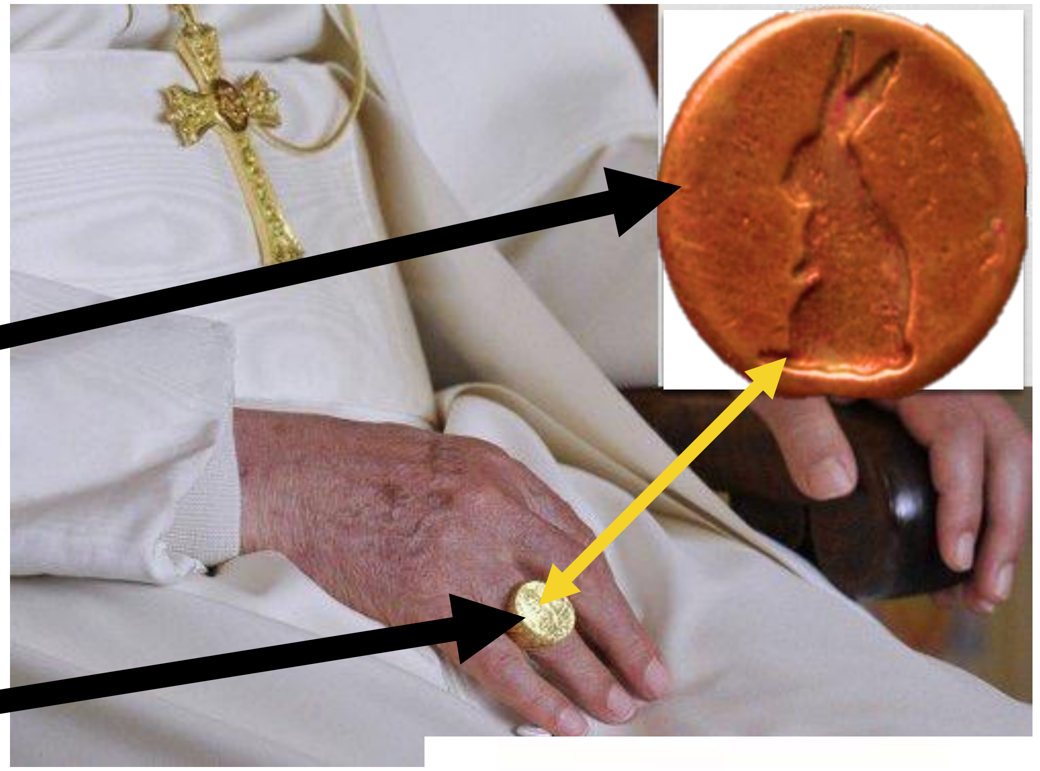
Digital Signatures

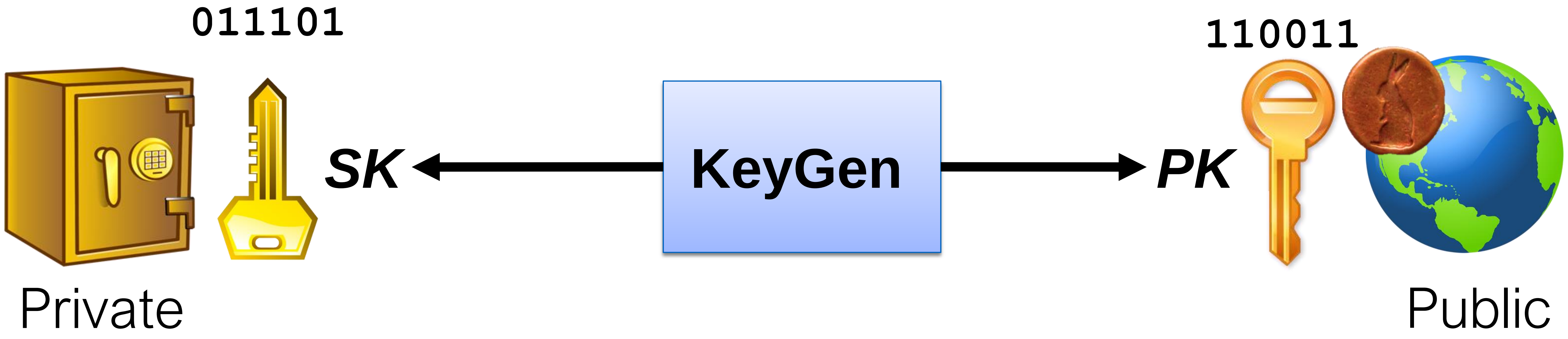
Thanks to Ari Juels for parts of this deck!

How digital signatures work: An analogy

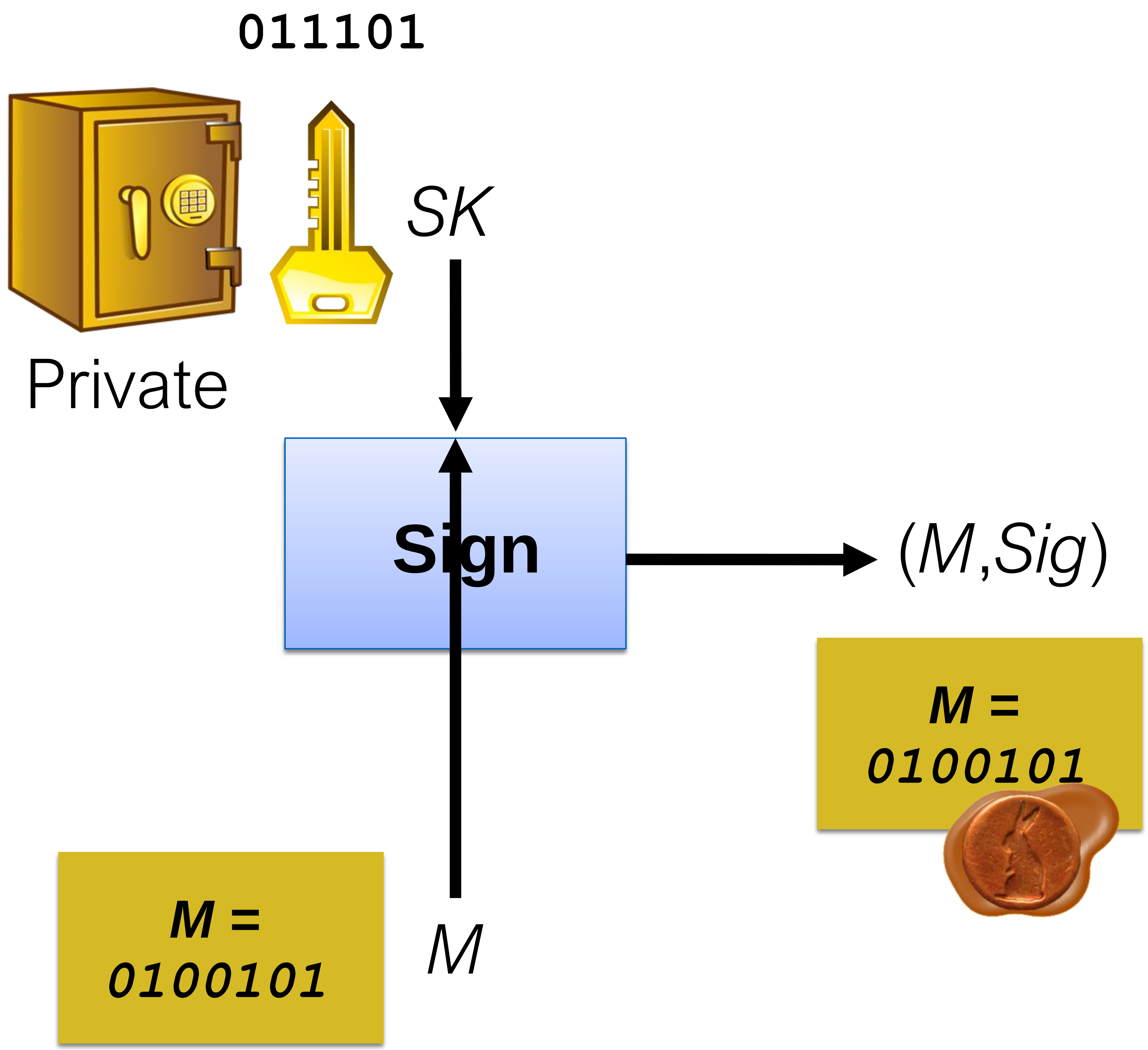
- Suppose you had an ***ideal*** signet ring, i.e.,
  - Everyone knows what your seal looks like
    - "Public key" ***PK***
  - But it can only be produced by someone with your ring
    - "Private key" ***SK***
- *Anyone* can verify authenticity of seal ***Sig*** on message ***M***, but *only* holder of rabbit ring can create one
  - Rabbit seal proves ring holder signed message



