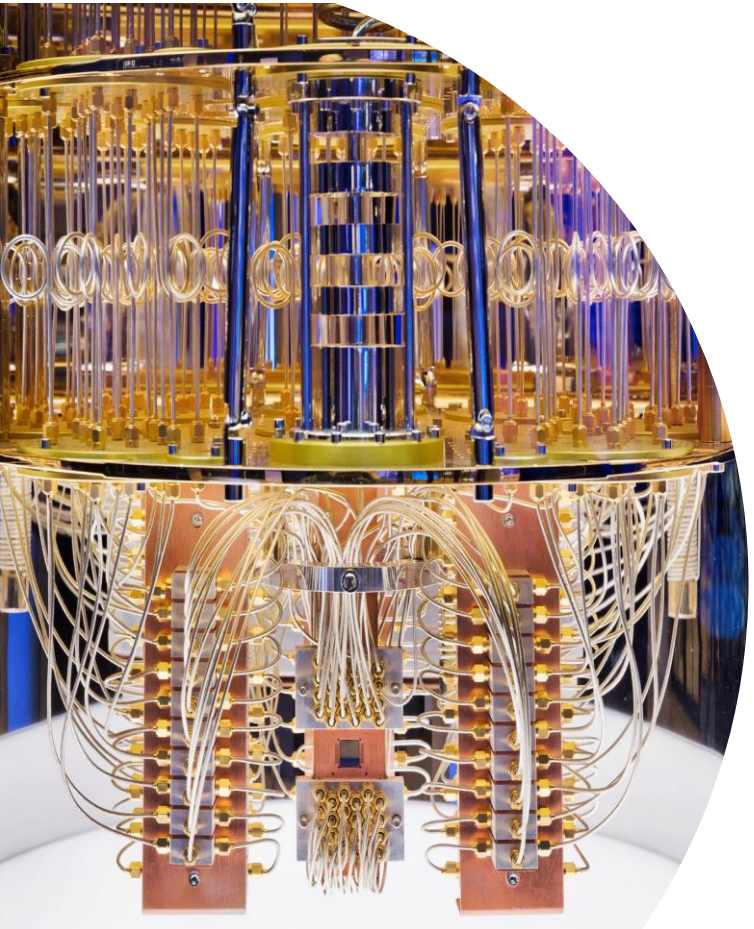
Post-quantum crypto: Countering future attacks that break today's messages

SNiC 2022

Kathrin Hövelmanns

November 30th, 2022

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY



How are these pictures related?

Brief history of communicating secrets

Scytale

Bodymod steganography
(Herodotus)

Caesar cipher

700 BC

440 BC

50 BC

Brief history of communicating secrets

Scytale

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(Herodotus)

Caesar cipher

‚Add 3‘ rule:

A	→	D
T		W
T		W
A		D
C		F
K		N

700 BC

440 BC

50 BC

Brief history of communicating secrets

Scytale

Bodymod steganography
(Herodotus)

Caesar cipher

Problem:

Techniques will never remain secret.

700 BC

440 BC

50 BC

Brief history of communicating secrets

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Bodymod steganography (Herodotus)

Caesar cipher

'It should not be a problem if [the system] falls into enemy hands.'

Kerckhoffs, 1883

700 BC

440 BC

50 BC

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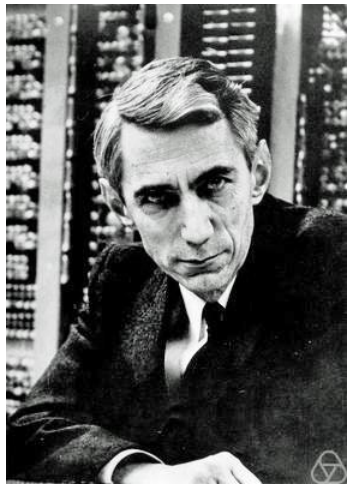
Caesar cipher

'The enemy knows the system.'



Shannon, 1949

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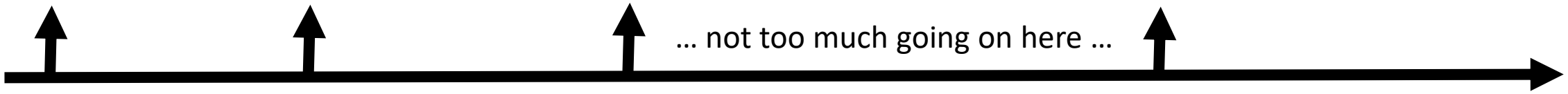
Vigenère



Brief history of communicating secrets

‚Caesar with codeword‘:

Codeword:
CRYPTO

A	A -> C	C
T	A -> R	K
T	A -> Y	R
A	A -> P	P
C	A -> T	V
K	A -> O	Y

Vigenère

… not too much going on here …

700 BC

440 BC

50 BC

1500 AD

Brief history of communicating secrets

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No codeword -> no secret

Vigenère

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Brief history of communicating secrets

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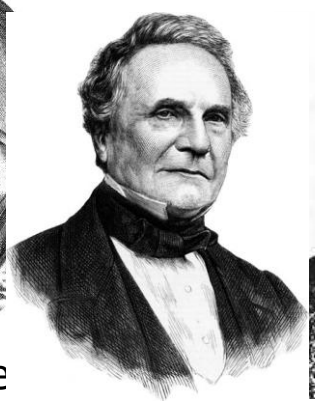
No codeword -> no secret

Actually… Statistics!

Vigenère



Babbage
1854

Kasiski
1863

… not too much going on here …

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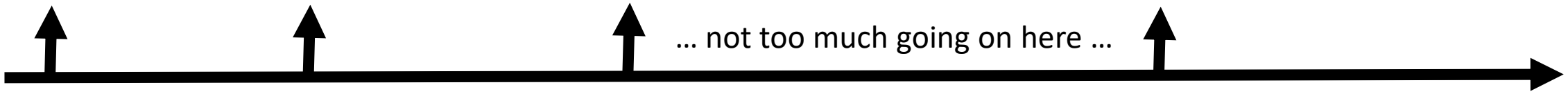

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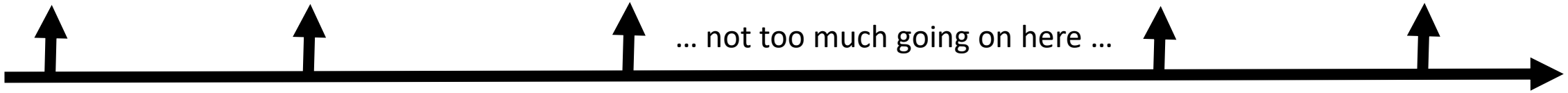
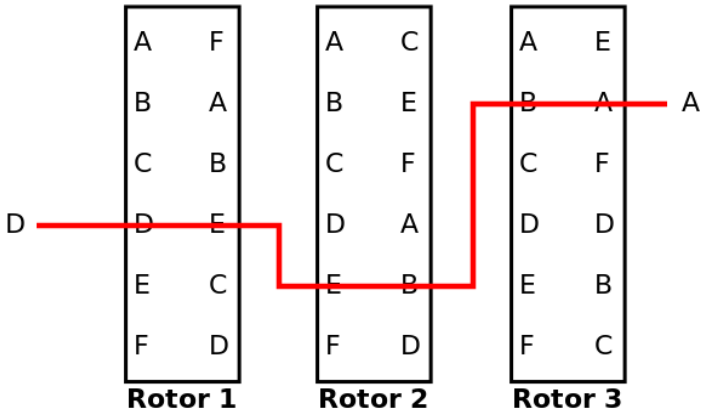
Enigma



Brief history of communicating secrets

Scrambling letters multiple times:



turning after each keystroke

Scyta

Vigenère

Enigma

… not too much going on here …

700 BC

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1930 AD

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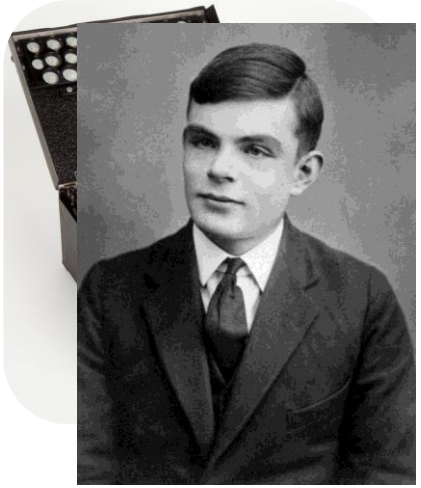

Turing broke Enigma

… not too much going on here …

700 BC

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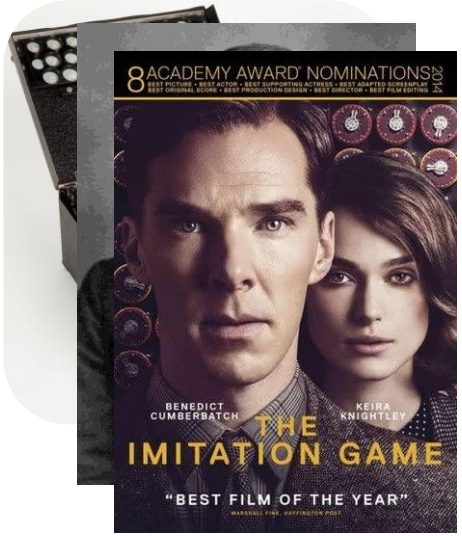

and got movie famous

700 BC

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… not too much going on here …

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Brief history of communicating secrets

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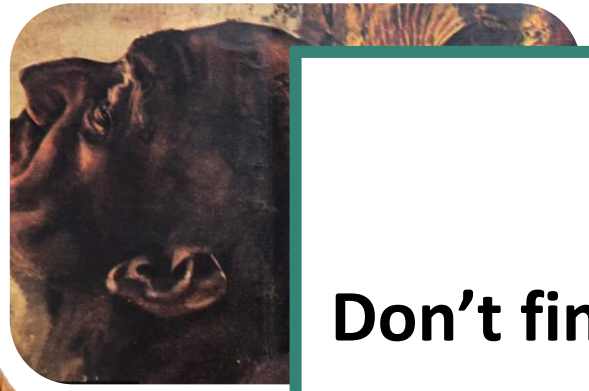

Bodymod st
(Hero

Problem 1:

Don’t find any attacks against your secret communication?

Doesn’t mean no one else does!

Caesar cipher

Vigenère

and got movie famous

… not too much going on here …

700 BC

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Brief history of communicating secrets

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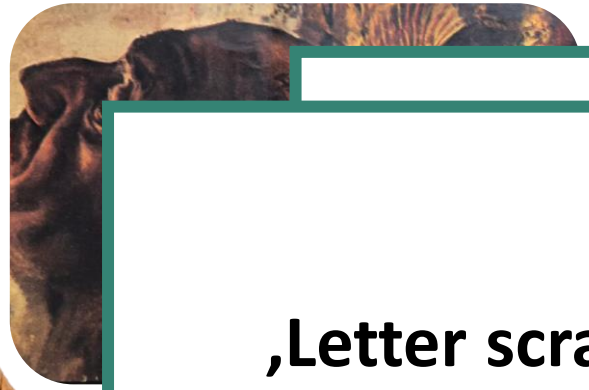


Bo

Problem 2:

‚Letter scrambling' needs a shared secret.

How to get it from A to B?

tion?

broke Vigenère cipher

famous

… not too much going on here …

700 BC

440 BC

50 BC

1500 AD

1930 AD

Brief history of communicating secrets

Enigma

Public-Key Crypto

Avoids pre-shared secrets!

1930

Late 1970s

Brief history of communicating secrets

Enigma

Public-Key Crypto

Merkle, Hellman, Diffie

Rivest, Shamir, Adleman

1930

Late 1970s

Brief history of communicating secrets

Enigma

Public-Key Crypto

Ellis, Cocks, Williamson

Merkle, Hellman, Diffie

Rivest, Shamir, Adleman

1930

1973

Late 1970s

Brief history of communicating secrets

Enigma

Public-Key Crypto

Ellis, Cocks, Williamson

(until 1997)

Merkle, Hellman, Diffie

Rivest, Shamir, Adleman

1930

1973

Late 1970s

Today, crypto is much more!

Why care?

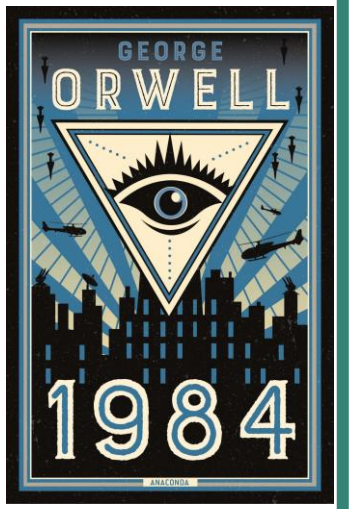
Why care?

Why care?

Miller attempts to rescue the Jeep after its brakes were remotely disabled, sending it into a ditch. ANDY GREENBERG/WIRED

Why care?

