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HUMAN
ELEMENT

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Public Key Cryptography: Theory One-More Assumptions Do Not Help Fiat-Shamir-type Signature Schemes in NPROM

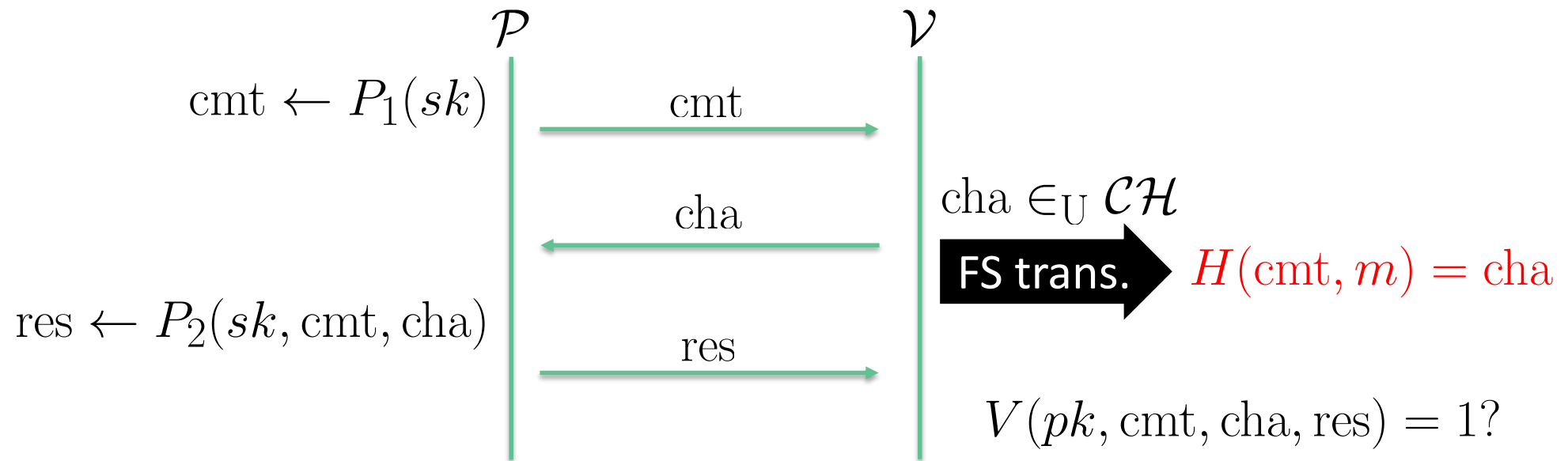


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Fiat-Shamir-type (FS-type) Signature Schemes

Signature Schemes derived via the FS transformation [FS87]
 e.g. Schnorr [Sch91], Guillou-Quisquater (GQ) [GQ88], Okamoto [Oka93],
 Lyubashevsky [Lyu08]



Security Proofs in Random Oracle Model

There are affirmative results on the provable security of FS-type sig.

