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Rethinking Verifiably Encrypted Signatures: A Gap in Functionality and Potential Solutions

SESSION ID: cryp-r02

Sarah Meiklejohn

Graduate researcher
UC San Diego

Models for cryptographic primitives

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Models for cryptographic primitives

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- But it's also incredibly important to accurately model **functionality**!
- We look at definitions for verifiably encrypted signatures (VES)
  - First show a generic construction based **solely on signatures**
  - Then propose **new definition(s)**

An application: fair contract signing [ASW88]

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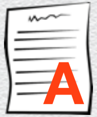

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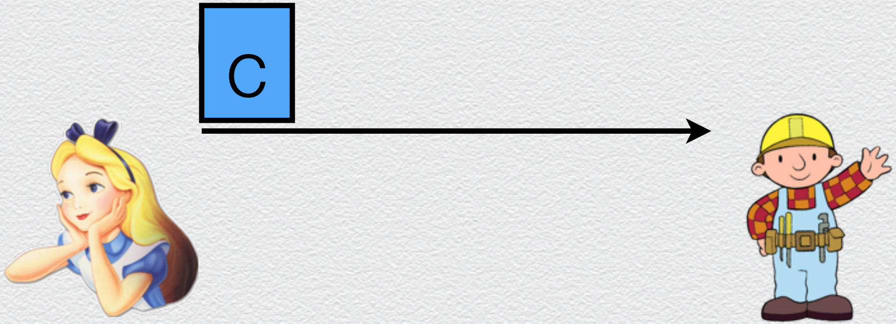

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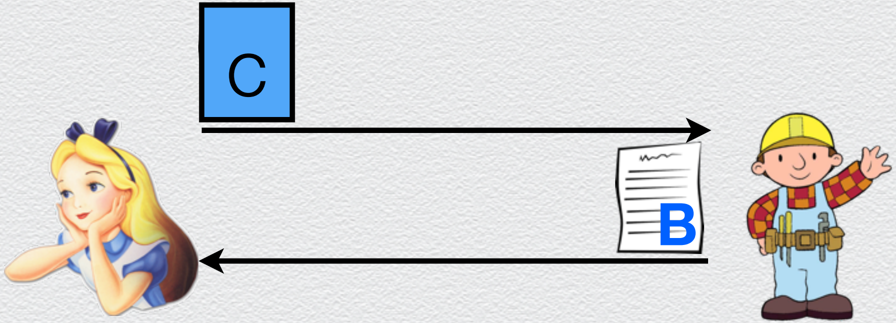

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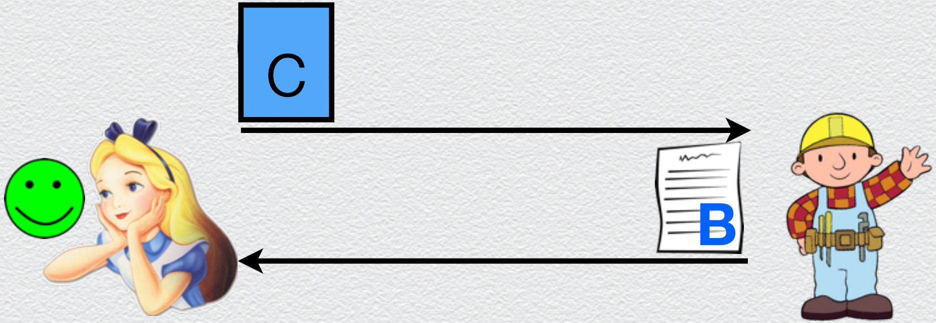

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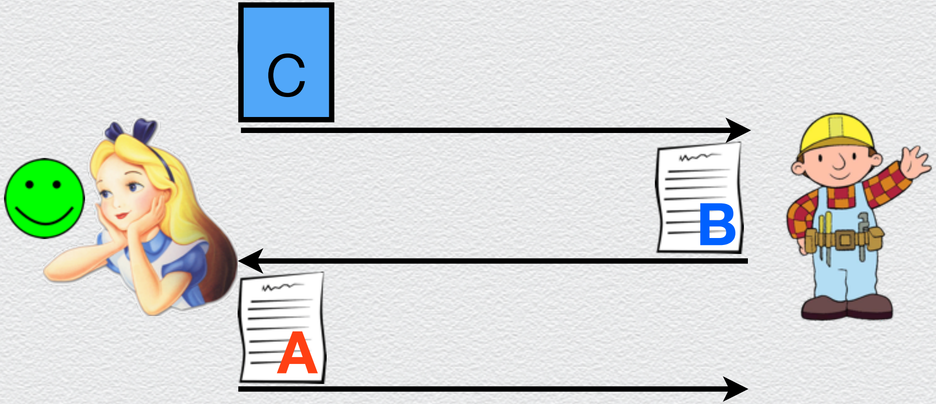

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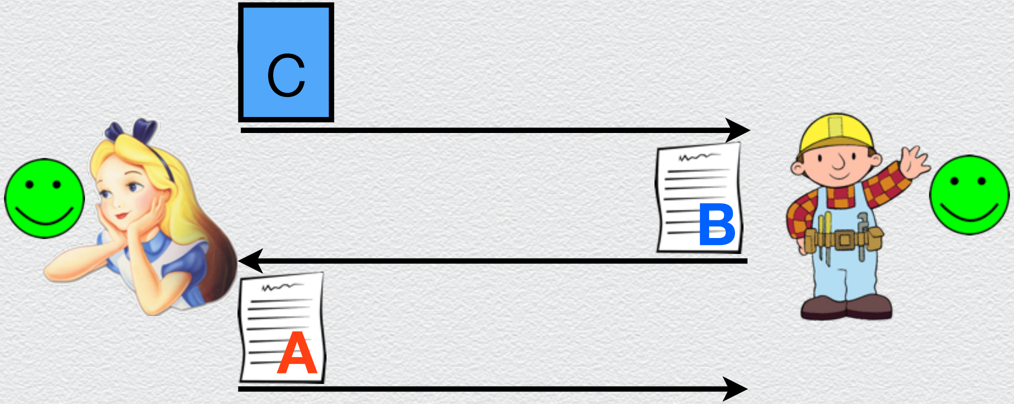