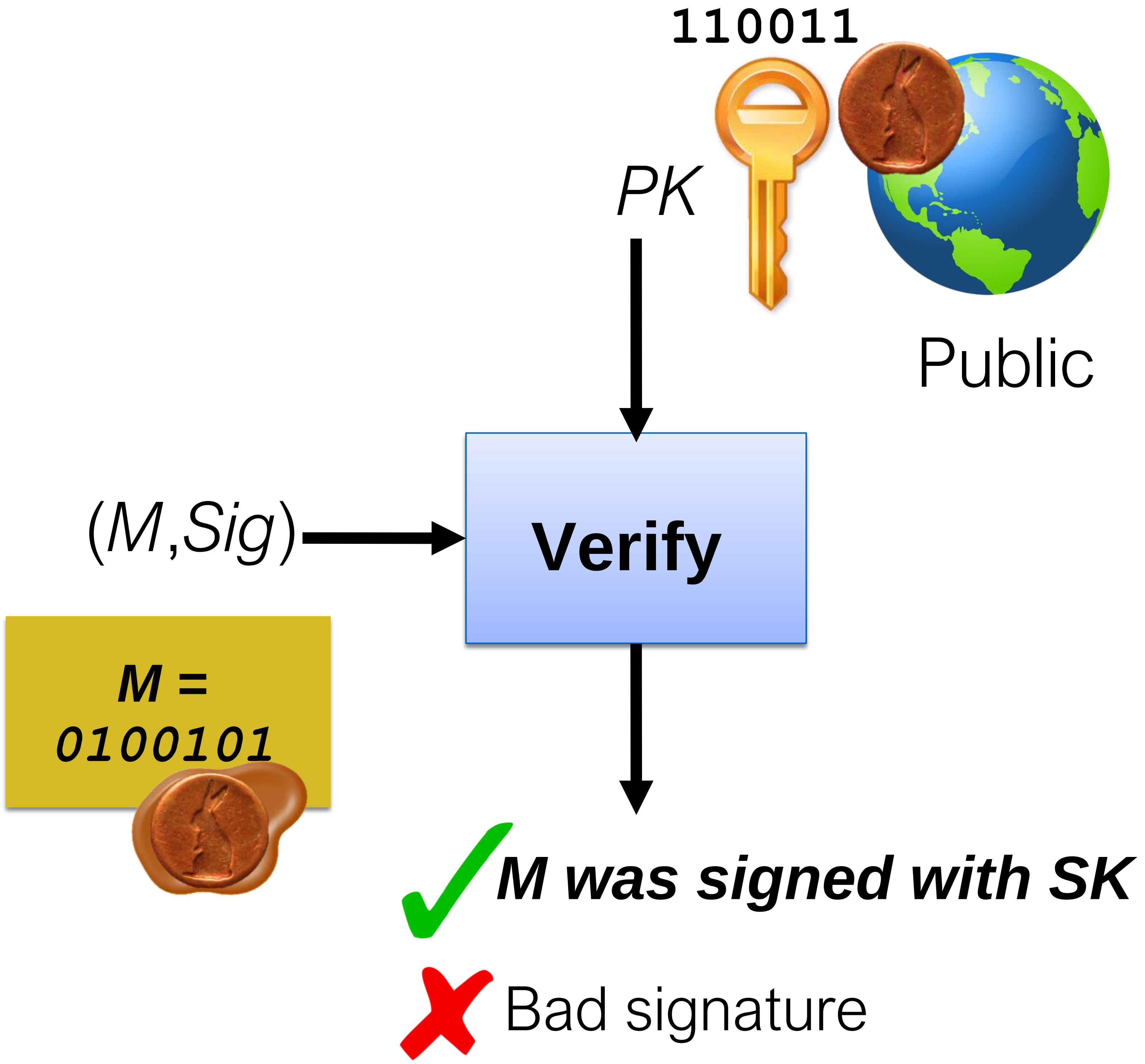
Digital signatures: Technical view



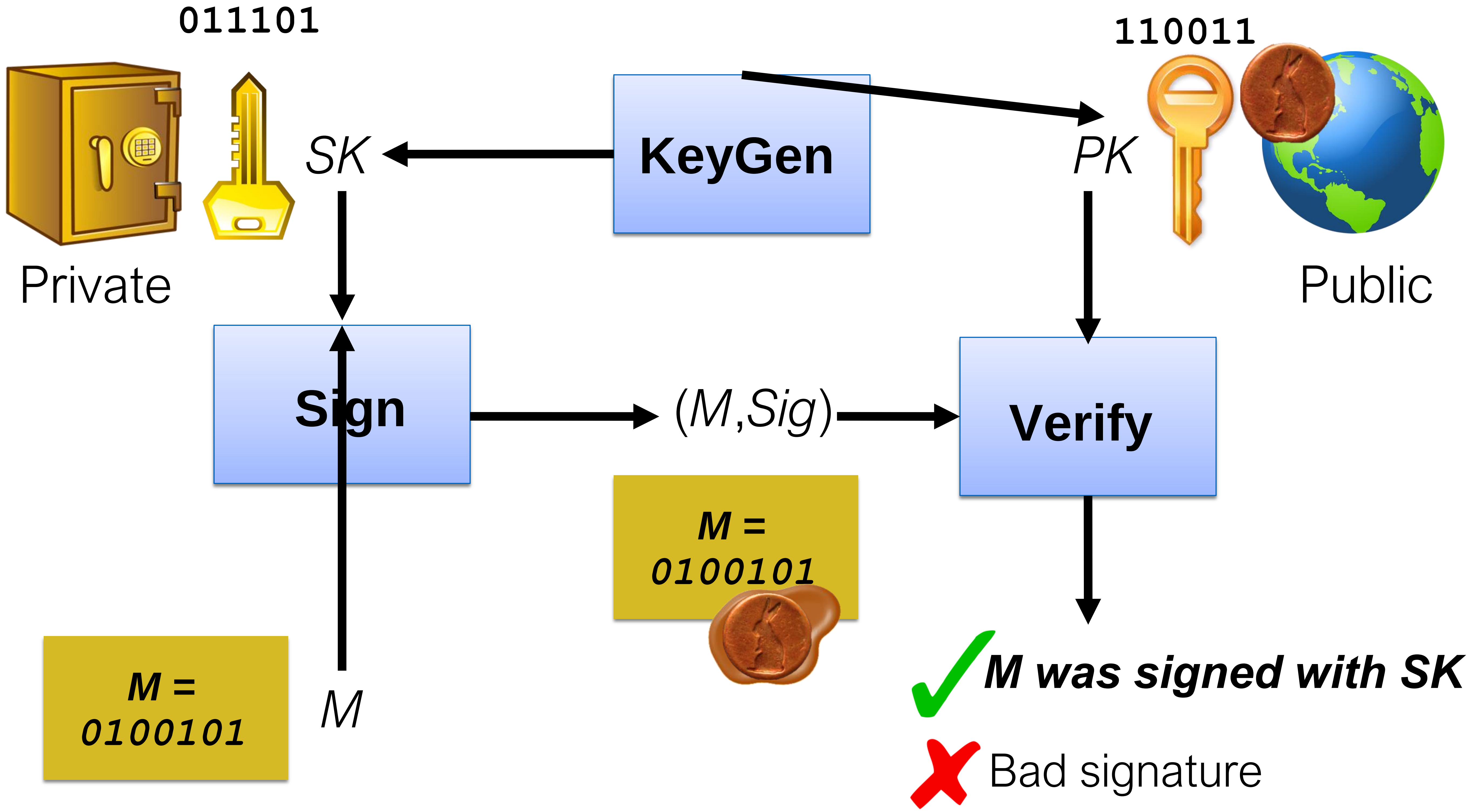
Digital signatures: Technical view



Digital signatures: Technical view

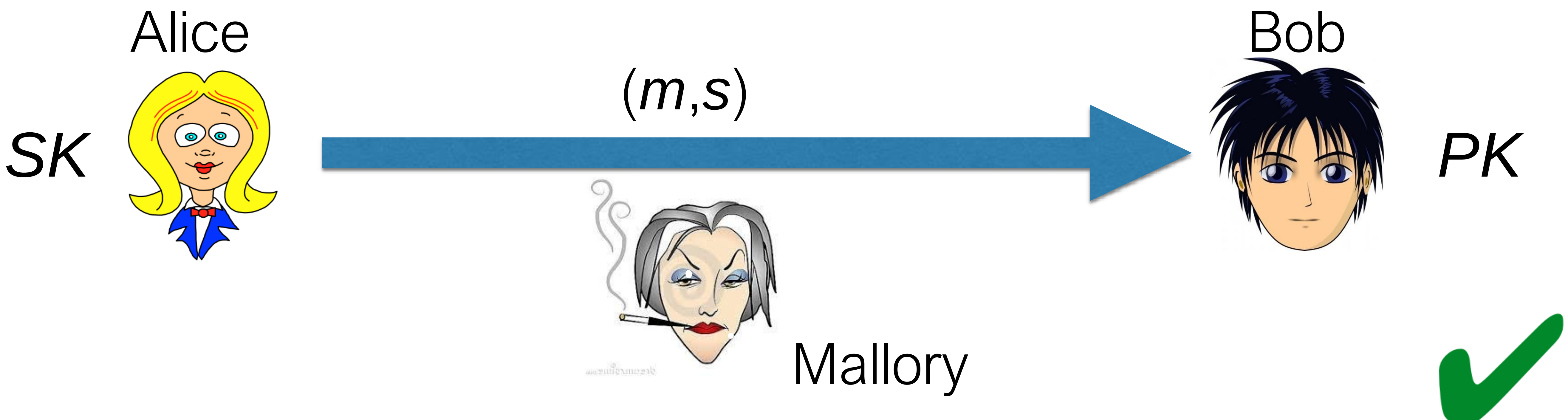


Digital signatures: Technical view

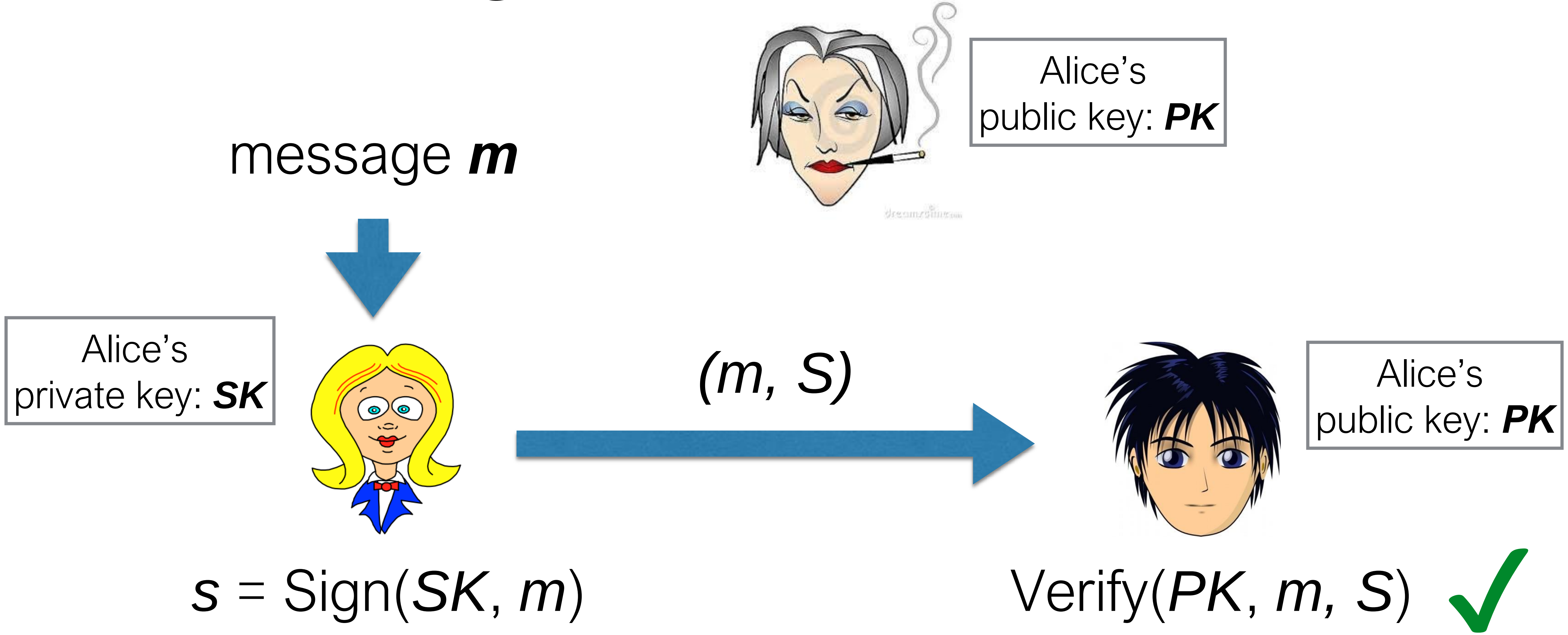


Digital signatures

- Use to achieve security goal of *message integrity* (prevent tampering)