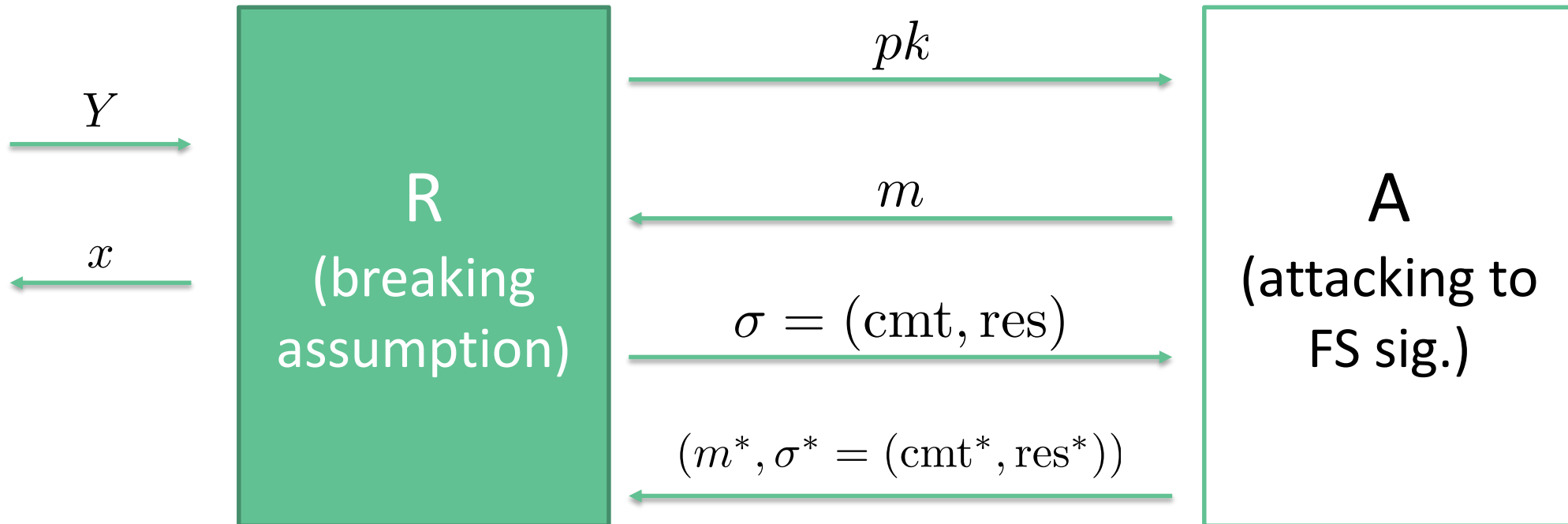
	Assumption on Underlying ID		Provable Security Of its FS-type sig.
[PS00]	HVZKPoK	\Rightarrow	seuf-cma
[AABN08]	imp-pa secure	\Leftrightarrow	seuf-cma

Instantiations:

- Schnorr signature scheme is secure under the discrete log (DL) assumption
- GQ signature scheme is secure under the RSA assumption

What Does Mean FS-type Signature Is Secure?

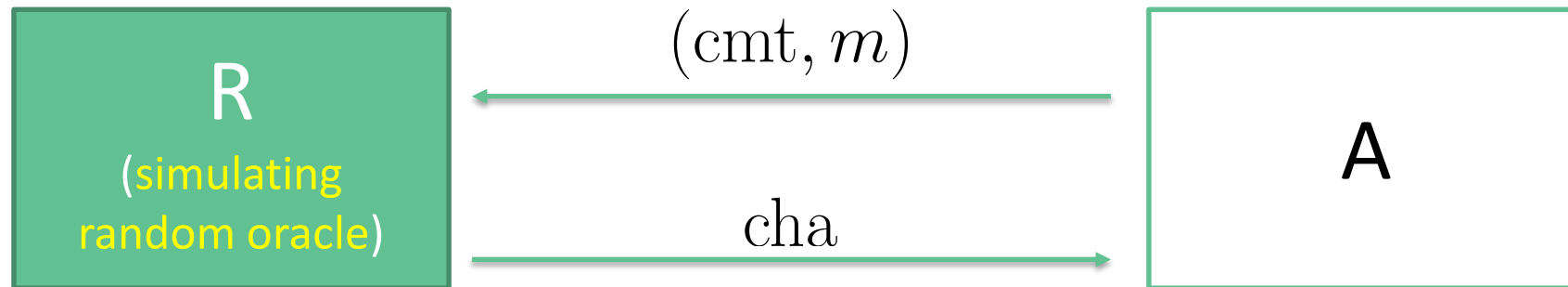
There is a polytime reduction algorithm R which breaks an underlying cryptographic assumption by accessing an adversary algorithm A against a designated FS-type signature scheme.



Proof Techniques

The results [PS00, AABN08] rely on the followings:

- Forking Lemma
- **Random Oracle Model**
 - Is a.k.a. Ideal security model
 - Restricts any party to obtain any hash value from the random oracle
 - Is applied to prove the security of many cryptographic schemes



Impossibility Result: Security Proof in Standard Model

The security of FS-type signature schemes is known to be unprovable in standard model [PV05].