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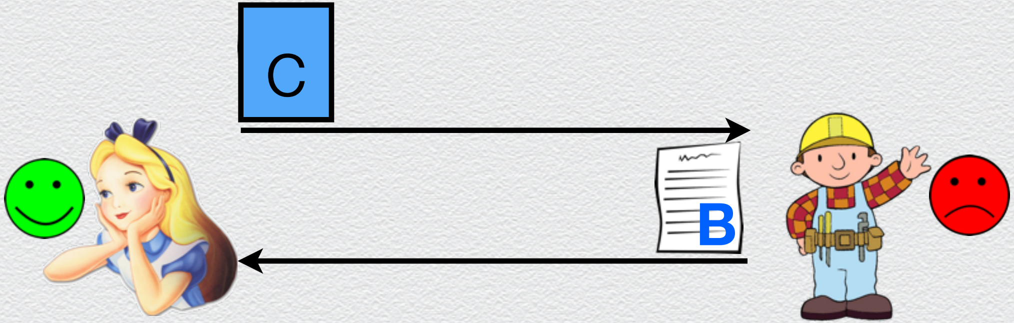

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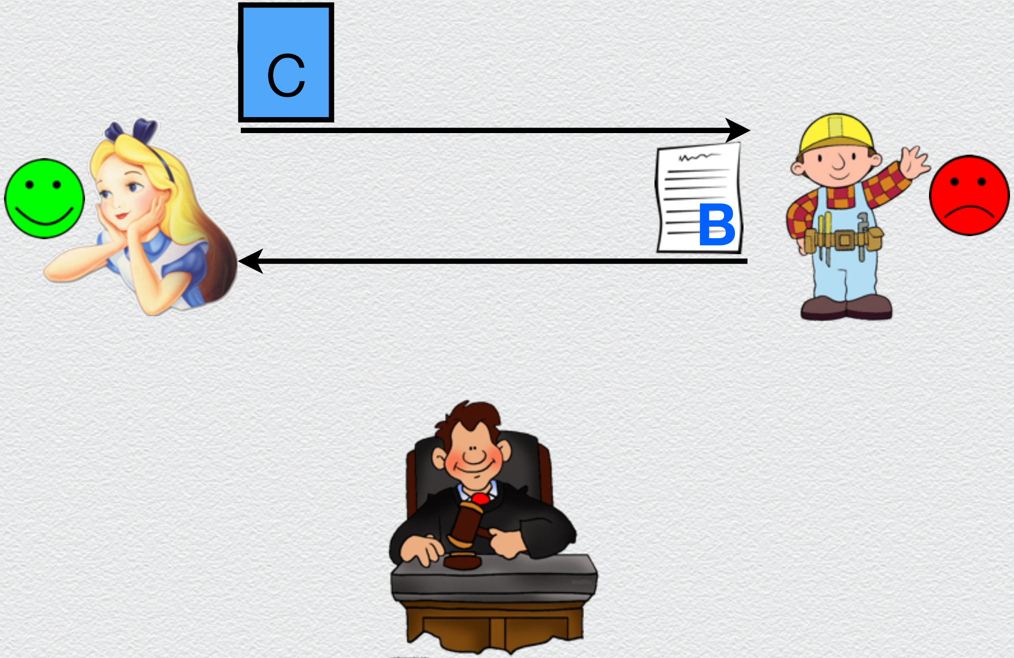

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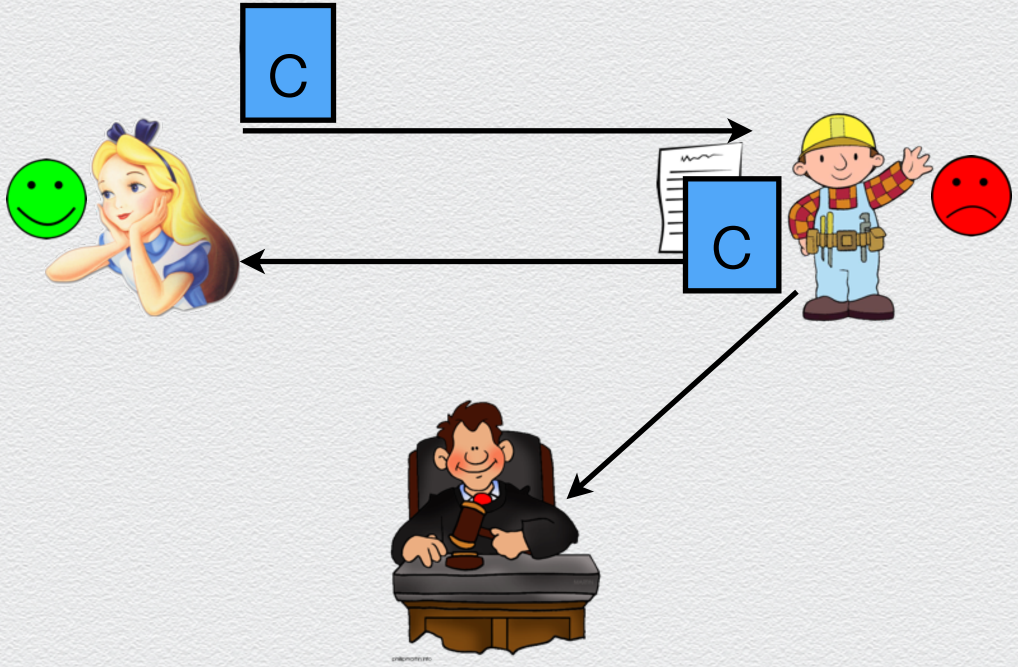