What we want from digital signatures

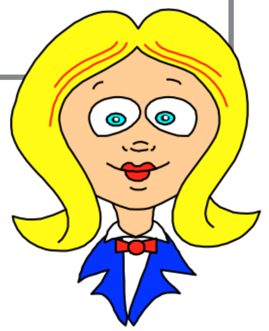


- Security property:
  - Should only be possible to sign using *SK, even though:*
  - Alice's public key *PK* is published, i.e., known to world;
  - Anyone can verify using *PK.*

Schnorr identification ("interactive signature") scheme

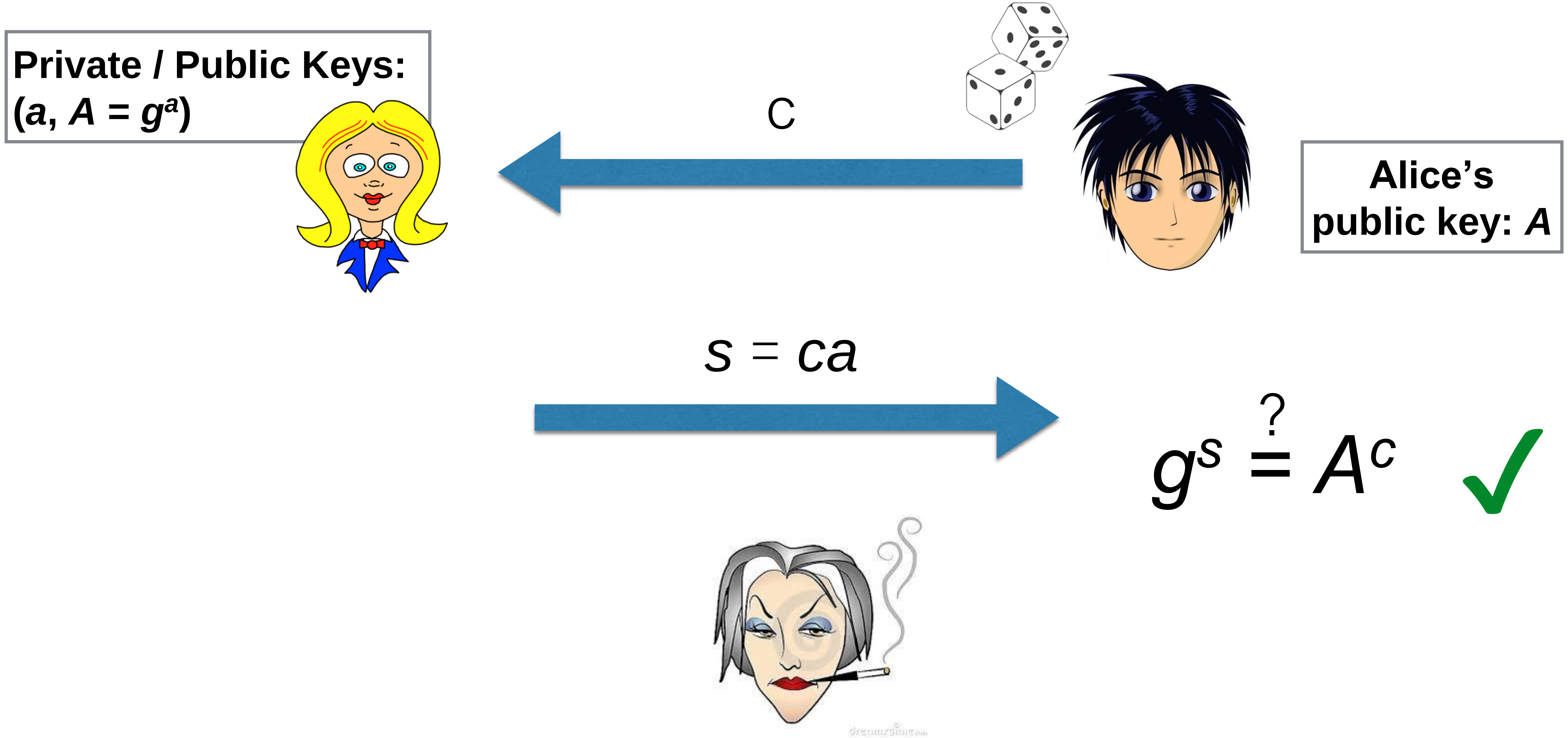
Goal: Alice identifies herself to Bob by proving knowledge of her private key.

