CSE 484 : Computer Security and Privacy

Software Security [Wrap-Up]
Cryptography [Intro]

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Admin

- Lab 1
  - Checkpoint due today (11:59pm)
  - Sploits 4-7 due 02/01 (11:59pm)
  - Reminder that you have 5 late days you can use throughout the quarter
    - Up to 3 at a time
    - Everyone in a group uses them simultaneously
    - You must indicate on the assignment how many late days you are taking!

Software Security:
So what do we do?

Vulnerability Analysis and Disclosure

- What do you do if you've found a security problem in a real system?
- Say
  - A commercial website?
  - UW grade database?
  - Boeing 787?
  - TSA procedures?

security@ — .com

Vulnerability Analysis and Disclosure

- Suppose companies A, B, and C all have a vulnerability, but have not made the existence of that vulnerability public
- Company A has a software update prepared and ready to go that, once shipped, will fix the vulnerability; but B and C are still working on developing a patch for the vulnerability
- ~~Company A learns that attackers are exploiting this vulnerability in the wild~~
- *Should Company A release their patch, even if doing so means that the vulnerability now becomes public and other actors can start exploiting Companies B and C?*
- *Or should Company A wait until Companies B and C have patches?*

Realistic Security

How do we make everything secure?

- "Educate users!" — phished / good pws
  - Then they can't make mistakes!
- "Educate developers!" — no buffer overflows
  - Then they can't make mistakes!

security challenges

- Or…

build tools that "just work"

users applications that are secure by default

Next Major Section of the Course: Cryptography

Aside: “blockchain” and “crypto”

- Rising interest, mostly in the cryptocurrency space
- Crypto will, for this course, exclusively mean “cryptography”
- While blockchain sometimes has neat crypto ideas, its not going to come up here