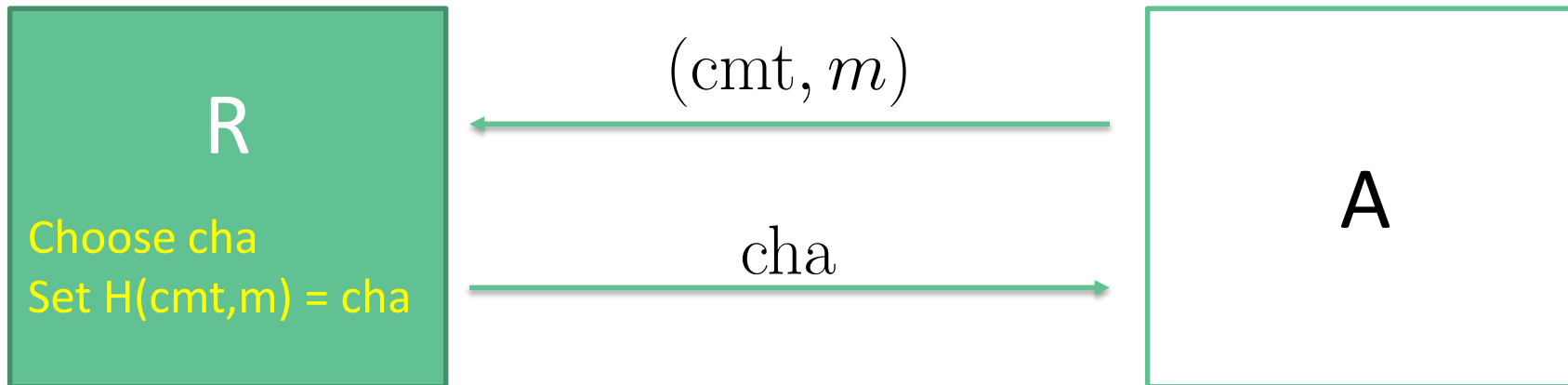
As far as some restricted reductions are concerned,

- OM-DL assumption holds \Rightarrow
Schnorr signature scheme cannot be proven from the DL assumption.
- OM-RSA assumption holds \Rightarrow
GQ signature scheme cannot be proven from the RSA assumption.

Why is ROM Strong?

A reduction R in ROM utilize the following ideal properties:

- Observing Property
 - R can observe all pairs of a query and its response on the random oracle.
- Programming Property
 - R can arbitrarily set a hash value of any query.



Intermediate Model between Standard Model and ROM

	Computing Hash	Programming	
ROM	By Random Oracle	Allowed	Ideal
NPROM	By Random Oracle	Not Allowed	↕
Standard Model	Self	Not Allowed	real

Non-Programmable ROM [FLRSST10] is a security model in which a random oracle;

- outputs a hash value as in the ROM; but
- is dealt with an independent party.

Impossibility Result: Security Proof in NPROM

- Fischlin-Fleischhacker [FF13]
OM-DL assumption holds \Rightarrow
Schnorr signature is unprovable to be secure in NPROM
from the **DL assumption** via single-instance reductions.
- Fukumitsu-Hasegawa [FH16, FH18]
Extend Fischlin-Fleischhacker result to cover many FS-type
signature schemes

These results only consider the security from
non-interactive assumptions.

Impossibility results from interactive assumptions

There are impossibility results on the provable security of **only** Schnorr signature from interactive assumptions:

- Fukumitsu-Hasegawa [FH17]
 - in NPROM
 - from the OM-DL assumption
- Fleischhacker-Jager-Schröder [FJS19]
 - even in ROM
 - from specific interactive assumptions
 - but, only for tight and generic reduction

Remained Question

Can one prove that FS-type signatures are secure from **interactive assumptions** in **NPROM** via a **reasonable reduction**?