Private / Public Keys:
(a, $A = g^a$)

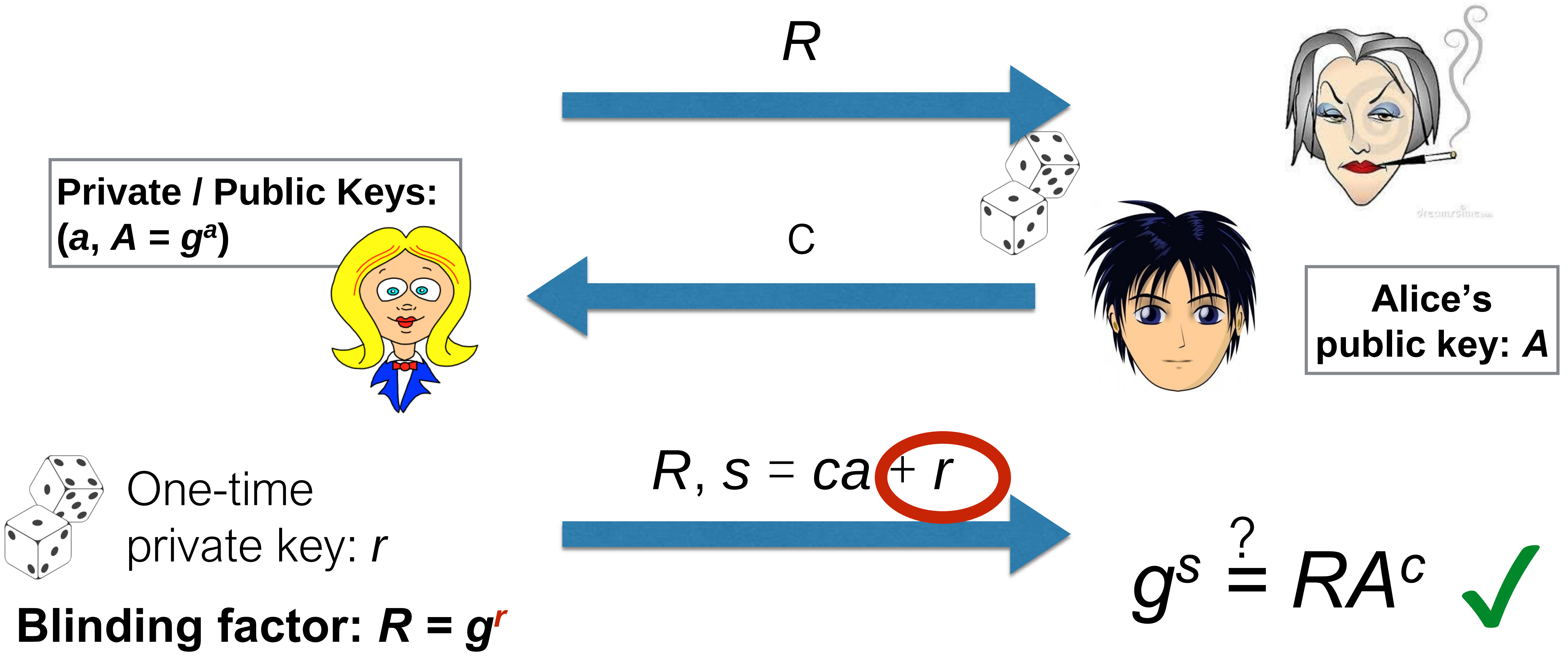


Alice's public key: A

First try


Private / Public Keys:
(a, $A = g^a$)
c
Alice's public key: A
$s = ca$
$g^s \stackrel{?}{=} A^c$ ✓

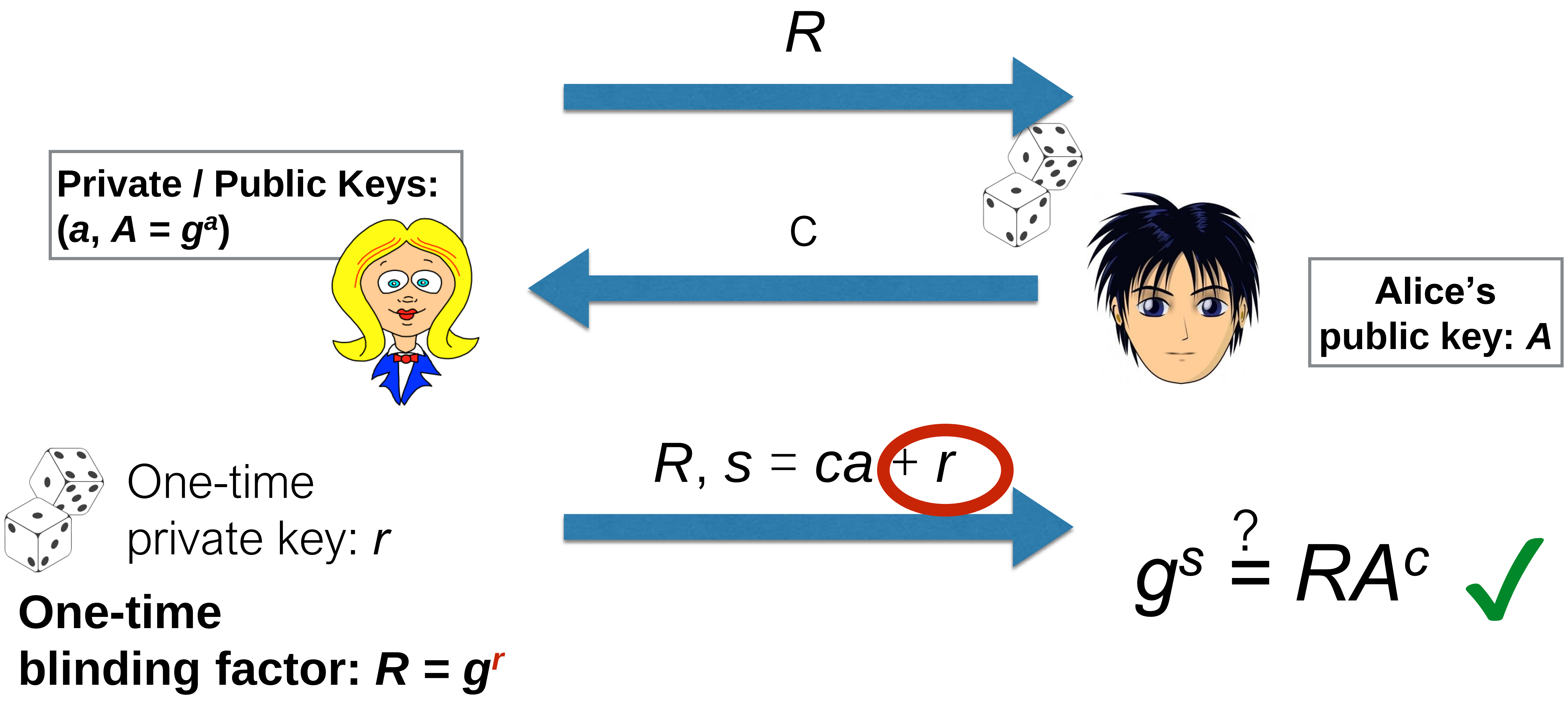
Better approach



Intuition:

- Bob can verify that ***a*** is properly "mixed in"—so it's really Alice.
- Alice removes ***a*** from exponent space—reveals it in *s*, but…
- *r* is a *one-time value* that *blinds*, i.e., conceals ***a***.