Next Major Section of the Course: Cryptography

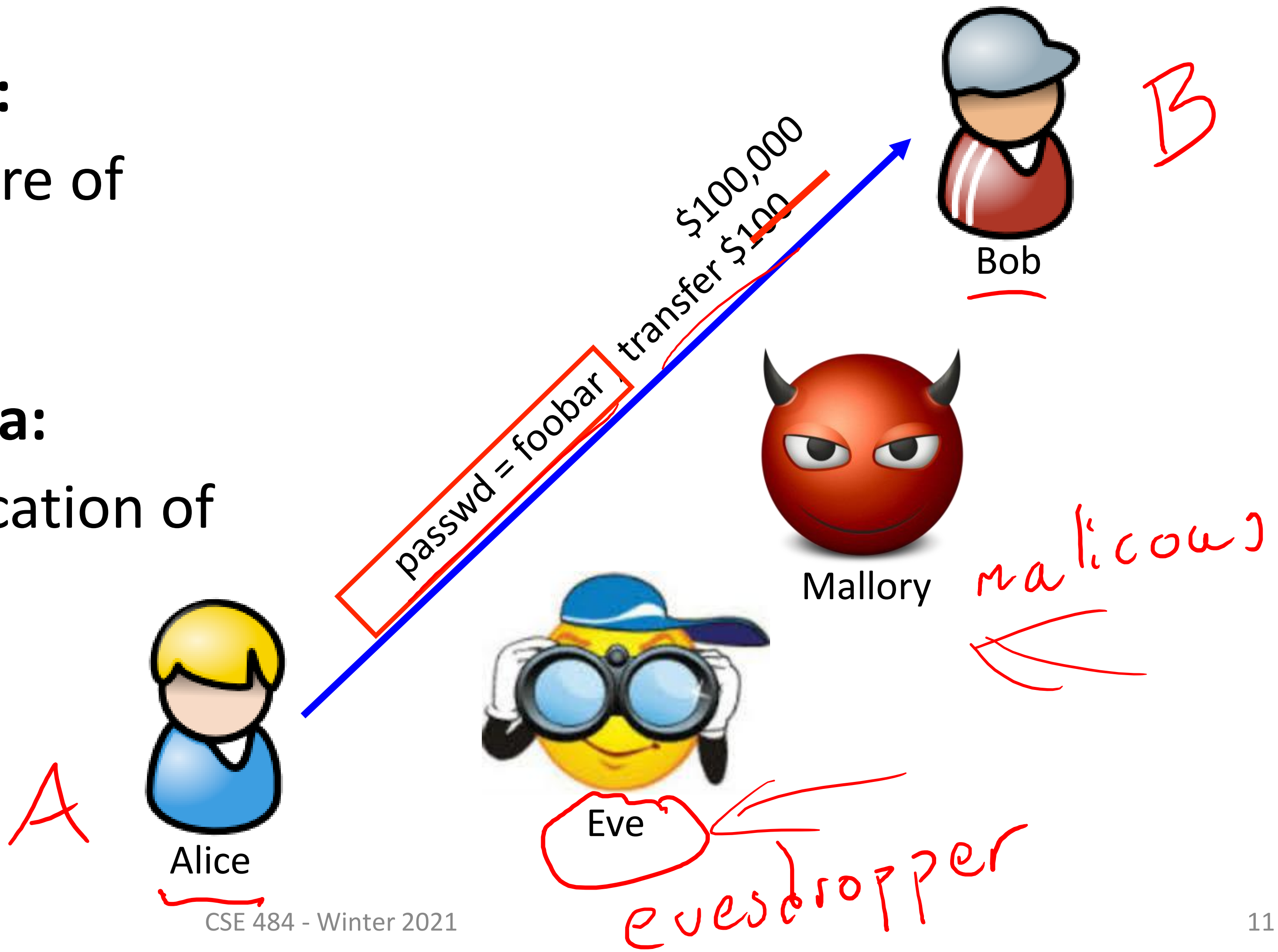
Common Communication Security Goals

Privacy of data:

Prevent exposure of information

Integrity of data:

Prevent modification of information

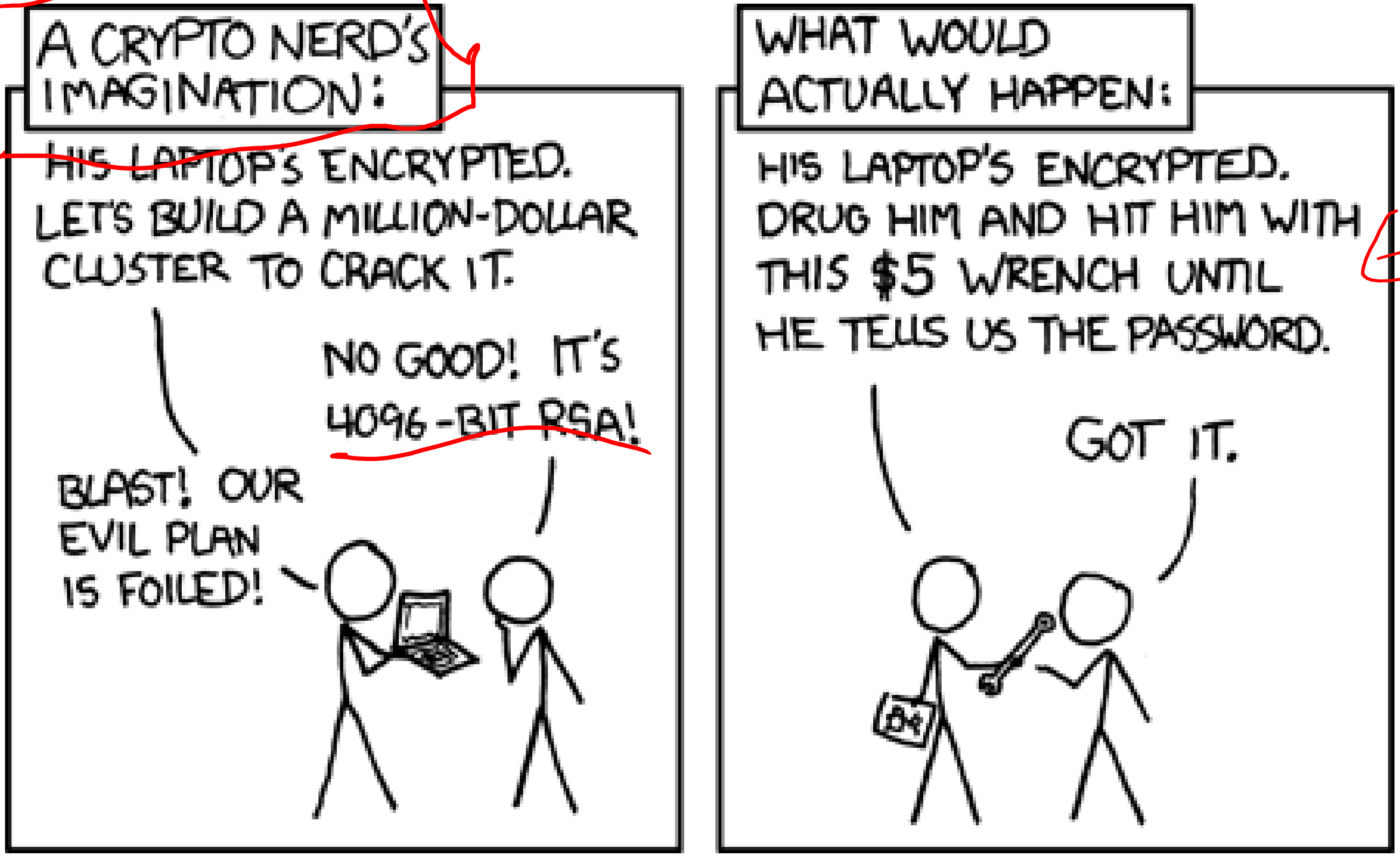


Recall Bigger Picture

- Cryptography only one small piece of a larger system
- Must protect entire system
  - Physical security
  - Operating system security
  - Network security
  - Users
  - Cryptography (following slides)
- Recall the weakest link

- Still, cryptography is a crucial part of our toolbox

XKCD: http://xkcd.com/538/



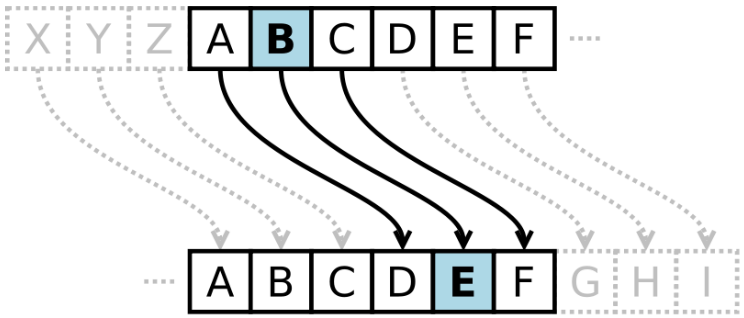
History

- Substitution Ciphers
  - Caesar Cipher
- Transposition Ciphers
- Codebooks
- Machines

- Recommended Reading: **The Codebreakers** by David Kahn and **The Code Book** by Simon Singh.

History: Caesar Cipher (Shift Cipher)

- Plaintext letters are replaced with letters a fixed shift away in the alphabet.



- Example:
  - Plaintext: `The quick brown fox jumps over the lazy dog`
  - Key: Shift 3

```
ABCDEFGHIJKLMNOPQRSTUVWXYZ
DEFGHIJKLMNOPQRSTUVWXYZABC
```

  - Ciphertext: `WKHTX LFNEU RZQIR AMXPS VRYHU WKHOD CBGRJ`

History: Caesar Cipher (Shift Cipher)

- ROT13: shift 13 (encryption and decryption are symmetric)
- What is the key space? 25? $\log_2(25)$
  - 26 possible shifts.
- How to attack shift ciphers?
  - Brute force.

