SLEEP BETTER WITH

# CONTENT ENCRYPTION

Jens Neuhalfen

# WHO AM I?

- Jens Neuhalfen
- Age: Forty something
- IT since: ever
- Skills: Bridge between IT and business, IT-Security Management, writing software
- https://github.com/neuhalje

# SUMMARY

Regulations apply - whatever you do!

Encryption is not for free!

No encryption might be way more expensive!

Maintenance is 60%-80% of total cost.
It is sensible to safe there!

**–> Assess risks & cost, plan, implement!**

# SUMMARY

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**–> Assess risks & cost, plan, implement!**

I AM NOT A CRYPTOGRAPHER!

I AM NOT A LAWYER!

# THIS TALK MADE ME A CRYPTOGRAPHY AND/OR LEGAL EXPERT

said no-one ever

I AM NOT A LAWYER!

I AM NOT A CRYPTOGRAPHER!

# CRYPTOGRAPHY: ENCRYPTION (SYMMETRIC, ASYMMETRIC), HASHING, KEY EXCHANGE, INTEGRITY PROTECTION, AUTHENTICATION, CRYPTOGRAPHIC PROTOCOLS, . . . , BLOCKCHAINS(*)

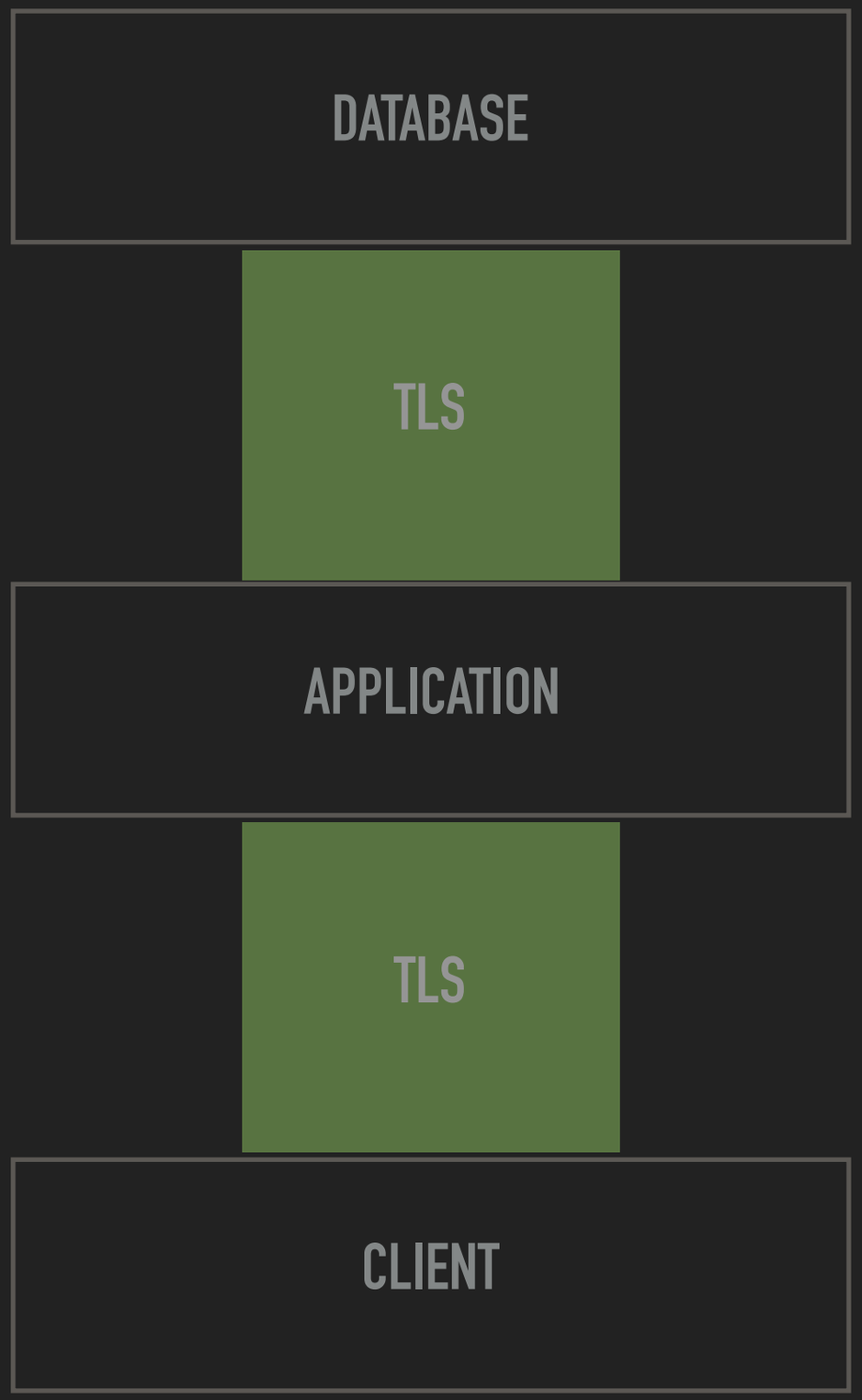
(*) Blockchains are now an official requirement for all talks that mention “cryptography”


WHAT IS

# CONTENT ENCRYPTION?

# YOUR FATHERS CRYPTO (*)

- CLIENT sends request
- APPLICATION applies logic
- DATABASE stores result
- Data encrypted via TLS

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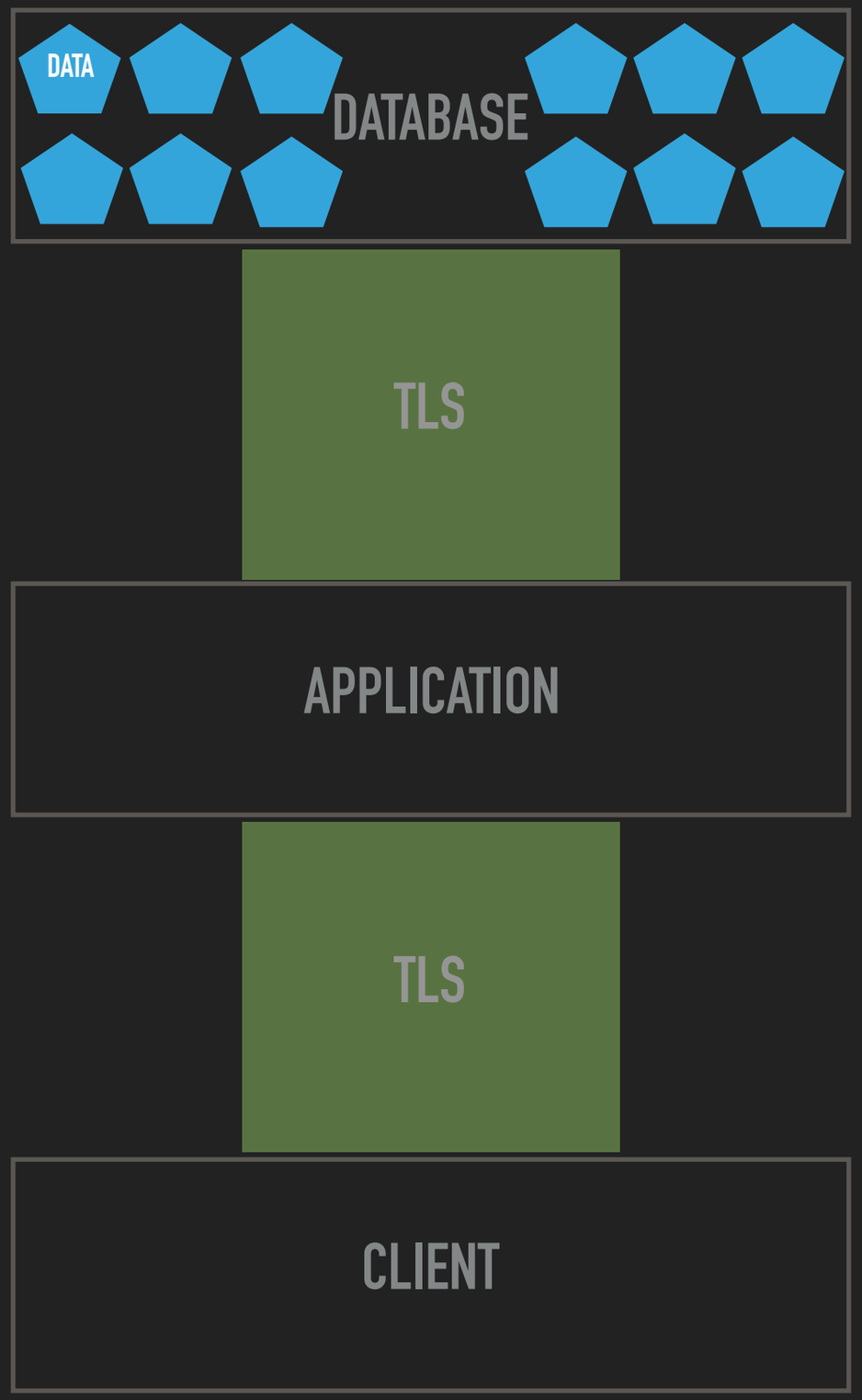


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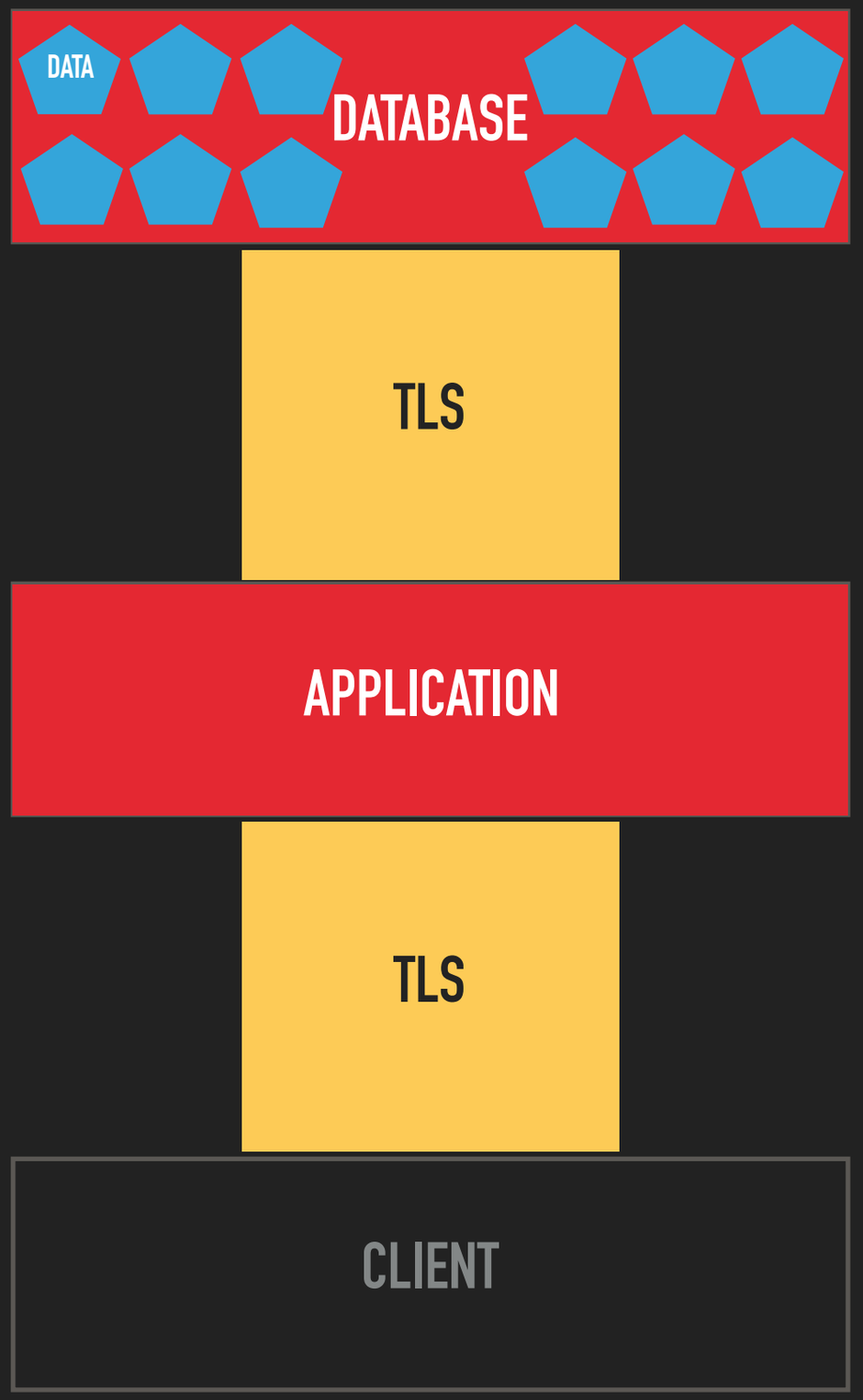


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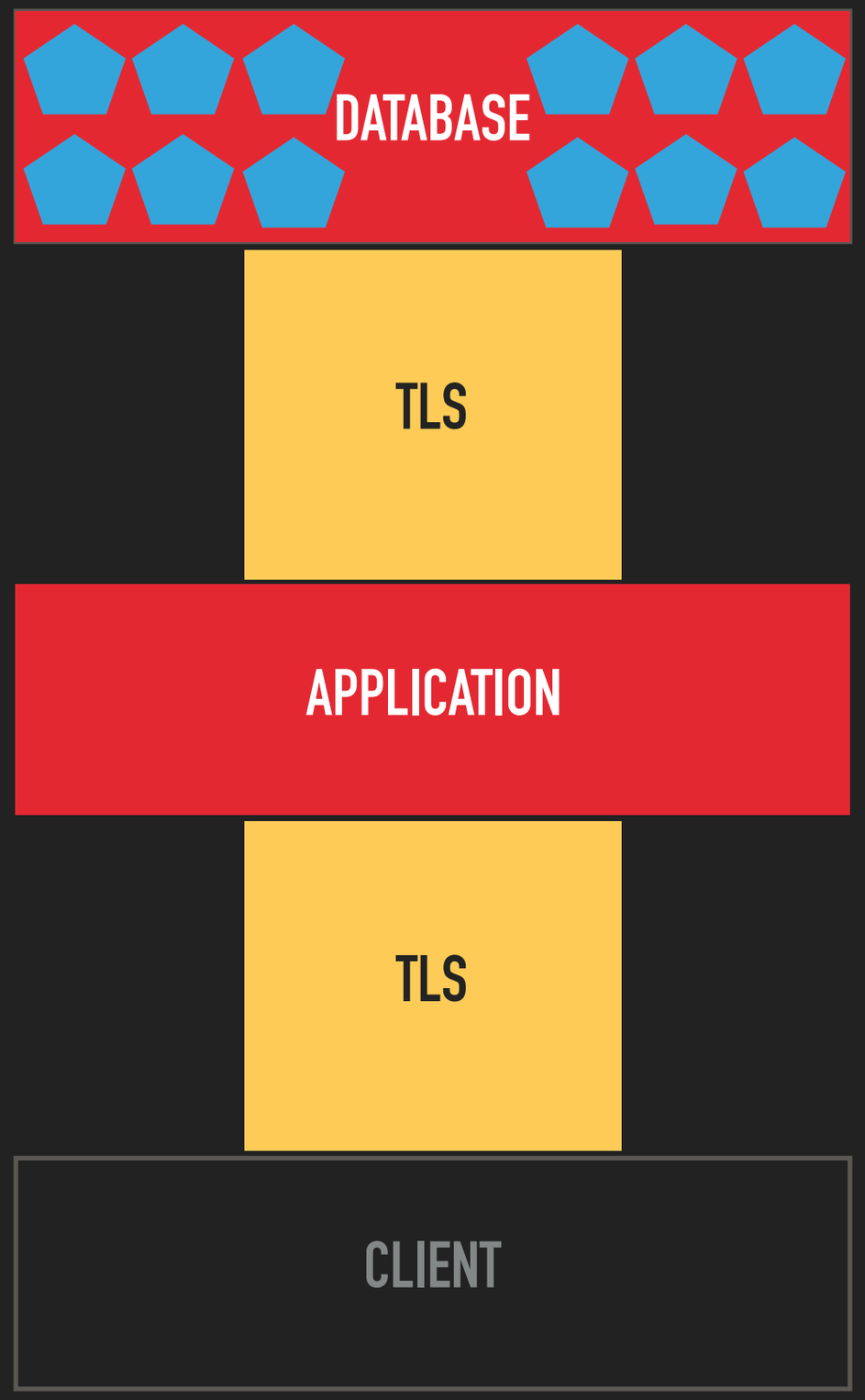
# WHAT ABOUT TLS?

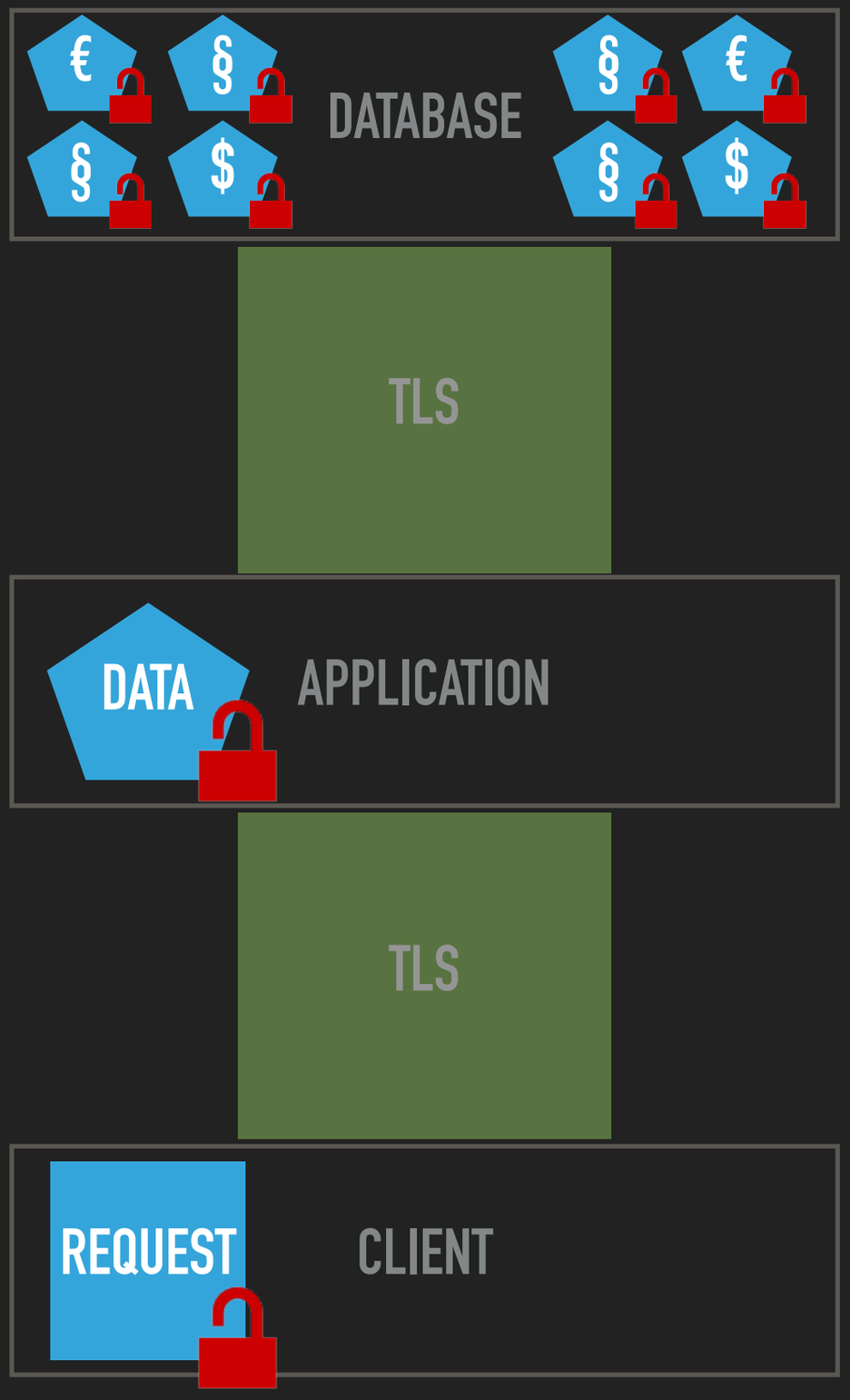
- Data is at rest for ~99.99998% of the time (*)
- Also: Heartbleed, POODLE, DROWN, Lucky13, Logjam, FREAK, …
- Also: Backups!

# WHAT IS CONTENT ENCRYPTION?

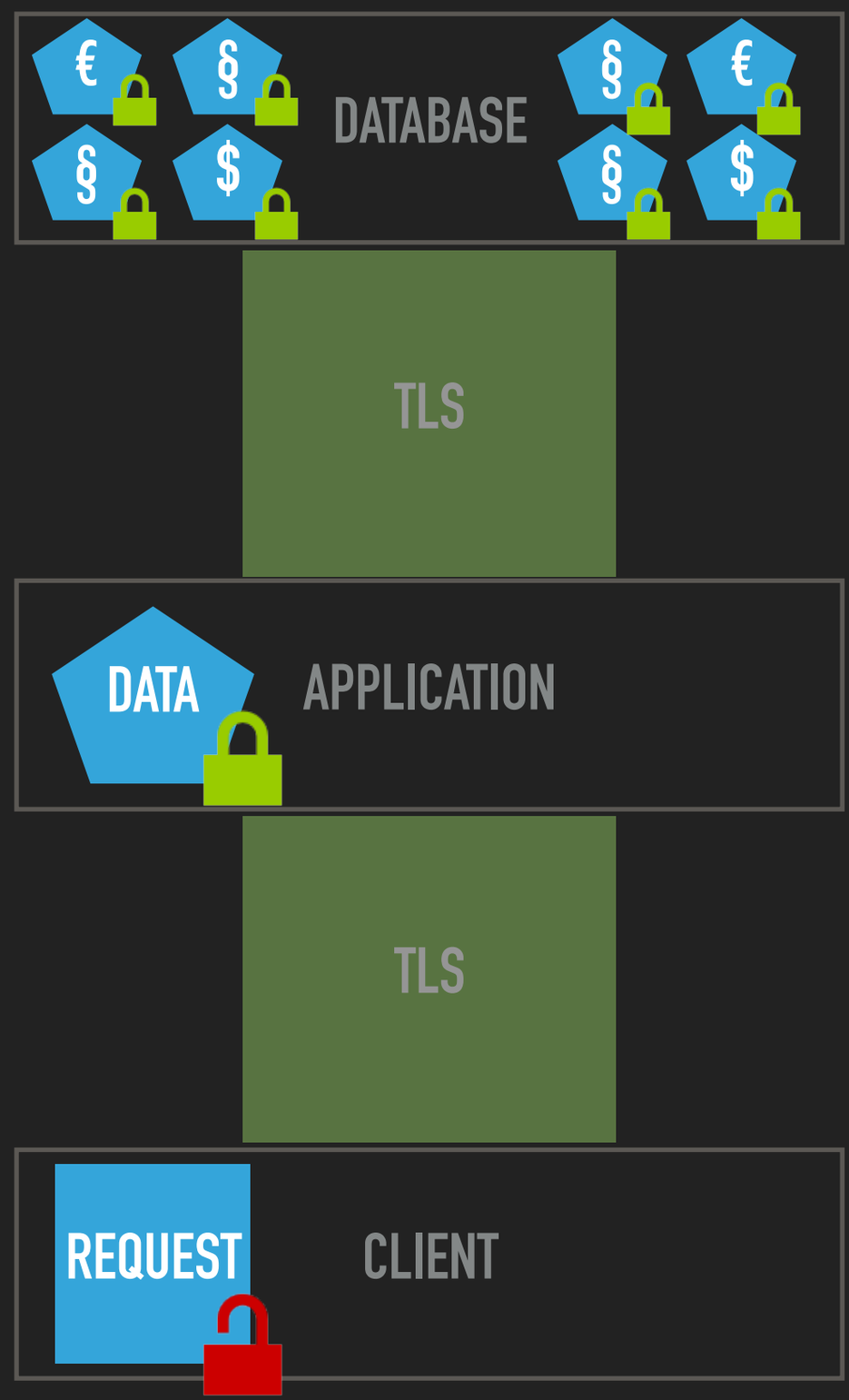
- Encrypt** data ‘itself’
- E.g. encrypted** data at rest
- Even: Encrypted** data while working with it




(*) 10s transit / 2 years storage (**) Cryptographically protected - details later!