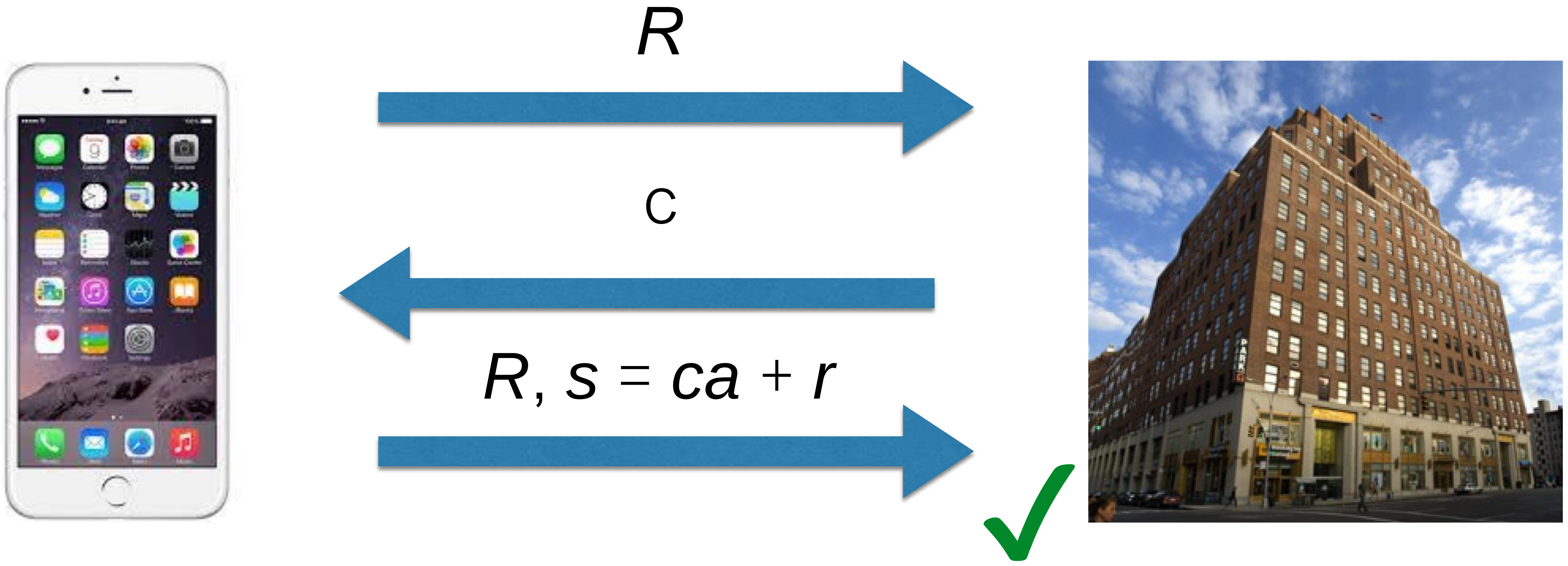
Why isn't this a signature scheme?



- Requires interaction
- Bob can't prove to another person that Alice "signed" c

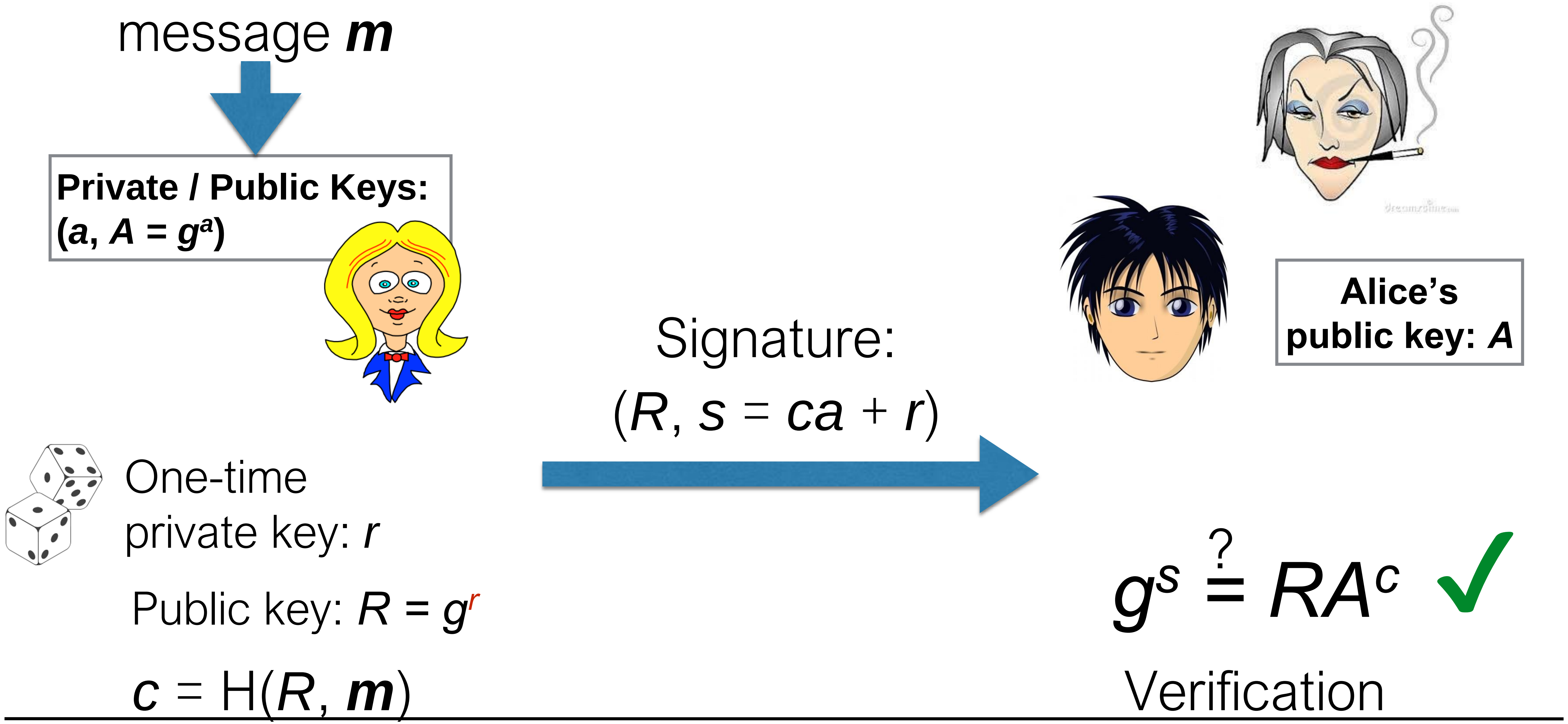
Where might you use an identification scheme?

Building badge



- What's the benefit of using public-key, rather than symmetric-key cryptography?
  - Why not use secret *K* shared by phone and building?