History: Substitution Cipher

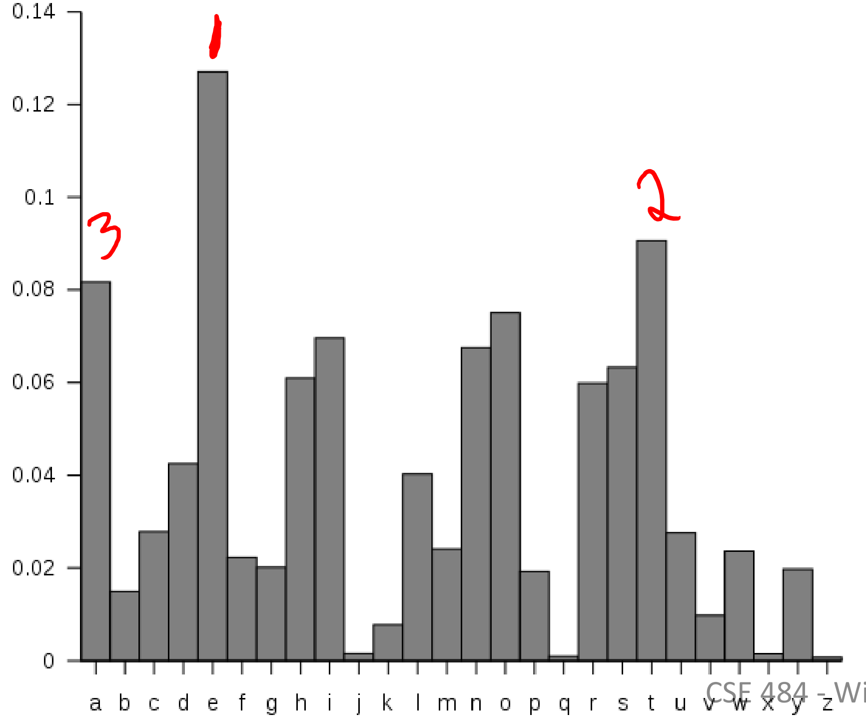
- Superset of shift ciphers: each letter is substituted for another one.
- One way to implement: Add a secret key
- Example:
  - Plaintext: `ABCDEFGHIJKLMNOPQRSTUVWXYZ`
  - Cipher: `ZEBRASCDFGHIJKLMNOPQTUVWXY`
- "State of the art" for thousands of years

ABCD

BDCA

History: Substitution Cipher

- What is the key space?
- How to attack?
  - Frequency analysis.



26! ~= 2^88

Bigrams:

th 1.52%	en 0.55%	ng 0.18%
he 1.28%	ed 0.53%	of 0.16%
in 0.94%	to 0.52%	al 0.09%
er 0.94%	it 0.50%	de 0.09%
an 0.82%	ou 0.50%	se 0.08%
re 0.68%	ea 0.47%	le 0.08%
nd 0.63%	hi 0.46%	sa 0.06%
at 0.59%	is 0.46%	si 0.05%
on 0.57%	or 0.43%	ar 0.04%
nt 0.56%	ti 0.34%	ve 0.04%
ha 0.56%	as 0.33%	ra 0.04%
es 0.56%	te 0.27%	ld 0.02%
st 0.55%	et 0.19%	ur 0.02%

Trigrams:

1. the	6. ion	11. nce
2. and	7. tio	12. edt
3. tha	8. for	13. tis
4. ent	9. nde	14. oft
5. ing	10.has	15. sth