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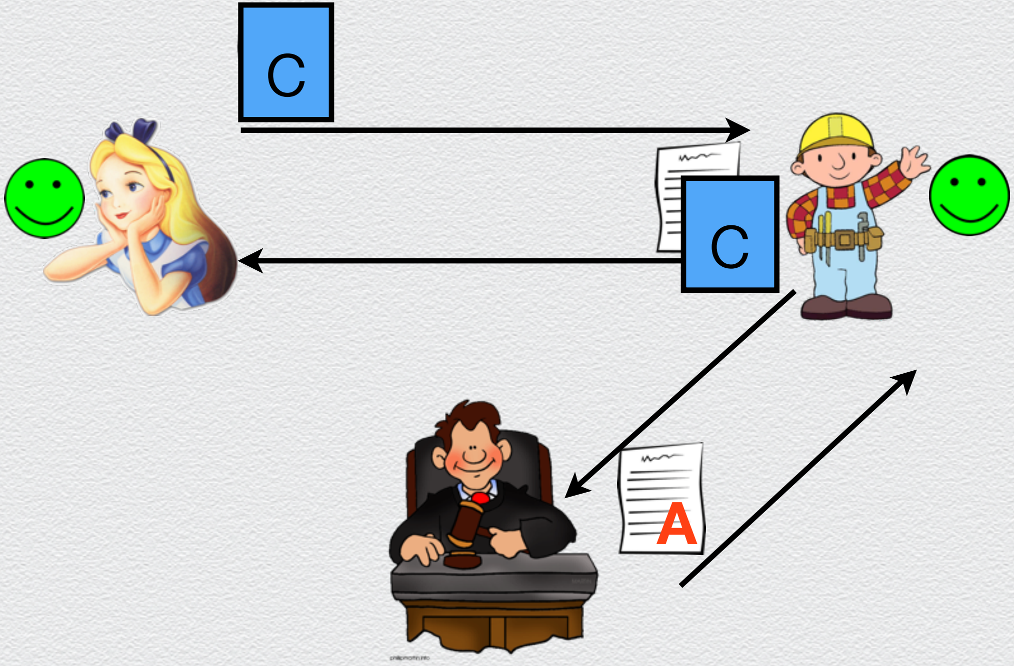

Definitions for VES:

- Unforgeability
- Opacity
- Extractability

Verifiably encrypted signatures [BGLS03]

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$(pk_B, sk_B) \leftarrow KG(1^k)$

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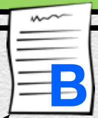
$\sigma =$ 

$= \mathrm{Sign}(sk_B, m)$

VEVerify(pk_A,apk,ω,m)

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Verifiably encrypted signatures [BGLS03]

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Verify(pk_B,σ,m)

ω = VESign(sk_A,apk,m)

VEVerify(pk_A,apk,ω,m)

$(pk_A,sk_A) \leftarrow KG(1^k)$

σ =  = Sign(sk_B,m)

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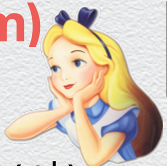

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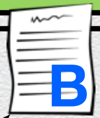
σ = 

= Sign(sk_B,m)

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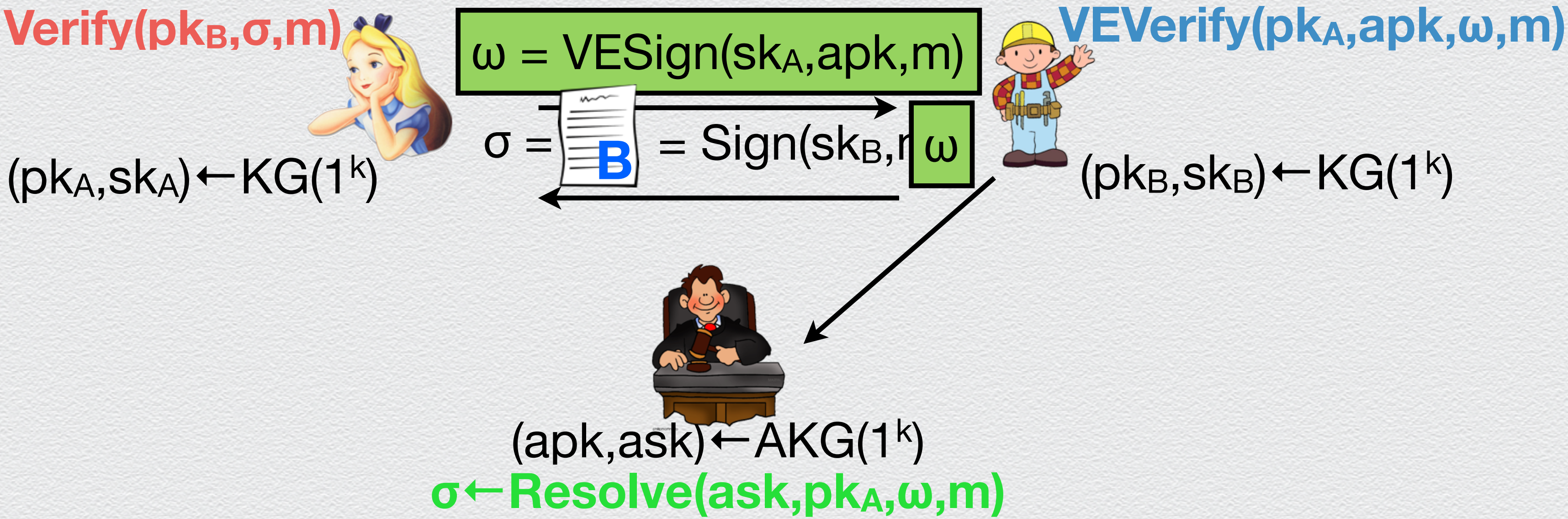