Got nothing to hide?



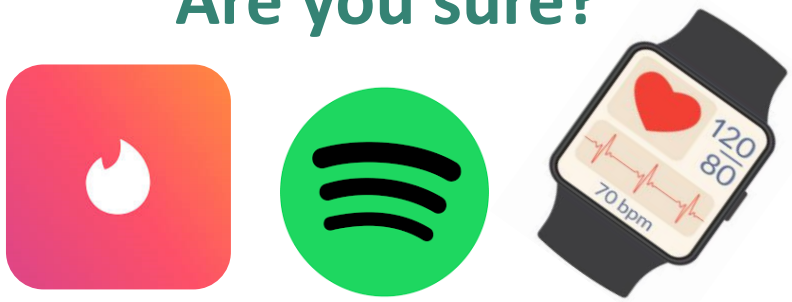
Why care?

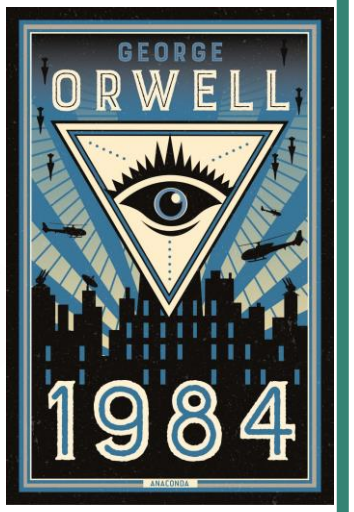

Got nothing to hide?
Are you sure?
120
80
70 bpm
GEORGE
ORWELL
1984

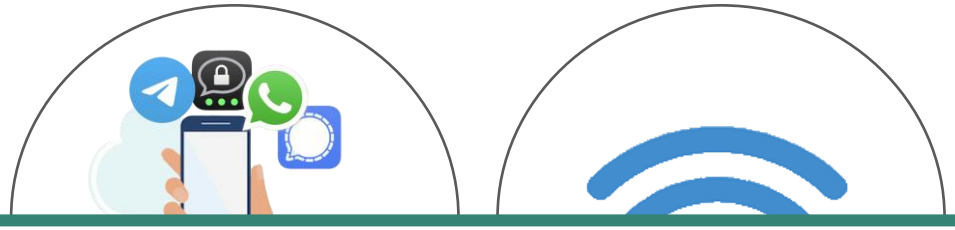
Why care?

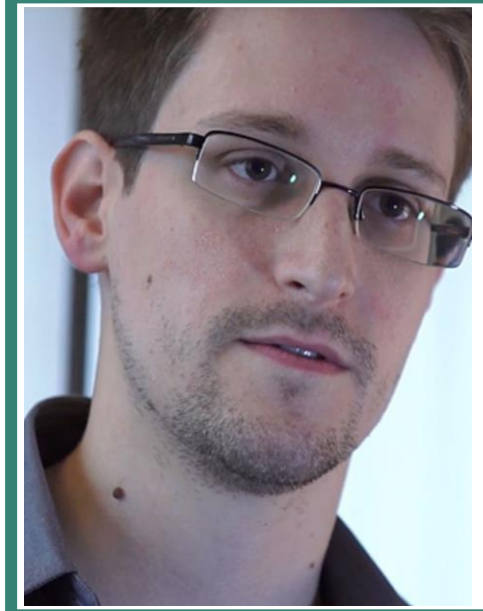
Got nothing to hide?

Are you sure?









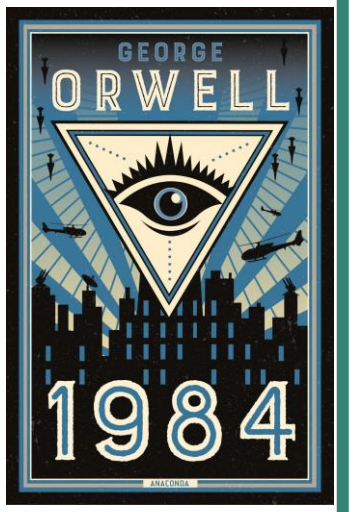
‘You simply have to eventually fall under suspicion […], even by a wrong call, and then they can use the system to go back in time and scrutinize every decision you’ve ever made, every friend you’ve ever discussed something with, and […] derive suspicion from an innocent life and paint anyone in the context of a wrongdoer.’

Edward Snowden

Why care?

Got nothing to hide?

What about others?



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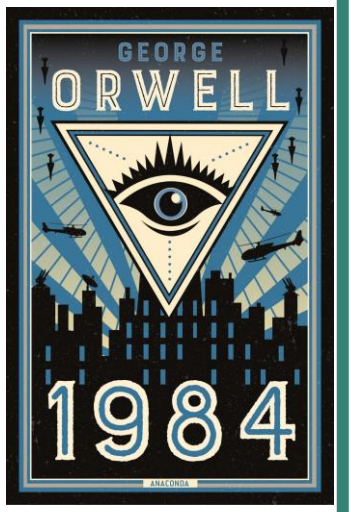

slate.com/technology/2022/09/russia-domestic-surveillance.html

Russia Wants Citizens to Like, Comment, Subscribe for More Surveillance

BY TAMARA EVDOKIMOVA SEPT 14, 2022 • 5:50 AM

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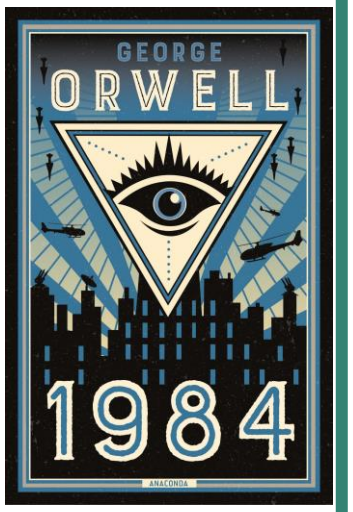

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Turkey Doubles Down on Violations of Digital Privacy and Free Expression

BY KATITZA RODRIGUEZ AND HILAL TEMEL | NOVEMBER 4, 2020

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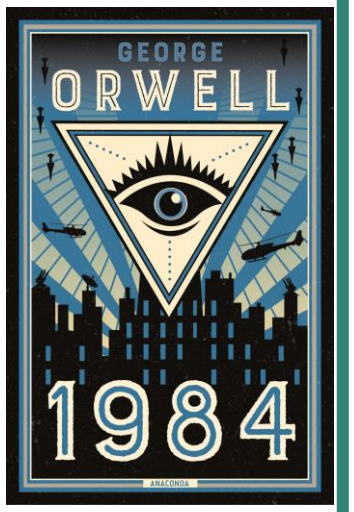

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Turkey
Expres

BY KATITZA ROD

https://www.nytimes.com/2022/06/21/world/asia/china-surveillance-investigation.html

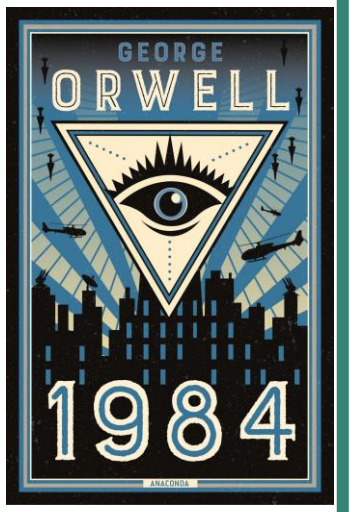
Four Takeaways From a Times Investigation Into China's Expanding Surveillance State

Times reporters spent over a year combing through government bidding documents that reveal the country's technological road map to ensure the longevity of its authoritarian rule.

Give this article 147

Why care?

Got nothing to hide?



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ELECT
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Turkey
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BY KATITZA ROD

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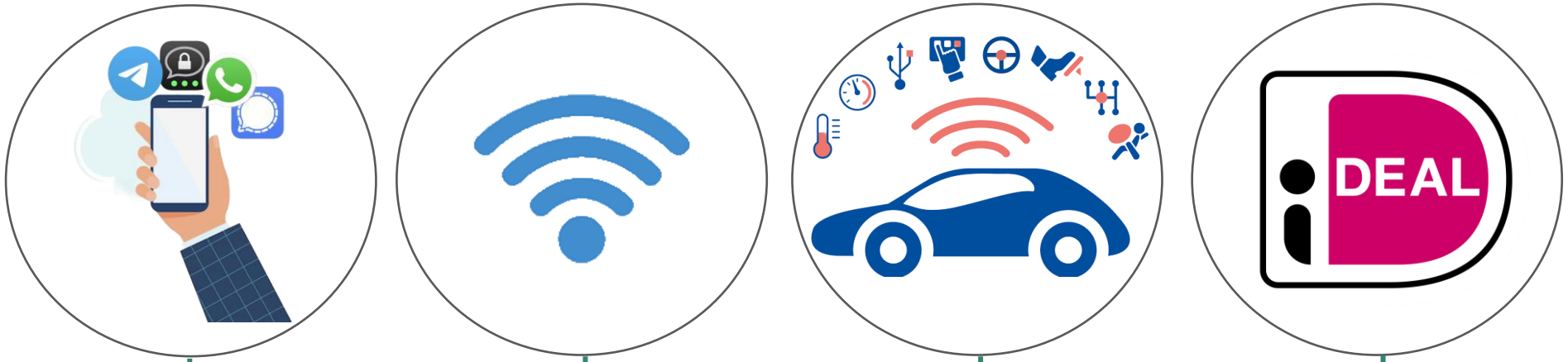
Online anonymity project:

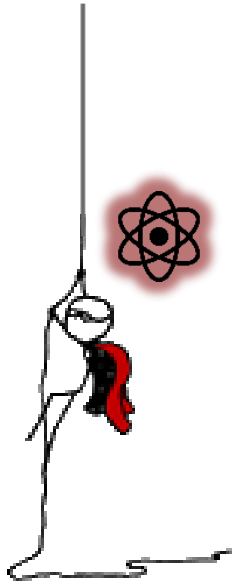
‚Quantum kills the internet‘

‚Quantum kills the internet‘



Uses public-key crypto (Rivest-Shamir-Adleman, Diffie-Hellman)

‚Quantum kills the internet‘



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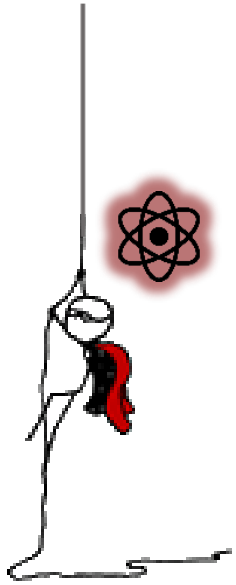
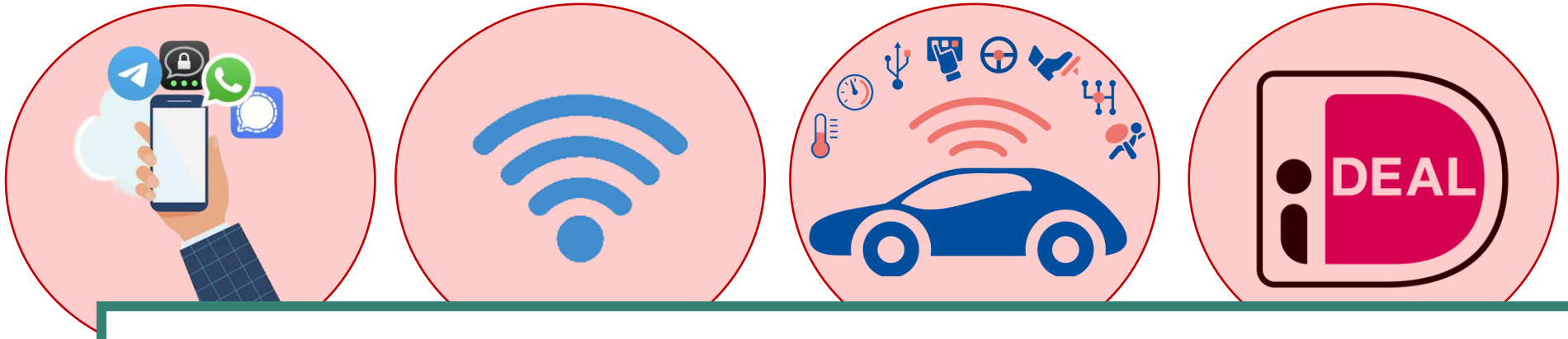




What exactly goes wrong?