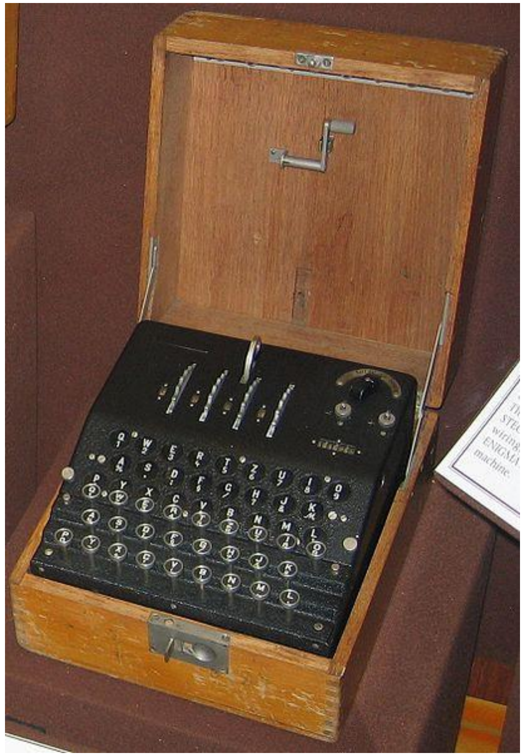
L

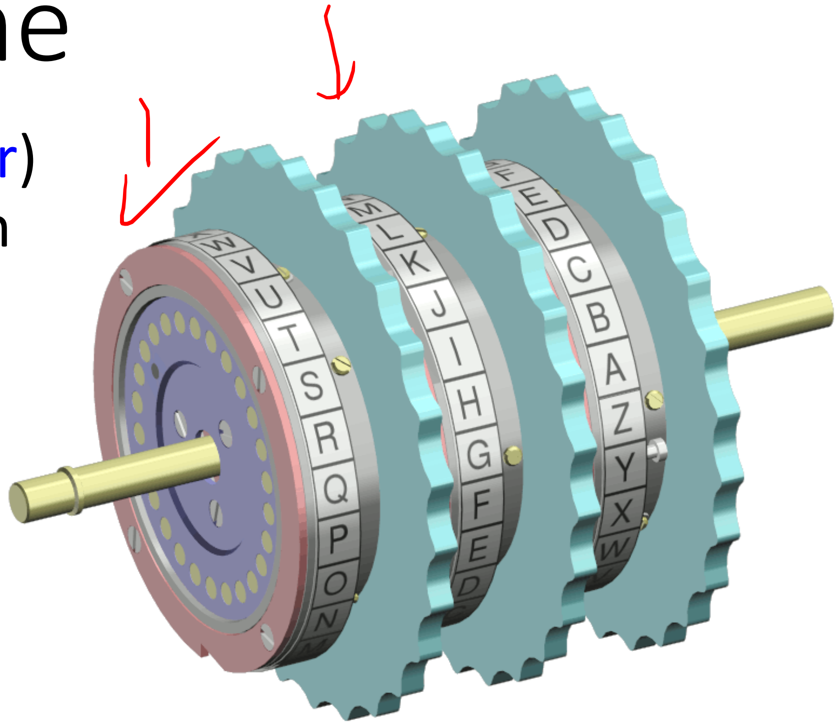
E T

L U

History: Enigma Machine

Uses rotors (substitution cipher) that change position after each key.





Key = initial setting of rotors

Key space?

26^n for n rotors

How Cryptosystems Work Today

- **Layered approach:** Cryptographic protocols (like "CBC mode encryption") built on top of cryptographic primitives (like "block ciphers")
- **Flavors of cryptography:** Symmetric (private key) and asymmetric (public key)
- Public algorithms (Kerckhoff's Principle)
- Security proofs based on assumptions *(not this course)* if a, b, c $\Rightarrow$ secure

- Be careful about inventing your own! (If you just want to use some crypto in your system, use vetted libraries!)

Cryptographic tools, primitives, and more

primitives	conceptual	tools
RSA	E2E	SSH
SHA		

The Cryptosystem Stack

- Primitives:
  - AES / DES / etc
  - RSA / ElGamal / Elliptic Curve (ed25519)
- Modes:
  - Block modes (CBC, ECB, CTR, GCM, …)
  - Padding structures
- Protocols:
  - HTTPS
  - TLS / SSL / etc
- Usage of Protocols:
  - Browser security
  - SSH connections

Hashing: SHA, MD5, etc

Kerckhoff’s Principle

- Security of a cryptographic object should depend only on the secrecy of the secret (private) key.
- Security should not depend on the secrecy of the algorithm itself.