Schnorr signature scheme



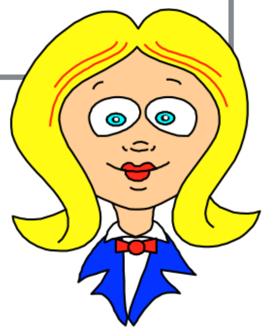
Intuition:

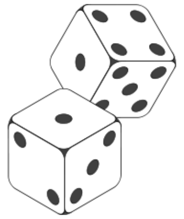
- Generate "challenge" c from m

Schnorr signature scheme

message $\boldsymbol{m}$

Private / Public Keys:
(a, $A = g^a$)





One-time
private key: r

Public key: $R = g^r$

$c = \text{H}(R, \boldsymbol{m})$

Signature:
$(R, s = ca + r)$

Alice's
public key: A

$g^s \stackrel{?}{=} RA^c$ ✓

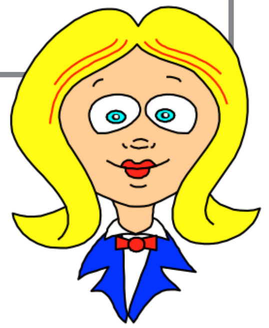
Verification

Very similar to
ECDSA ("Elliptic-Curve Digital Signature Algorithm"),
which is much more widely used

Schnorr signature scheme

message ***m***

Private / Public Keys:
(a, $A = g^a$)



One-time
private key: r

Public key: $R = g^r$

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Signature:
$(\mathrm{R}, s = ca + r)$

Alice's
public key: *A*

$g^s \stackrel{?}{=} RA^c$ ✓

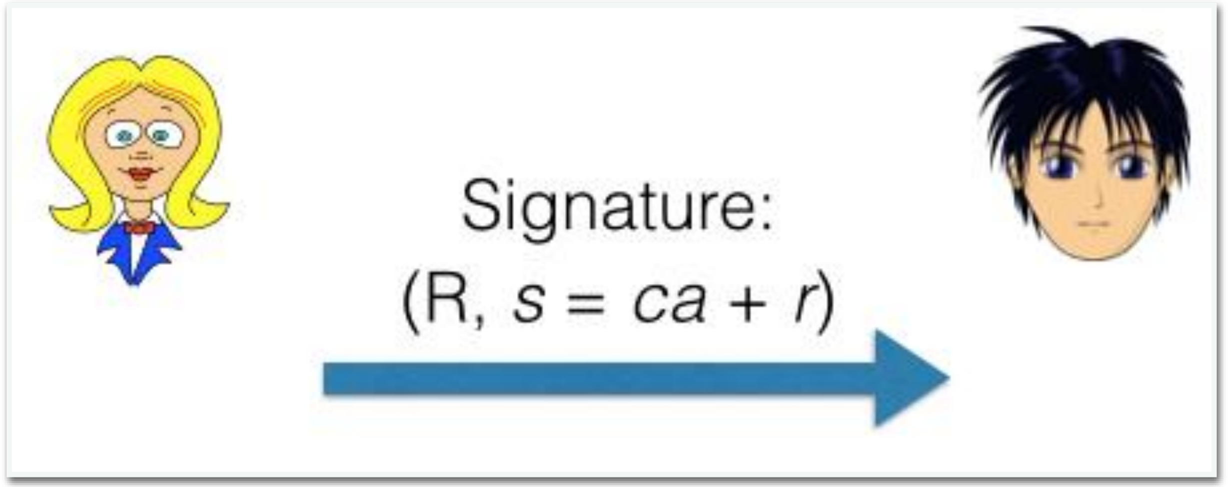
Verification

Does this really have to be one-time?

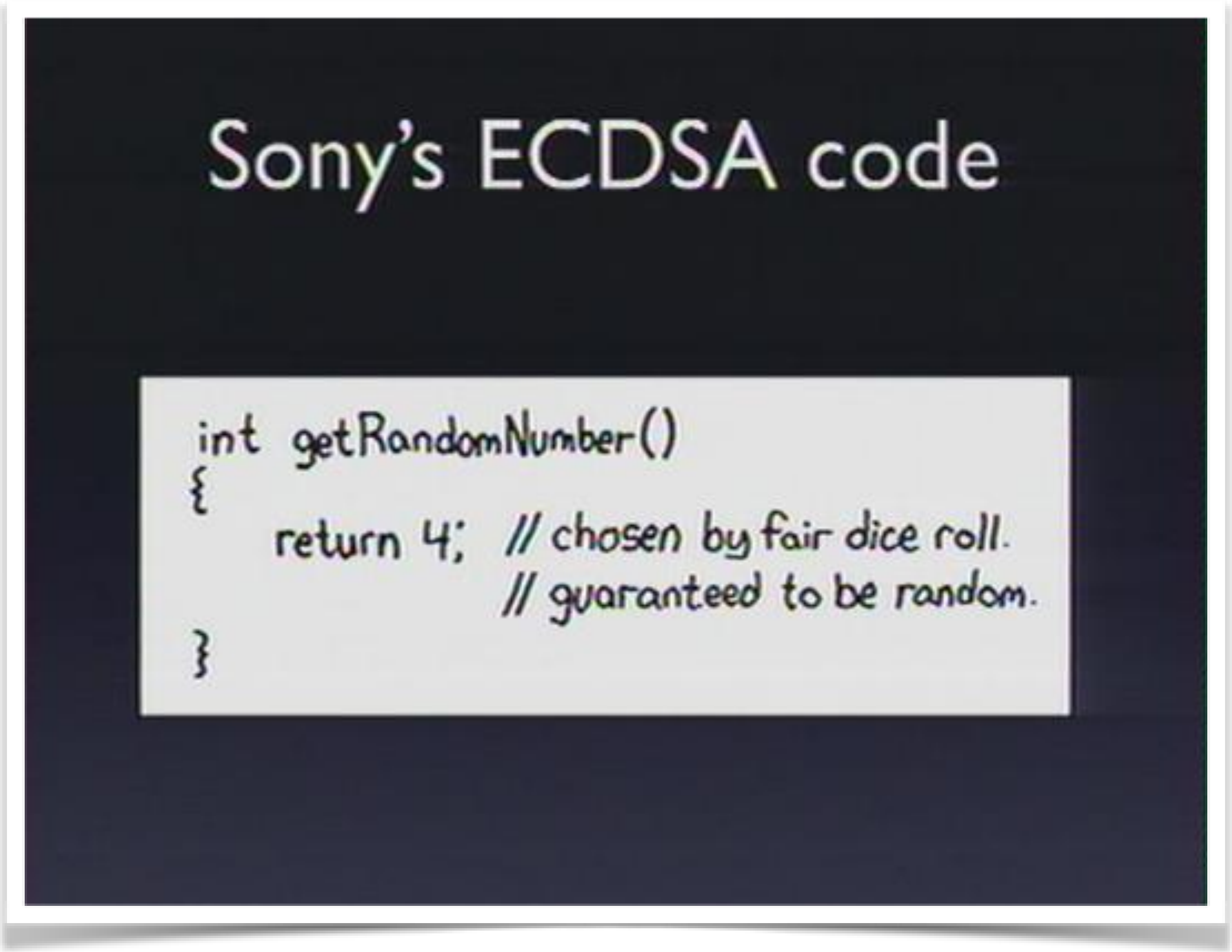
The Sony PS3 break

- PS3 used ECDSA for code signing
  - (Who's signing and who's verifying?)
  - Box *only* accepts code signed by Sony.
  - (Why is this better than use of secret key / MAC?)
- In late 2010, the crypto in the PS3 was broken
  - George "Geohot" Hotz and Fail0verflow team, Dec. 2010
- How did it happen?
- Sony used the same "one-time" *r* in *every* signature.

The Sony PS3 break



- Simplified version:
- George got two sigs.:
  - $s_1 = c_1 a + r$
  - $s_2 = c_2 a + r$
- $s_1 - s_2 = (c_1 - c_2) a$
- $a = (s_1 - s_2) / (c_1 - c_2)$
- Game over!