Uses public-key crypto (Rivest-Shamir-Adleman, Diffie-Hellman)

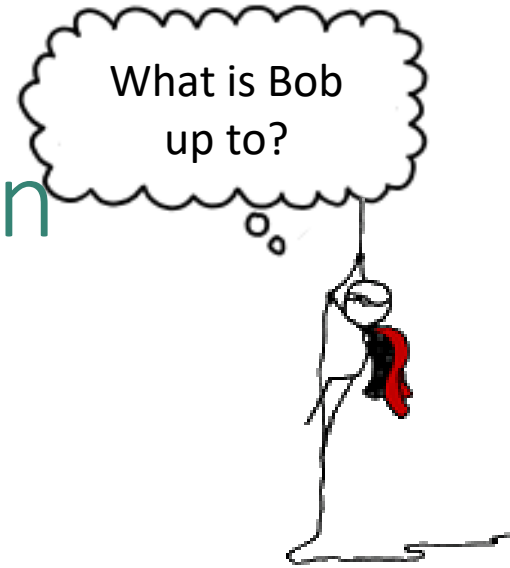
Rivest-Shamir-Adleman (RSA) encryption

Alice

Bob

Image source: xkcd.com

Rivest-Shamir-Adleman (RSA) encryption



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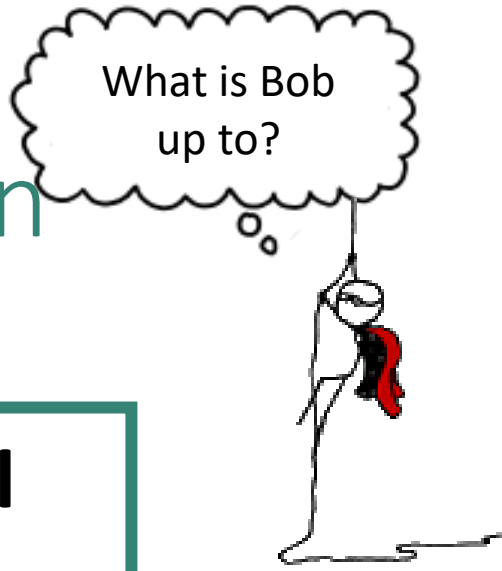

Alice

How can Alice safely tell Bob to sell over the internet?

Bob

Image source: xkcd.com

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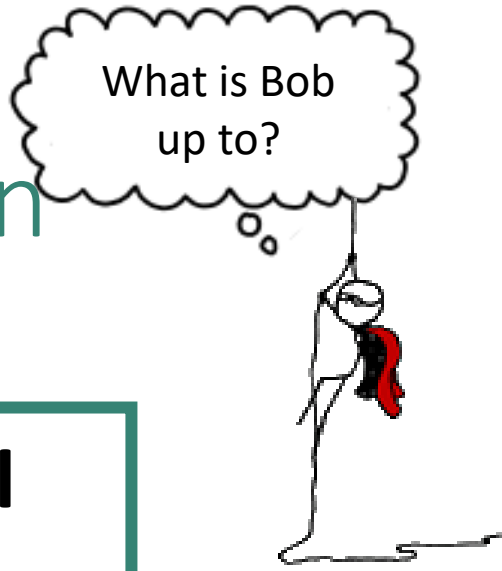

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Computations with primes!

Bob

Image source: xkcd.com

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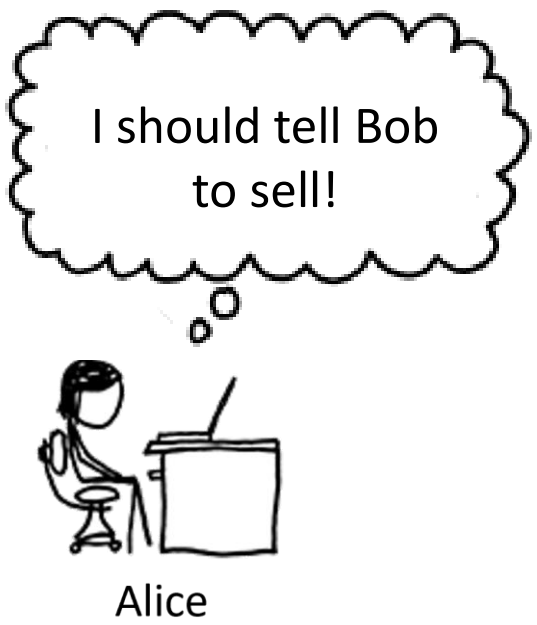

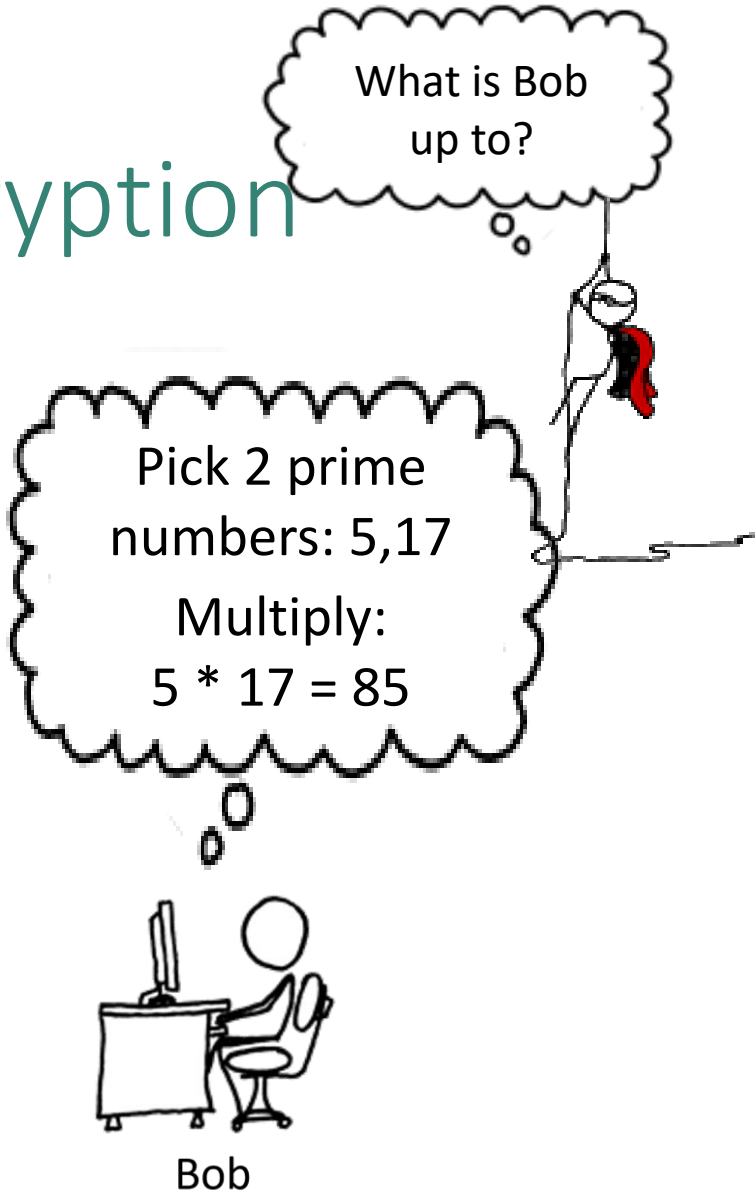

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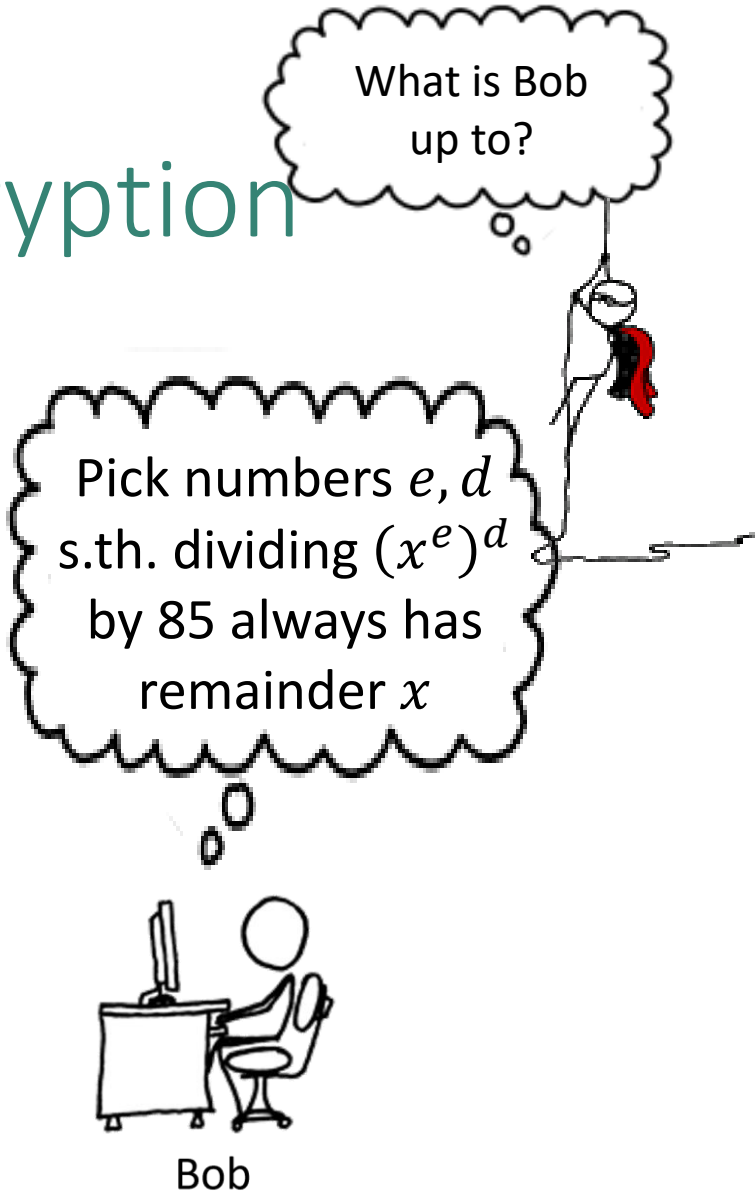


Image source: xkcd.com

Rivest-Shamir-Adleman (RSA) encryption

Example:

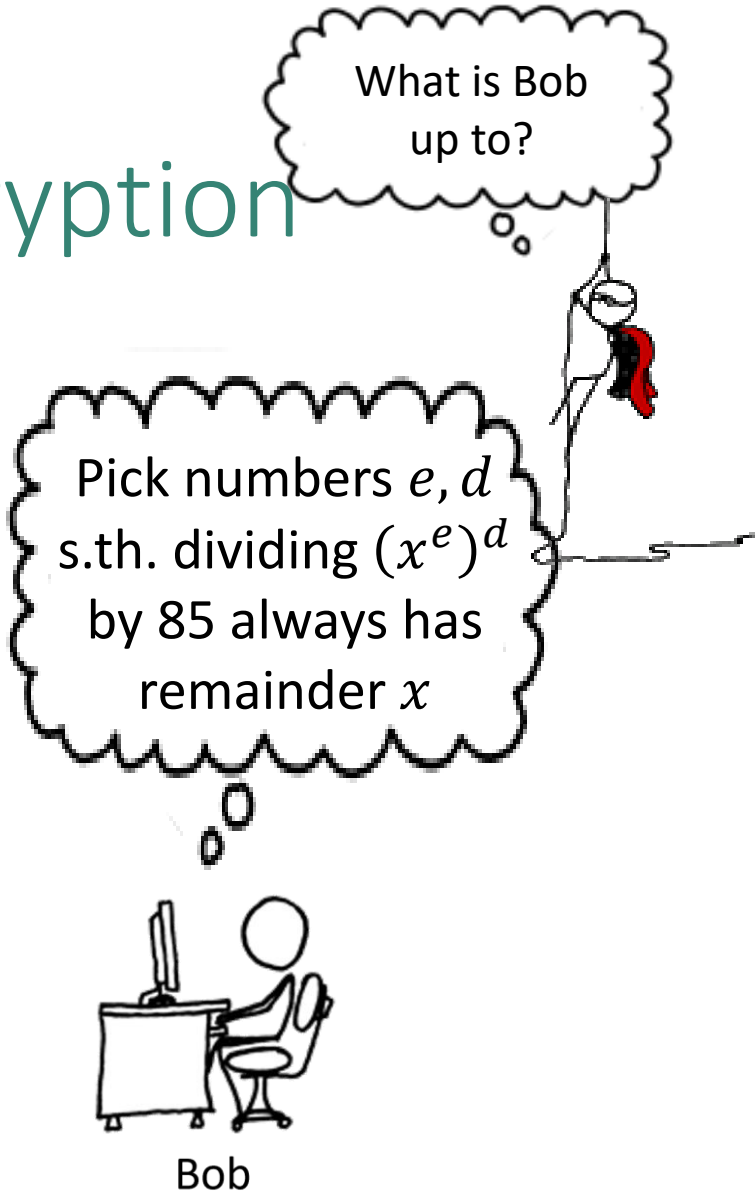
$e = 5, d = 13$

$x = 2$

$x^e = 2^5 = 32$

$(2^e)^d = 32^{13}$ (large, but has remainder 2!)