DATABASE
TLS
DATA
APPLICATION
TLS
REQUEST
CLIENT

VS.


DATABASE
TLS
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WHY USE

# CONTENT ENCRYPTION?

# IT'S THE LAW

- A lot of (German) laws take data protection seriously
- Bundesdatenschutzgesetz (BDSG)
- Telemediengesetz (TMG)
- Telekommunikationsgesetz (TKG)
- Strafgesetzbuch (StGB)
- Sozialgesetzbuch (SGB)
- IT Sicherheitsgesetz (ITSiG)
- EUDSGV

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# BUNDESDATENSCHUTZGESETZ

## Applies to: Everyone working with personal data

- **§ 3 Weitere Begriffsbestimmungen**

  (1) Personenbezogene Daten sind Einzelangaben über persönliche oder sachliche Verhältnisse einer bestimmten oder bestimmbaren natürlichen Person (Betroffener).
  …
  (9) Besondere Arten personenbezogener Daten sind Angaben über die rassische und ethnische Herkunft, politische Meinungen, religiöse oder philosophische Überzeugungen, Gewerkschaftszugehörigkeit, Gesundheit oder Sexualleben.

- **§ 42a Informationspflicht bei unrechtmäßiger Kenntniserlangung von Daten**

  Stellt [eine verarbeitende Stelle] fest, dass bei ihr gespeicherte
  1. besondere Arten personenbezogener Daten (§ 3 Absatz 9),
  2. personenbezogene Daten, die einem Berufsgeheimnis unterliegen,
  3. […] strafbare Handlungen oder Ordnungswidrigkeiten […]
  4. personenbezogene Daten zu Bank- oder Kreditkartenkonten
  unrechtmäßig übermittelt […], und drohen schwerwiegende Beeinträchtigungen für die Rechte oder schutzwürdigen Interessen der Betroffenen […]
  **[Meldung an Aufsichtsbehörde und Betroffenen, ggfs. halbseitige Anzeige]**

BDSG

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# TELEMEDIENGESETZ

## Applies to: Everyone providing websites for profit

- **§ 13 Pflichten des Diensteanbieters**

(7) Diensteanbieter haben […] durch technische und organisatorische Vorkehrungen sicherzustellen, dass
1. [Zugriff auf] technischen Einrichtungen möglich ist und
2.diese
a) **gegen Verletzungen des Schutzes personenbezogener Daten …**

Vorkehrungen nach Satz 1 müssen den Stand der Technik berücksichtigen. **Eine Maßnahme nach Satz 1 ist insbesondere die Anwendung eines als sicher anerkannten Verschlüsselungsverfahrens.**

# TMG

- **§ 16 Bußgeldvorschriften**

…
(3) Die Ordnungswidrigkeit kann mit einer **Geldbuße bis zu fünfzigtausend Euro** geahndet werden.

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# TELEKOMMUNIKATIONSGESETZ

**Applies to: Everyone providing communication services (*)**

- **§ 109a Daten- und Informationssicherheit**
  (1) [...] im Fall einer Verletzung [...] unverzüglich [...] BNetzA & BfDI ...] zu benachrichtigen. Ist anzunehmen [...] schutzwürdigen Interessen beeinträchtigt werden, hat der Anbieter [...] zusätzlich die Betroffenen unverzüglich von dieser Verletzung zu benachrichtigen. In Fällen, [...] durch geeignete technische Vorkehrungen gesichert, insbesondere [...] Verschlüsselungsverfahrens gespeichert wurden, ist eine Benachrichtigung nicht erforderlich.

TKG

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(*) to “non-closed usergroups” E.g. public E-Mail services!

# STRAFGESETZBUCH

**Applies to: Everyone - here to Doctors, Lawyers, Health insurance,..**

- **§ 203 Verletzung von Privatgeheimnissen**

(1) Wer unbefugt ein fremdes Geheimnis, namentlich ein zum persönlichen Lebensbereich gehörendes Geheimnis oder ein Betriebs- oder Geschäftsgeheimnis, offenbart, das ihm als [Berufsgeheimnisträger] anvertraut worden oder sonst bekanntgeworden ist, wird mit Freiheitsstrafe bis zu einem Jahr oder mit Geldstrafe bestraft.

# §203 StGB

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# SOZIALGESETZBUCH

**Applies to: Everyone working with social data**

- You know when it applies!

# SGB

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# GENERAL DATA PROTECTION REGULATION

## Applies to: You (starting May 2018)

- **Art. 32 Security of processing**

  Taking into account the state of the art […] as well as the risk […] for the rights and freedoms of natural persons […] **the controller and the processor** shall implement appropriate technical […] measures to ensure a level of security appropriate to the risk, including inter alia as appropriate:

  A. the **pseudonymisation and encryption** of personal data;

  B. the ability to **ensure the ongoing confidentiality, integrity**, availability and resilience of processing systems and services;

  C. …

- recitals 83: Security of processing

GDPR

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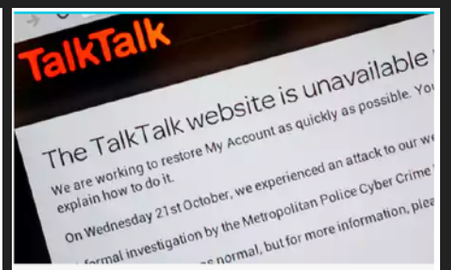
# IT'S COMPLIANCE

- Company rules require encryption
- PCI DSS
- ISO 27001
- ...

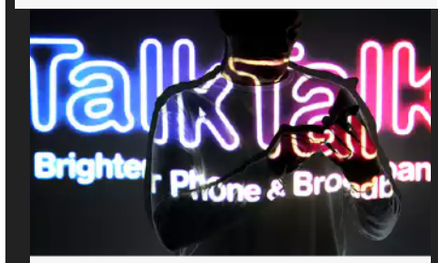
# NOT CONVINCED YET?

# ASK THE COMPETITION!

# ASK THE COMPETITION PT. 1


TalkTalk profits halve after cyber-attack




TalkTalk hit with record £400k fine over cyber-attack

https://www.bloomberg.com/quote/TALK:LN

https://www.theguardian.com/business/2016/may/12/talktalk-profits-halve-hack-cyber-attack

https://www.theguardian.com/business/2016/feb/02/talktalk-cyberattack-costs-customers-leave

# ASK THE COMPETITION PT. 2

**Adultery Website AshleyMadison Seeks IPO as Demand Booms**

Kristen Schweizer
15 April 2015, 13:27 CEST

before

after

A data dump, 9.7 gigabytes in size, was posted on Tuesday to the dark web using an Onion address accessible only through the Tor browser. The files appear to include account details and log-ins for some 32 million users of the social networking site, touted as the premier site for married individuals seeking partners for affairs. Seven years worth of credit card and other payment transaction details are also part of the dump.

In August 2015, after its customer records were leaked by hackers, a $576 million class-action lawsuit was filed against the company.[48]

https://www.bloomberg.com/news/articles/2015-04-15/adultery-website-ashleymadison-seeks-ipo-as-demand-booms

https://www.wired.com/2015/08/happened-hackers-posted-stolen-ashley-madison-data/

https://en.wikipedia.org/wiki/Ashley_Madison

# ASK THE COMPETITION PT. 3

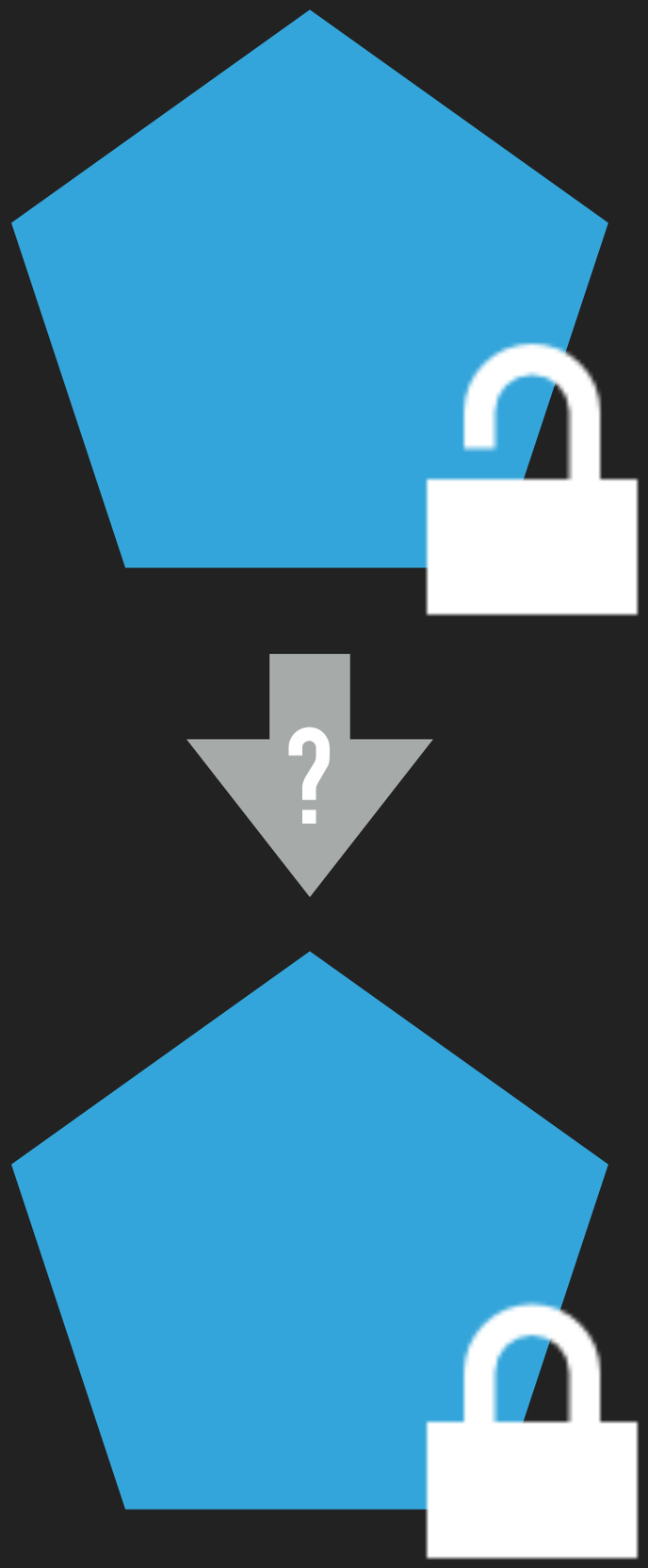
## Breached Organizations Lose Millions in Market Value, Finds New Report

> *"For a typical FTSE 100 firm the impact of 1.8 per cent equates to a permanent loss of market capitalization of £120 million," explains the report – which amounts close to $150 million USD.*

> *"Lost shareholder value across European markets could rise by as much as a factor of 10 when the new regulations take effect in May 2018," **Rogoyski told Infosecurity Magazine**.*

https://www.tripwire.com/state-of-security/latest-security-news/breached-organizations-lose-millions-marke value-finds-new-report/

http://breachlevelindex.com/




HOW TO DESIGN

# CONTENT ENCRYPTION

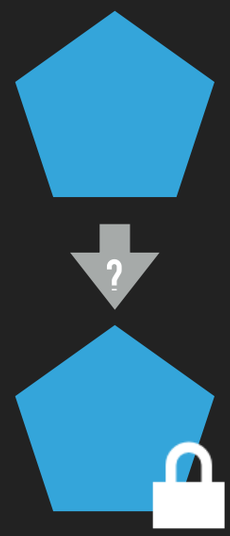
# 0 – REGULATIONS & INITIAL RISK ASSESSMENT


# 1 – DATA CLASSIFICATION

# 2 – DATA TREATMENT PLAN

# 3 – IMPLEMENTATION PLAN

# 0 – REGULATIONS & INITIAL RISK ASSESSMENT




1. List all relevant **laws, regulations**, etc. with a legal expert
2. List all **data items** (“Adress”, “Bank Account”, …)
3. Estimate **initial risks** (damage & probability) for CIA violations with management and legal expert

# 1 – DATA CLASSIFICATION


Classify all data items with respect to regulations

| Item | Regulation | |
|---|---|---|
| **Customer** | | |
| - Name | BDSG | Pers. bez. Datum |
| - Bank Account | BDSG | bes. PbD |
| ... | ... | ... |
| **Marketing E-Mail** | | |
| - Recipient | BDSG | Pers. bez. Datum |
| - Text | ??? | ??? |
| - Protocol | ??? | ??? |

THIS DEPENDS ON YOUR SPECIFIC APPLICATION/SCENARIO!

I AM NOT A LAWYER!

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**Classification depends on context!**

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# 2 – DATA TREATMENT PLAN


Create a data treatment plan, and for each data item

- describe how (*) this data must be
- **... stored**
- **... transmitted**
- **... logged**
- **... backed up**
- and when it must be **deleted**!

(*) how: plain, masked (“XXXXX 123”), pseudonymised, anonymised, encrypted, hashed.

**Also**: consider integrity protection.

| Item | Store | Transmit | Log | Backup | Delete |
|---|---|---|---|---|---|
| **Customer** | | | | | |
| - Name | Plain | Encrypted | Pseud. | Encrypted | BDSG |
| - Bank | Encrypted | Encrypted | Masked | Encrypted | BDSG |
| … | … | … | | | |
| **Marketing E-Mail** | | | | | |
| - Recipient | Plain | Encrypted | Pseud. | Encrypted | BDSG |
| - Text | ??? | ??? | | | |
| - Protocol | ??? | ??? | | | |

**Also**: consider integrity protection.

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# 3 – IMPLEMENTATION PLAN


Update the requirements

- Merge Use Cases & data treatment plan
- Add cryptographic use cases

LONGER STORY: WRITE A CRYPTOGRAPHY & SECURITY CONCEPT

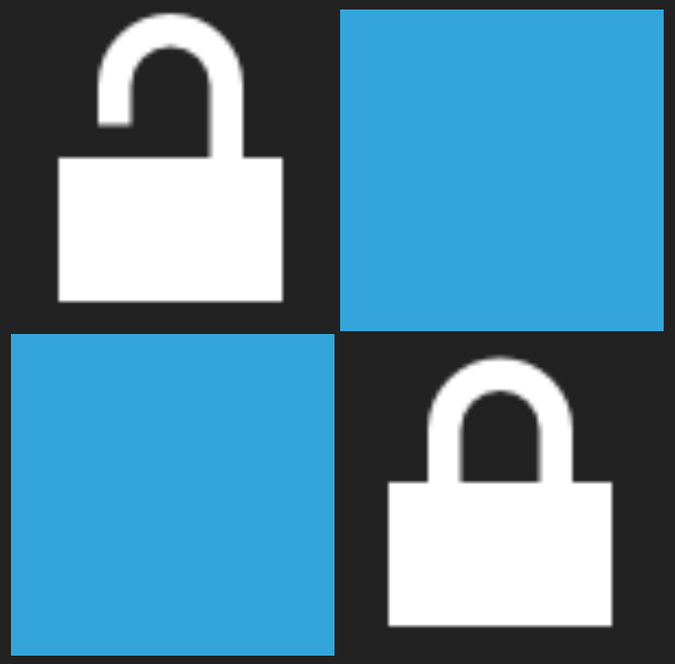
# RECAP

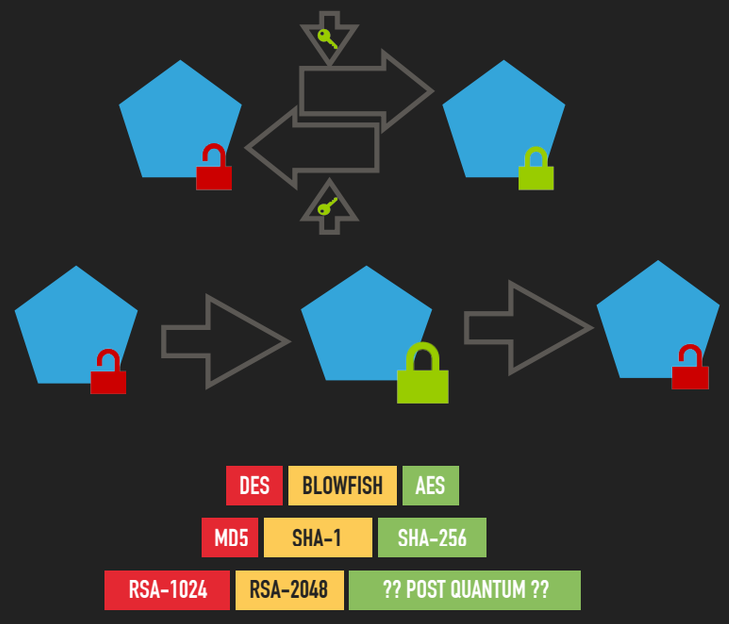

0 - Regulations & initial risk assessment ✓

1 - Data classification ✓

2 - Data treatment plan ✓

**3 - Implementation Plan** ✓

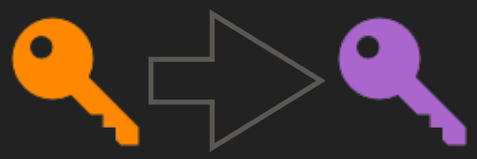






- [x] Data treatment ...
- [x] Use existing ...
- [x] ...


0X123456...



DATA

```
int getRandomNumber()
{
    return 4;  // chosen by fair dice roll.
               // guaranteed to be random.
}
```

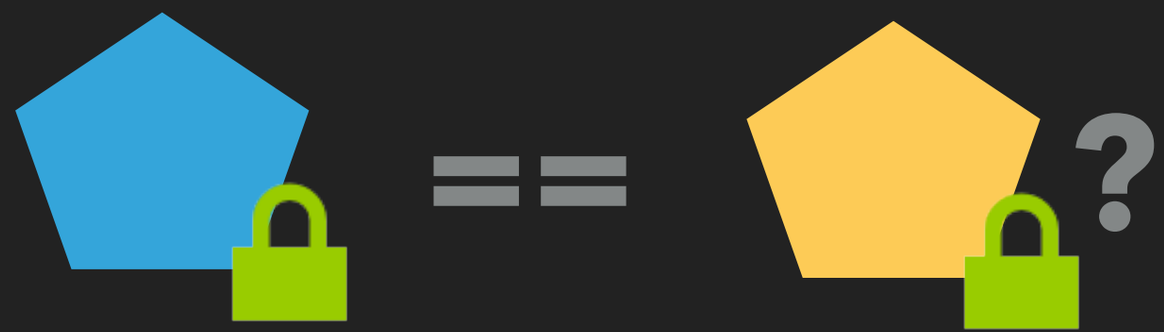
# CONTENT ENCRYPTION

# PATTERNS

# MOST IMPORTANT ADVICE: GET AN EXPERT OR AT LEAST READ AND UNDERSTAND THE DOCUMENTATION!

Like all power tools: Better RTFM than to lose an eye!

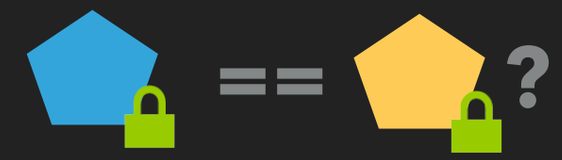
- At least be able to explain: “Hash vs. encryption”, “Integrity vs. encryption”, “Stream vs. block”, “Mode of operation”, “IV”, “Nonce”, “Padding”, “Key derivation”
- Identify and name  your trust anchors