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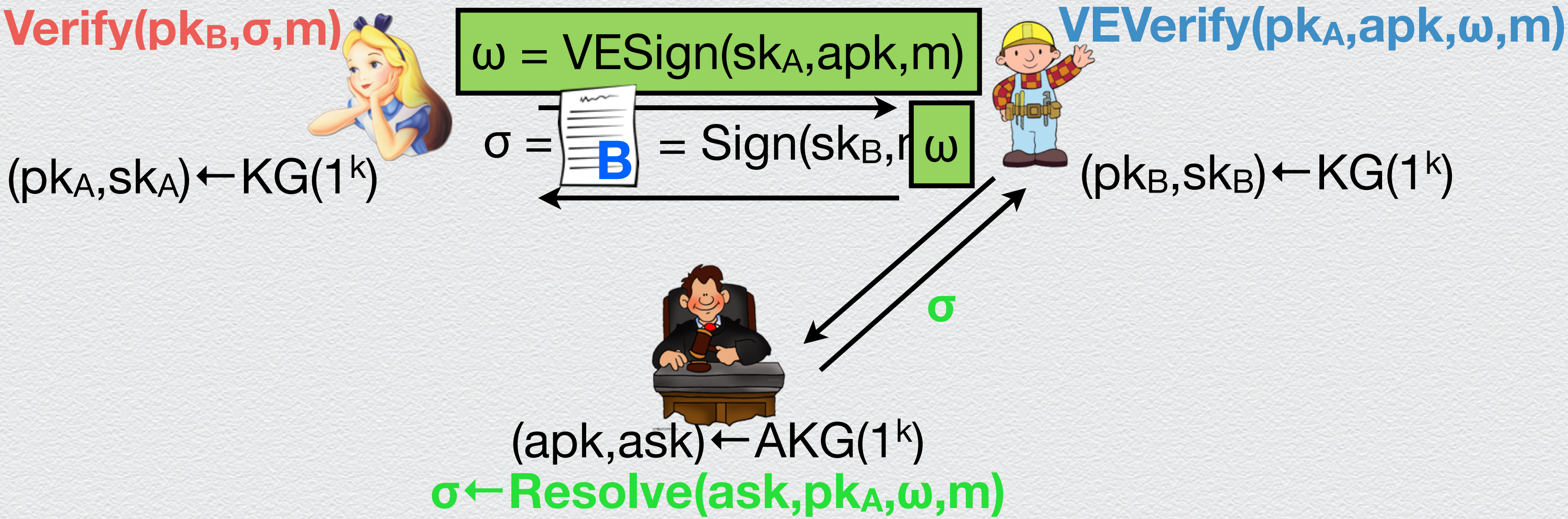

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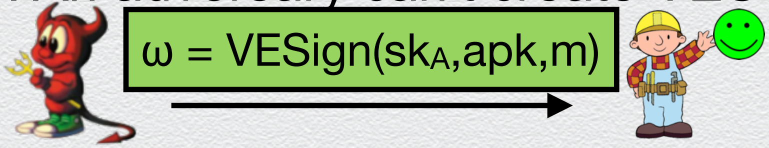

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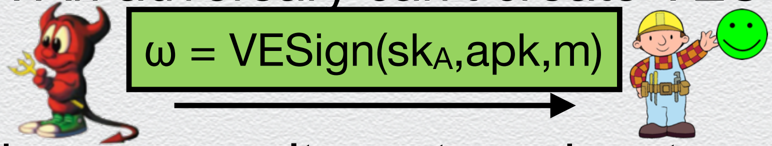
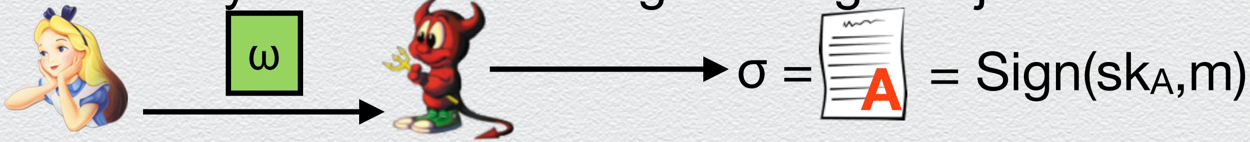


  - **Opacity**: An adversary can't create a signature given just VES



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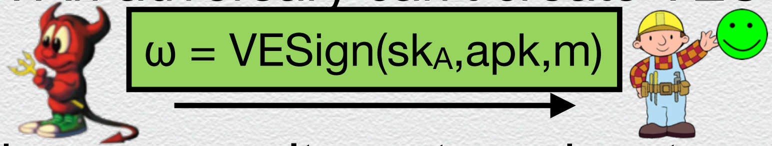

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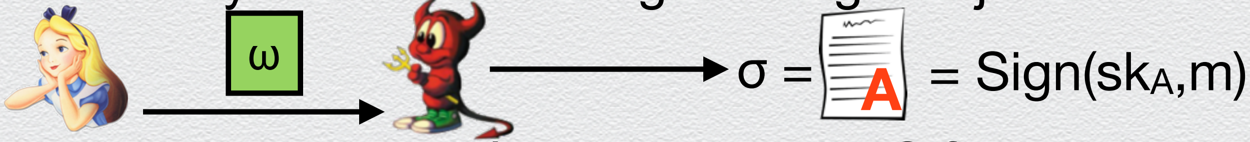
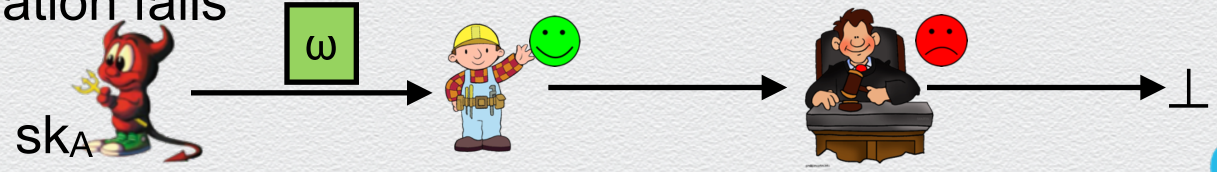