Also works for $x = 3, x = 4, x = 5, \ldots$



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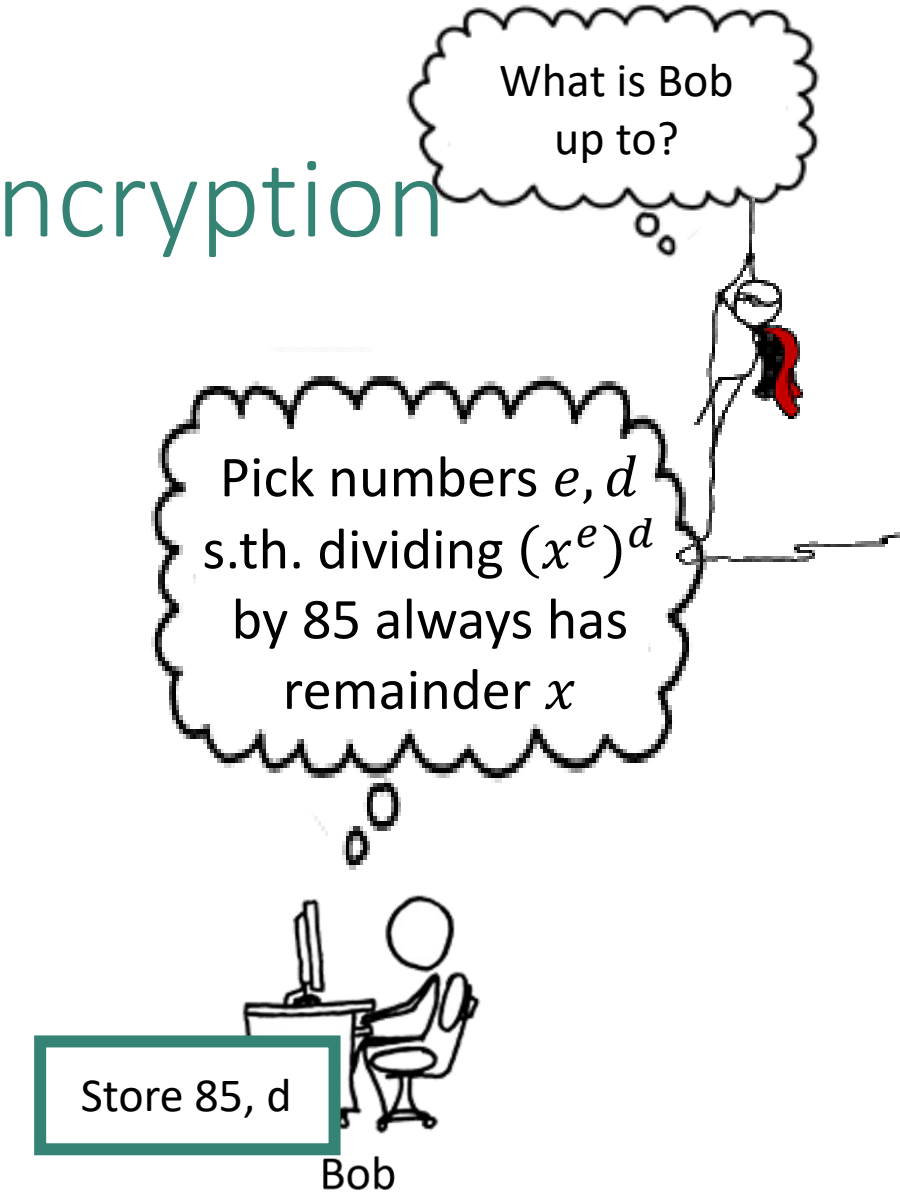

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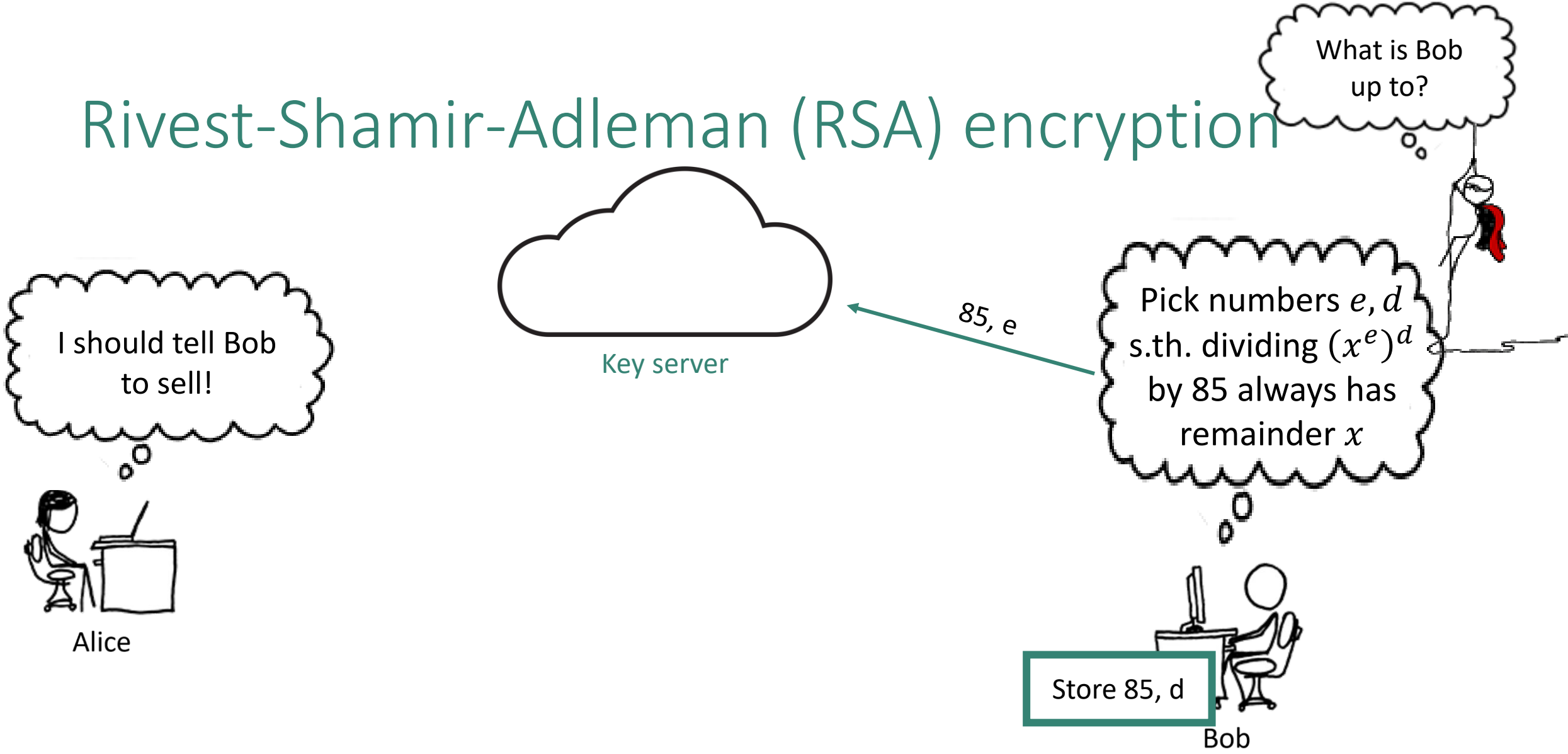

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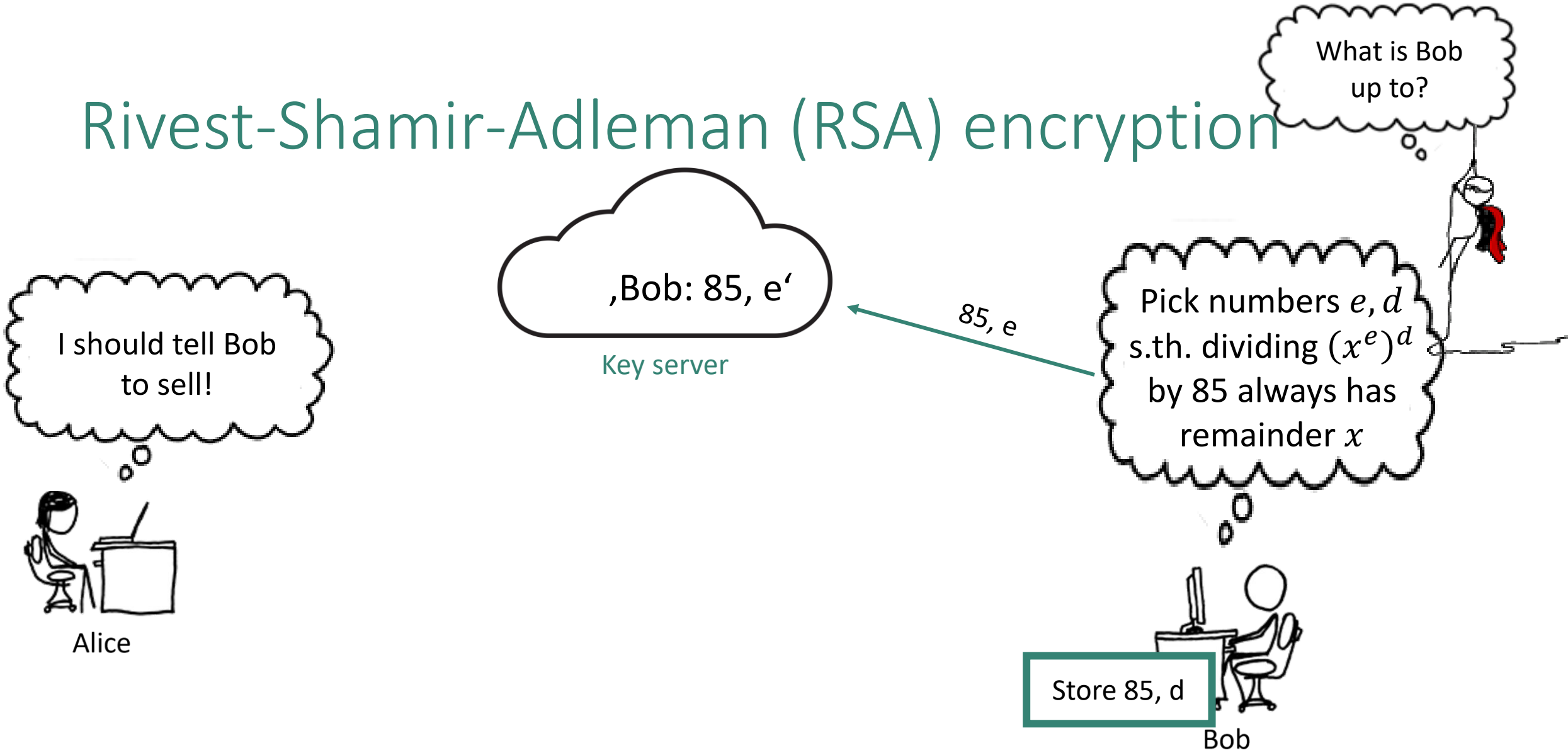

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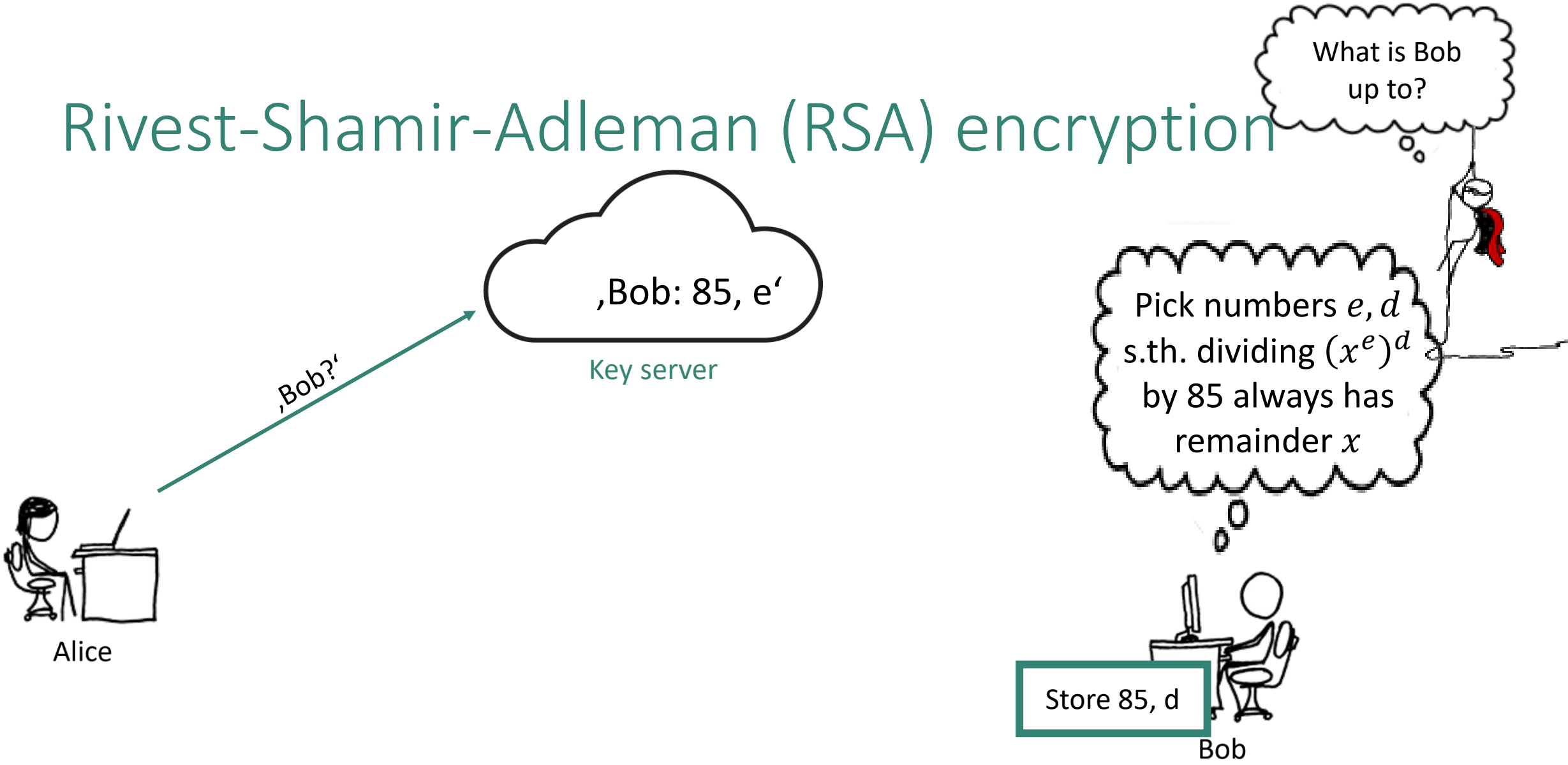