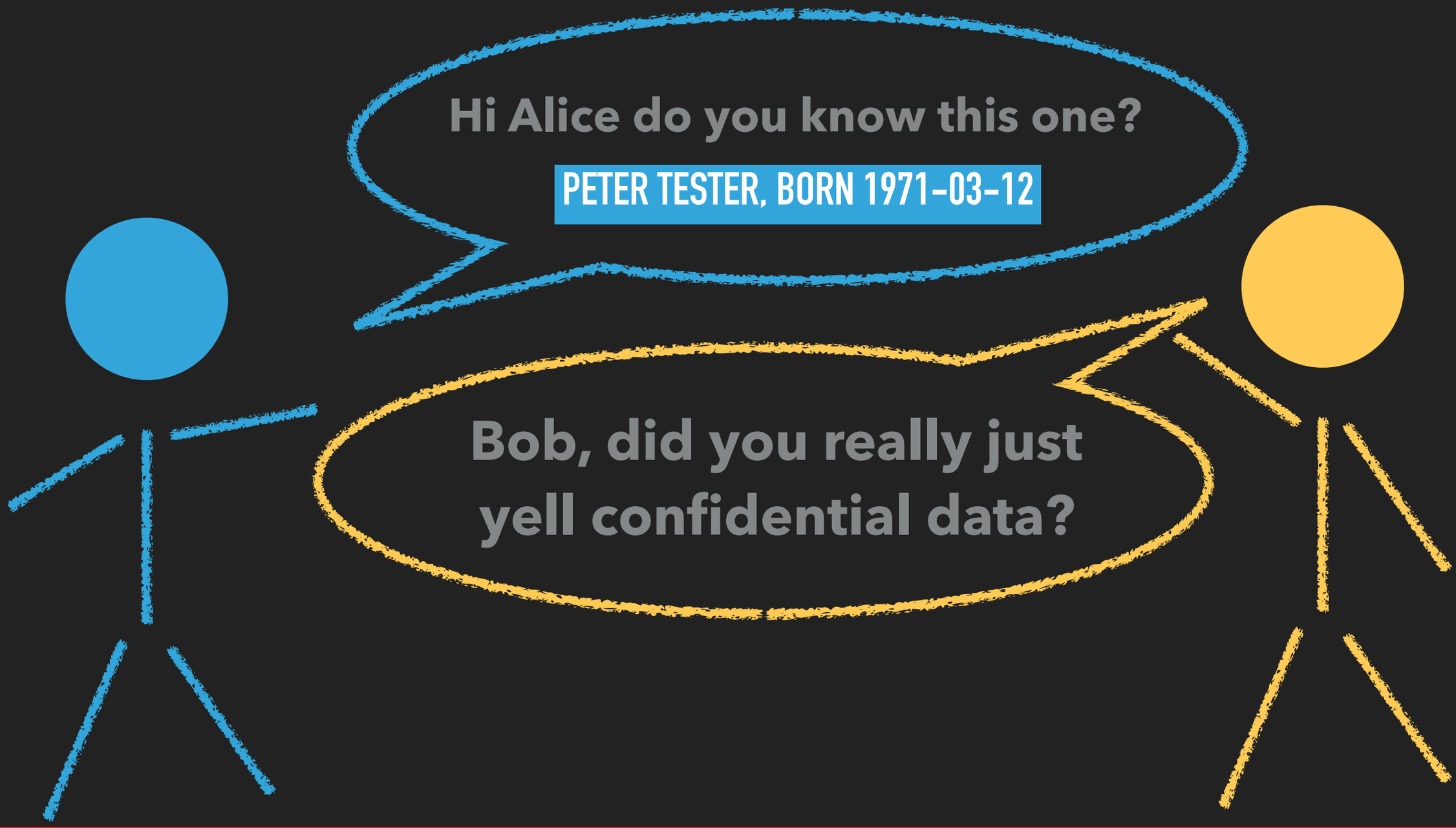

PATTERNS

# COMPARING

# COMPARE DATA




**Problem:** Securely compare two data items



# COMPARE DATA

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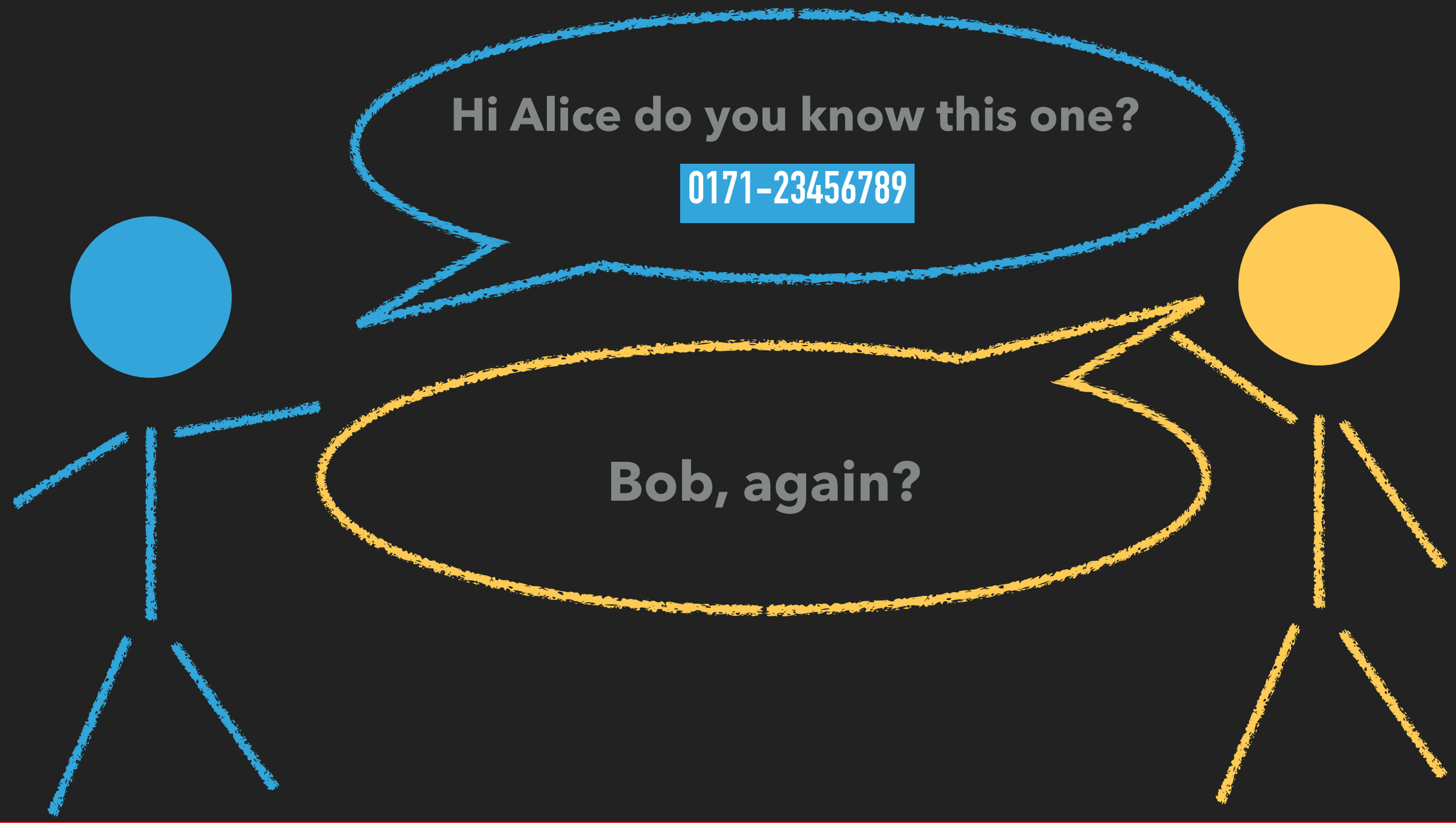



CONFIDENTIAL DATA EXCHANGED!

# COMPARE DATA


**Problem:** Securely compare two data items

Hi Alice do you know this one?

AF7ABC231....

Yes, I already have that one!

NO CONFIDENTIAL DATA EXCHANGED.

# COMPARE DATA


**Problem:** Securely compare two data items

**Solution:** Normalise & hash data, compare hashes

LOREM IPSUM . . . == LOREM IPSUM . . .

# COMPARE DATA

**Problem:** Securely compare two data items

**Solution:** Normalise & hash data, compare hashes

LOREM IPSUM . . . == LOREM IPSUM . . .

=> sha256( LOREM IPSUM . . . ) == sha256( LOREM IPSUM . . . )

# COMPARE DATA


**Problem:** Securely compare two data items

**Solution:** Normalise & hash data, compare hashes

LOREM IPSUM . . . == LOREM IPSUM . . .

=> **sha256(** LOREM IPSUM . . . **) == sha256(** LOREM IPSUM . . . **)**

★ Collisions [**A != B** but **sha256(A) == sha256(B)**] are mathematically possible, but practically not relevant

# COMPARE DATA


**Problem:** Securely compare two data items

**Solution:** Normalise & hash data, compare hashes

LOREM IPSUM . . . == LOREM IPSUM . . .

=> sha256( LOREM IPSUM . . . ) == sha256( LOREM IPSUM . . . )

<=> 4C53E9C9. . . == 4C53E9C9. . .

★ Collisions [**A != B** but **sha256(A) == sha256(B)**] are mathematically possible, but practically not relevant

# COMPARE DATA

**Problem:** Securely compare two data items

**Solution:** Normalise & hash data, compare hashes

## 1 - Normalize

E.g. J. EDGAR HOOVER ⇨ HOOVER, JOHN EDGAR ⇨* H160, J500 E326

## 2 - Hash

Use *hash(salt + data)* to prevent precomputing attacks. Use multiple iterations of hashing.

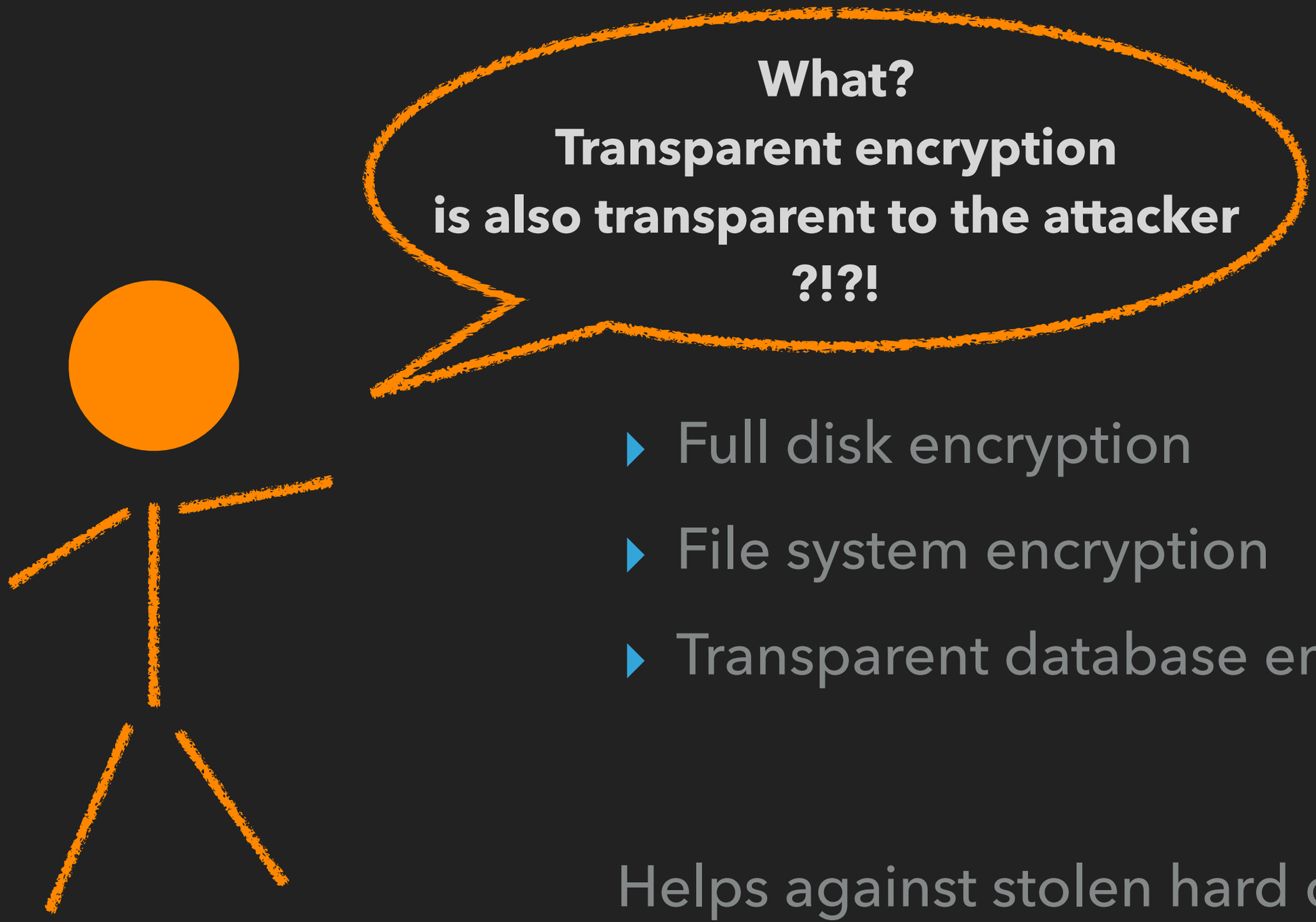
- *public salt* => treat hash as *pseudonymised*
- *secret salt* => treat hash as *anonymised*

* *Soundex - but choose whatever normalisation works for you*


PATTERNS

# TRANSPARENT ENCRYPTION

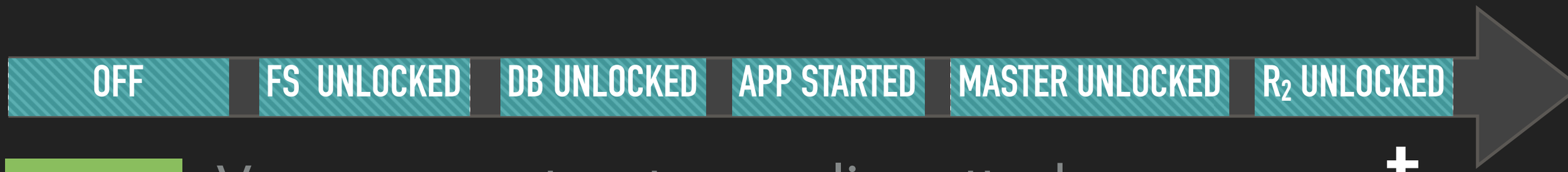
# TRANSPARENT ENCRYPTION


- Full disk encryption
- File system encryption
- Transparent database encryption

Helps against stolen hard disks.

# TRANSPARENT ENCRYPTION (ATTACKS VIA APPLICATION)


Very secure at rest, no online attack

Very secure at rest, key in RAM

Very secure at rest, data in RAM

Completely accessible

* Filesystem

# TRANSPARENT ENCRYPTION (ATTACKS VIA APPLICATION)


FS*

OFF | FS UNLOCKED | DB UNLOCKED | APP STARTED | MASTER UNLOCKED | $R_2$ UNLOCKED

t

Very secure at rest, no online attack

Very secure at rest, key in RAM

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Completely accessible

* Filesystem

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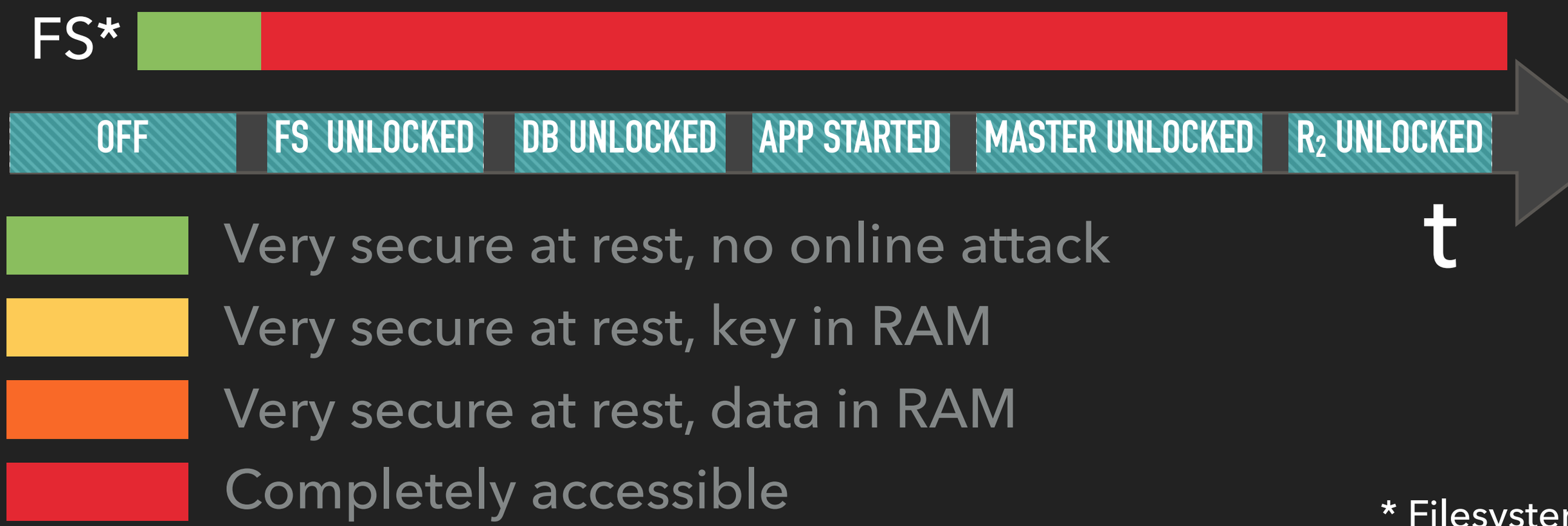

# TRANSPARENT ENCRYPTION (ATTACKS VIA APPLICATION)





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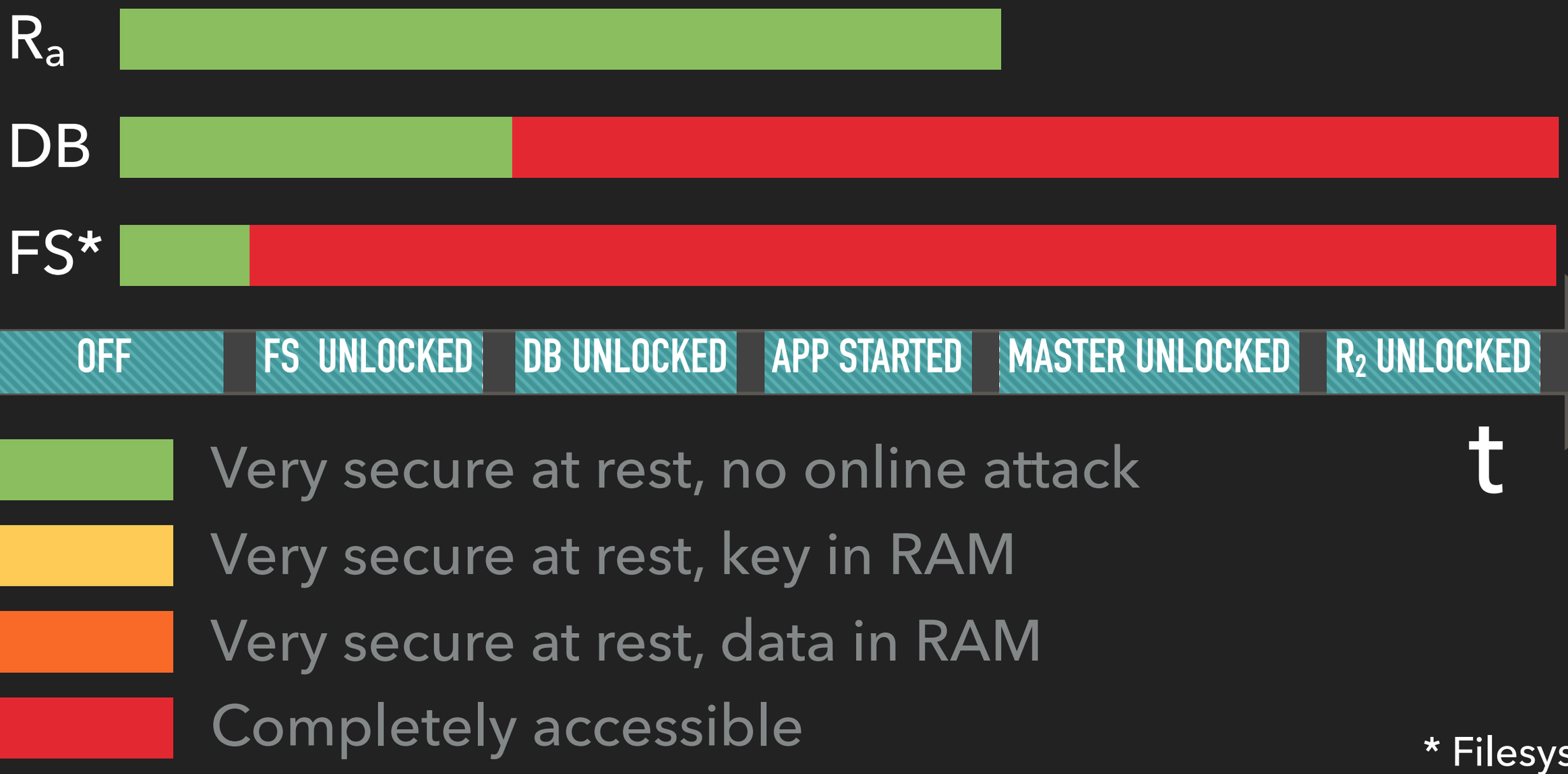


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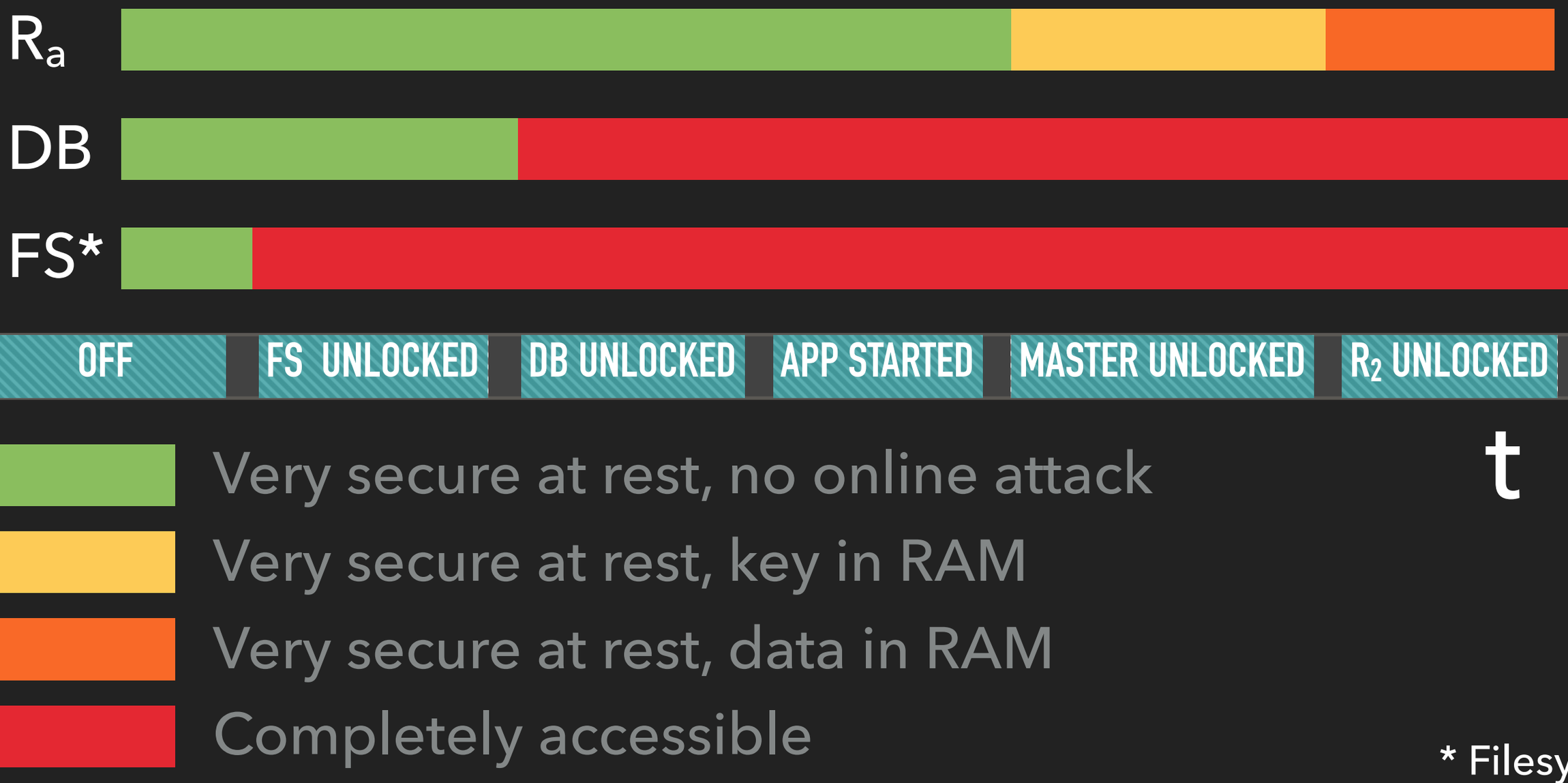
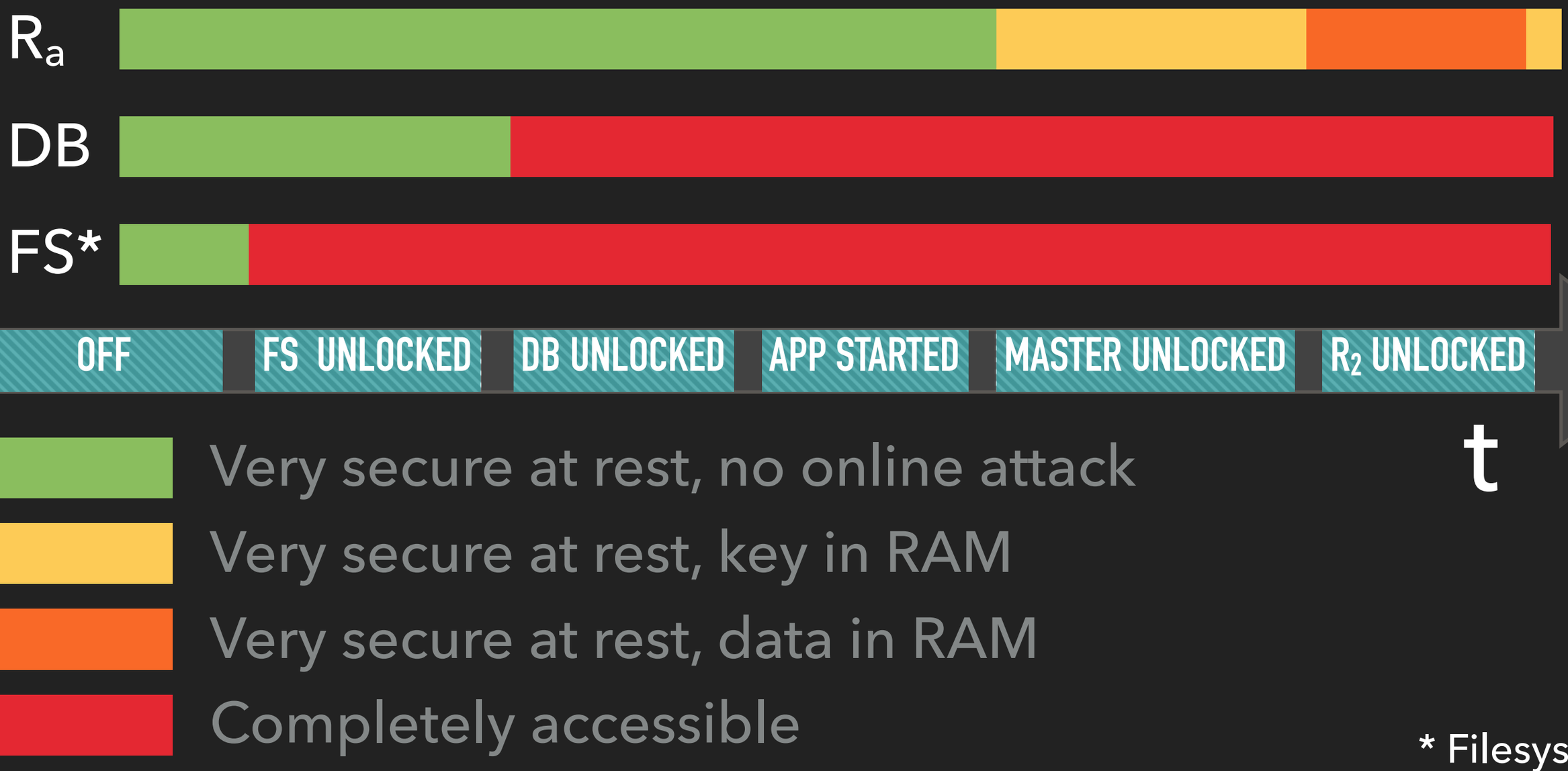
* Filesystem