  - **Extractability**: An adversary can't create valid VES for which arbitration fails



A signature-based VES

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Sign

T(m,⊥,⊥,⊥)

VESign

T(m,apk,0,⊥)

Resolve

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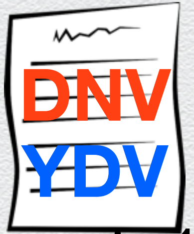
$T(m,\perp,\perp,\perp)$

VESign

$T(m,apk,0,\perp)$

Resolve



$T(m,apk,1,\omega)$

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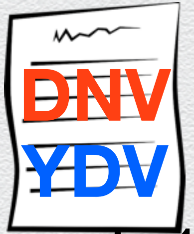

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- There are **two signatures**, and Verify checks for both

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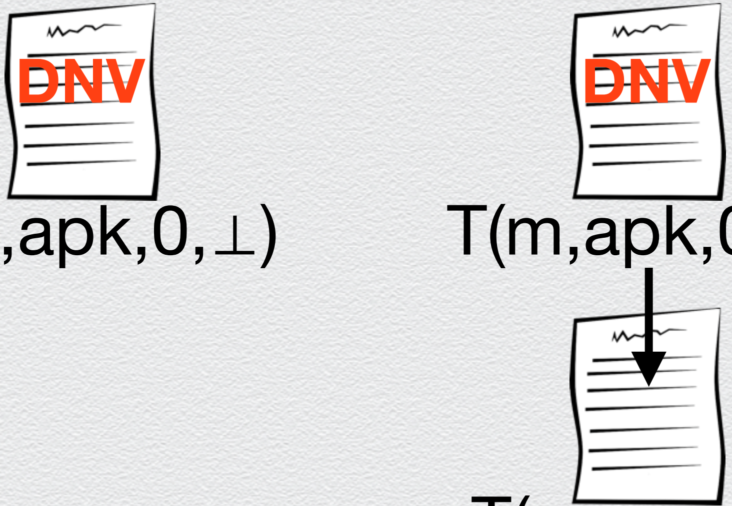

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Security of signature-based construction

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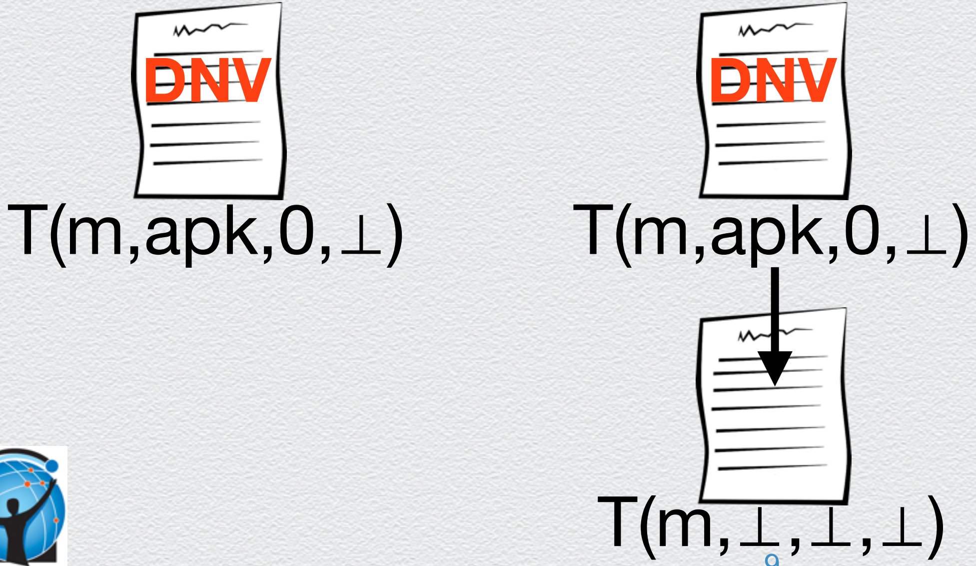

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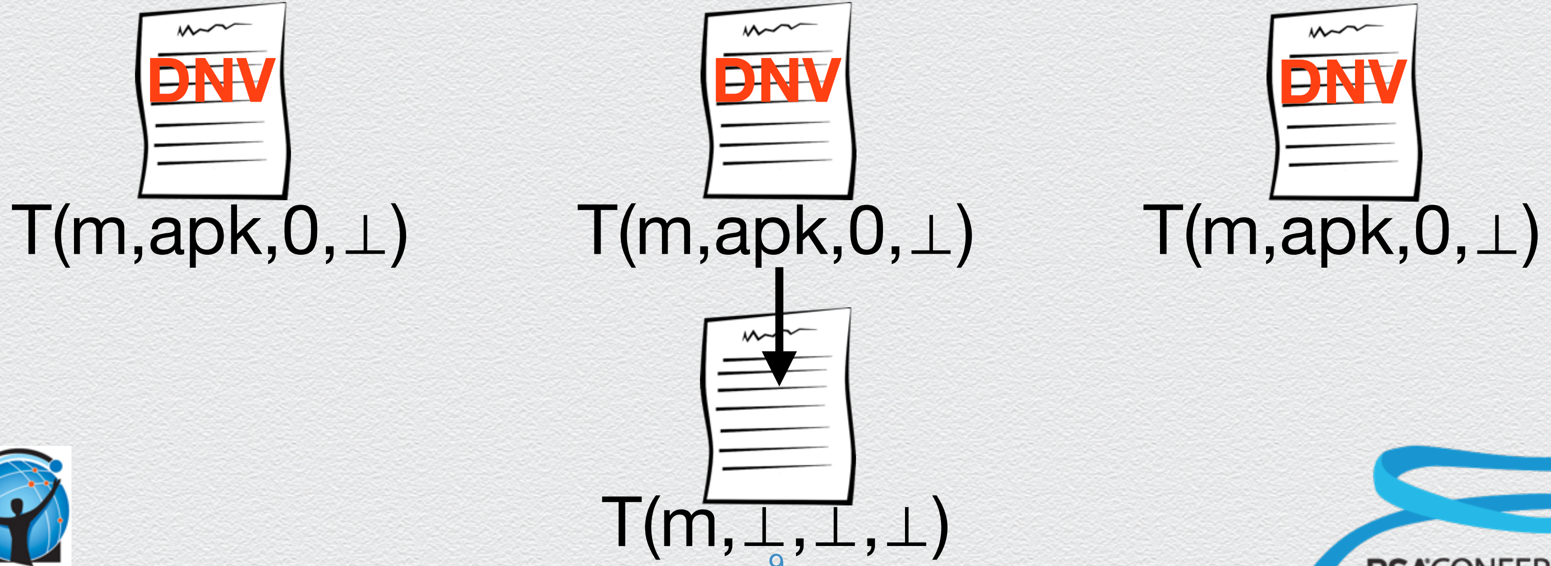