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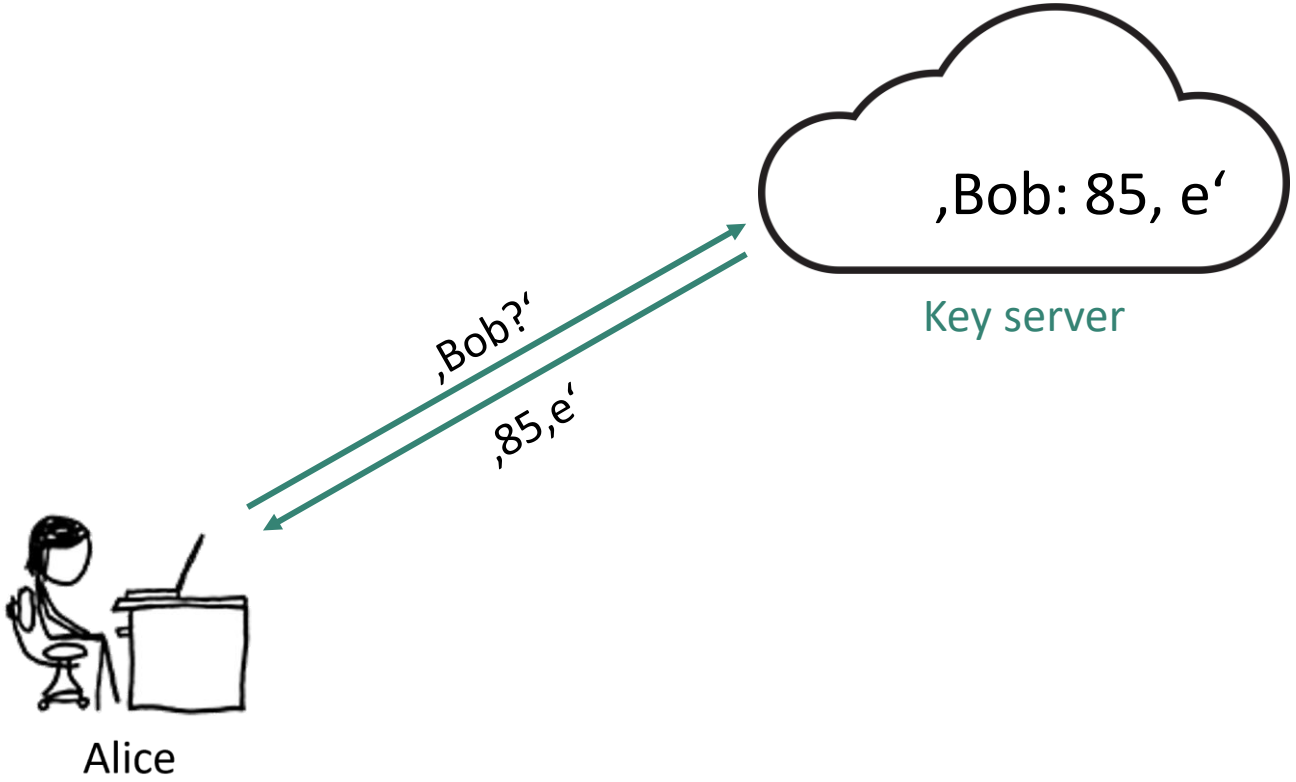

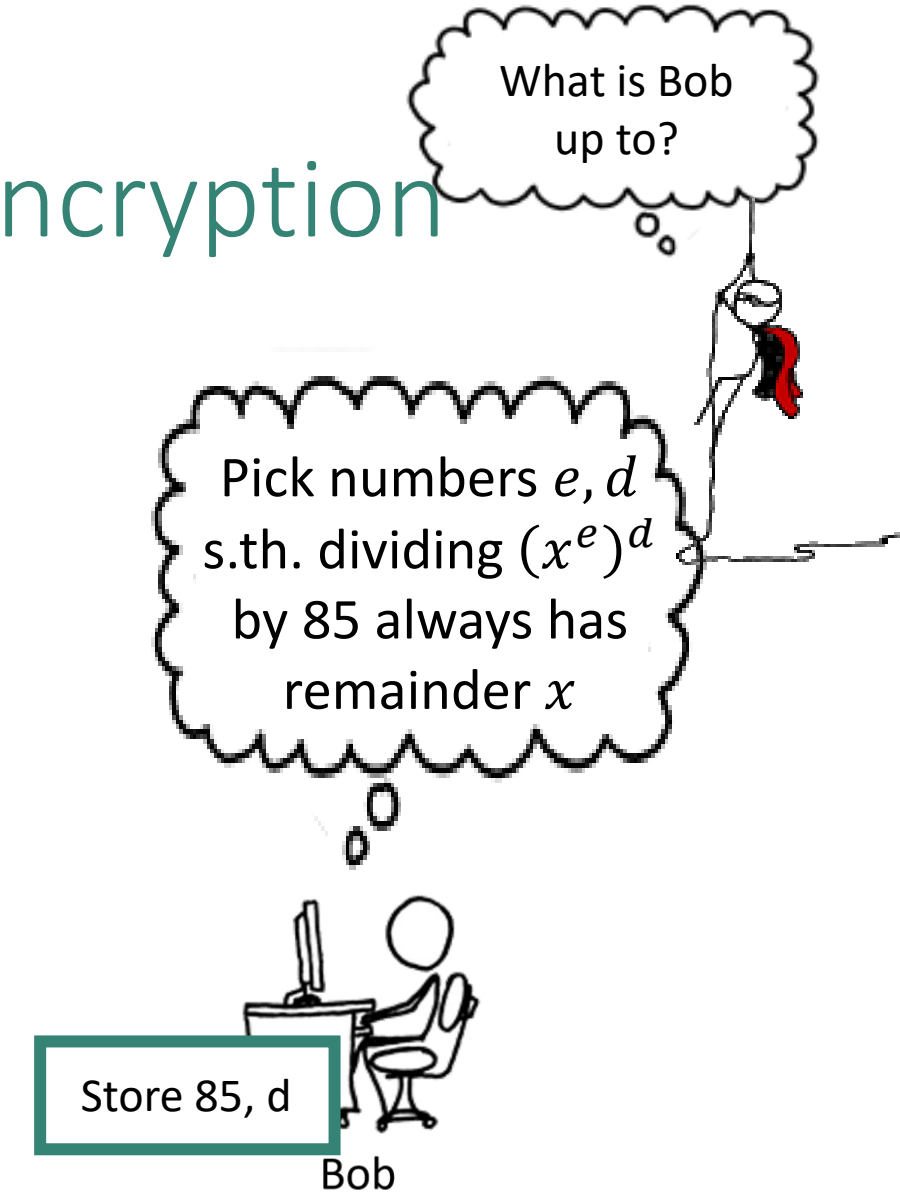

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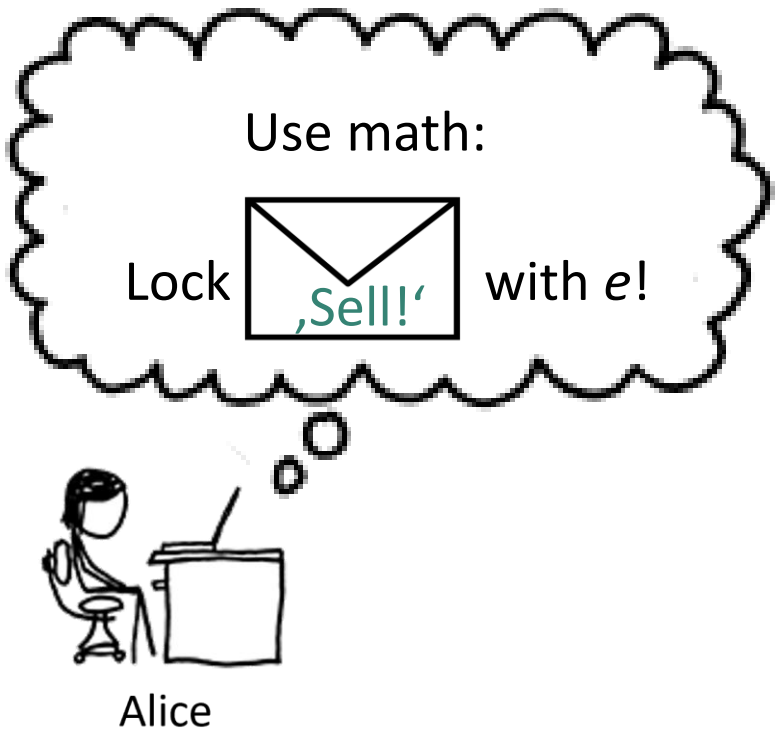