# TRANSPARENT ENCRYPTION (ATTACKS VIA APPLICATION)

# TRANSPARENT ENCRYPTION (ATTACKS VIA APPLICATION)


Very secure at rest, no online attack

Very secure at rest, key in RAM

Very secure at rest, data in RAM

Completely accessible

* Filesystem

# TRANSPARENT ENCRYPTION (ATTACKS VIA APPLICATION)


$R_b$

$R_a$

DB

FS*

OFF | FS UNLOCKED | DB UNLOCKED | APP STARTED | MASTER UNLOCKED | $R_2$ UNLOCKED

t

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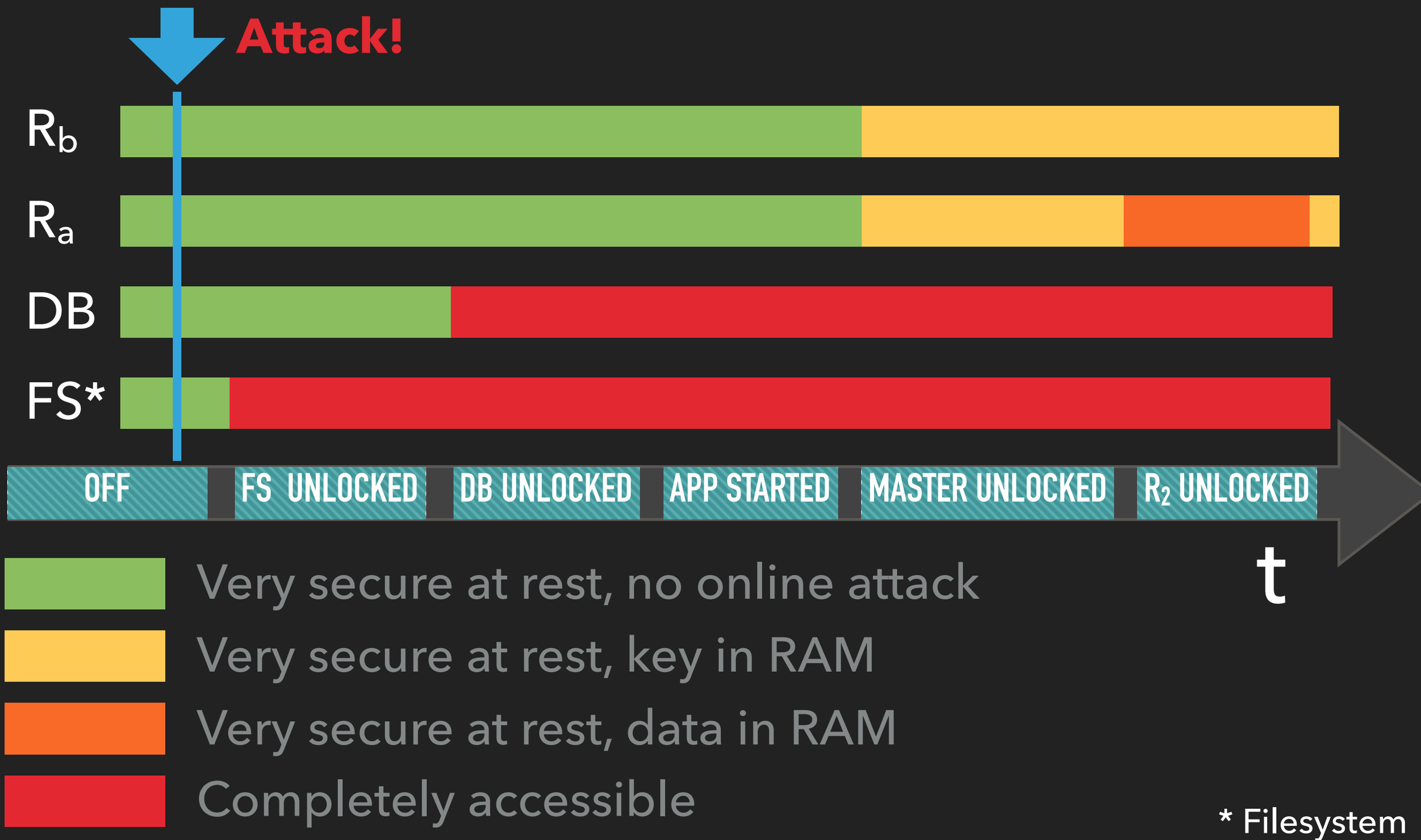

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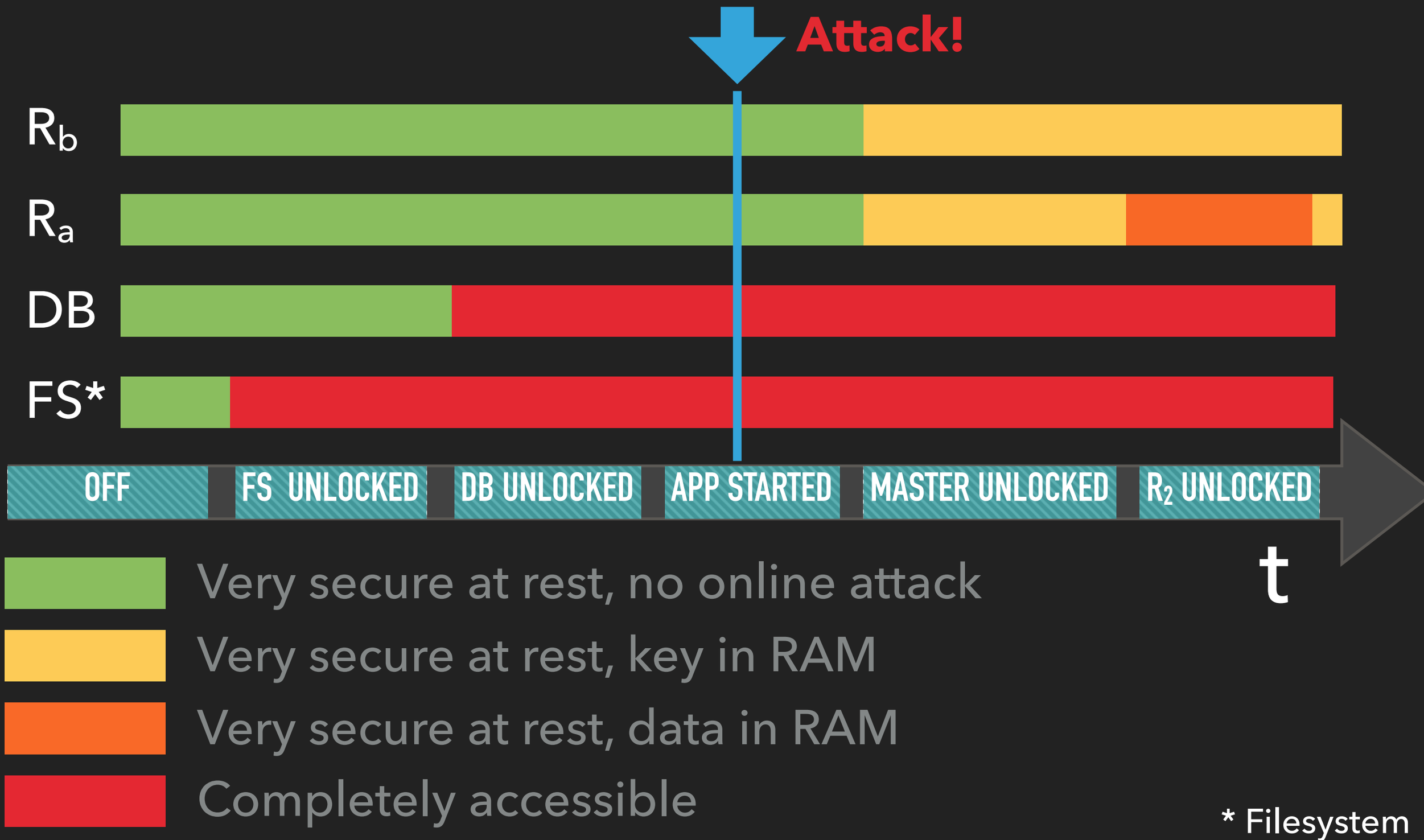

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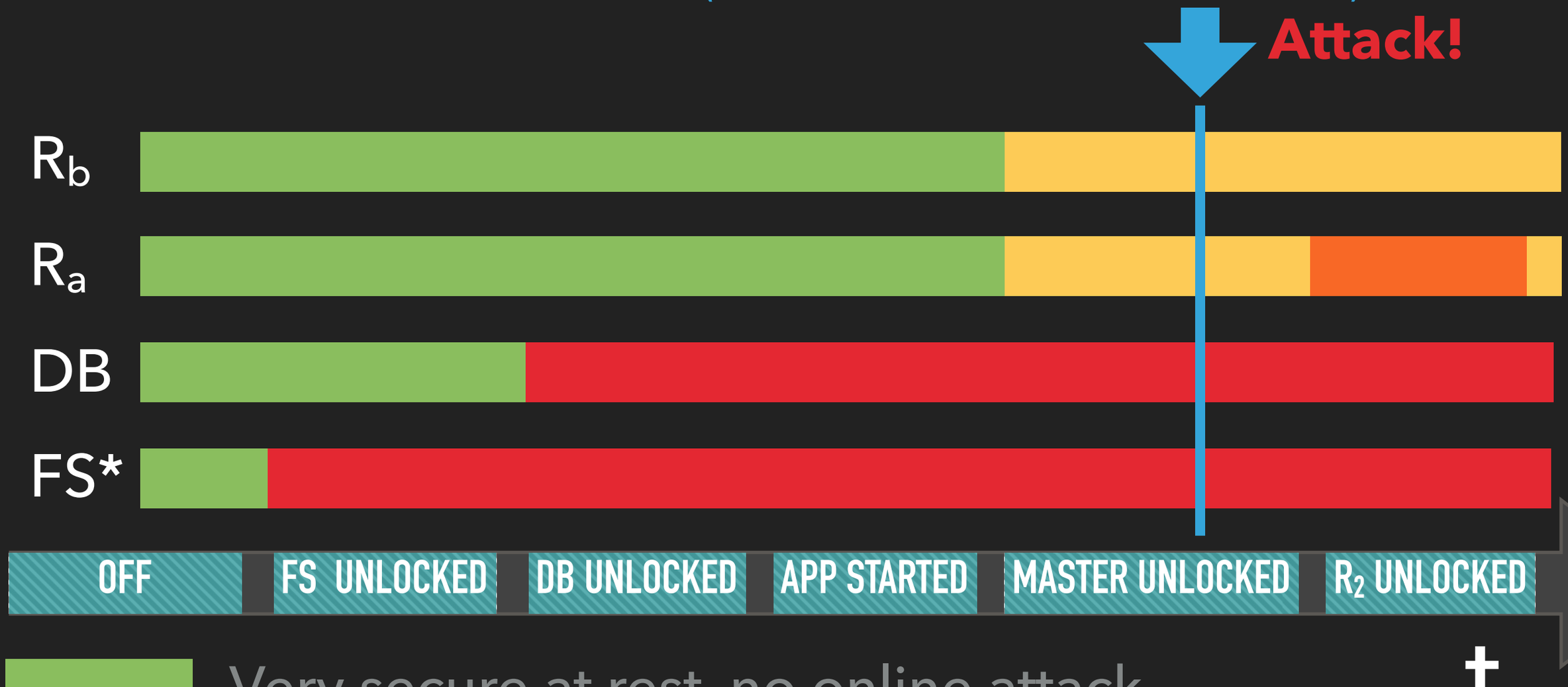


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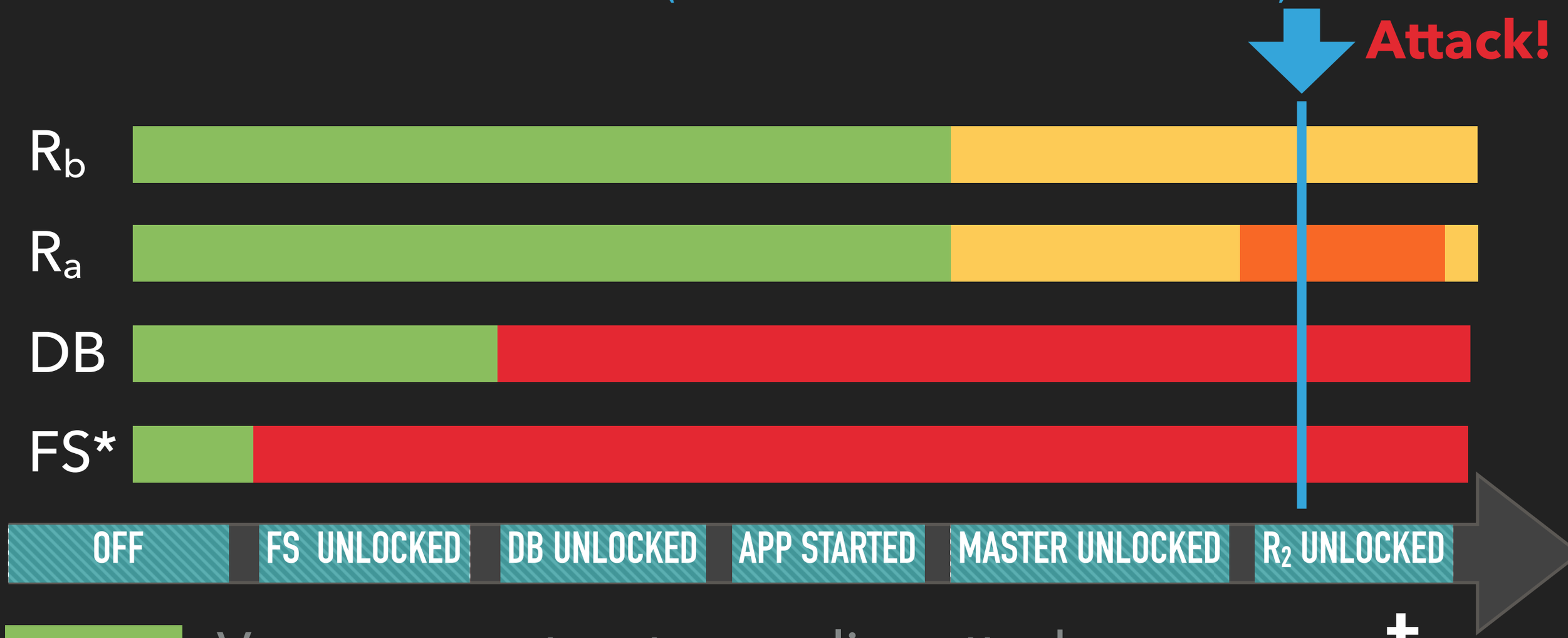


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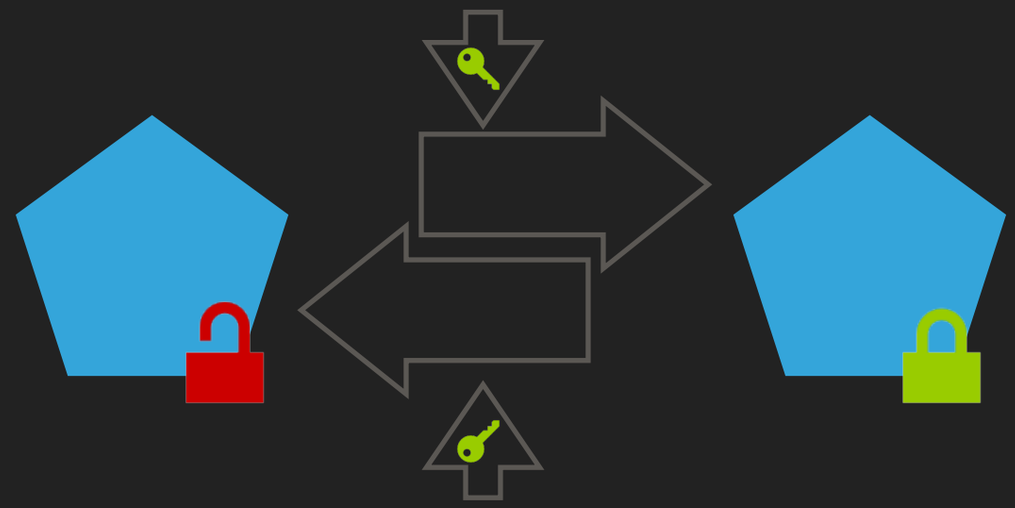
Completely accessible

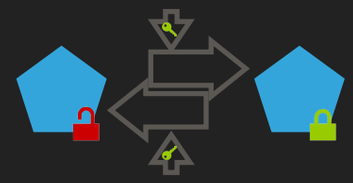
* Filesystem



PATTERNS

# STORING

# SECURE MULTIPLE DATA RECORDS

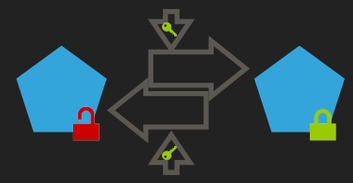


**Problem:** Multiple records are read and written by the same application.

**Solution:** Use symmetric encryption to protect the records.

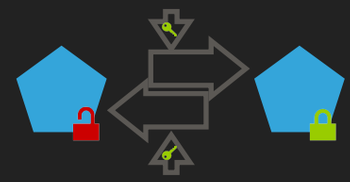

Reading and writing plaintext record ‘R’ 

# SECURE MULTIPLE DATA RECORDS




En-/decrypt Data ‘R’ (record) with key ‘K’.🔑

# SECURE MULTIPLE DATA RECORDS

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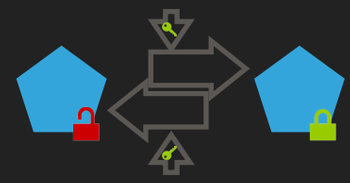
# SECURE MULTIPLE DATA RECORDS

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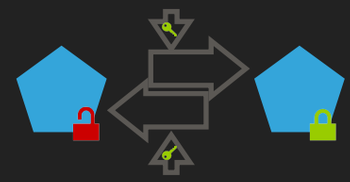
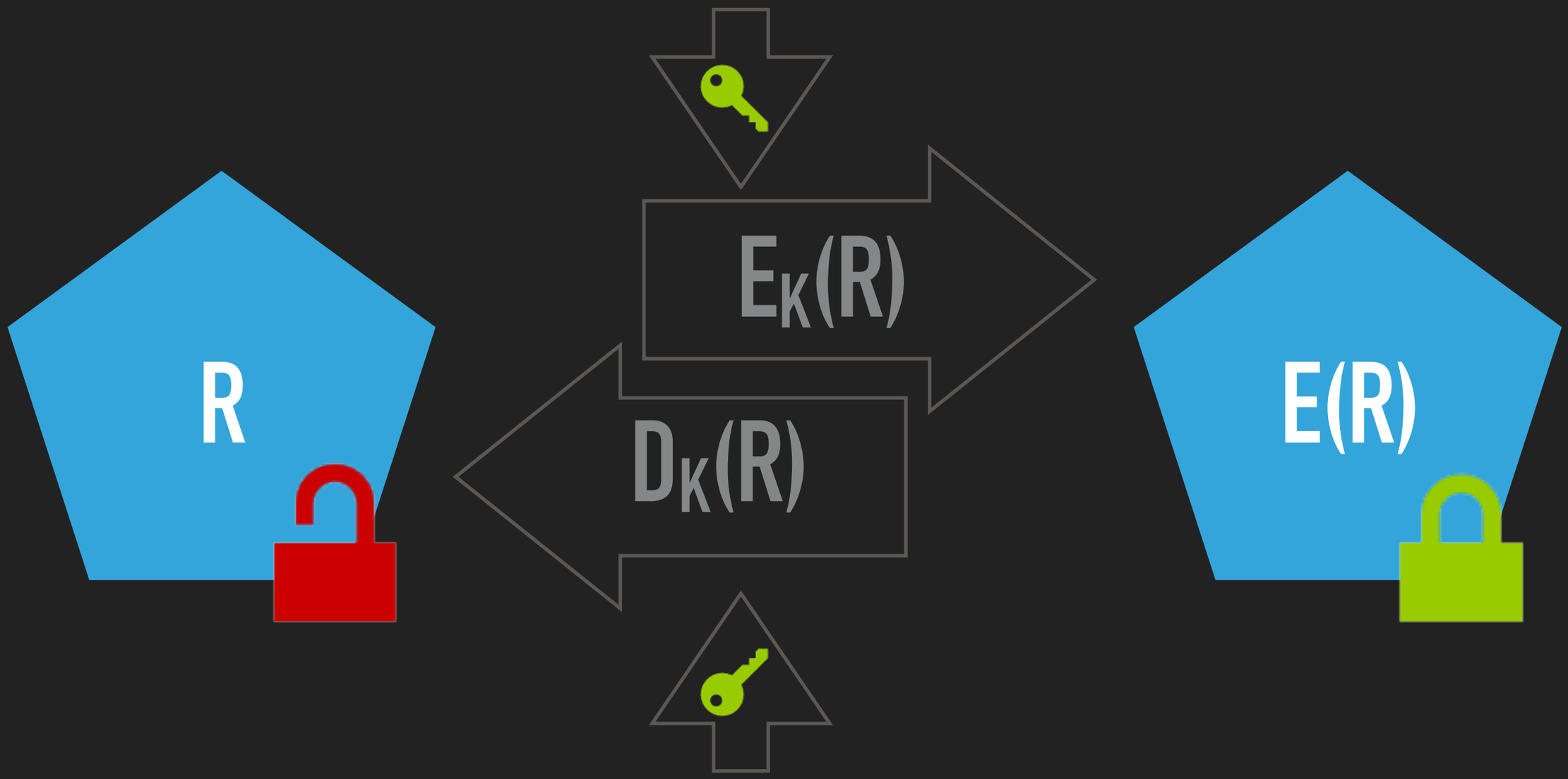
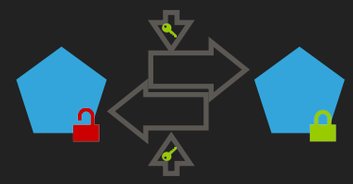
# SECURE MULTIPLE DATA RECORDS

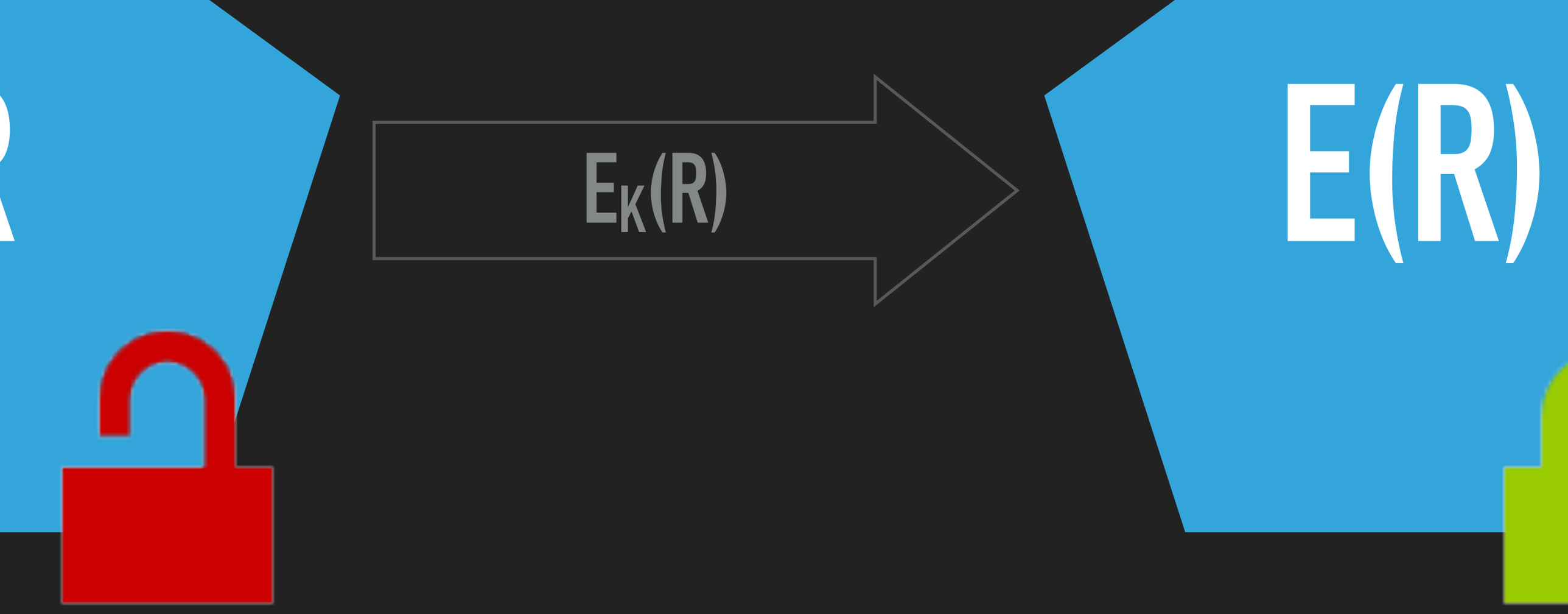




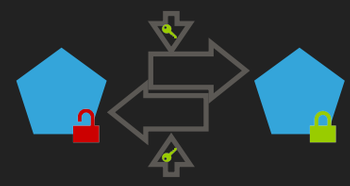

En-/decrypt Data ‘R’ (record) with key ‘K’.