Literally!
(Perhaps minus comment)

Android Security Vulnerability

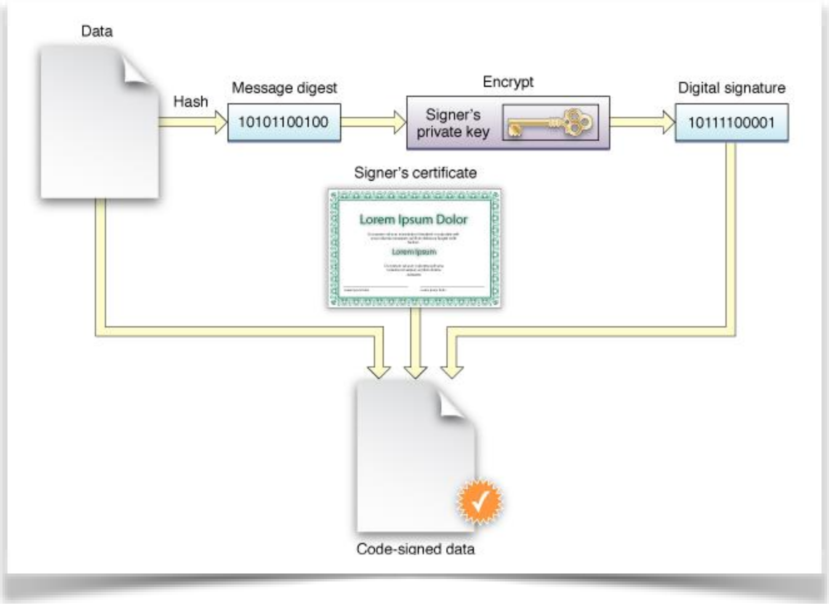
11 August 2013

What happened

We recently learned that a component of Android responsible for generating secure random numbers contains critical weaknesses, that render all Android wallets generated to date vulnerable to theft. Because the problem lies with Android itself, this problem will affect you if you have a wallet generated by any Android app. An incomplete list would be Bitcoin Wallet, blockchain.info wallet, BitcoinSpinner and Mycelium Wallet. Apps where you don't control the private keys at all are not affected. For example, exchange frontends like the Coinbase or Mt Gox apps are not impacted by this issue because the private keys are not generated on your Android phone.

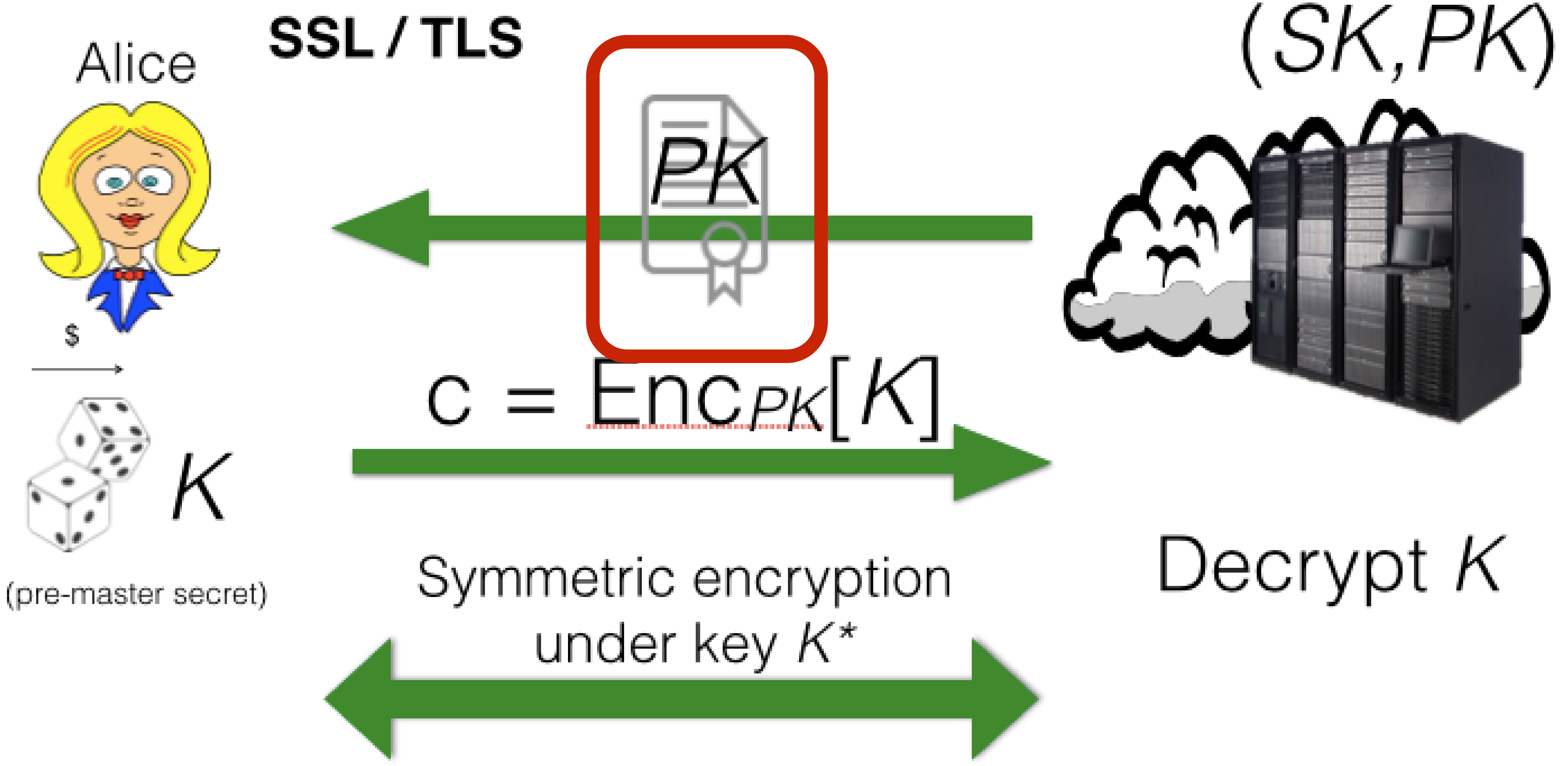
Where are digital signatures used?

- Code signing



- Bitcoin
  - Wallets / transaction signing (ECDSA)
- Authentication
  - E.g., EMV

Where are digital signatures used?



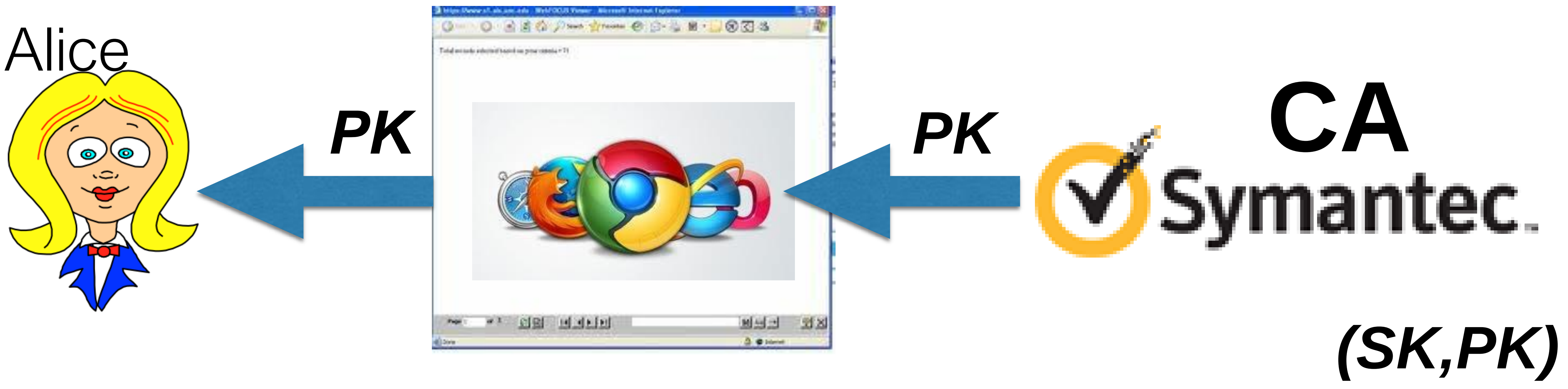
Comparison:
RSA sigs. vs. ECDSA

	RSA signatures	ECDSA
Pros	• Factoring hardness well studied • Widespread use • Fast verification	• Fast signing • Short signatures (448-bit) • Short keys (224-bit*) • Limited use: iMessage, Bitcoin, etc.
Cons	• Slow signing • Long signatures (2048-bit) • Long keys (2048-bit*)	• EC DL problem not well studied • Slower verification than RSA

*NIST recommended key length for years 2010-2030

Certificates authorities and public-key infrastructure (PKI)

- Idea: Certificates are signed by Certificate Authorities (CA)



Certificates authorities and public-key infrastructure (PKI)

- Certificate Authority (CA) issues certificates to owners of domain names

bigbank.com

(*pk*,*sk*)

Certificate please on *pk*?