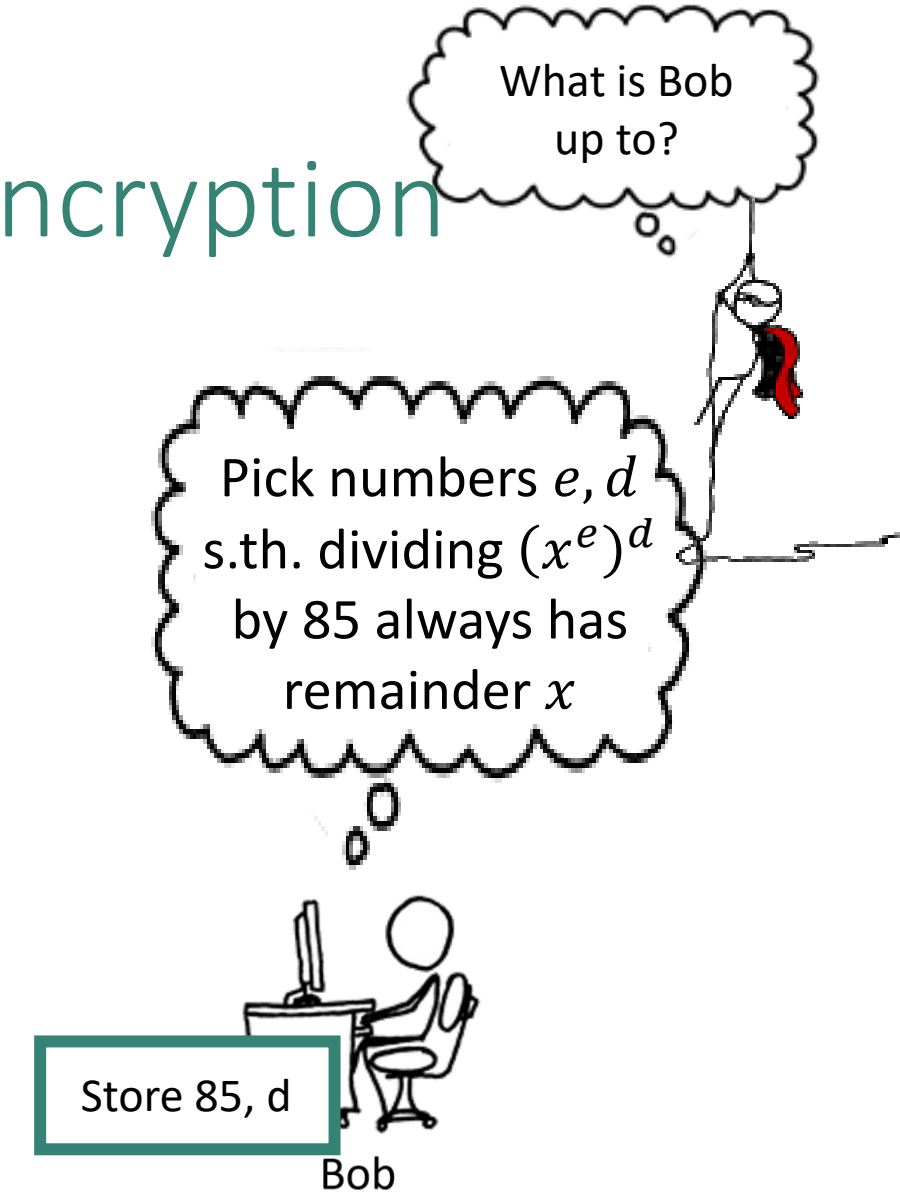

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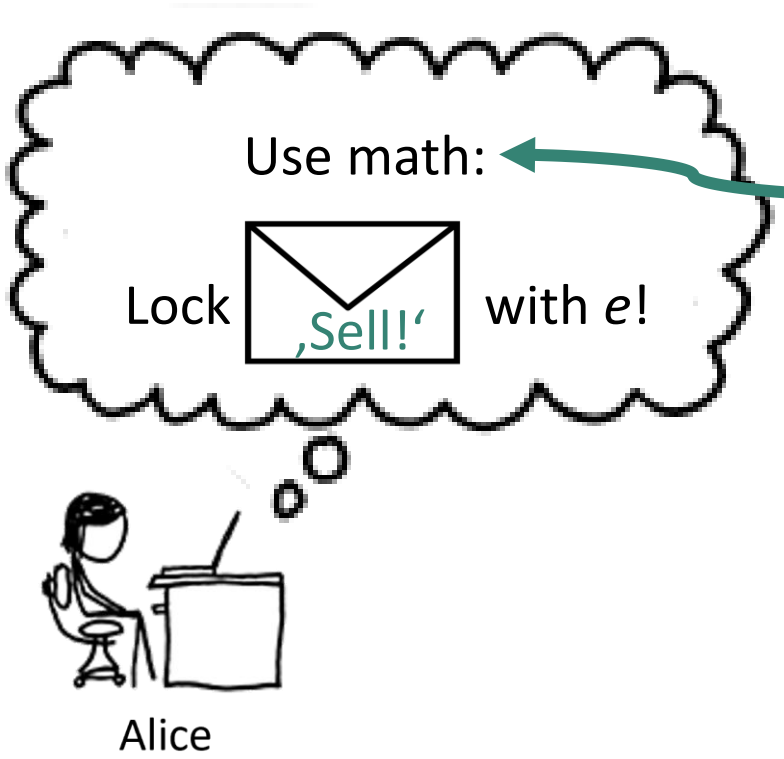
Rivest-Shamir-Adleman (RSA) encryption



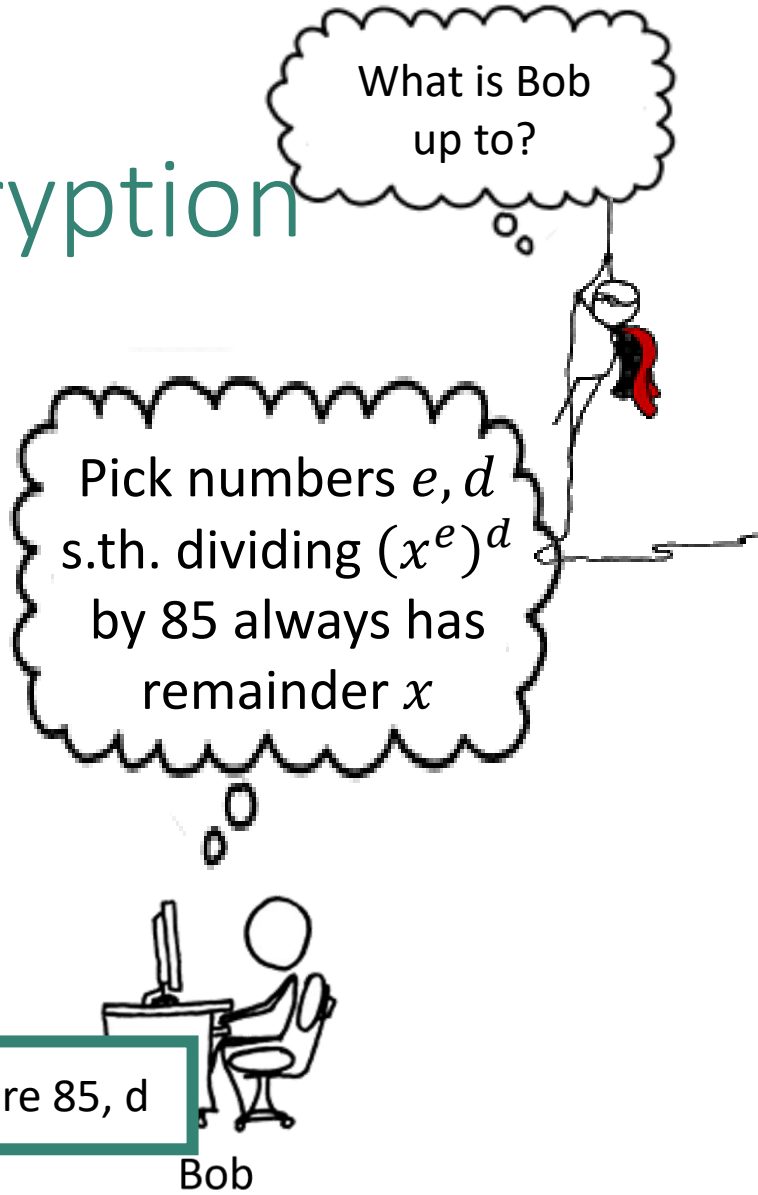
The math:

Convert ‚Sell‘ to a number $m < 85$

Compute m^e

Divide by 85, keep the remainder

Use the remainder as ‚Sell!‘



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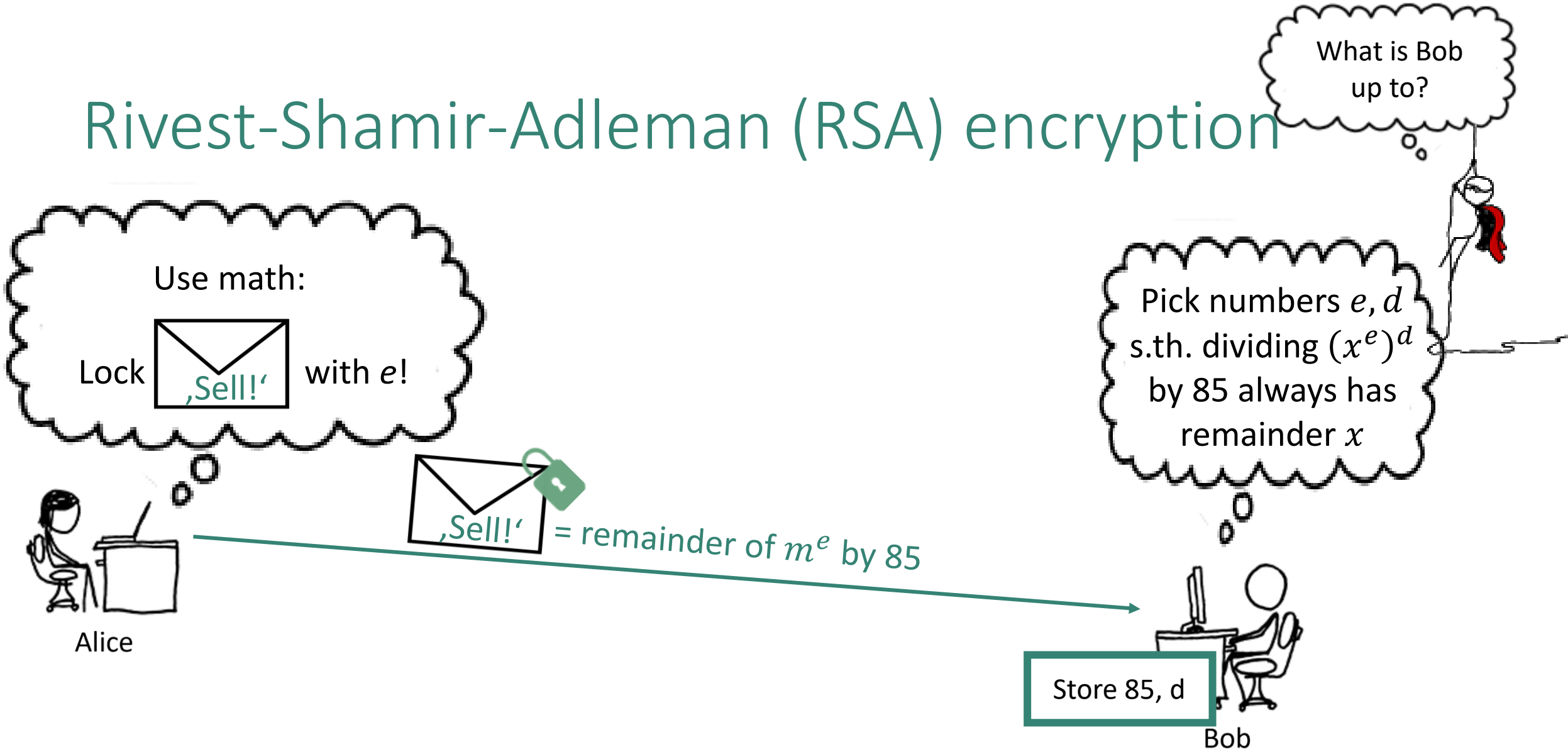