# SECURE SMALL KEY(S)



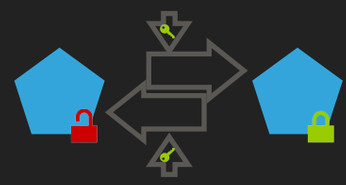


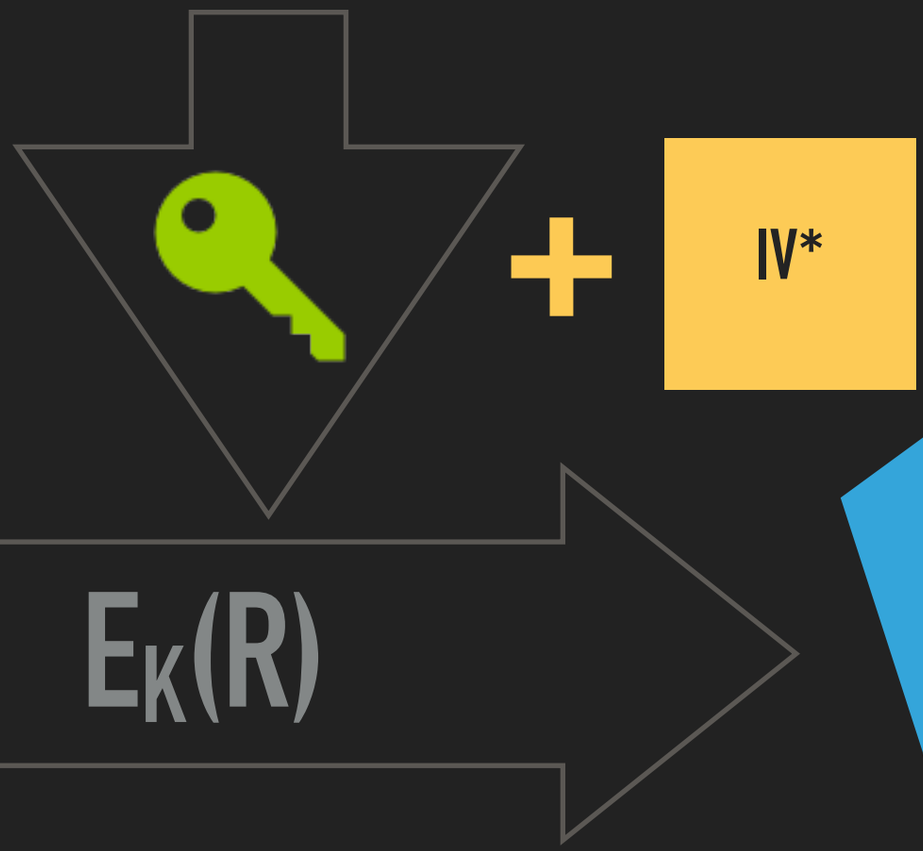
# SECURE SMALL KEY(S)




E(R)

# SECURE SMALL KEY(S)



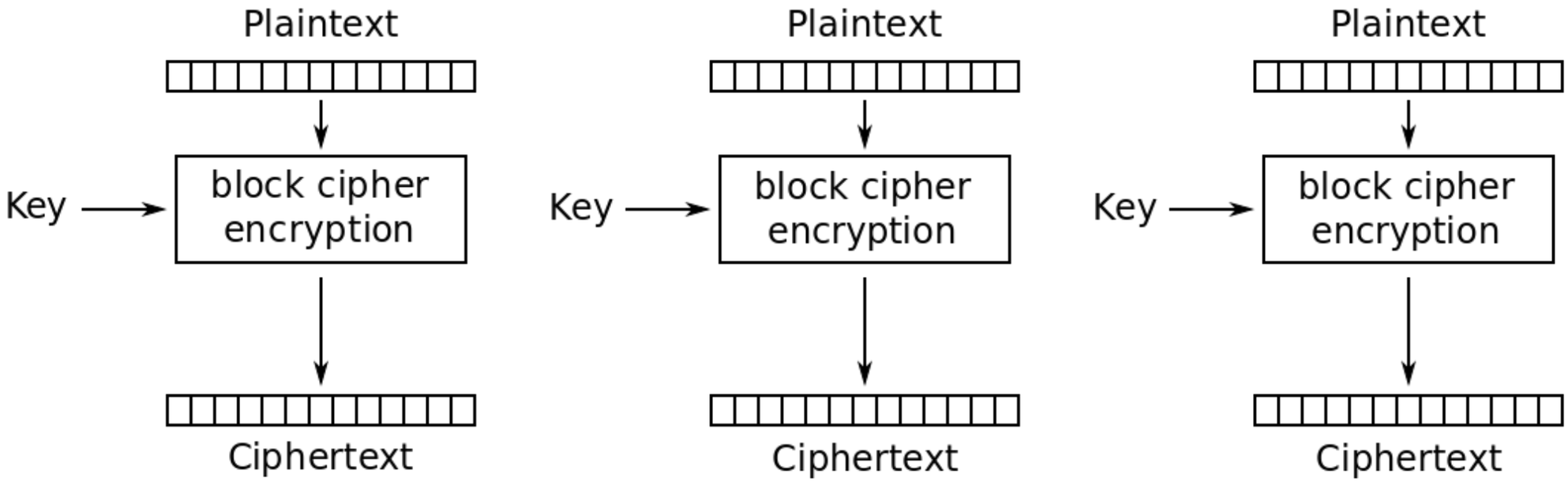



E(R)

IV

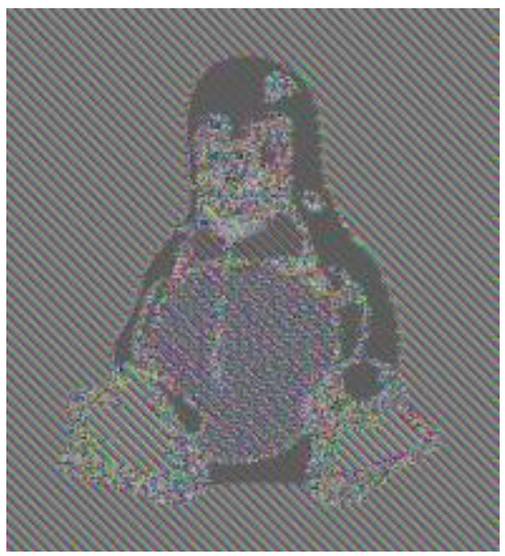
(*) IV - Initialisation Vector. Used in many cryptographic operations. Like a salt. Must be random, might be public.

# BLOCK CIPHERS AND THE IV




Electronic Codebook (ECB) mode encryption

Original

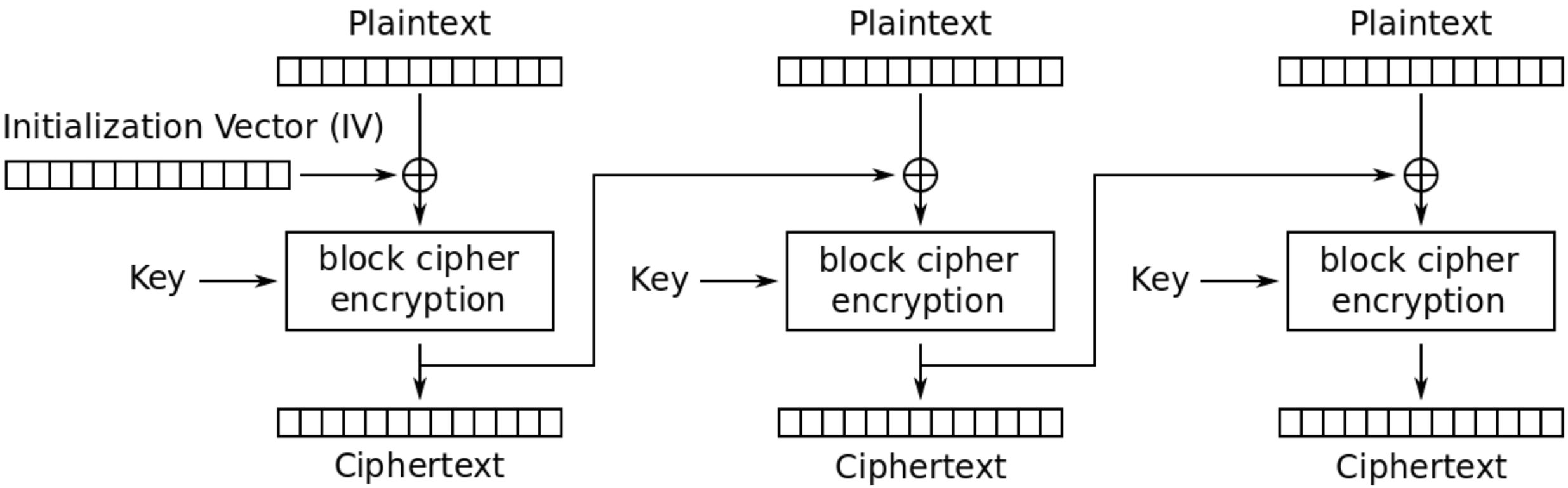


ECB

CBC (or other)

https://en.wikipedia.org/wiki/Block_cipher_mode_of_operation

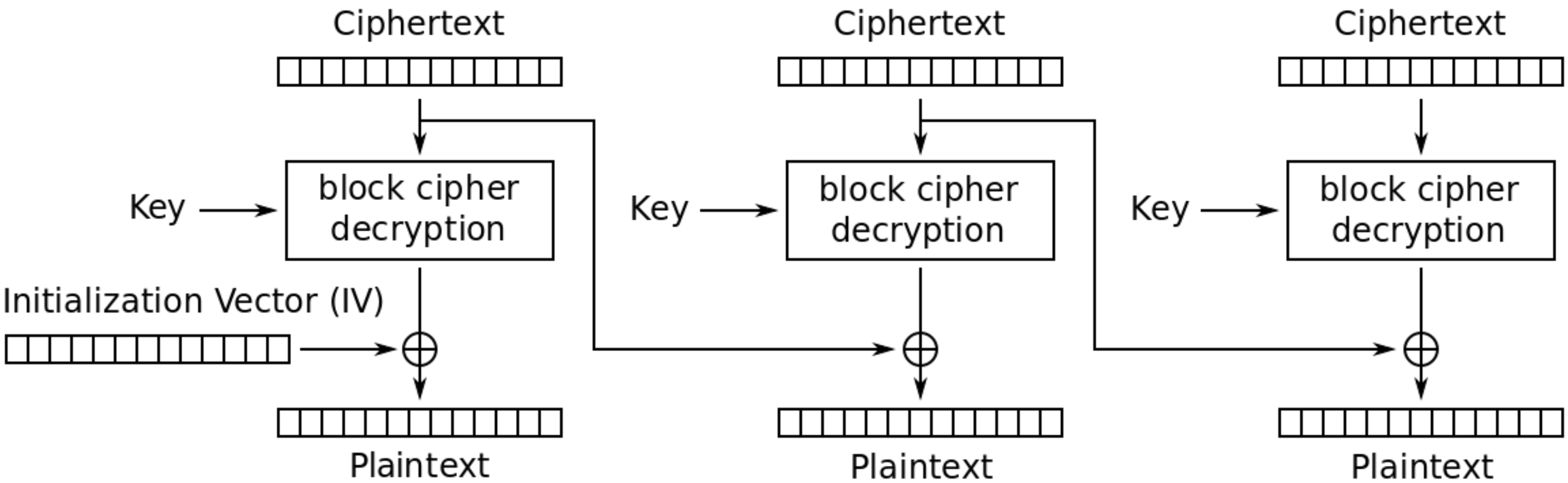
# BLOCK CIPHERS AND THE IV




Cipher Block Chaining (CBC) mode encryption

https://en.wikipedia.org/wiki/Block_cipher_mode_of_operation

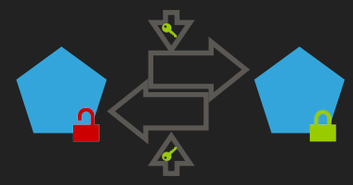
# BLOCK CIPHERS AND THE IV



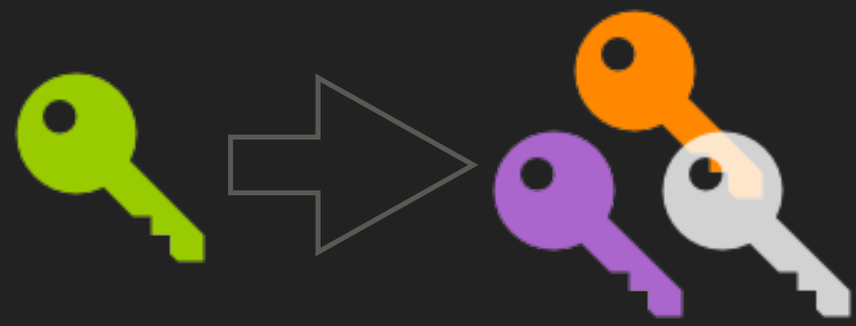

Cipher Block Chaining (CBC) mode decryption

https://en.wikipedia.org/wiki/Block_cipher_mode_of_operation

# SOLUTIONS FOR SECURING KEY(S)



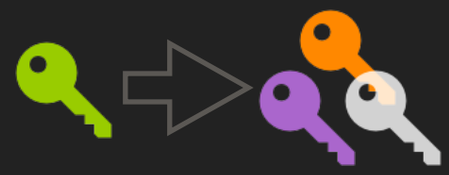
| | | |
|---|---|---|
| Master key in different storage | **E.g. records in DB, master key on filesystem.** | Baseline. Easy. Protects (only) agains DB theft (e.g. SQL injection) |
| Encrypt master key | **Use baked in 'obfuscation key' to encrypt master key. Better: Store master key in OS keyring.** | Easy. Some protection against FS access (e.g. remote file inclusion) |
| Derive per-record key | **Unique per record key derived from master key.** *Bonus: Protect integrity. Bind to record.* | Mostly easy. Protects against some cipher text attacks. *Use AEAD!* |
| Crypto Host | **All crypto operations on a dedicated host. (Master)key never leaves Crypto Host.** | Depends on architecture. Helps w. key distribution. Makes key theft difficult. |
| HSM | **Use Hardware Security Module as Crypto Host.** | Expensive & difficult. "Crypto Host on steroids". |



PATTERNS

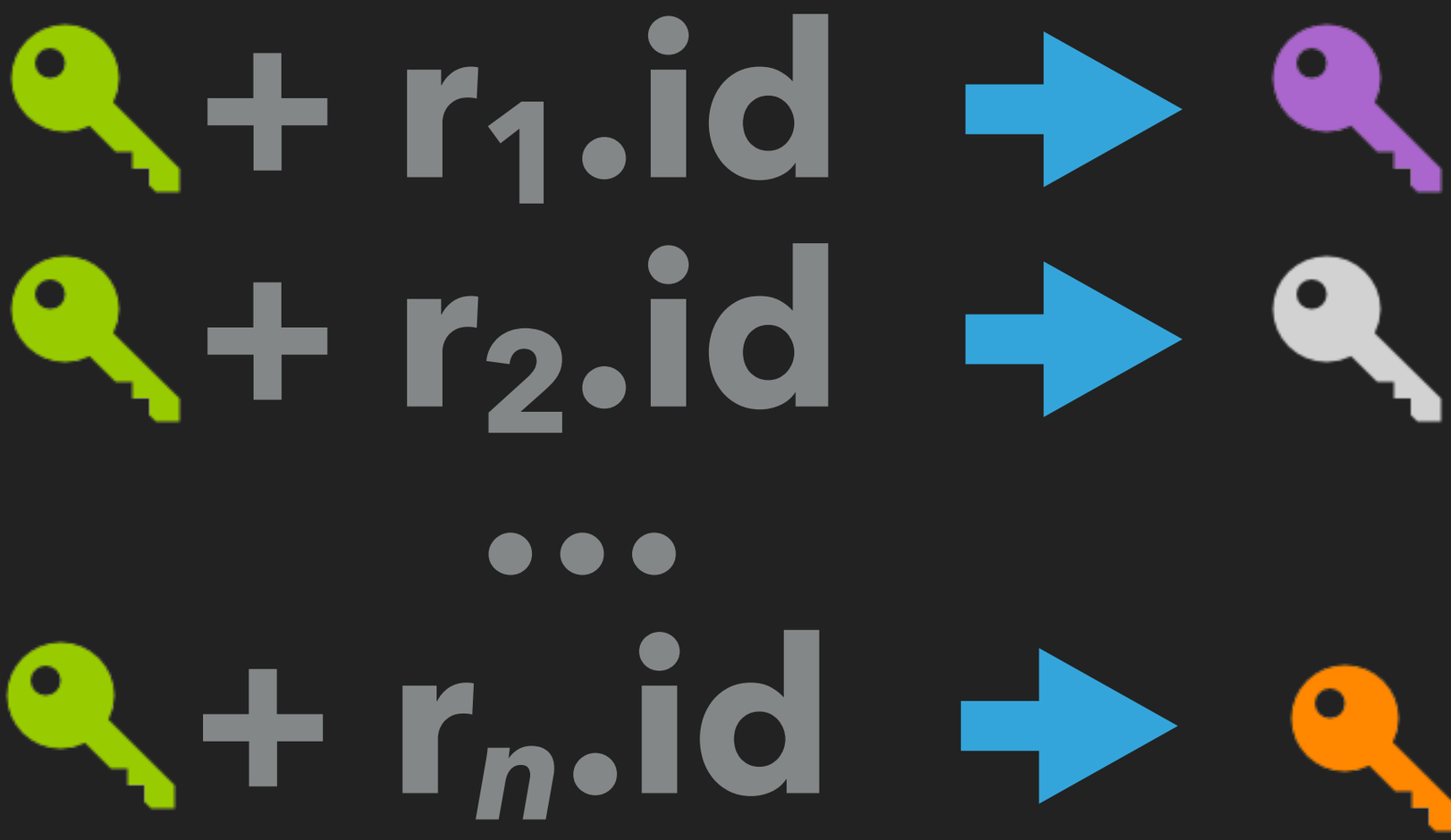
# KEY DERIVATION

# DERIVE PER RECORD KEYS



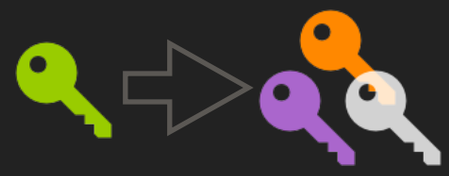
**Problem:** Use different keys for different records, only store master key.

**Solution:** Use key derivation to derive per-record keys.




MAKE SURE THAT THE MASTER KEY HAS ENOUGH ENTROPY FOR DERIVED KEY AND DERIVED IV

# DERIVE PER RECORD KEYS



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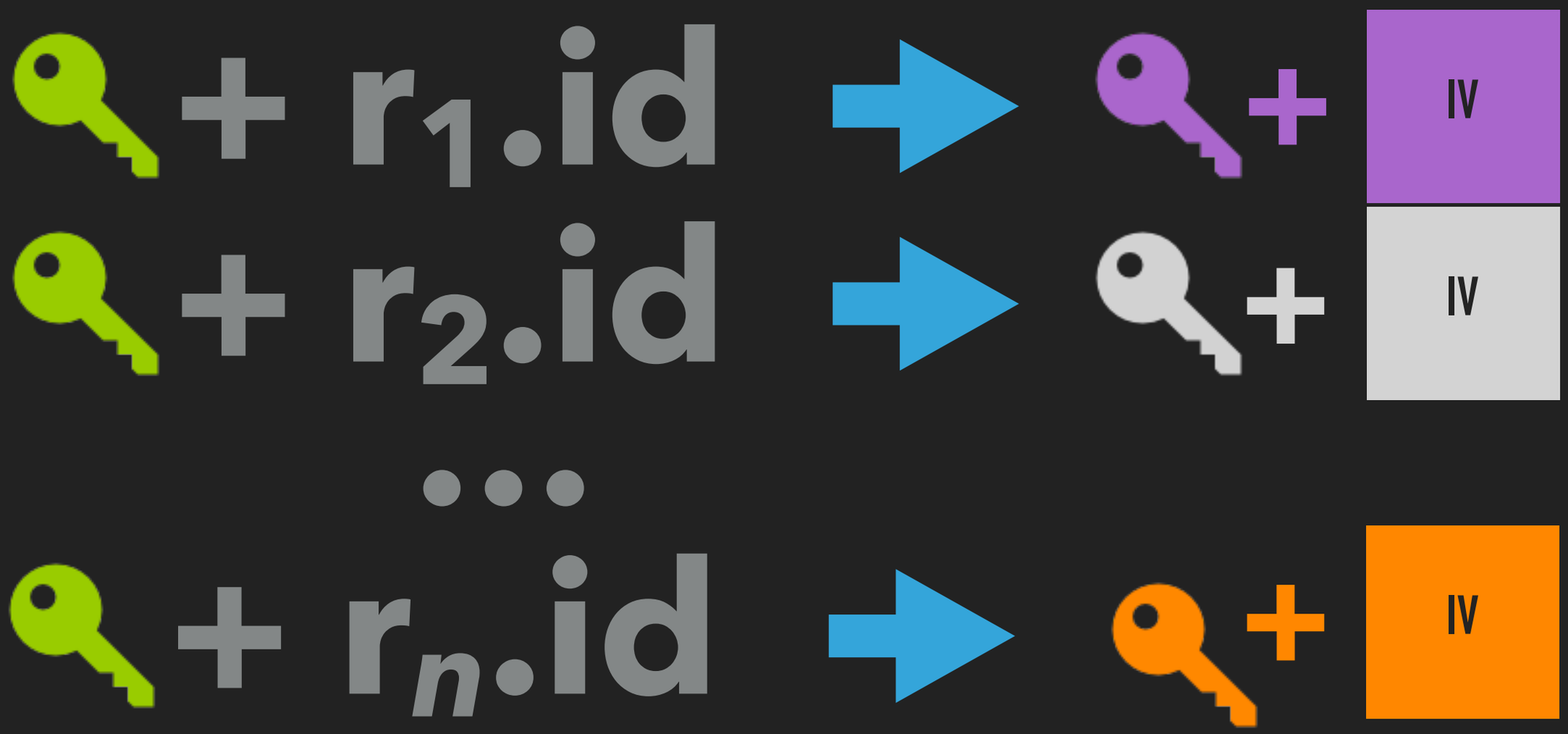


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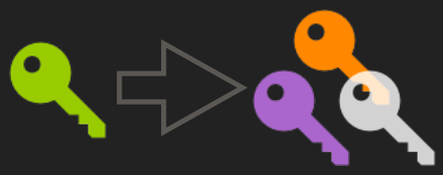
# SOLUTIONS FOR DERIVING KEY(S)



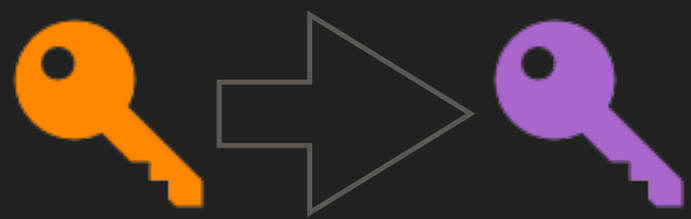
```
// Input:
//  Master_key and
//  (DB) primary_key target record
// Output:
//  AES-Key and
//  salt for encrypting target record
```

```
// AES-Key and salt for target record. "||" concatenates
// AES-CBC uses 128 bit IV. AES-GCM uses a 96 bit IV
byte[32] keyAndIV = derive_key( master_key ||
                                primary_key, 256 bit)

byte[16] derived_iv   = keyAndIV[0..15]
byte[16] derived_key  = keyAndIV[16..31]
```

- derive_key needs an additional *installation specific* salt of >= 128 bit. PBKDF2 with HMAC sha256 is an example of derive_key, as is scrypt or argon2.
- Use same process for decryption.
- No need to store the *generated* IV value.