- Can one expand a result for many types?
 - GQ, KW, Okamoto, Lyubashevsky, ...
- Reasonable reductions
 - non-restriction on the tightness and internal operations

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Our Contribution

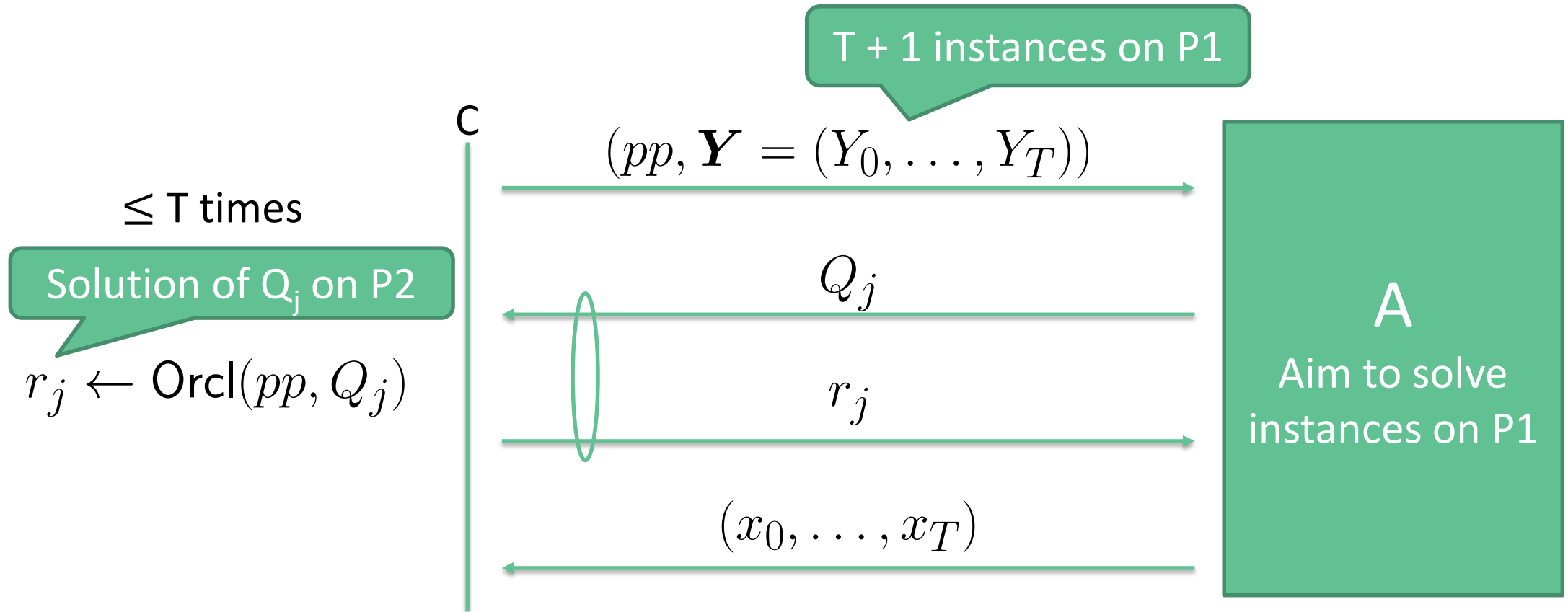
Informal Statement

We give a negative circumstantial evidence on the remained question by the following theorem.

Some FS-type signatures are unprovable to be secure in NPROM from the generalized One-More cryptographic assumptions.

Generalized One-More Cryptographic Assumption [ZZCGZ14]: T-(P1,P2) Assumption

Any PPT adversary A cannot win the following game.



Scope of Type on Underlying ID Schemes

- Special Soundness

- (cmt, cha, res) and (cmt, cha', res') have been found, then a secret key of pk can be extracted in polytime.
 - s.t. $\text{cha} \neq \text{cha}'$ and $V(\text{pk}, \text{cmt}, \text{cha}, \text{res}) = V(\text{pk}, \text{cmt}, \text{cha}', \text{res}') = 1$

- Unique Key

- Any public key pk has only one secret key sk.

- Certified (proposed)

- One can check whether pk has a secret key.
- DL-based ID schemes [Hes03, Sch91] have this property.
- This is inspired by [KK13].