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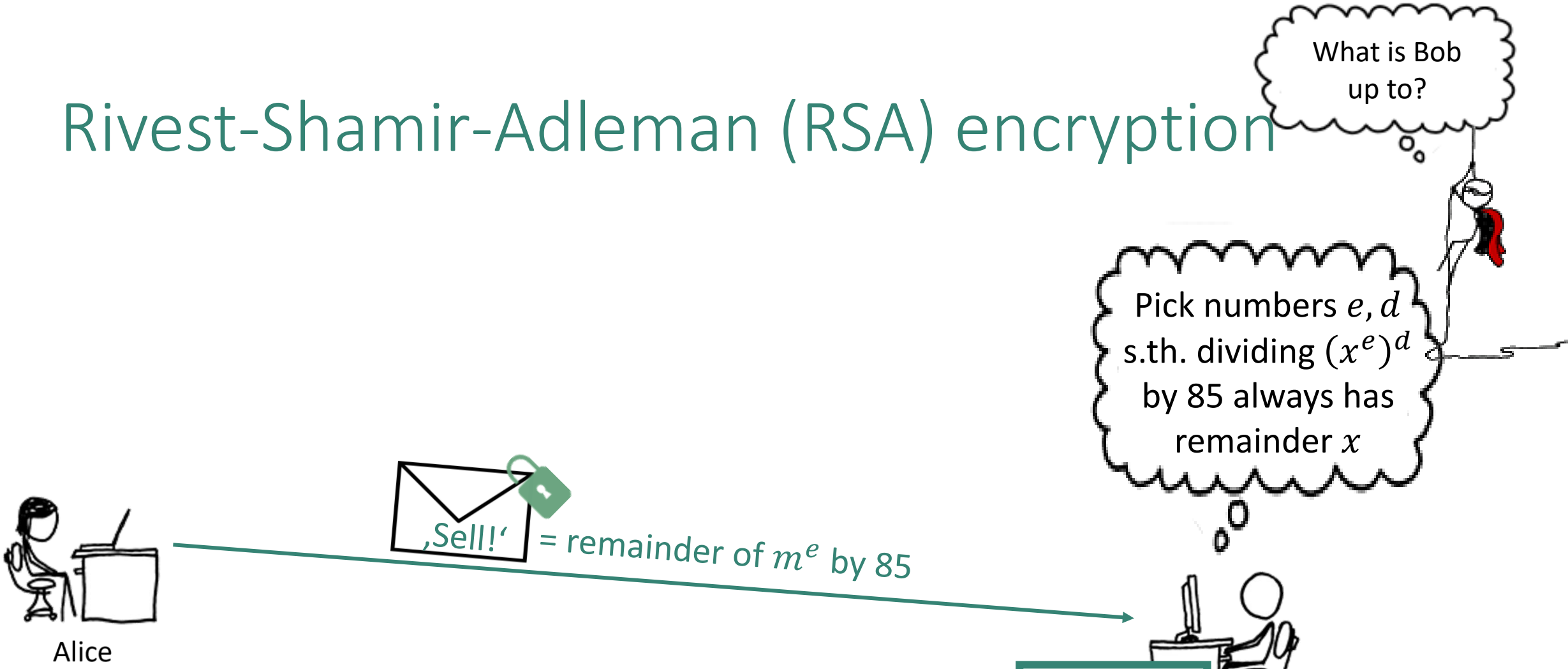
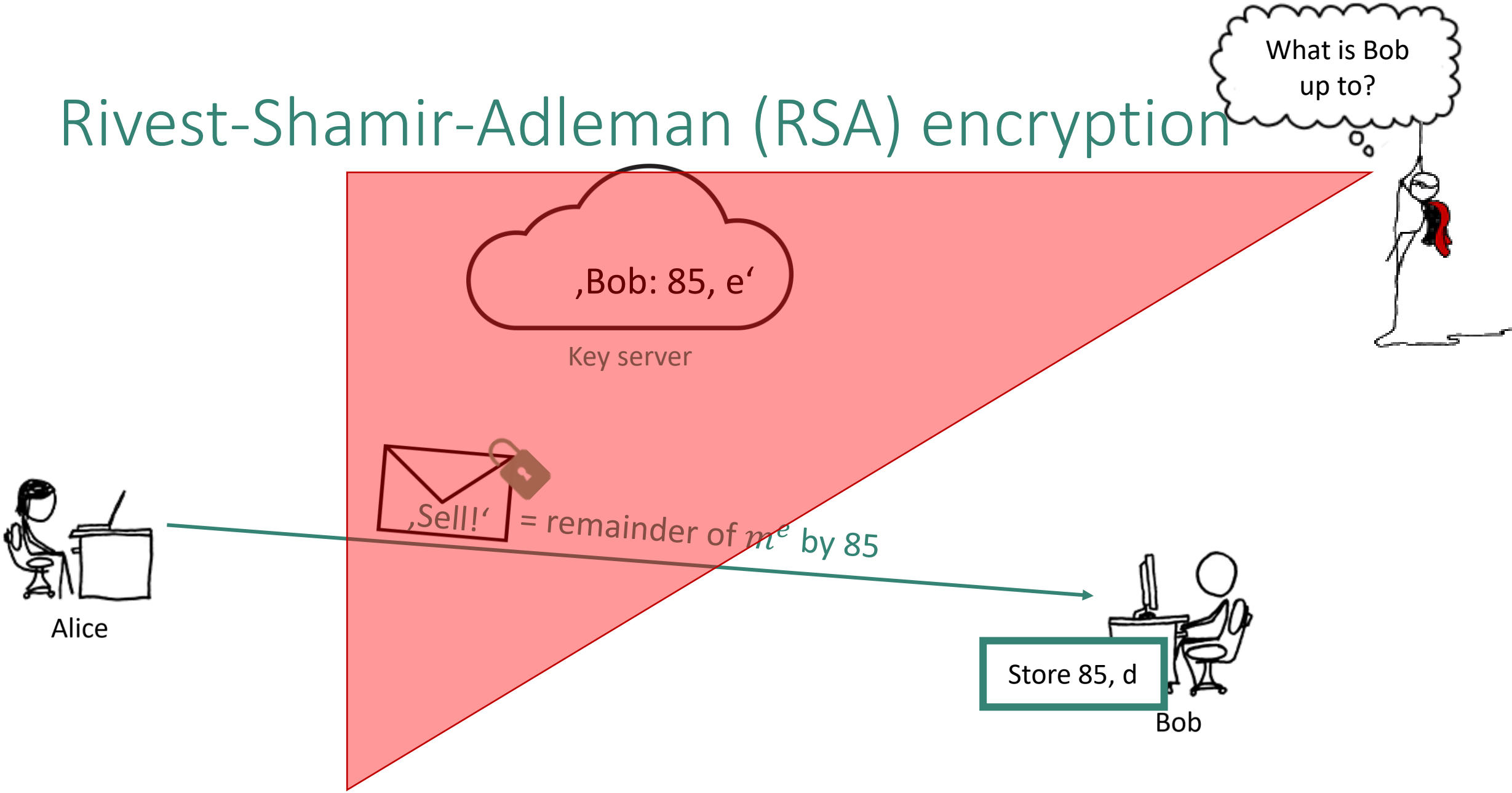


Unlocking

message $m = remainder(m^e)^d$

Image source: xkcd.com

Rivest-Shamir-Adleman (RSA) encryption



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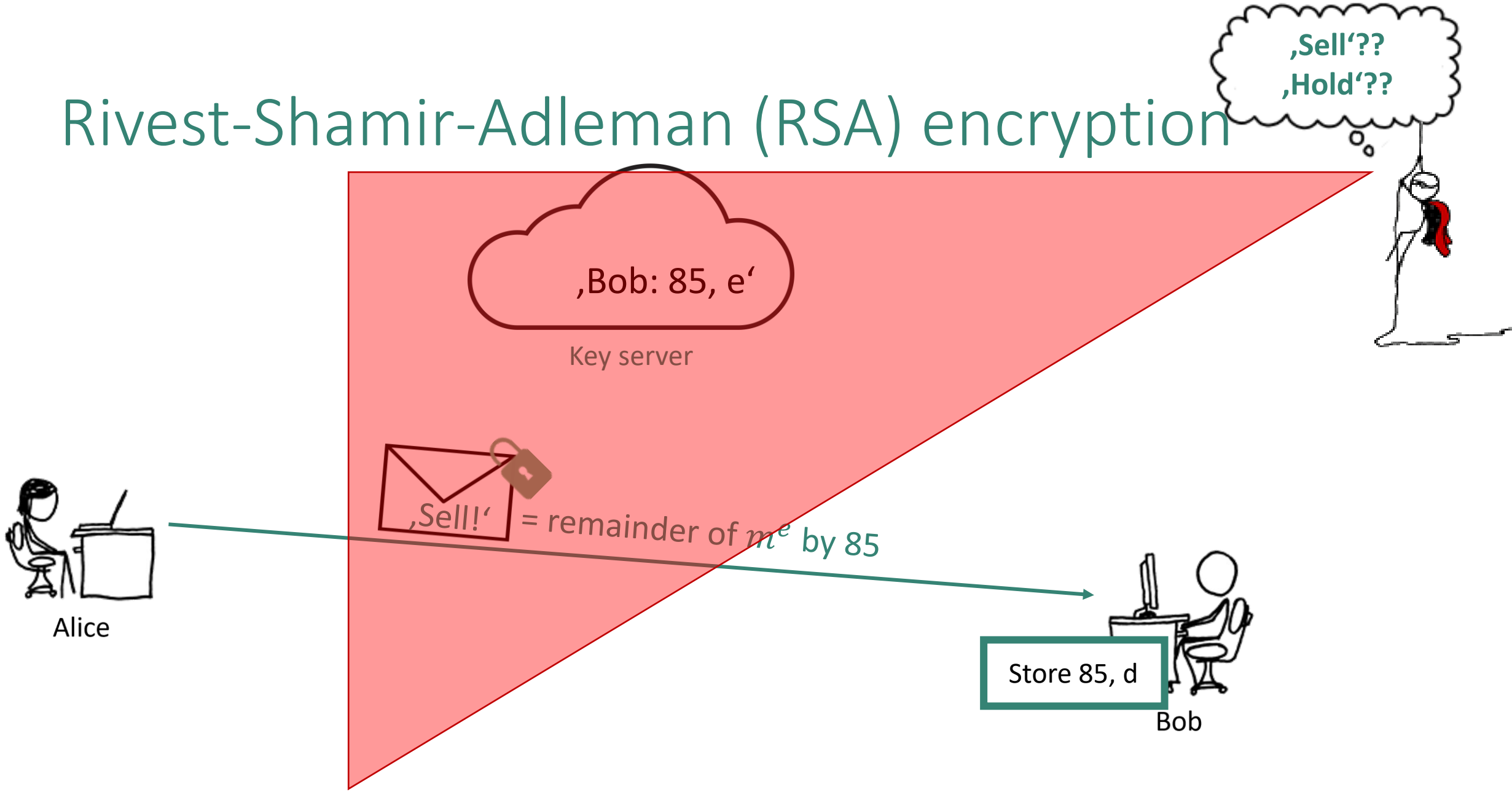

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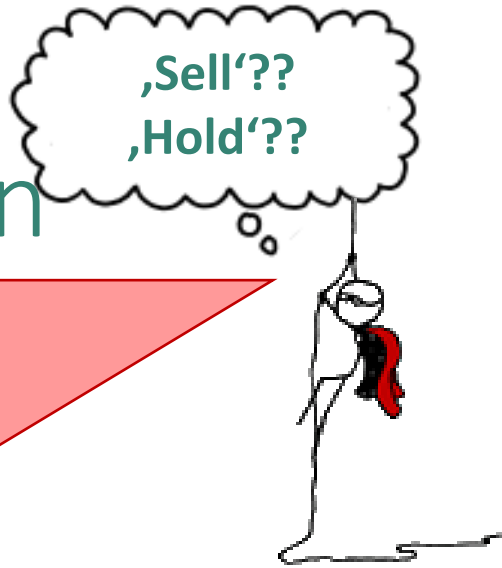
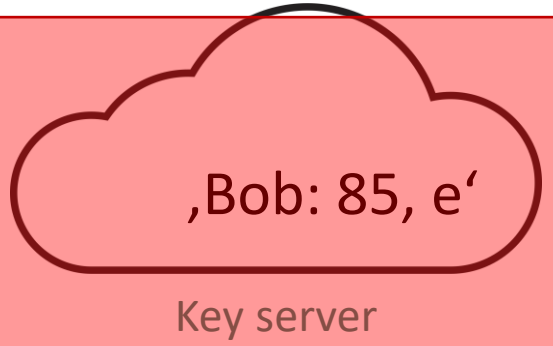
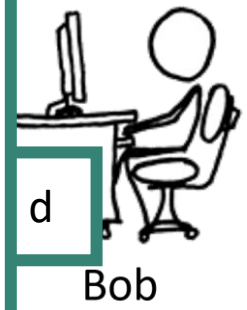




Breaking 

is as hard as factoring 85 into 5 and 17



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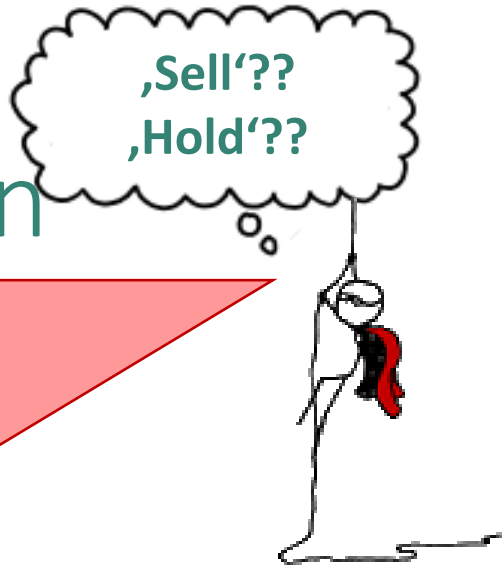

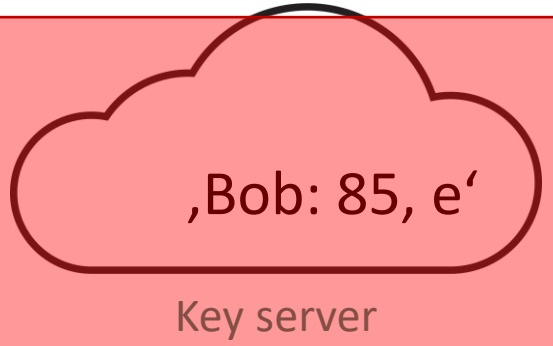

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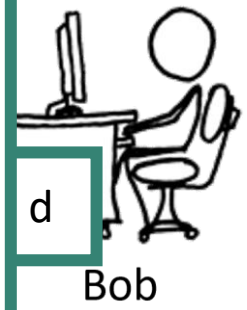
Wait, is that hard…?



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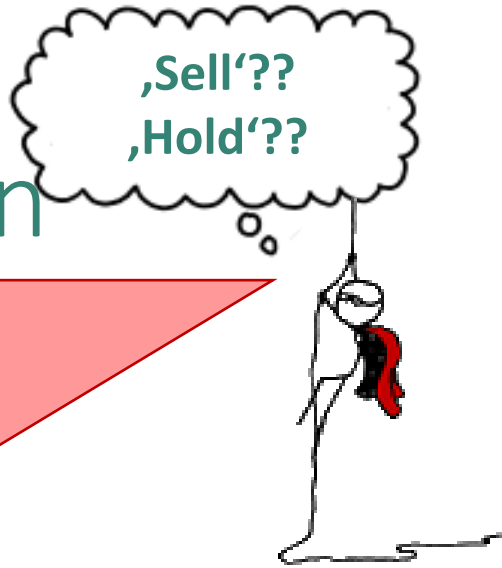

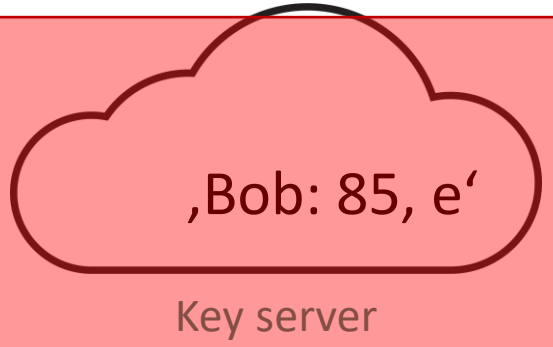

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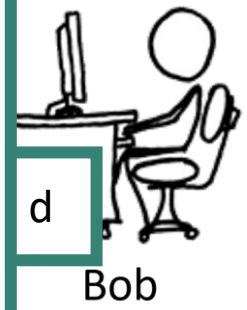
Wait, is that hard…?

