our design goal: post-quantum security from **symmetric primitives only**

Picnic Signatures [CDGORRSZ17]

Uses ZKB++ MPC-in-the-head type proof system [IKOS07, GMO16]
i.e. proof of knowledge from symmetric primitives

High-level idea: Signature is proof of knowledge of preimage
of a one-way function
e.g. I know sk such that $f(sk)=y$

Our Basic Approach [BMW03,CG04]

Join

User generates pk, sk

Group manager signs pk to form cert

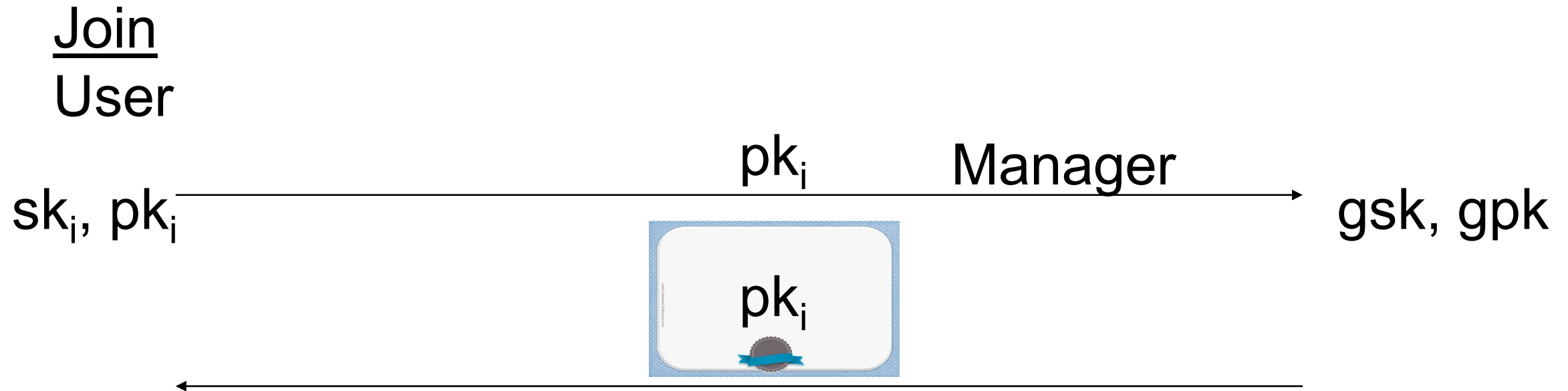
Sign

User signs message with sk

User publishes proof of knowledge of signature as σ

Additionally need to support revocation

Our Basic Approach [BMW03,CG04]



Sign

$$s = \text{Sign}(sk_i, m)$$

Proof of Knowledge: I have a certificate on a key sk^* and a signature s on message m signed with sk^*



Post-Quantum EPID Signature

Join

User

sk_i

Manager

gsk, gpk

Post-Quantum EPID Signature

Join

User

sk_i

Manager

gsk, gpk

c



Post-Quantum EPID Signature

Join

User

sk_i

Manager

gsk, gpk

c

$t^{join} = f(sk_i, c)$

t^{join}

Post-Quantum EPID Signature

Join

User

sk_i

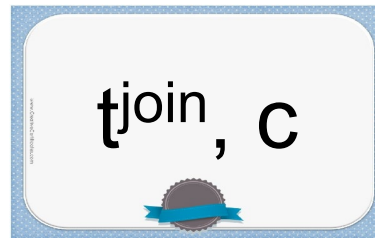
Manager

gsk, gpk

c

$t^{join} = f(sk_i, c)$

t^{join}



Post-Quantum EPID Signature

Sign

$r \leftarrow \{0,1\}^\lambda$

$t = f(\text{sk}_i, r), r$

Post-Quantum EPID Signature

Sign

$r \leftarrow \{0,1\}^\lambda$

$t = f(\text{sk}_i, r), r$

Proof of Knowledge:

1. I know a valid certificate for t^{join}, c

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Sign

$r \leftarrow \{0,1\}^\lambda$

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2. I know sk_i such that $t = f(\text{sk}_i, r)$ and $t^{\text{join}} = f(\text{sk}_i, c)$

Post-Quantum EPID Signature

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$r \leftarrow \{0,1\}^\lambda$

$t = f(sk_i, r), r$

Proof of Knowledge:

1. I know a valid certificate for t^{join}, c
2. I know sk_i such that $t = f(sk_i, r)$ and $t^{\text{join}} = f(sk_i, c)$
3. There is no signature in SIG-RL such that $f(sk_i, r')=t'$

publish proof and t as signature



Instantiation

Need	Choices
Zero Knowledge PoK	ZKB++, Ligerio, zk-STARK
PRF/CRHF	
Post-Quantum Signature from symmetric primitives	



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Post-quantum EPID signature size (group size 2^{30}):

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Post-quantum EPID signature size (group size 2^{30}): **217MB**
Way too big!! Culprit: signature verification inside PoK

Post-Quantum EPID Signature

Sign

$r \leftarrow \{0,1\}^\lambda$

$t = f(\text{sk}_i, r), r$

Proof of Knowledge:

1. I know a valid certificate for t^{join}, c
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publish proof and t as signature

Requires signature verification!
How can we remove this?



The Attestation Setting

Each Intel SGX attestation involves contacting Intel, who verifies the attestation for you.



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How can we leverage this to reduce signature sizes?

Idea: If group manager has to be online, maybe it can update users' certificates

User anonymity sets relative to last certificate update



Signatures for Attestation

Manager puts user credentials in a Merkle tree and signs root

Users get newest Merkle root/inclusion proof when they connect to the manager



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Signature on Merkle tree root can be verified outside PoK

Only need much smaller Merkle inclusion proof inside PoK

Signatures for Attestation

$r \leftarrow \{0,1\}^\lambda$

$t = f(\text{sk}_i, r), r$

Proof of Knowledge:

1. I know an inclusion proof for t^{join}, c
2. I know sk_i such that $t = f(\text{sk}_i, r)$ and $t^{\text{join}} = f(\text{sk}_i, c)$
3. There is no signature in SIG-RL such that $f(\text{sk}_i, r') = t'$

publish proof, t , and **signed Merkle root** as signature

Similar to post-quantum Ring signatures of Derler et al [DRS17]

Signature Sizes

Group Size	RO Model*	QRO Model*
2^7	1.37MB	2.64MB
2^{10}	1.85MB	3.59MB
2^{20}	3.45MB	6.74MB
2^{30}	5.05MB	9.89MB
2^{40}	6.65MB	13.0MB

Potential application: large data transfer, e.g. streaming movies

*under ideal cipher assumption on LowMC

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