Flavors of Cryptography

older

AES, DES

- Symmetric cryptography
  - Both communicating parties have access to a shared random string K, called the key.
- Asymmetric cryptography
  - Each party creates a public key pk and a secret key sk.
  - *Hard concept to understand, and revolutionary! Inventors won Turing Award* ☺

RSA

EC

Received April 4, 1977

asymmetric

A Method for Obtaining Digital Signatures and Public-Key Cryptosystems

R.L. Rivest, A. Shamir, and L. Adleman*

RSA

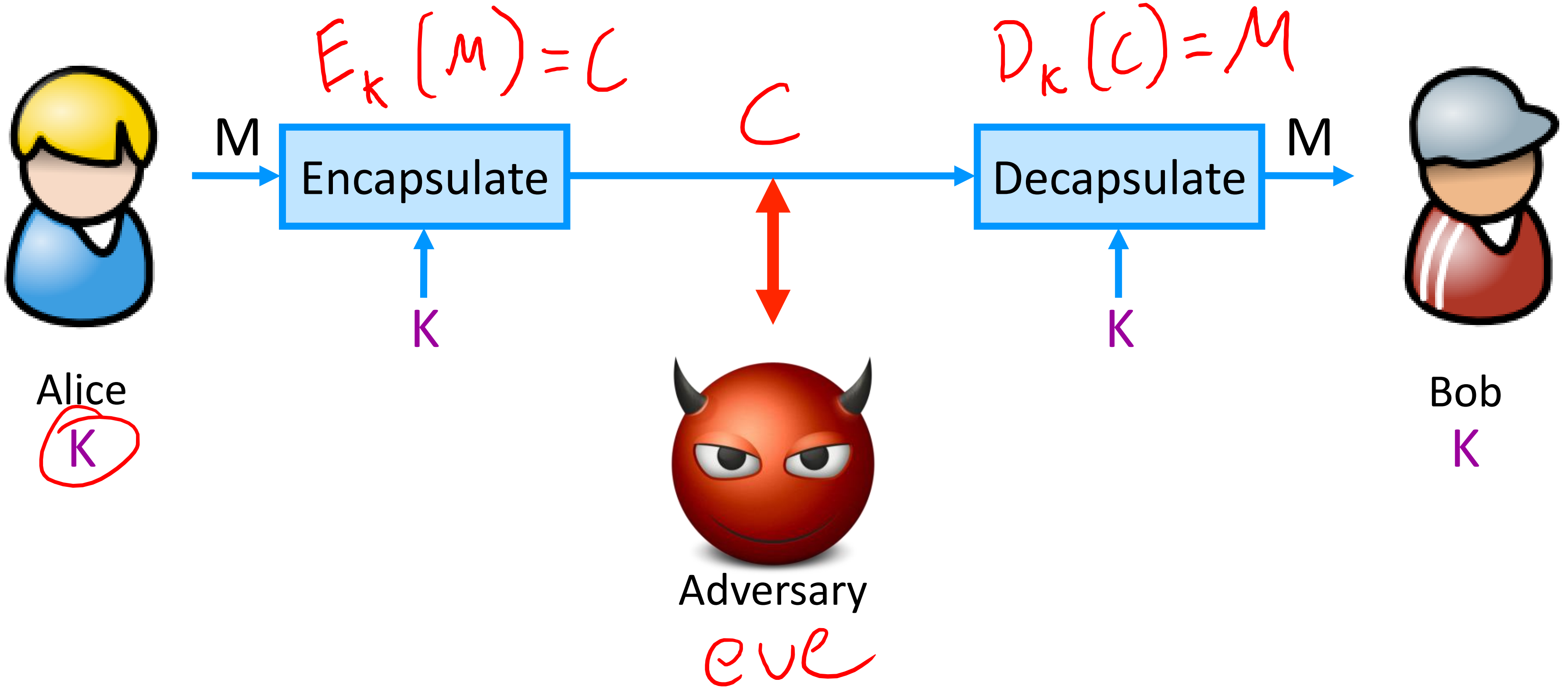
Abstract

An encryption method is presented with the novel property that publicly revealing an encryption key does not thereby reveal the corresponding decryption key. This has two important consequences:

1. Couriers or other secure means are not needed to transmit keys, since a message can be enciphered using an encryption key publicly revealed by the intended recipient. Only he can decipher the message, since only he knows the corresponding decryption key.
2. A message can be "signed" using a privately held decryption key. Anyone can verify this signature using the corresponding publicly revealed encryption key. Signatures cannot be forged, and a signer cannot later deny the validity of his signature. This has obvious applications in "electronic mail" and "electronic funds transfer" systems.