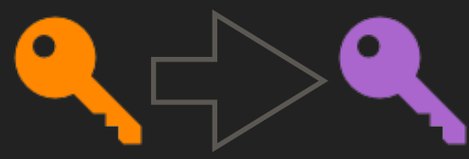
**MAKE SURE THAT THE MASTER KEY HAS ENOUGH ENTROPY FOR DERIVED KEY AND DERIVED SALT**



PATTERNS

# KEY REFRESH

# KEY REFRESH



**Problem:** Keys must only be used for a limited amount of data

**Solution:** Design for constant key rollover

| Record-ID | … | Masterkey ID | (Data…) |
|---|---|---|---|
| B9E10DEE-C97E-… | … | B874920B-E801-… | … |
| FDE0C6E3-8BF0-… | … | 9A6580FC-1248-… | … |
| … | … | 9A6580FC-1248-… | … |

DES BLOWFISH AES

MD5 SHA-1 SHA-256

RSA-1024 RSA-2048 ?? POST QUANTUM ??

PATTERNS

# ALGORITHM ROLLOVER

# ALGORITHM ROLLOVER

DES BLOWFISH AES
MD5 SHA-1 SHA-256
RSA-1024 RSA-2048 ?? POST QUANTUM ??

**Problem:** Algorithms must be changed and data migrated

**Solution:** Design for online data migration

| Record-ID | … | Masterkey ID | (Data…) |
|---|---|---|---|
| B9E10DEE-C97E-… | … | B874920B-E801-… | … |
| FDE0C6E3-8BF0-… | … | 9A6580FC-1248-… | … |
| … | … | 9A6580FC-1248-… | … |

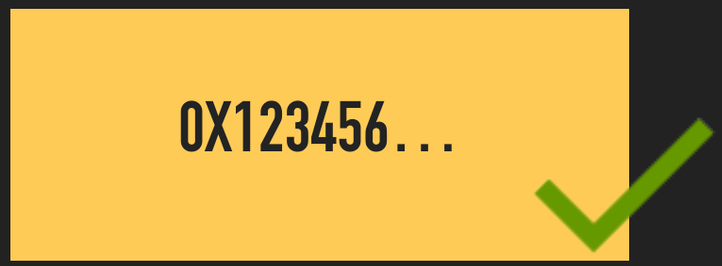
# ALGORITHM ROLLOVER

DES BLOWFISH AES
MD5 SHA-1 SHA-256
RSA-1024 RSA-2048 ?? POST QUANTUM ??

**Problem:** Algorithms must be changed and data migrated

**Solution:** Design for online data migration

| Record-ID | Algorithms | Masterkey ID | (Data…) |
|---|---|---|---|
| B9E10DEE-C97E-… | ▸ PBKDF2(…)<br>▸ AES128–GCM | B874920B-E801-… | … |
| FDE0C6E3-8BF0-… | ▸ SCRYPT(…)<br>▸ AES256–CBC<br>▸ PKCS#5 | 9A6580FC-1248-… | … |
| … | … | 9A6580FC-1248-… | … |




PATTERNS

# INTEGRITY

# DATA INTEGRITY & ASSOCIATION

0X123456…

**Problem:** Sensitive data can be manipulated.

| User | Salary | … |
|---|---|---|
| Alice | 3,141€ | … |
| Eve | 2,718 € | … |
| … | … | … |

# DATA INTEGRITY & ASSOCIATION

0X123456…

**Problem:** Sensitive data can be manipulated.

| User | Salary | … |
|---|---|---|
| Alice | 3,141€ | … |
| Eve | 10,000 € | … |
| … | | … |

EVE GETS AN INSTANT PROMOTION

# DATA INTEGRITY & ASSOCIATION

0X123456...

**Problem:** Sensitive data can be manipulated.

**Solution:** Use cryptographic checksums with a secret.

| User | Salary | Checksum* |
|---|---|---|
| Alice | 3,141€ | 0x4711... |
| Eve | 2,718 € | 0xabcd... |
| ... | ... | ... |

* Checksum with a secret: hmac, AEAD, public key signatures

# DATA INTEGRITY & ASSOCIATION

0X123456...

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| User | Salary | Checksum* |
|---|---|---|
| Alice | 3,141€ | 0x4711... |
| Eve | 10,000 € | 0xabcd... |

THE CHECKSUMS DON'T MATCH, PROMOTION IS DECLINED

* Checksum with a secret: hmac, AEAD, public key signatures

# DATA INTEGRITY & ASSOCIATION

0X123456…

**Problem:** Protected data can be “replayed”.

| User | Salary | Checksum* |
|---|---|---|
| Alice | 3,141€ | 0x4711… |
| Eve | 2,718 € | 0xabcd… |
| … | … | … |

# DATA INTEGRITY & ASSOCIATION

0X123456…

**Problem:** Protected data can be “replayed”.

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|---|---|---|
| Alice | 3,141€ | 0x4711… |
| Eve | 3,141€ | 0x4711… |

…

EVE GETS AN INSTANT PROMOTION

…

# DATA INTEGRITY & ASSOCIATION

0X123456…

**Problem:** Protected data can be “replayed”.

**Solution:** Cryptographically bind data to context.

| User | Salary | Checksum* |
|---|---|---|
| Alice | 3,141€ | 0xabcd… |
| Eve | 2,718€ | 0x9876… |
| … | … | … |

* including the username in the hash/hmac

# DATA INTEGRITY & ASSOCIATION

0X123456...

**Problem:** Protected data can be “replayed”.

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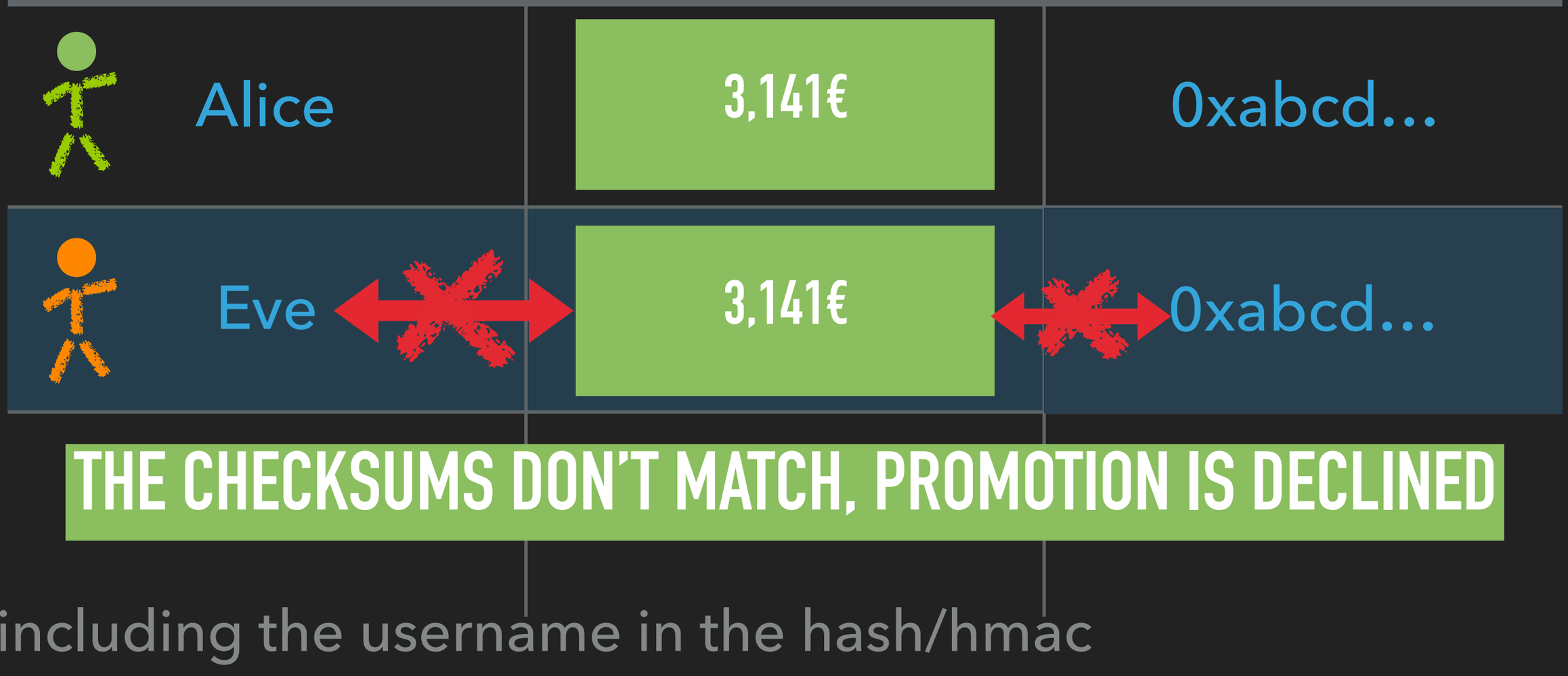



* including the username in the hash/hmac

# DATA INTEGRITY & ASSOCIATION

0X123456…

**Problem:** Protected data can be “replayed”.

**Solution:** Cryptographically bind data to context.

| User | Password Hash * | … |
|---|---|---|
| Alice | 0X123456… | … |
| Eve | 0XABCDEF… | … |
| … | … | … |

* including the username in the hash/hmac

# DATA INTEGRITY & ASSOCIATION

0X123456…

**Problem:** Protected data can be “replayed”.

**Solution:** Cryptographically bind data to context.

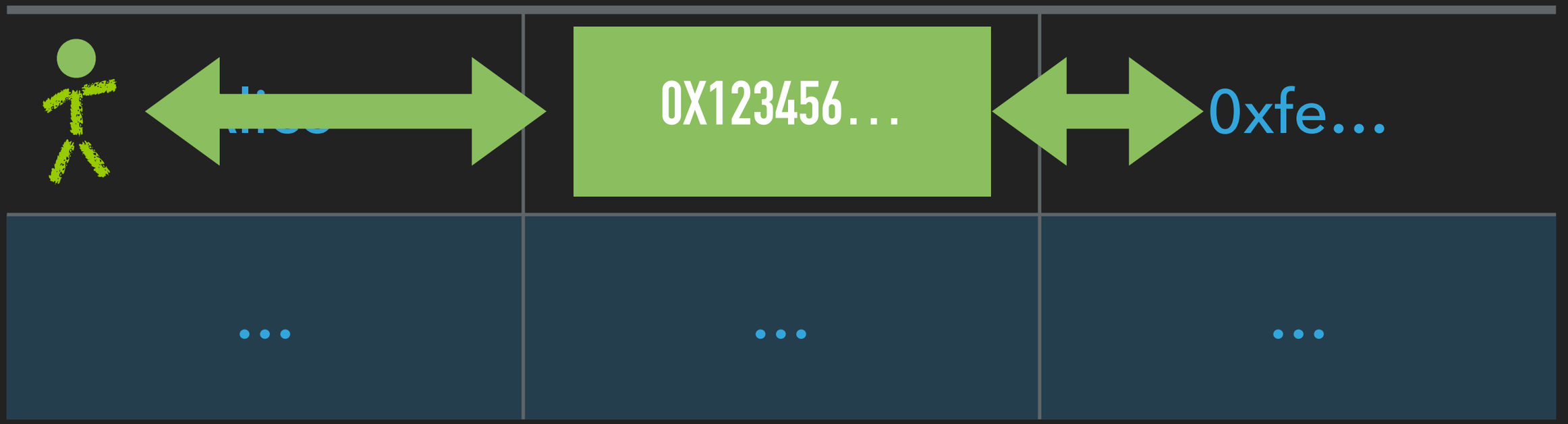
| User | Password Hash * | … |
|---|---|---|
| Alice | 0XABCDEF… | … |
| Eve | 0XABCDEF… | … |

**INTEGRITY PROTECTION BINDS USER TO SECRET**

* including the username in the hash/hmac

# DATA INTEGRITY & ASSOCIATION

0X123456…




- Add integrity checks to the data (HMAC, AEAD encryption, signatures)
- Include an association (here: “User”) in the integrity check

## PATTERNS

# MOVING

# MOVE DATA BETWEEN PARTIES

**Problem:** Data is exchanged between parties.

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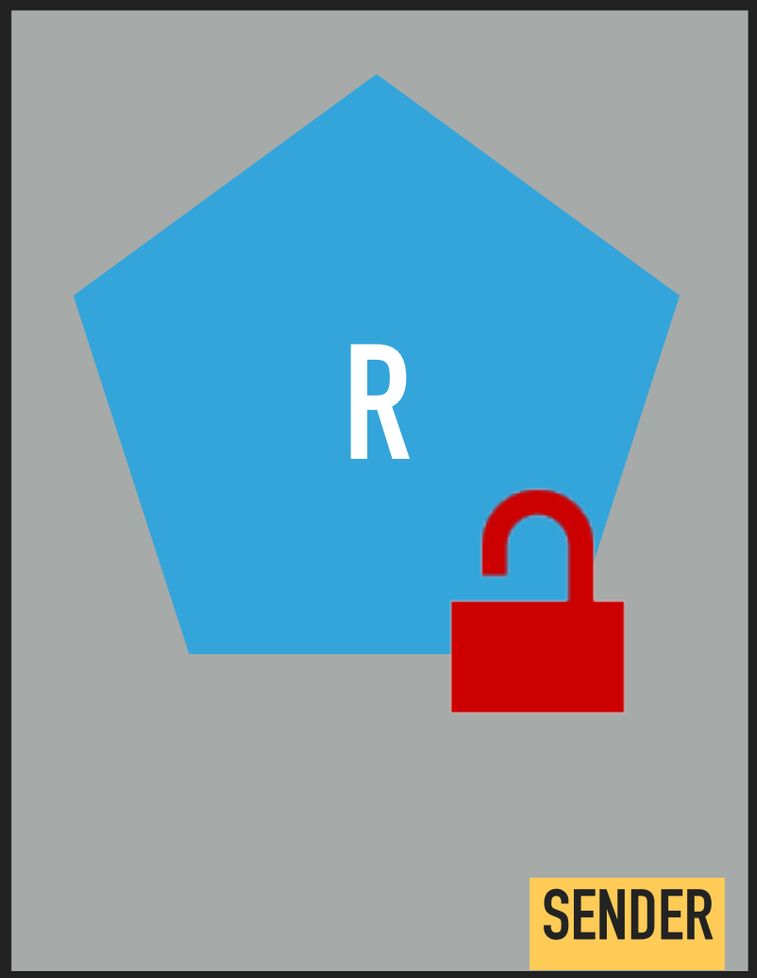
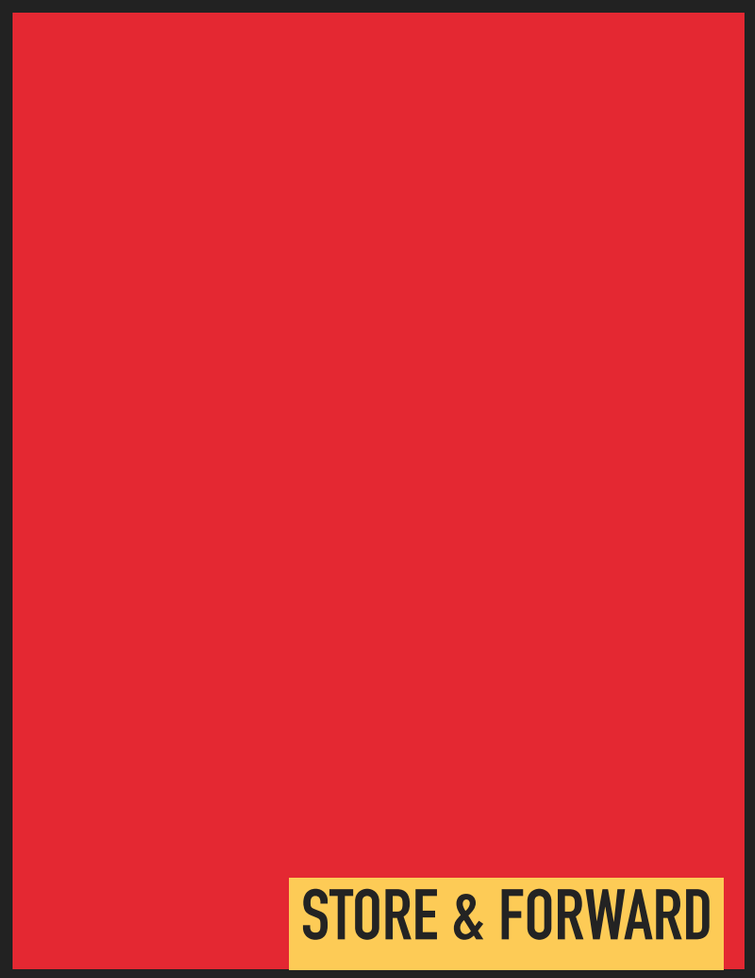
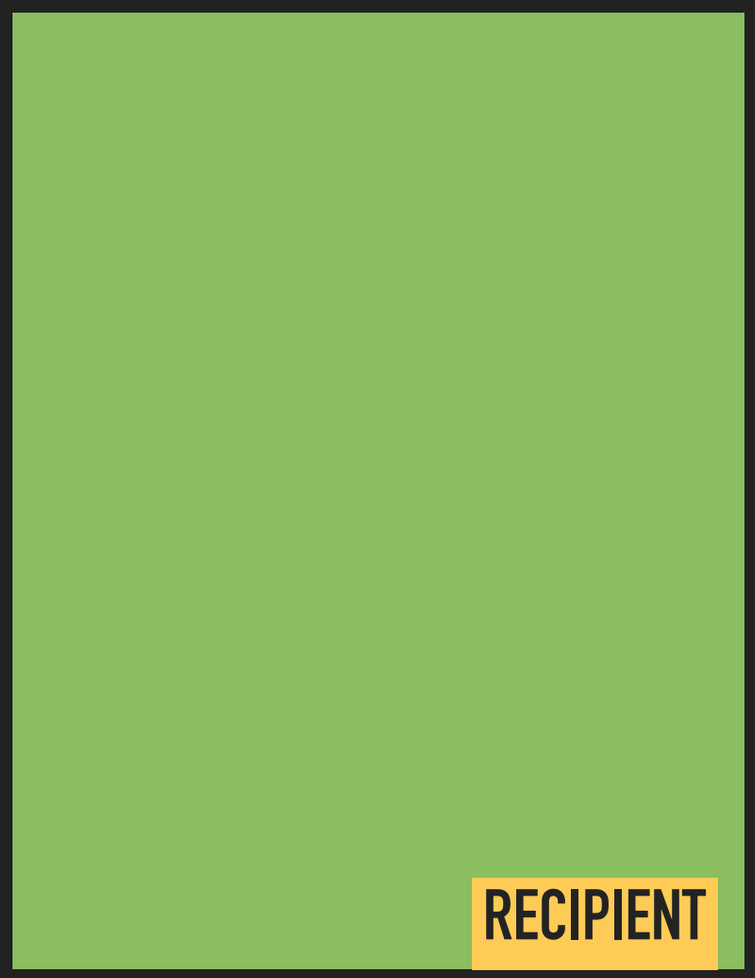
**Solution:** Use public key cryptography to protect data.