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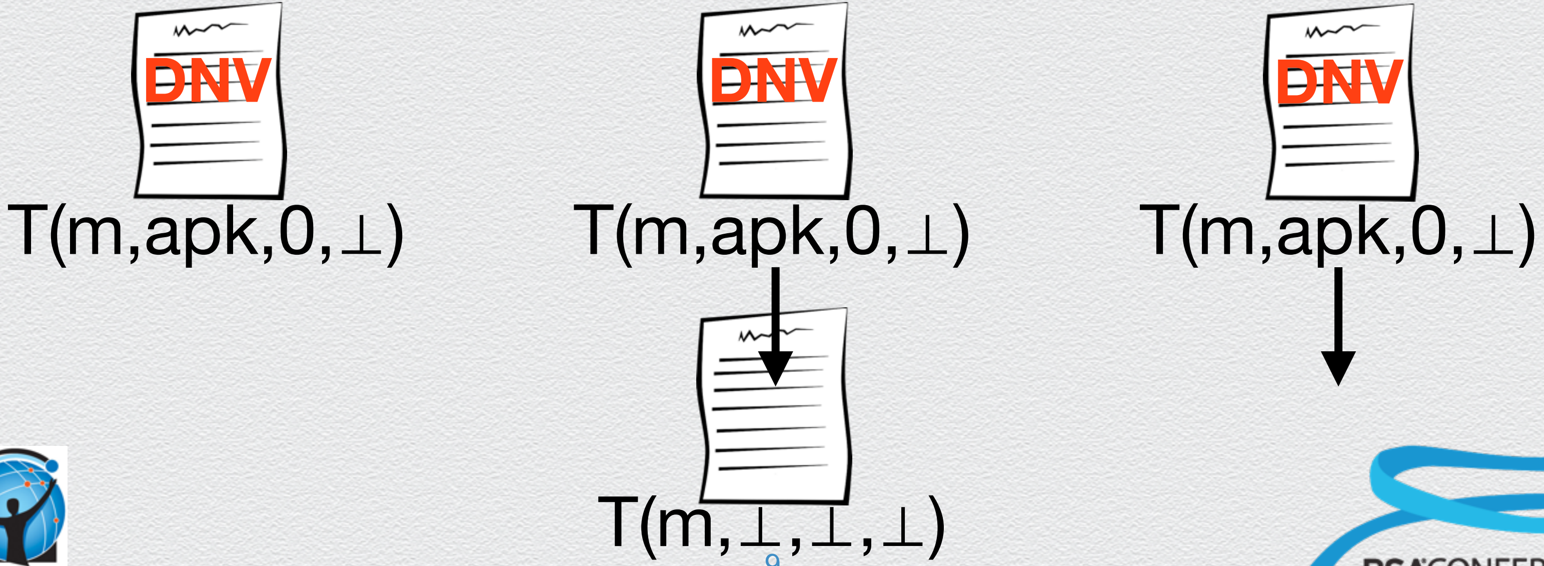

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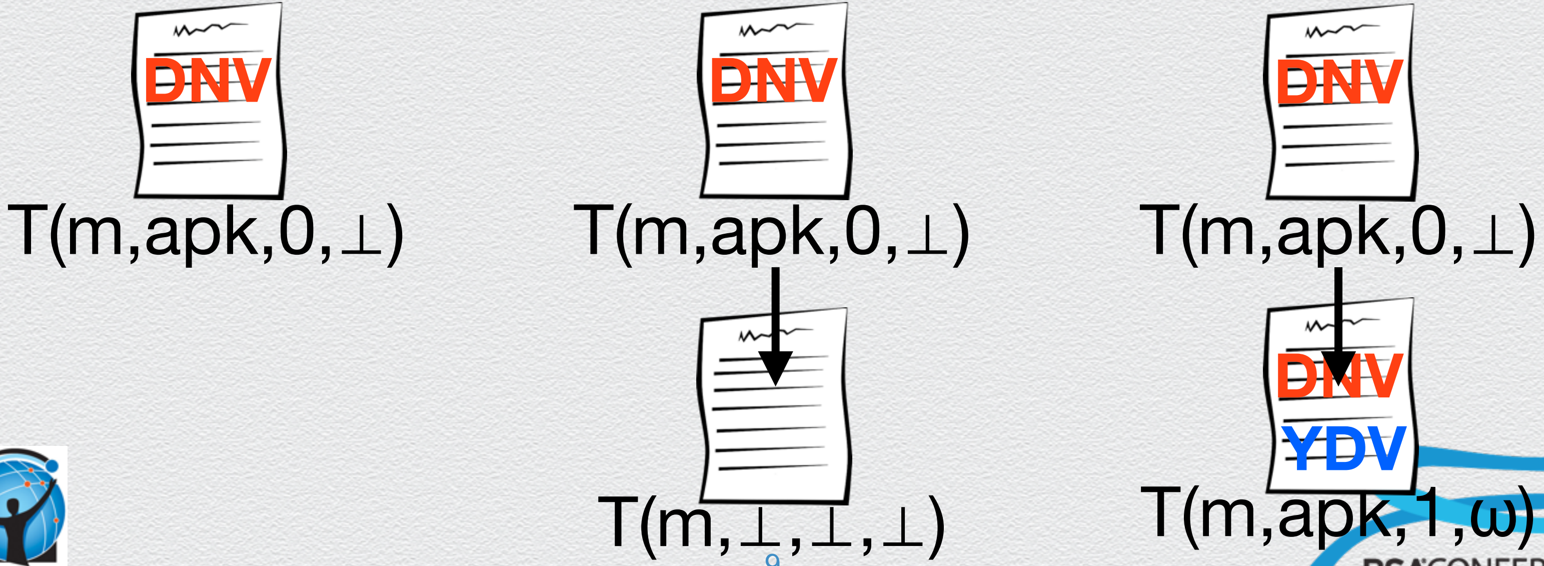