Use BIG prime products (> 2048 digits)



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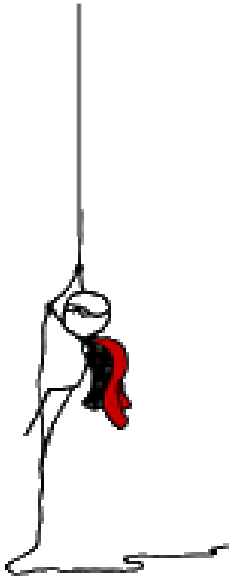


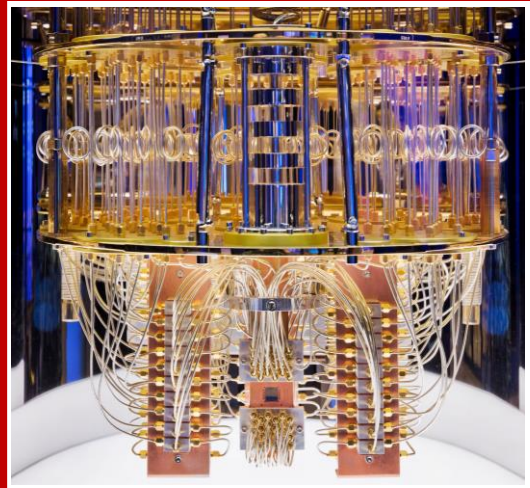
Take-away:

RSA idea: multiplying is easy, but factoring is hard.

Use BIG prime products (> 2048 digits)

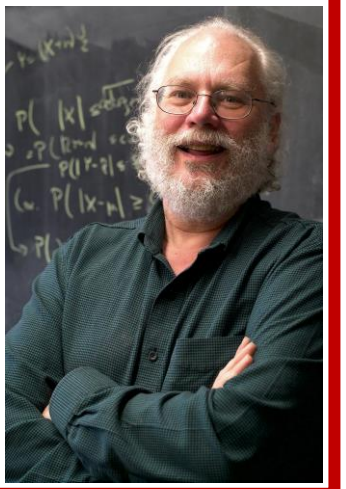
Image source: xkcd.com

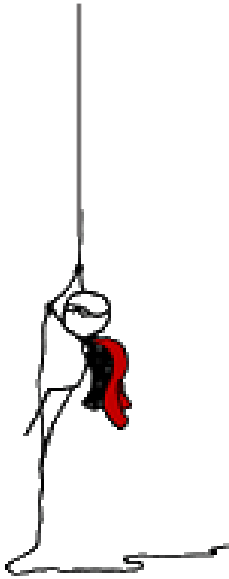
Rivest-Shamir-Adleman (RSA) encryption



Shor, 1994:

Large quantum computers: (essentially) factor as fast as they multiply.





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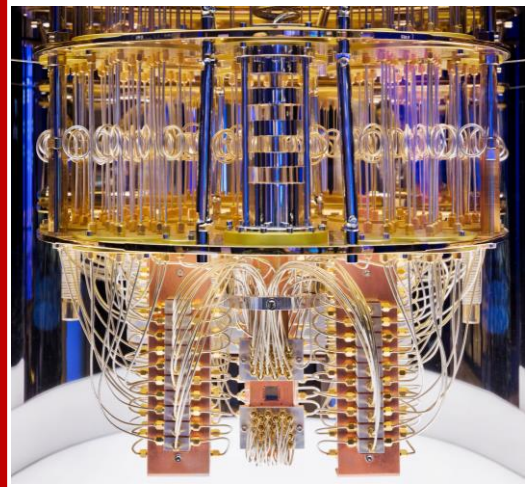

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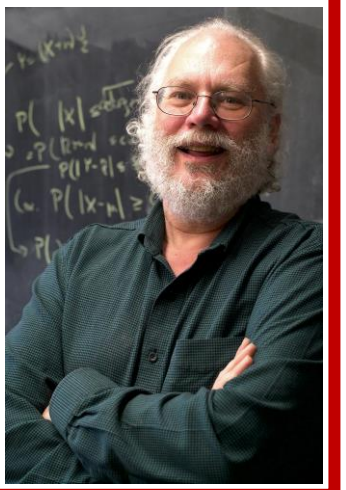

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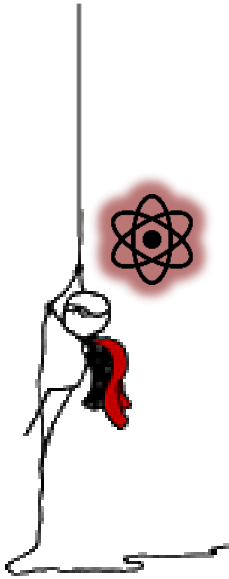
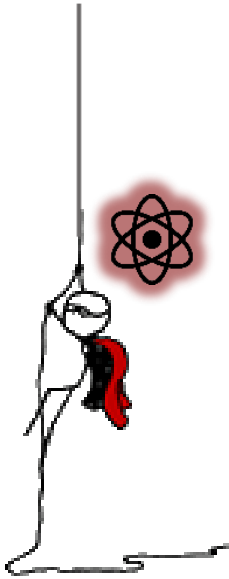
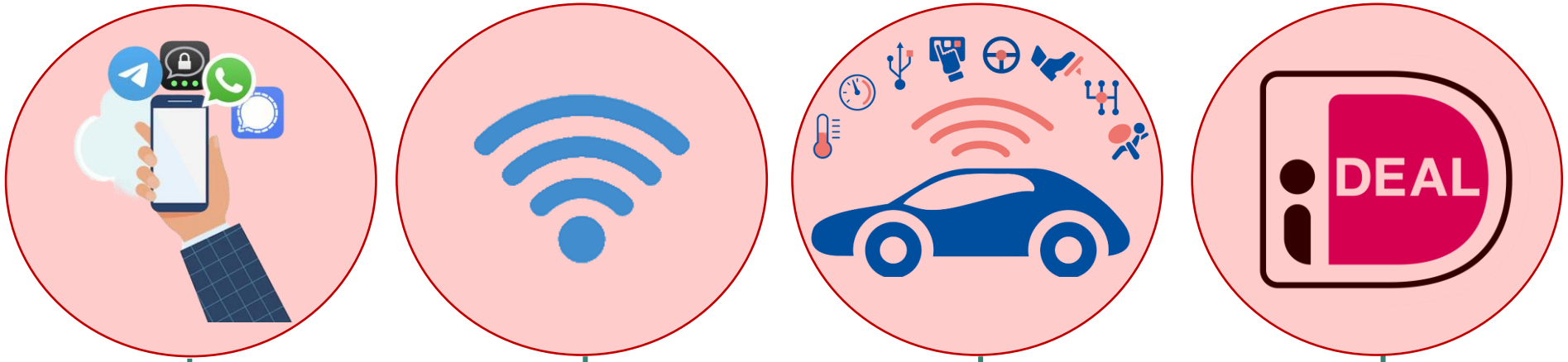


Image source: xkcd.com

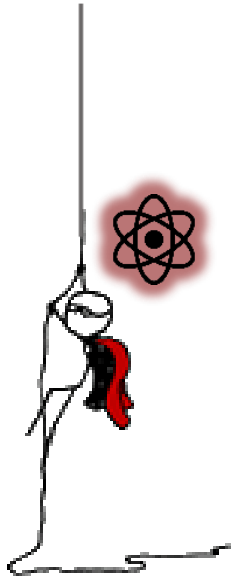
‚Quantum kills the internet‘





Uses public-key crypto (Rivest-Shamir-Adleman, Diffie-Hellman)

Should we worry?



x = time needed to migrate

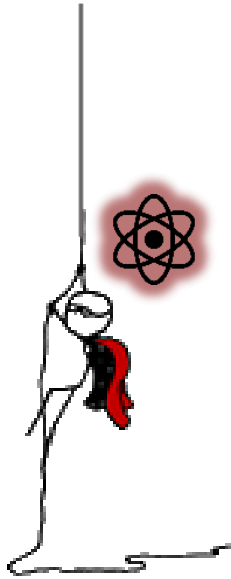
y = security shelf life

z = time to break system

Secret keys leaked

If $x + y > z$ then worry

Should we worry?



x = time needed to migrate

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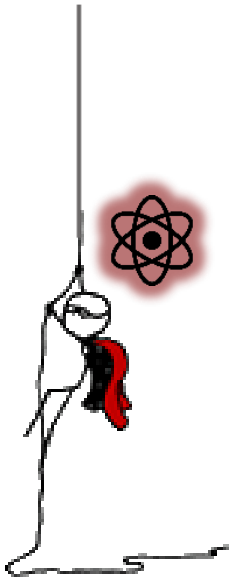
If $x + y > z$ then worry

'record now, break later' ⇒ **today's** data

Hm… And now?



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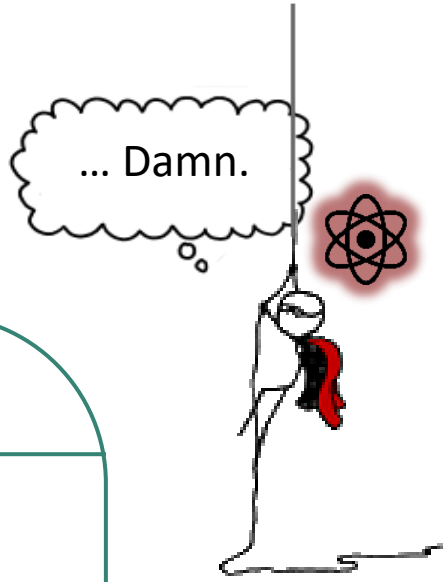


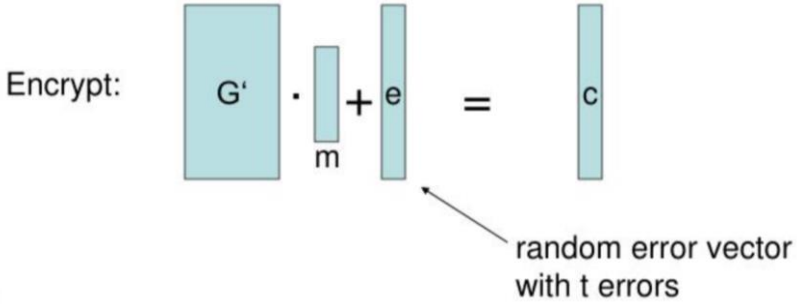
~~Factoring~~ Something that's hard even for quantum computers

Finding a shortest vector in a lattice

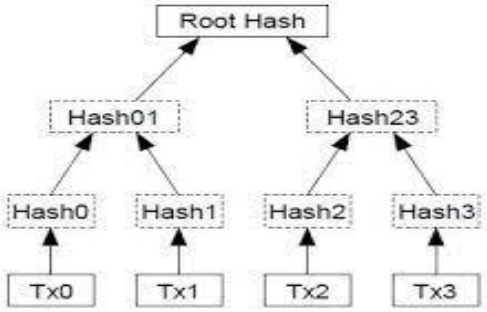
$$1000\,x + x^2 + 423\,y^2 z = 1$$
$$655\,y + 53\,yz = 13$$
$$29\,x + 3\,y^2 + 53\,xz^2 = 4$$

Solving polynomial equations with > 1 variables

Decoding error-correcting codes



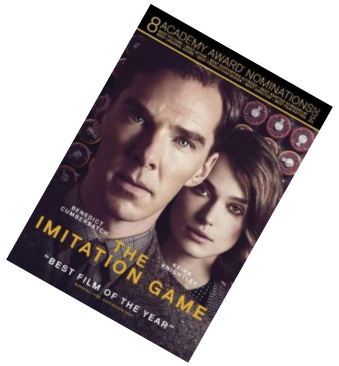
Finding collisions, preimages… in hash functions



Thanks for listening!

kathrin@hoevelmanns.net
Twitter: @quantum_bat

Like math and computer science? Look up (post-)quantum crypto!



Watch *The imitation game*.

Read Orwell's *1984*.

Help out the TOR project. (No crypto knowledge needed!)

Political aspects of crypto: 'Crypto wars' on Wikipedia.