Encrypt with public key

Decrypt with private key

NO SECRETS ON SENDER / STORE & FORWARD SERVER

# MOVE DATA BETWEEN PARTIES

**Problem:** Data is exchanged between parties.

**Solution:** Use public key cryptography to protect data.


Encrypt with public key

Decrypt with private key

NO SECRETS ON SENDER / STORE & FORWARD SERVER

# MOVE DATA BETWEEN PARTIES

```
KeyringConfig keyringConfig = KeyringConfigs
        .withKeyRingsFromFiles(
         "/…/pubring.gpg",
         "/…/secring.gpg",
         withPassword(secKeyRingPassword));
try (
    final InputStream cipherTextStream = Files.newInputStream(sourceFile);
    final OutputStream fileOutput = Files.newOutputStream(destFile);
    final BufferedOutputStream bufferedOut = …

    final InputStream plaintextStream = BouncyGPG
            .decryptAndVerifyStream()
            .withConfig(keyringConfig)
            .andRequireSignatureFromAllKeys("sender@example.com")
            .fromEncryptedInputStream(cipherTextStream)
    ) {
            Streams.pipeAll(plaintextStream, bufferedOut);
     }
```

https://github.com/neuhalje/bouncy-gpg/

```
int getRandomNumber()
{
    return 4;  // chosen by fair dice roll.
               // guaranteed to be random.
}
```

https://xkcd.com/221/

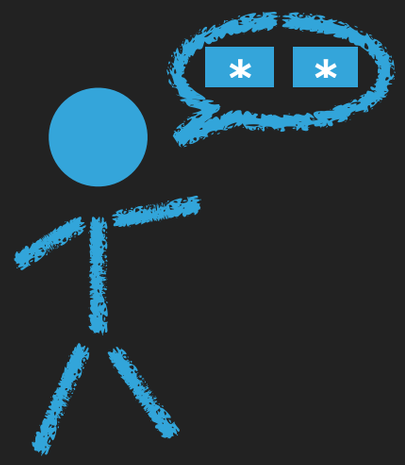
PATTERNS

# ENTROPY

# ENTROPY

```
int getRandomNumber()
{
    return 4;  // chosen by fair dice roll.
               // guaranteed to be random.
}
```

- Bad entropy compromises keys
- Computers are very bad at making things up! (not always)
- Entropy therefore often is limited (esp. after booting!)
- Use what the API provides (SecureRandom)
- **RTFM**




PATTERNS

# PASSWORD VERIFICATION

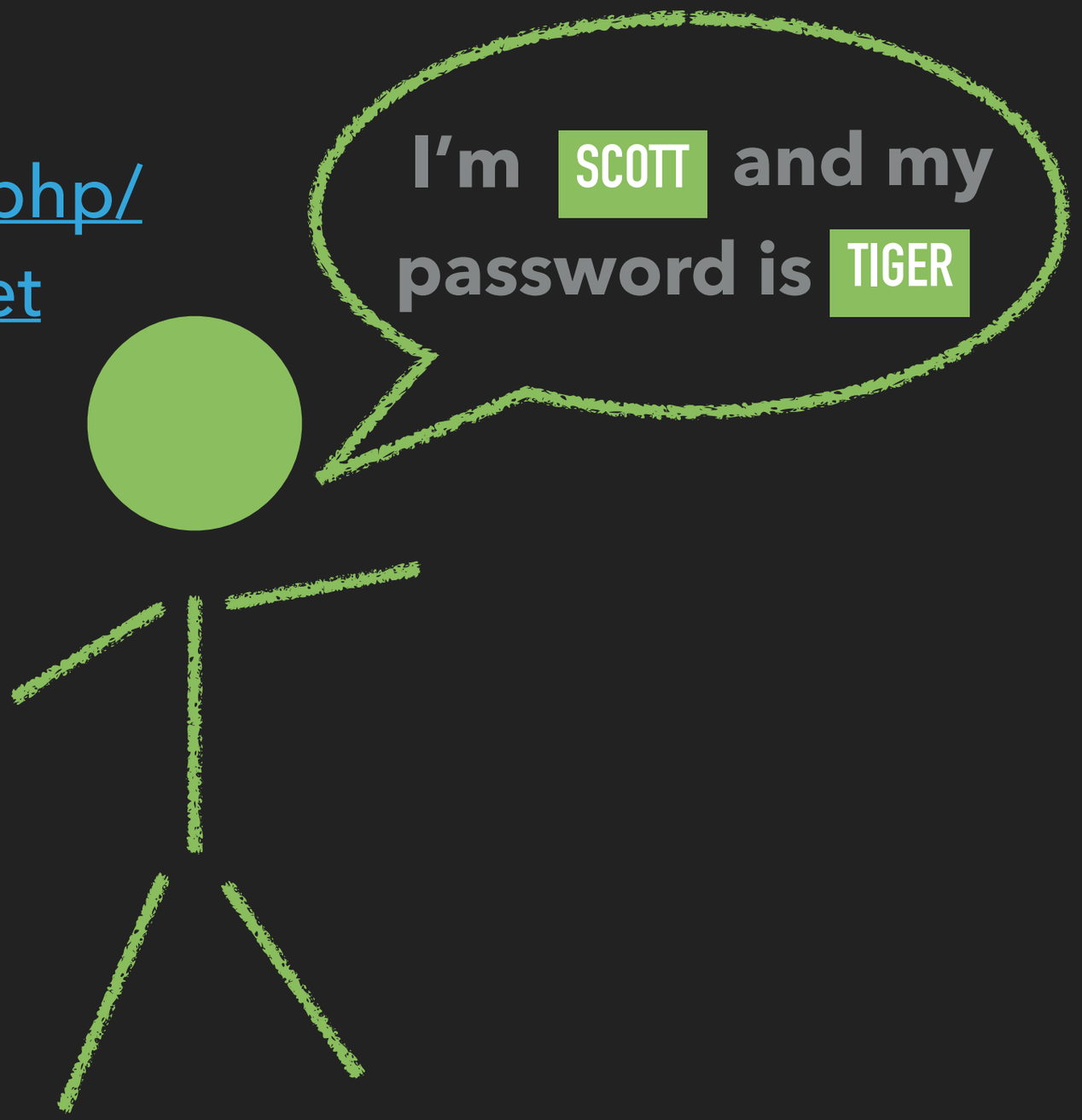
# USER LOGIN

**Problem:** Login a user

**Solution**: Not in scope here

https://www.owasp.org/index.php/Password_Storage_Cheat_Sheet

Also: OAUTH, Kerberos, …




PATTERNS

# ACCESS CONTROL

# ACCESS CONTROL

**Problem:** Make sure that data can only be accessed by some users

**Solution**: Use cryptographic access controls

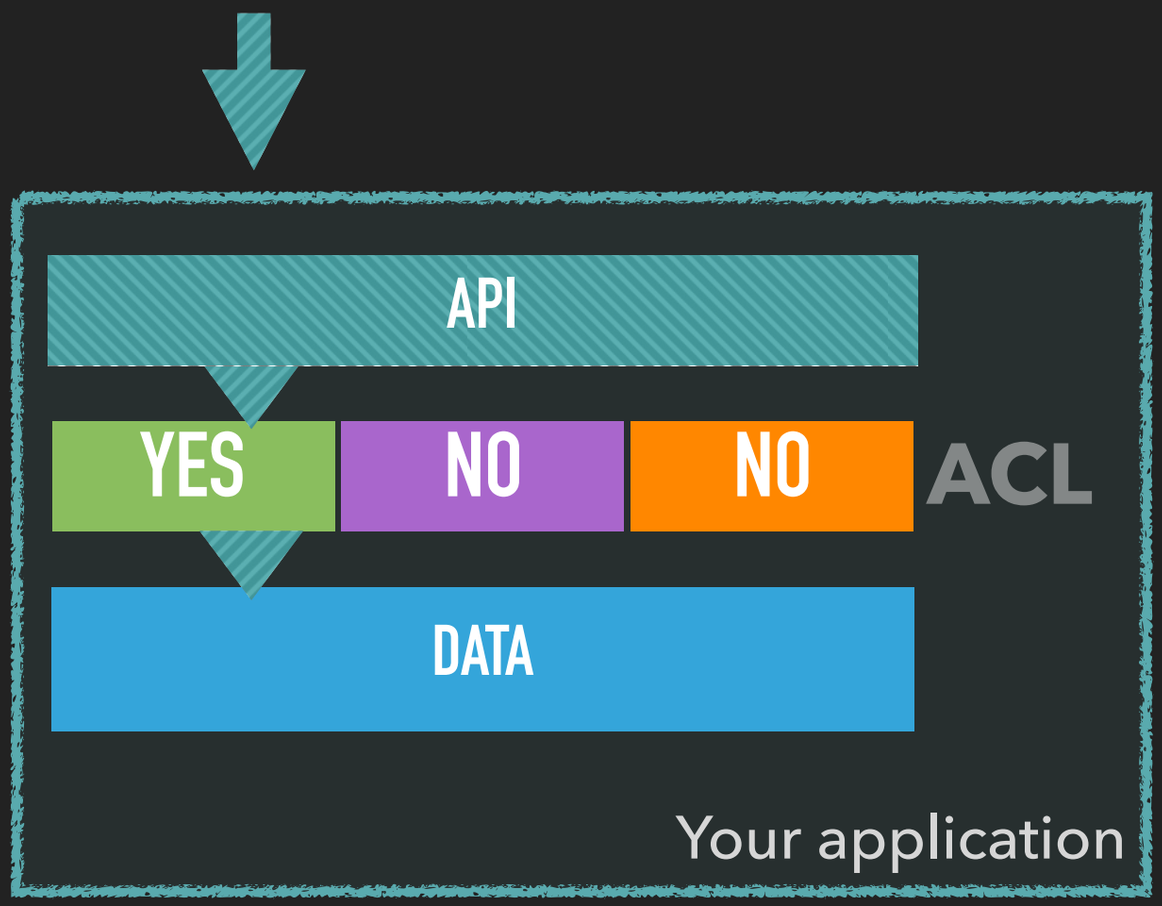
Applies primarily to

- Personal data (e.g. health data, personell records, ...)
- Top Secret data (e.g. company secrets)
- When “provable” access control is required

# ACCESS CONTROL



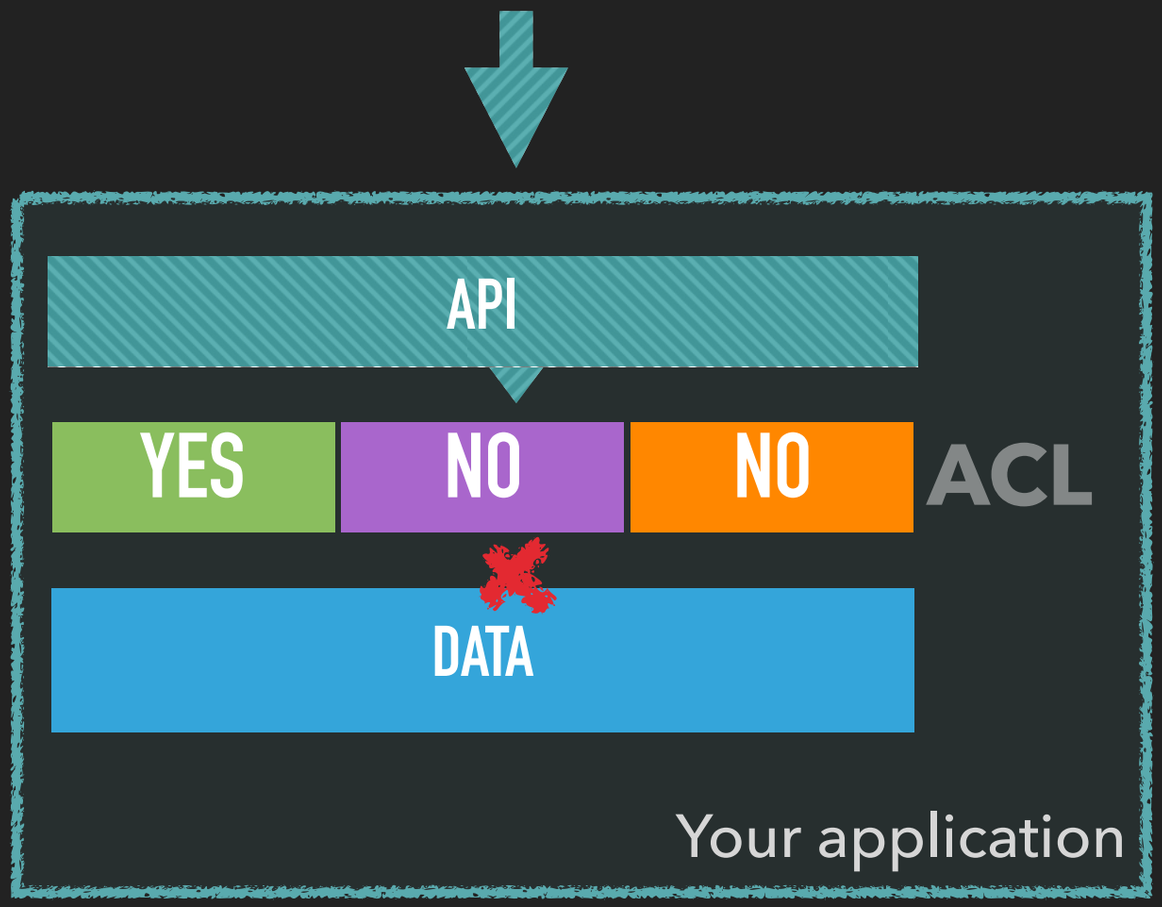
1. Alice tries to read data
2. Application validates ACL
3. Alice is granted access



# ACCESS CONTROL



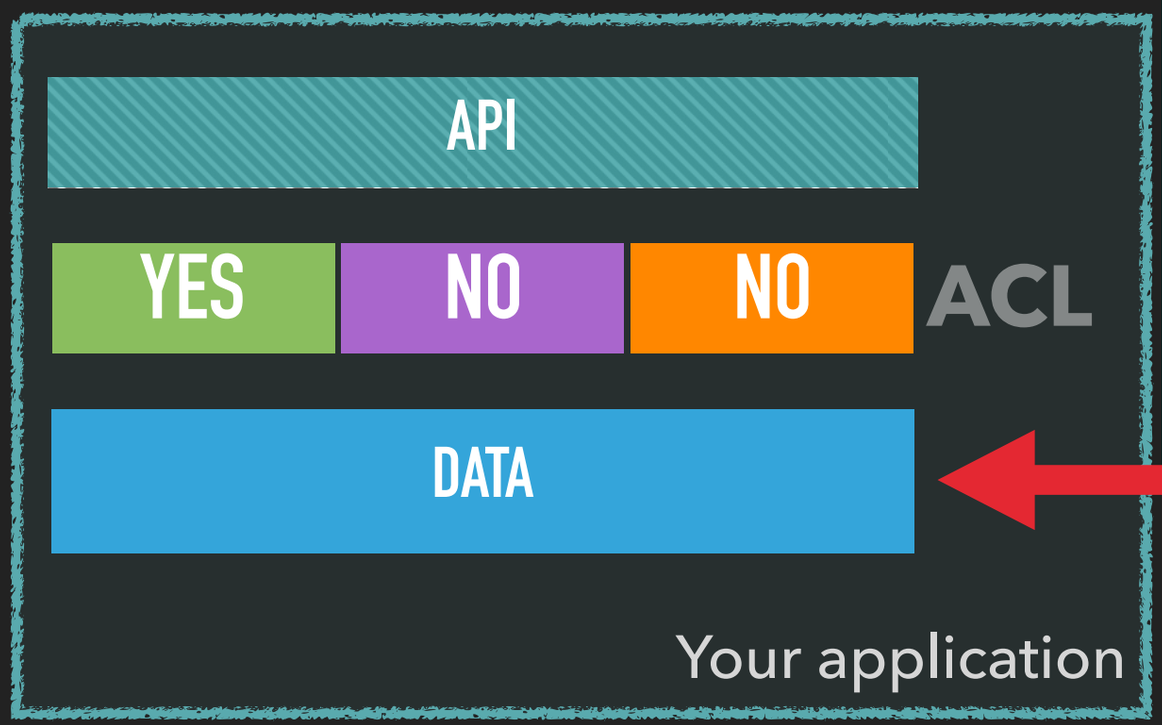
1. Bob tries to read data
2. Application validates ACL
3. Access is denied