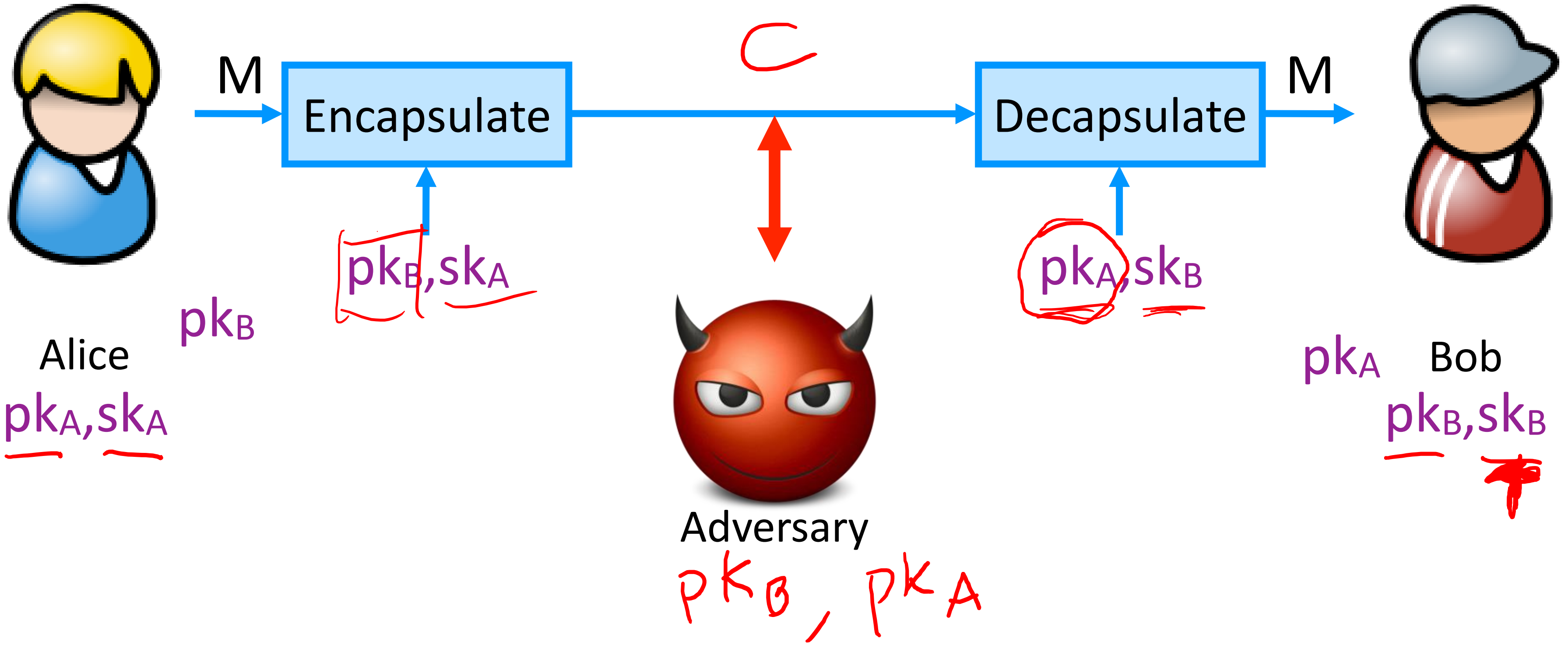
Symmetric Setting

Both communicating parties have access to a shared random string K, called the key.



Asymmetric Setting

Each party creates a public key pk and a secret key sk.



Flavors of Cryptography

- Symmetric cryptography
  - Both communicating parties have access to a shared random string K, called the key.
- Asymmetric cryptography
  - Each party creates a public key pk and a secret key sk.

Flavors of Cryptography

- Symmetric cryptography
  - Both communicating parties have access to a shared random string K, called the key.
  - Challenge: How do you privately share a key? key distribution / bootstrap
- Asymmetric cryptography
  - Each party creates a public key pk and a secret key sk.
  - Challenge: How do you validate a public key?

PKI

public key infrastructure

pk_A pk_A'

web-of-trust