Symantec

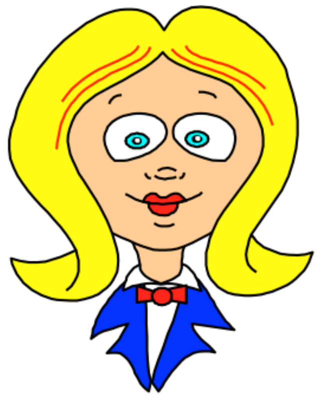
m = (*pk*, bigbank.com)

$\text{cert}_{BB} = \text{Sig}(\boldsymbol{PK}, m)$

Certificates authorities and public-key infrastructure (PKI)

- Certificate is verified by browser against CA key

Alice



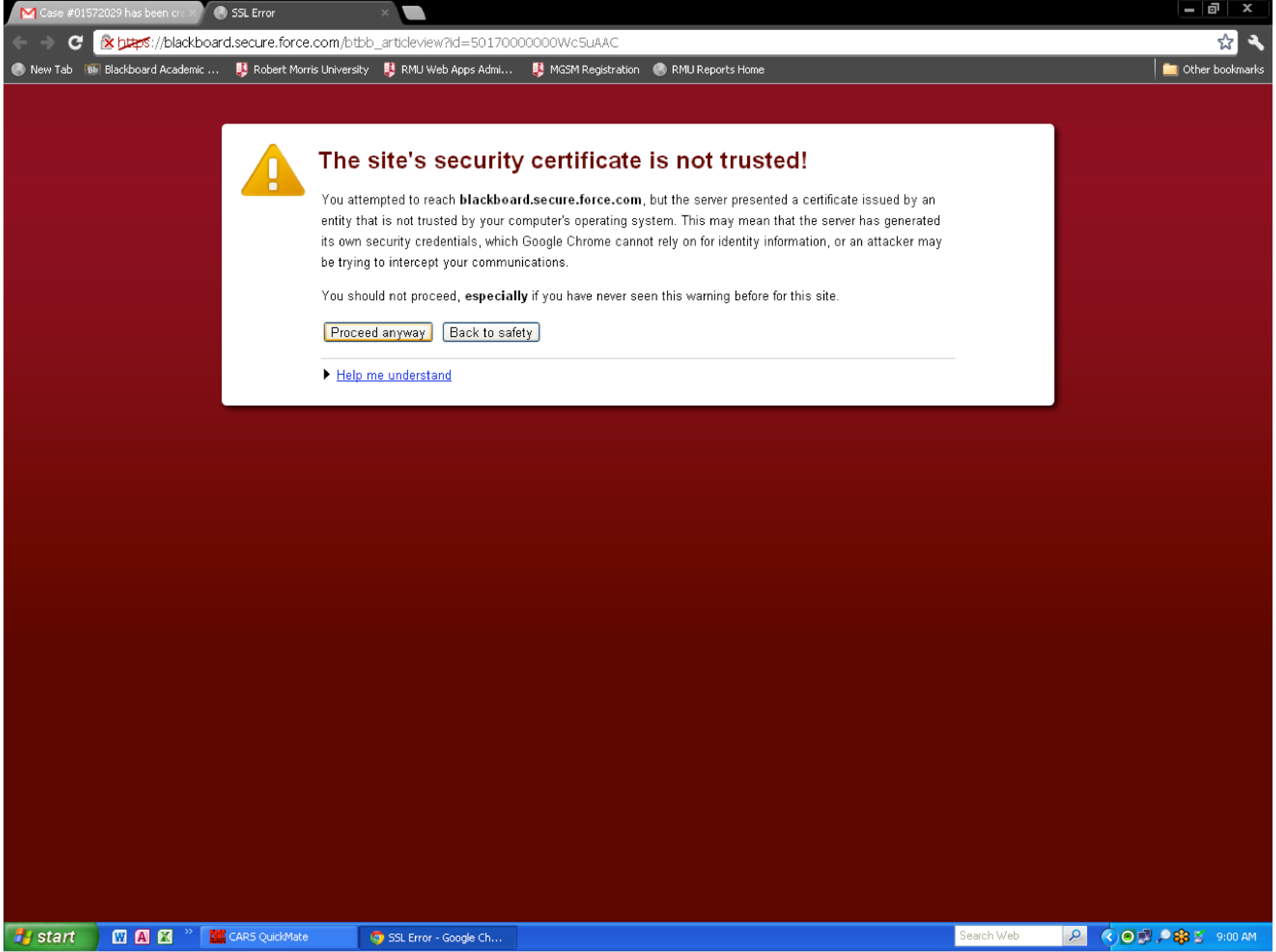
cert_{BB}, ***pk*** ←

bigbank.com

(*pk*,*sk*)

- cert_{BB} matches URL, ***pk*** ✔
- Ver(PK, cert_{BB}) ✔

Prevents man-in-the middle attacks


Case #01572029 has been cr
SSL Error
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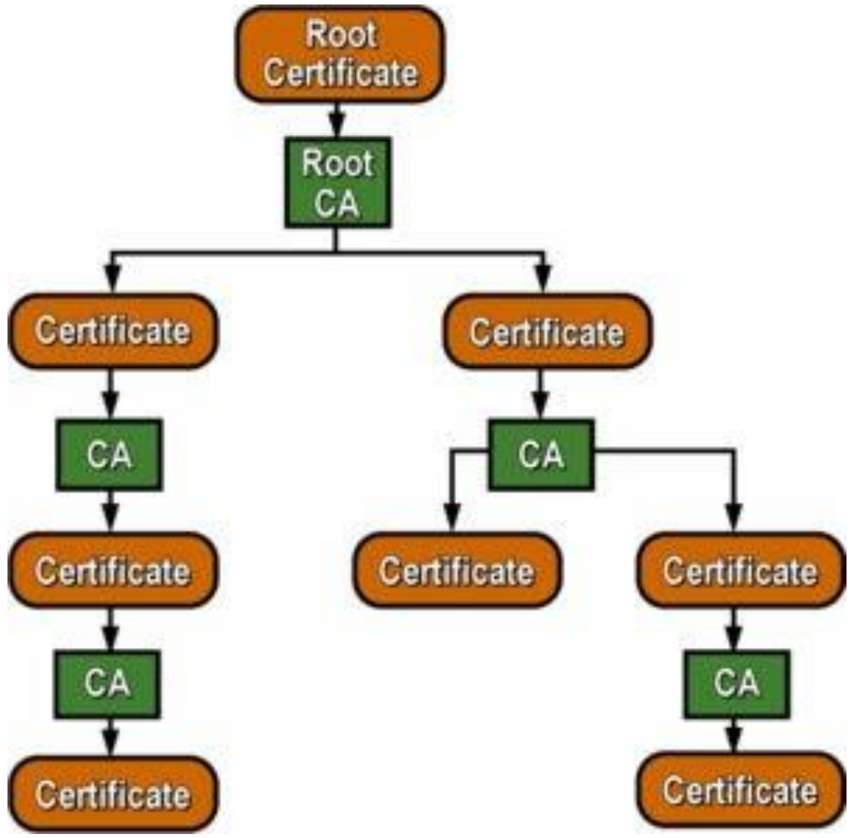
New Tab
Blackboard Academic ...
Robert Morris University
RMU Web Apps Admi...
MGSM Registration
RMU Reports Home
Other bookmarks
The site's security certificate is not trusted!
You attempted to reach blackboard.secure.force.com, but the server presented a certificate issued by an entity that is not trusted by your computer's operating system. This may mean that the server has generated its own security credentials, which Google Chrome cannot rely on for identity information, or an attacker may be trying to intercept your communications.
You should not proceed, especially if you have never seen this warning before for this site.
Proceed anyway
Back to safety
Help me understand
start
CARS QuickMate
SSL Error - Google Ch...
Search Web
9:00 AM

Certificate hierarchy



- 50+ root certificates in most major browsers
- 650+ CAs globally
    - EFF Observatory
- X.509 is predominant standard