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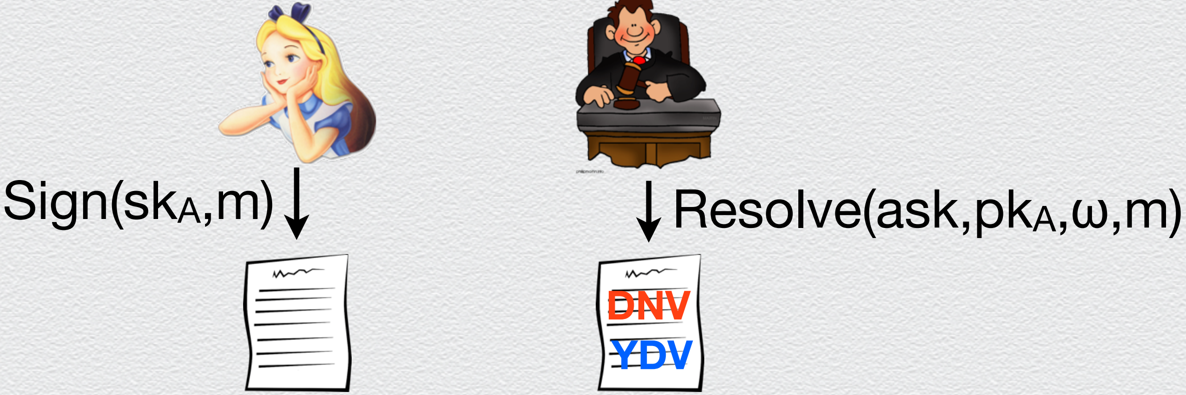

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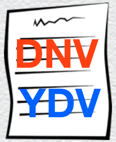
Sign(sk_A,m) ↓

↓ Resolve(ask,pk_A,ω,m)



- **Resolution independence**: the distributions {Sign(sk,m)} and {Resolve(ask,pk,ω,m)} are identical

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Separating our construction from existing ones

- Signature construction is not resolution independent: **σ vs. (apk,ω,ω')**

- But it is satisfied by all existing VES constructions
  - [BGLS03] uses bilinear groups, BLS signatures, deterministic Resolve
  - [LOSSW05] uses bilinear groups, Waters signatures, randomized Resolve
  - [R09] uses RSA groups and signatures, deterministic Resolve

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Resolution duplication

- Verifiably **encrypted** signatures: encryption really must be happening
- Can form **ω** so that no one can extract **σ** from **ω** (by **opacity**), except the arbiter can extract **σ′** from the same distribution (by **resolution independence**)
- Not quite encryption: **σ′ might be different from σ**
- **Resolution duplication** requires: (1) resolution independence, (2) deterministic Resolve, and (3) that there exists an algorithm Extract such that Extract(sk,m,r) = Resolve(ask,pk,VESign(sk,apk,m;r),m)

Constructing PKE with resolution duplication

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- With resolution duplication, Alice can form ω := VESign(sk,apk,m;r) so that no one can pull out Sign(sk,m) from ω (by opacity), except the arbiter can pull out σ, and Alice can duplicate σ using Extract(sk,m,r)

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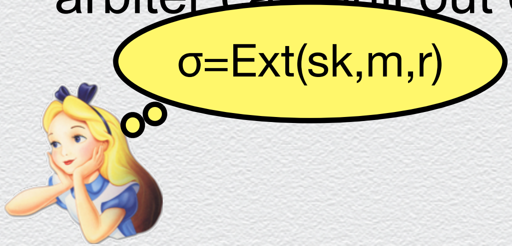

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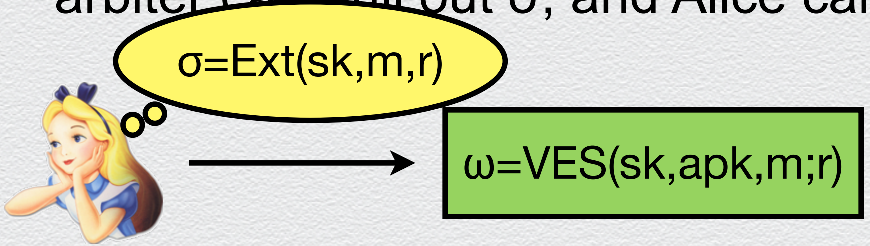