# ACCESS CONTROL

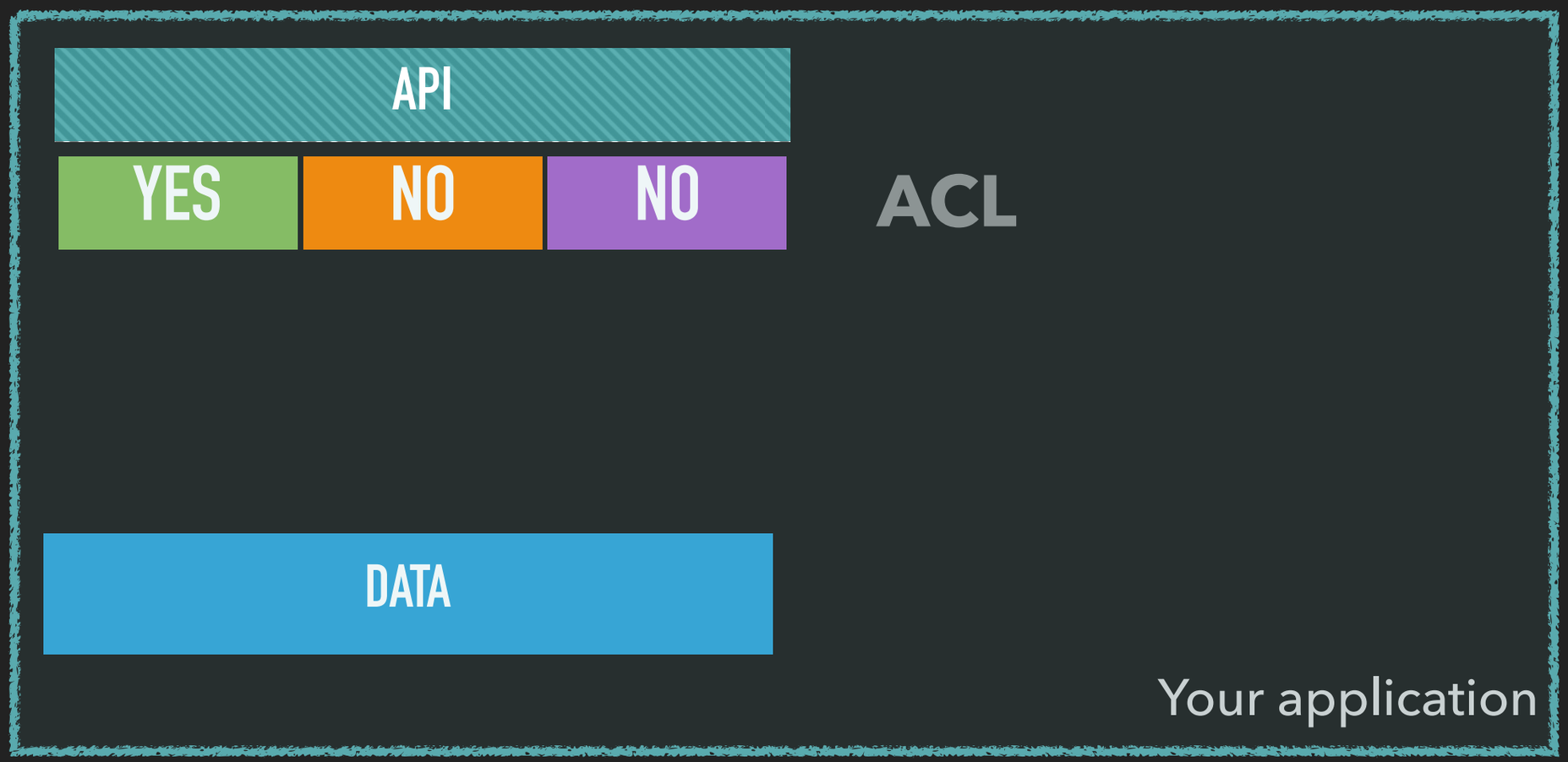


1. Eve exploits application
2. Application ????
3. Eve has access to data



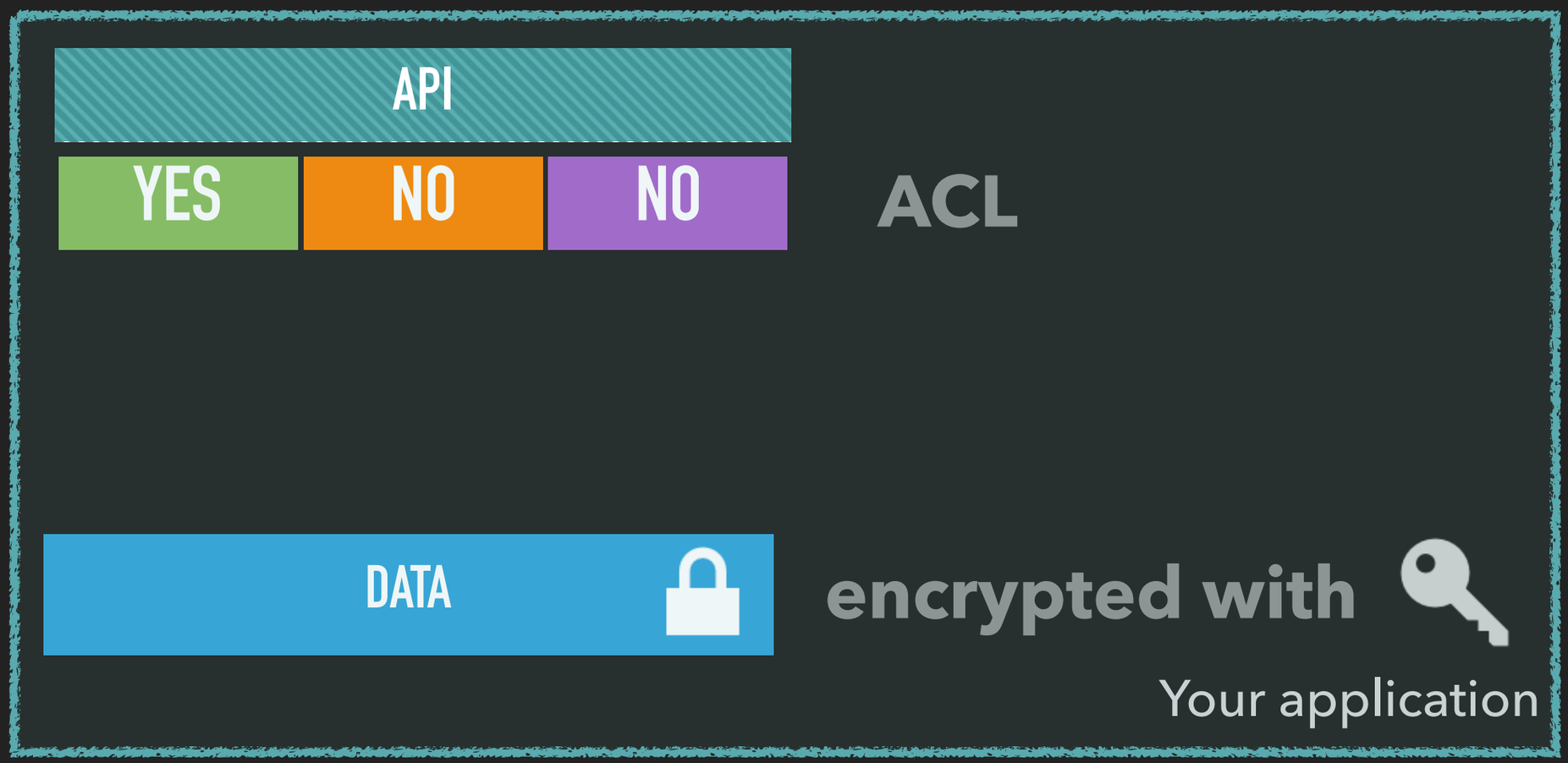
# ACCESS CONTROL





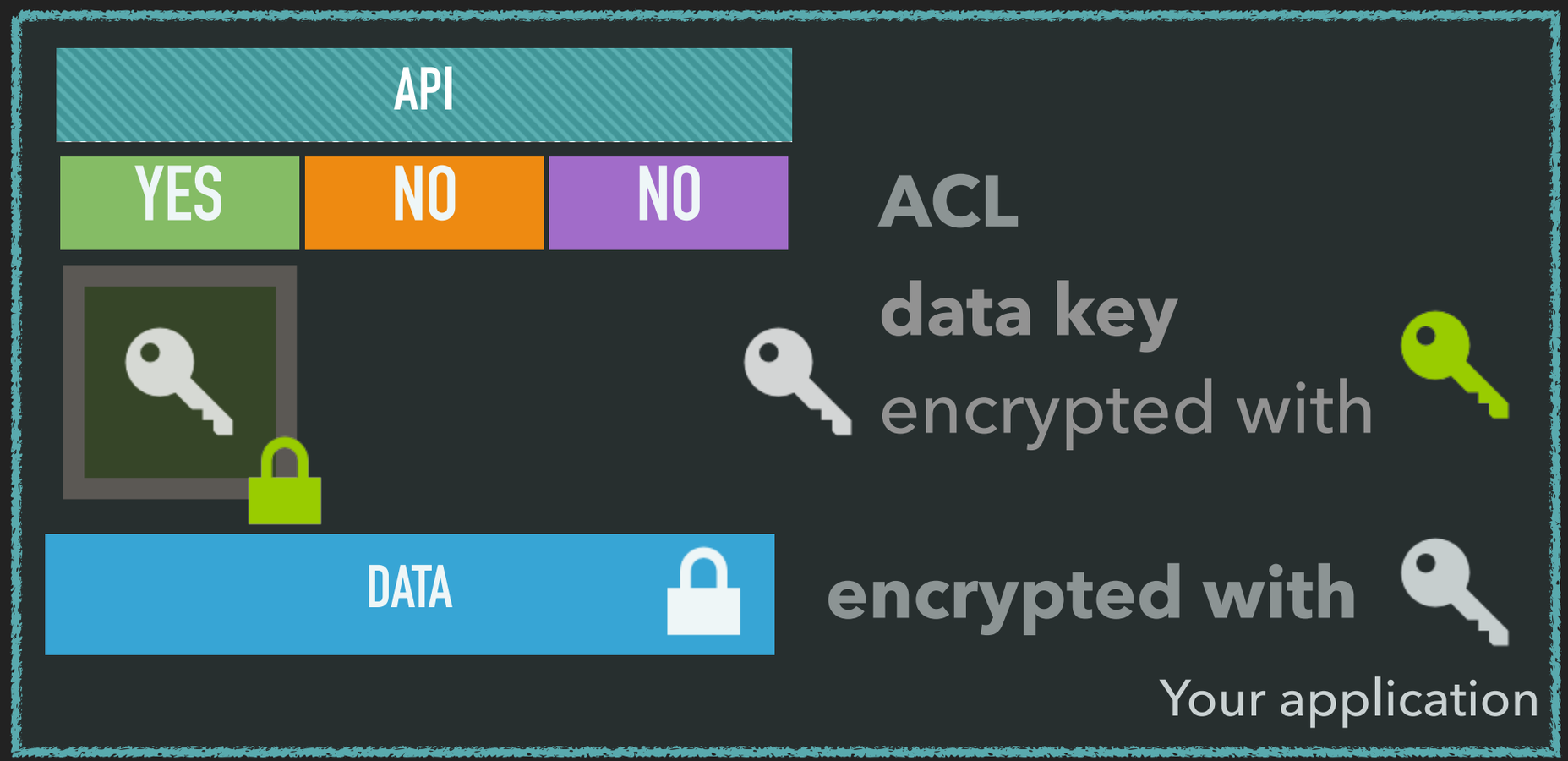
# ACCESS CONTROL





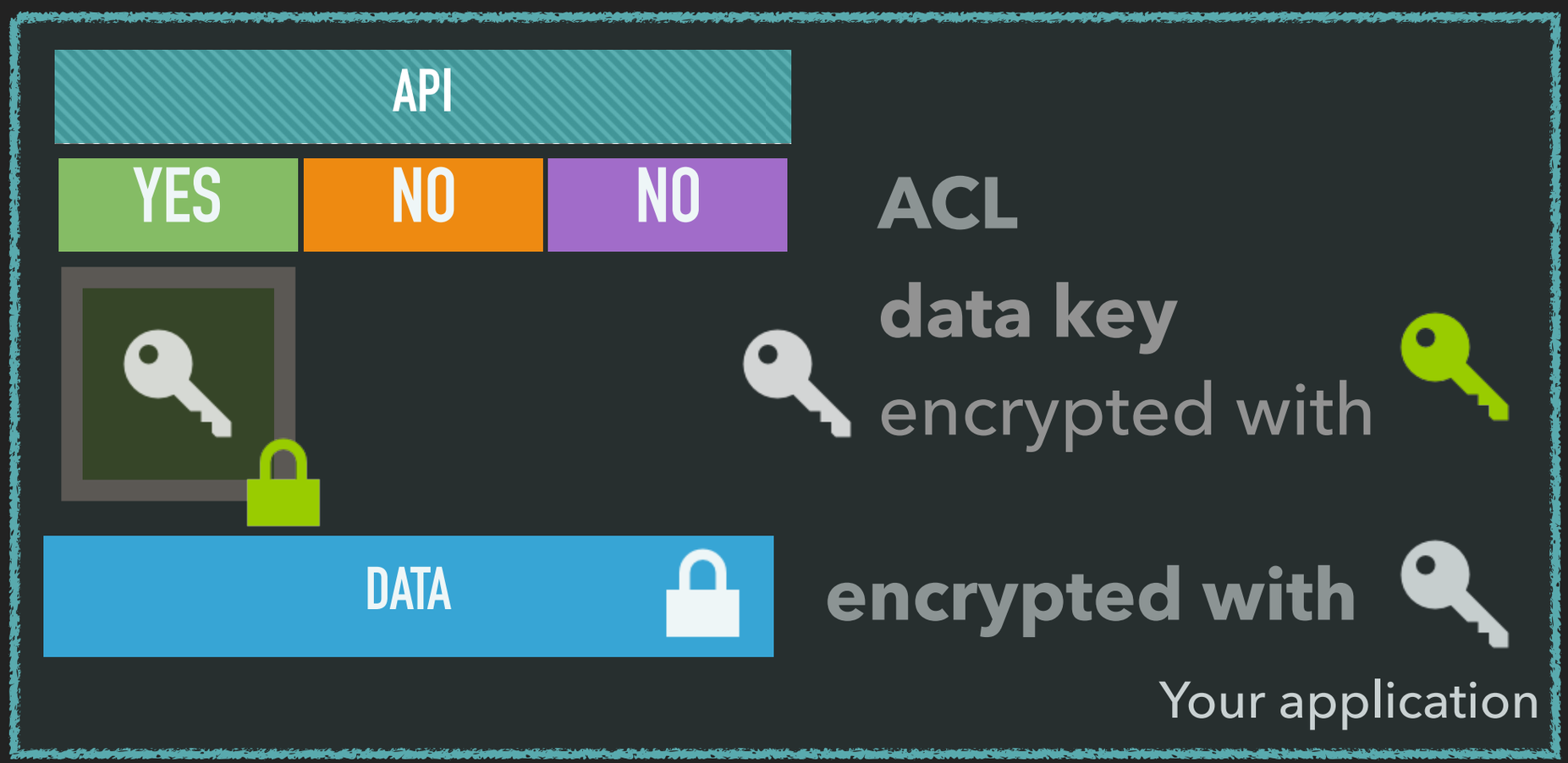
# ACCESS CONTROL





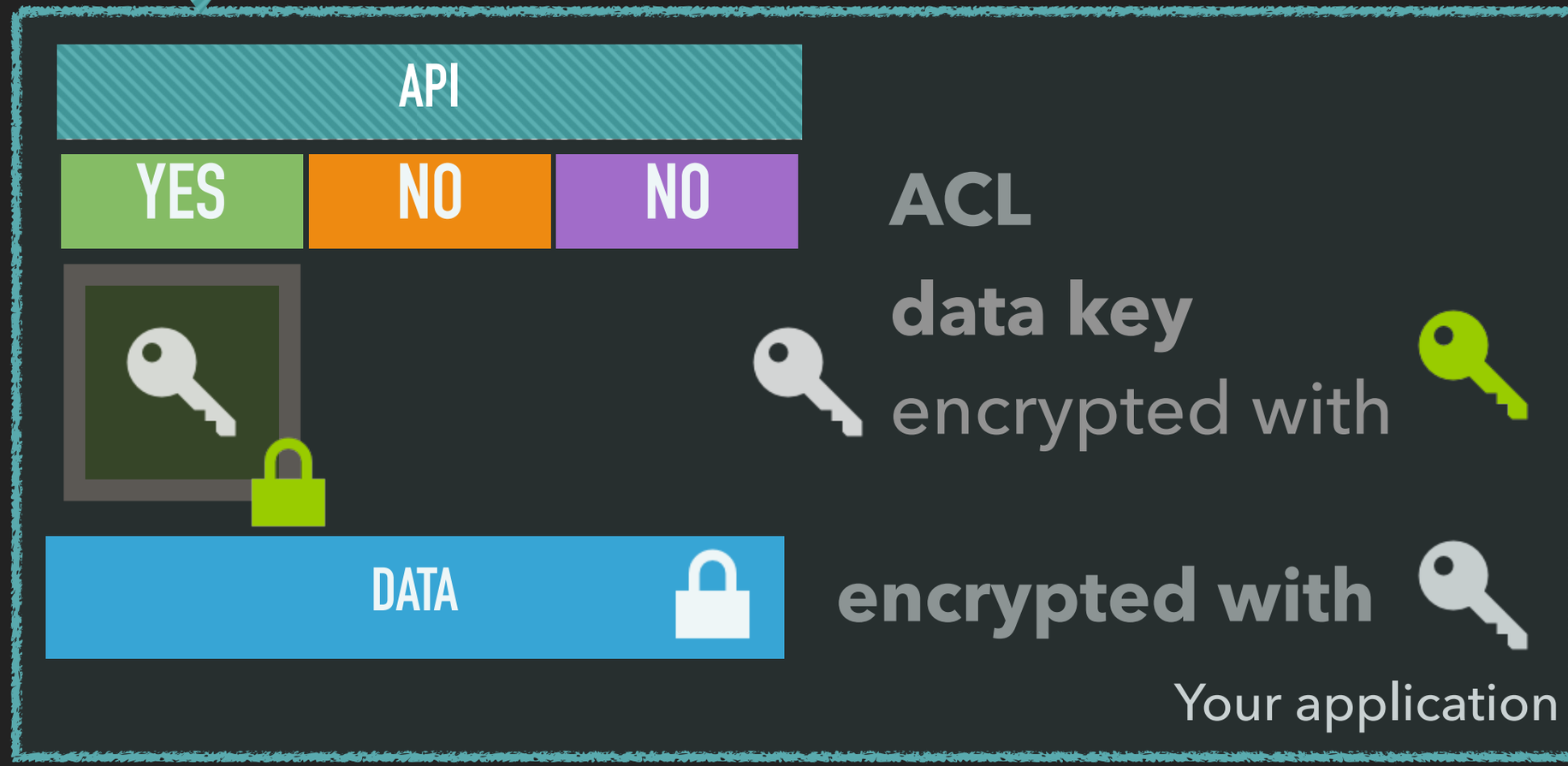
# ACCESS CONTROL





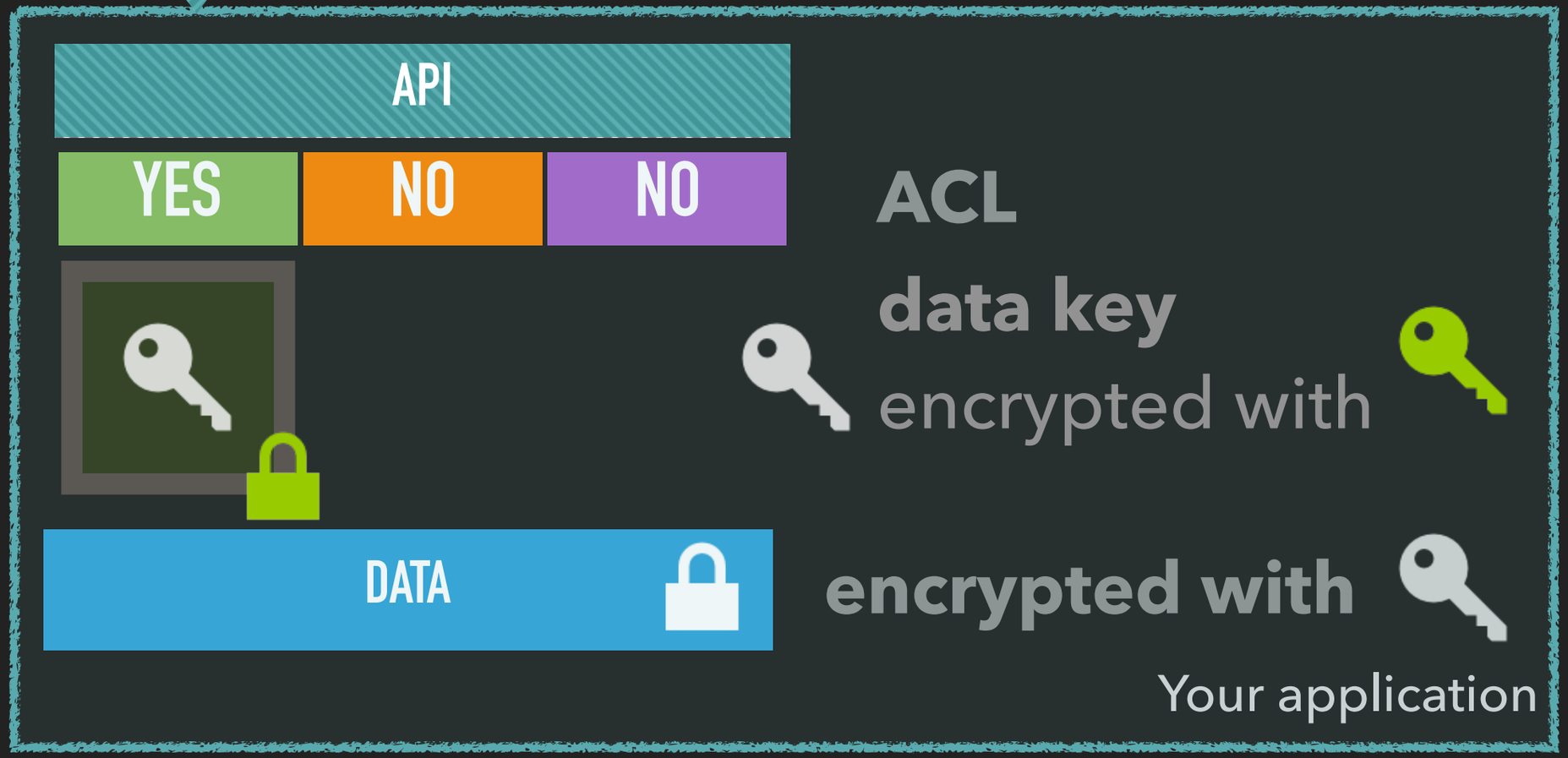
# ACCESS CONTROL



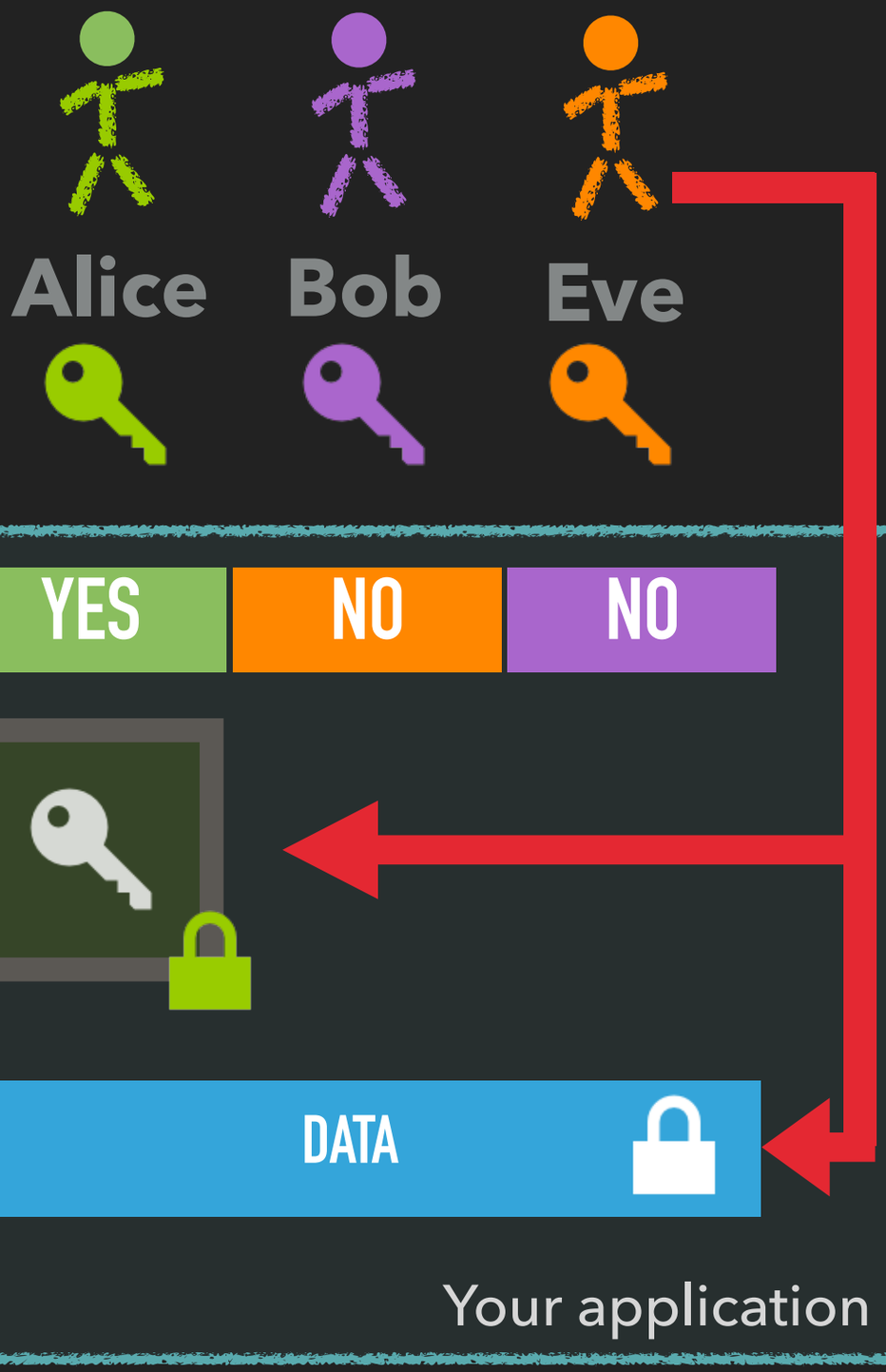


# ACCESS CONTROL


1. Alice tries to read data
2. Application validates ACL
3. Alice is granted access
4. Alice decrypts the “data key”
5. Alice decrypts data

# ACCESS CONTROL





1. Eve exploits application
2. Eve gets encrypted data key
   OR
   Eve gets encrypted data

# ACCESS CONTROL


1. Alice enters her password
2. Application decrypts her strong long-term key
3. Alice now has her long-term key

# ACCESS CONTROL


**Alice**

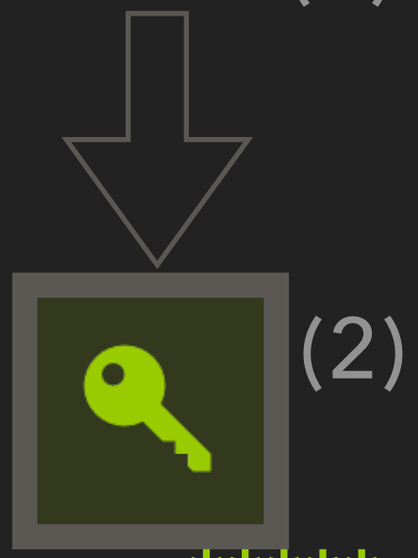
***** (1)

1. Alice enters her password
2. Application decrypts her strong long-term key
3. Alice now has her long-term key

# ACCESS CONTROL


**Alice**

***** (1)



(2)

*****

1. Alice enters her password
2. Application decrypts her strong long-term key
3. Alice now has her long-term key

**Alice' long term secret key** encrypted with her password.

# ACCESS CONTROL


**Alice**

1. Alice enters her password
2. Application decrypts her strong long-term key
3. Alice now has her long-term key

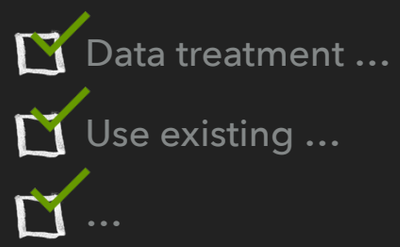

**Alice' long term secret key** encrypted with her password.

- [x] Data treatment …
- [x] Use existing …
- [x] …

PATTERNS

# CRYPTO CHECKLIST

# CRYPTO CHECKLIST




- ☐ Data treatment plan created and consequences accepted by management
- ☐ Trust anchors identified and named
- ☐ Existing (e.g. RFC 4880) protocols & formats used wherever possible
- ☐ Nonces used only once. Random salt used where possible
- ☐ Cryptographic concept written down & challenged in review
- ☐ (Master-)Key offsite backup established
- ☐ Key refresh after a few GiB of encrypted data implemented and tested
- ☐ Algorithm rollover implemented and tested
- ☐ Entropy source with enough entropy used
- ☐ Test cases include restore of old data (key/algorithm rollover)

# SUMMARY

Regulations apply - whatever you do!

Encryption is not for free!

No encryption might be way more expensive!

Maintenance is 60%-80% of total cost.
It is sensible to safe there

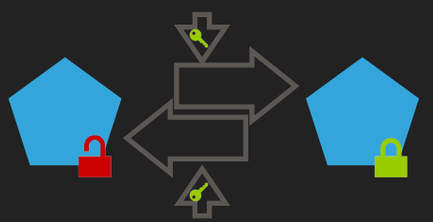
**–> Assess risks & cost, plan, implement!**

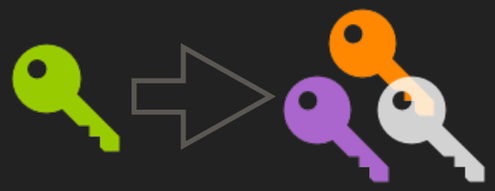
# SUMMARY

Comparing data

Transparent encryption

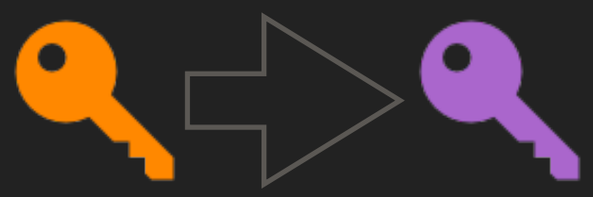
Storing data

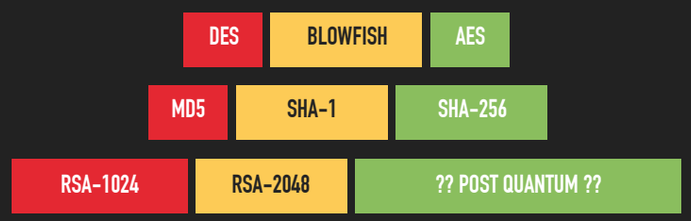




Key derivation

Key refresh






Algorithm rollover

# SUMMARY

0X123456…

Integrity

Moving Data

```
int getRandomNumber()
{
    return 4;  // chosen by fair dice roll.
               // guaranteed to be random.
}
```

Entropy

Access Control


Crypto Checklist

- [x] Data treatment …
- [x] Use existing …
- [x] …

# Q & A

# BACKUP

## LEGAL

# (PSEUDO|ANONYM)ISED?

# (PSEUDO|ANONYM)ISED?

## ANONYMISIERUNG

*„das Verändern personenbezogener Daten derart, dass die Einzelangaben über persönliche oder sachliche Verhältnisse nicht mehr oder nur mit einem unverhältnismäßig großen Aufwand an Zeit, Kosten und Arbeitskraft einer bestimmten oder bestimmbaren natürlichen Person zugeordnet werden können.“* § 3 Abs. 6 BDSG

## PSEUDONYMISIERUNG

*„das Ersetzen des Namens und anderer Identifikationsmerkmale durch ein Kennzeichen zu dem Zweck, die Bestimmung des Betroffenen auszuschließen oder wesentlich zu erschweren.“* § 3 Abs. 6a BDSG

## VERSCHLÜSSELUNG

*„Technisch versteht man unter Verschlüsselung den Vorgang, bei dem ein klar lesbarer Text (Klartext) oder auch Informationen anderer Art wie Ton- oder Bildaufzeichnungen mit Hilfe eines Verschlüsselungsverfahrens (Kryptosystem) in eine „unleserliche“, das heißt nicht einfach interpretierbare Zeichenfolge (Geheimtext) umgewandelt wird. Als entscheidend wichtige Parameter der Verschlüsselung werden hierbei ein oder auch mehrere Schlüssel verwendet. Man unterscheidet deshalb zwischen symmetrischer und asymmetrischer Verschlüsselung. Bei der symmetrischen Verschlüsselung wird zum Ver- und Entschlüsseln der gleiche Schlüssel verwendet; bei der asymmetrischen Verschlüsselung sind dies immer verschiedene Schlüssel, die aber zueinander passen müssen. Das Gesetz lässt allerdings offen, welche Art der Verschlüsselung Verwendung finden soll.“* BDSG-Kommentar von Simitis (§ 9, Rn. 166)

*Siehe auch https://www.datenschutz-notizen.de/unterschied-zwischen-anonymisierung-pseudony-misierung-und-verschluesselung-2916984/*

# ~BACKUP