Type of Reductions I: Vanilla Reductions

Our result only considers **vanilla reductions**

- Definition: A reduction R
 - can invoke an adversary A only once.
 - cannot rewind A
- Feature:
 - No restriction on the tightness, internal operations in R and pk queried to A

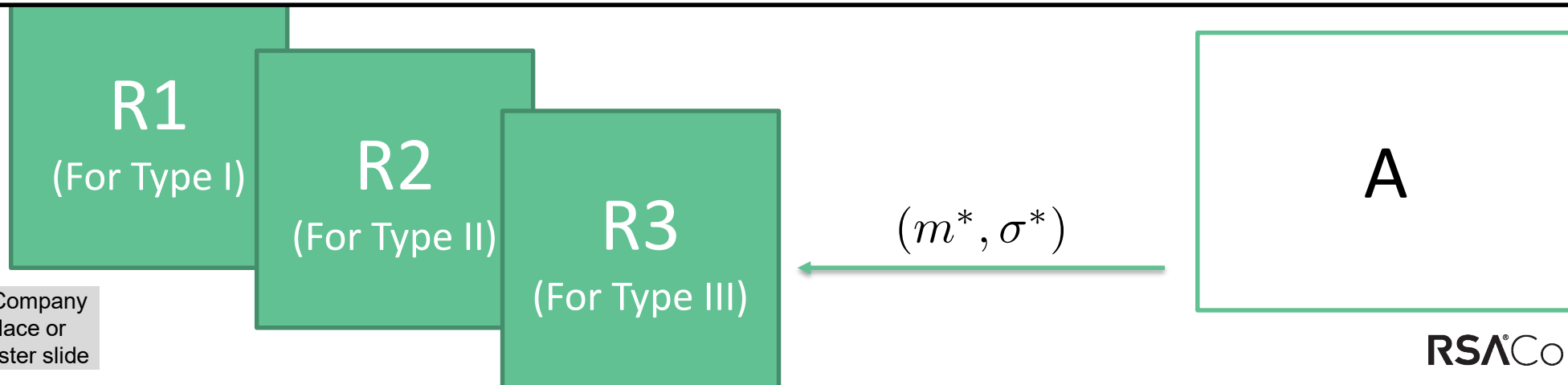
Type of Reductions II: Only for Specific Type of Forgery

A reduction works if the forgery (cmt^*, res^*) satisfies that a cmt^* part differs from all cmt which appear in the signing oracle phase.

By this restriction, the **type guess reduction technique** is avoided.

Type Guess Reduction Technique

A reduction is constructed by separating the forged signature by A into several types e.g. Cramer-Shoup signature [CS00]



Suggestions

- This is a generalization of [FF13, FH17, FH18].
 - Can apply our result to the case on Schnorr signature from the DL assumption and the OM-DL assumption.
- There is a possibility to prove the security of FS-type signatures from non-certified ID schemes:
 - RSA-based ID schemes
 - Lossy ID schemes [AFLT16]
- Other type of reductions has potential

Comparisons: Target Security Reductions

	Model	Security	Tight	Assumption	Type
[Thm8, PV05]	ROM	uuf-cma	only	Non-interact	Algebraic
[FF13]	NPROM	euf-cma		Non-interact	Single-inst.
[FH16]	NPROM	suf-sma		imp-pa of ID	SMI
[Thm.1 FH18]	NPROM	euf-koa		imp-pa of ID	Key-pres.
[Thm2. FH18]	NPROM	euf-cma		Non-interact	Single-inst. key-pres.
[Thm2. PV05]	Standard	uuf-cma		Non-interact	Algebraic
[ours]	NPROM	euf-cma		Generalized OM	Vanilla

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Concluding Remarks

Summary of Our Result

Some Fiat-Shamir-type signatures are unprovable to be secure in NPRM from T-(P1,P2) assumptions via a vanilla reduction.

- Restriction
 - ID scheme: special soundness, unique key and certified.
 - Reduction: only work when it is given (cmt^*, res^*) s.t. a cmt^* part differs from all cmt which appear in the signing oracle phase.
- Suggestion
 - Our result is a generalization of [FF13, FH17, FH18].
 - At least DL-based FS-type signatures may be unprovable to be secure only by the programming technique.
 - Other type of reductions has potential to prove the security proof.

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