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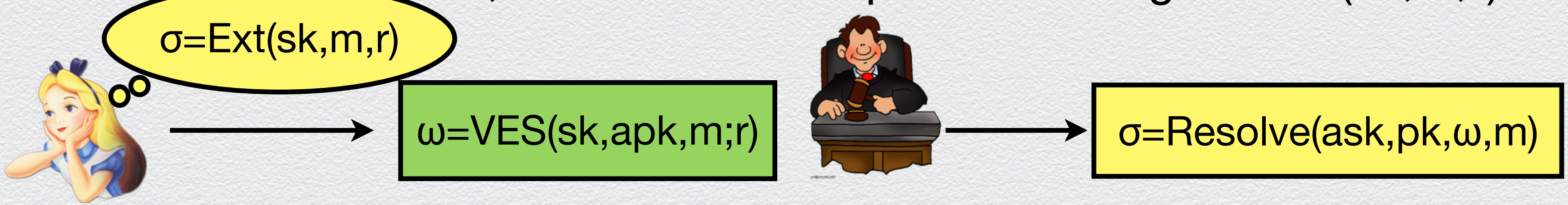

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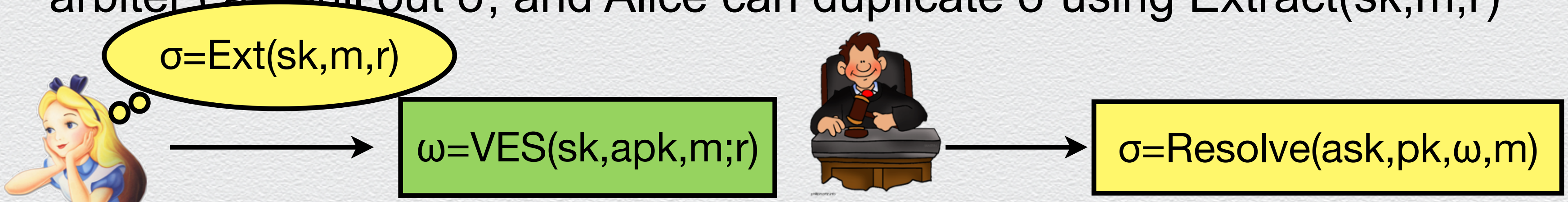
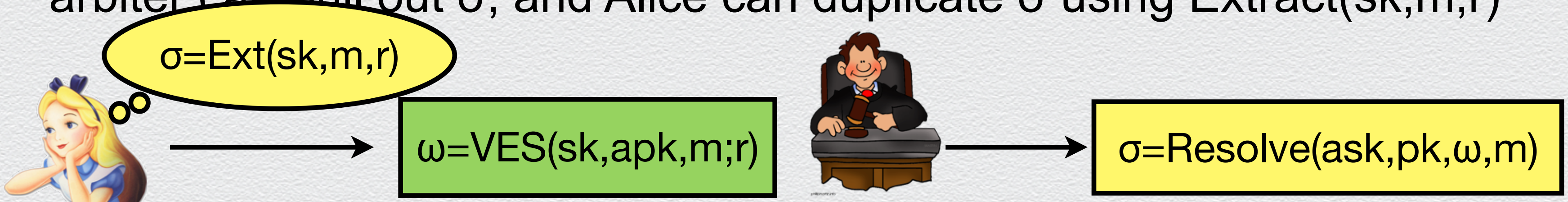


- This lets us “encrypt” signatures, but we want to encrypt arbitrary bits

Constructing PKE with resolution duplication

- With resolution duplication, Alice can form $\omega := \mathrm{VESign}(sk,apk,m;r)$ so that no one can pull out $\mathrm{Sign}(sk,m)$ from ω (by opacity), except the arbiter can pull out σ, and Alice can duplicate σ using $\mathrm{Extract}(sk,m,r)$



- This lets us “encrypt” signatures, but we want to encrypt arbitrary bits
- Adapt Goldreich-Levin trick [GL89]; show that it is hard to predict (compute) **$\langle\sigma,r\rangle = \sum \sigma_i \cdot r_i \bmod 2$** given just ω and r

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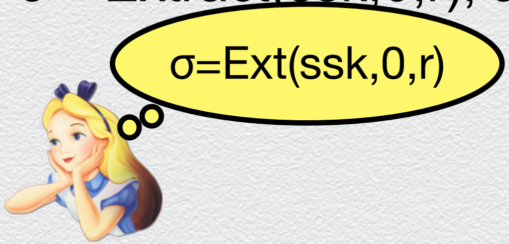

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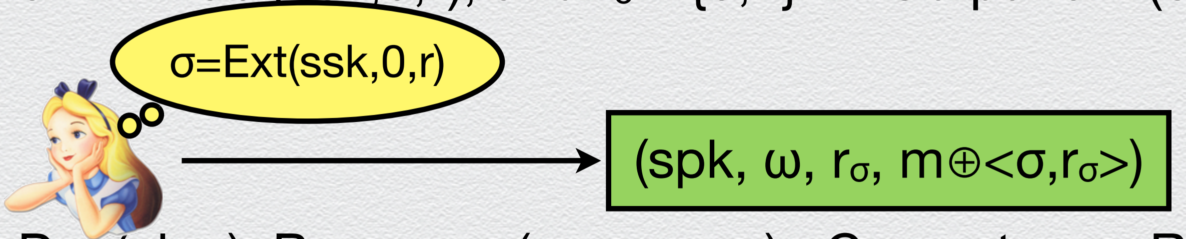

- Dec(sk,c): Parse $c = (c_1,c_2,c_3,c_4)$. Compute $\sigma = Resolve(sk,c_1,c_2,0)$ and output $c_4 \oplus \langle\sigma,c_3\rangle$

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The same by resolution duplication!

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- **IND-CPA security** follows fairly directly from opacity

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  - Provided a solely signature-based VES
  - Defined resolution independence to "separate" this construction from existing ones
  - Demonstrated how stronger resolution duplication could be used to construct public-key encryption
- Are VES just misnamed? Or would applications fail if encryption part were missing?