# Secure Communication on the Web

**CS-576 Systems Security**

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Fall 2018

# Overview

Establishing encrypted connections using PK encryption

Passive vs active adversaries

Securing communications

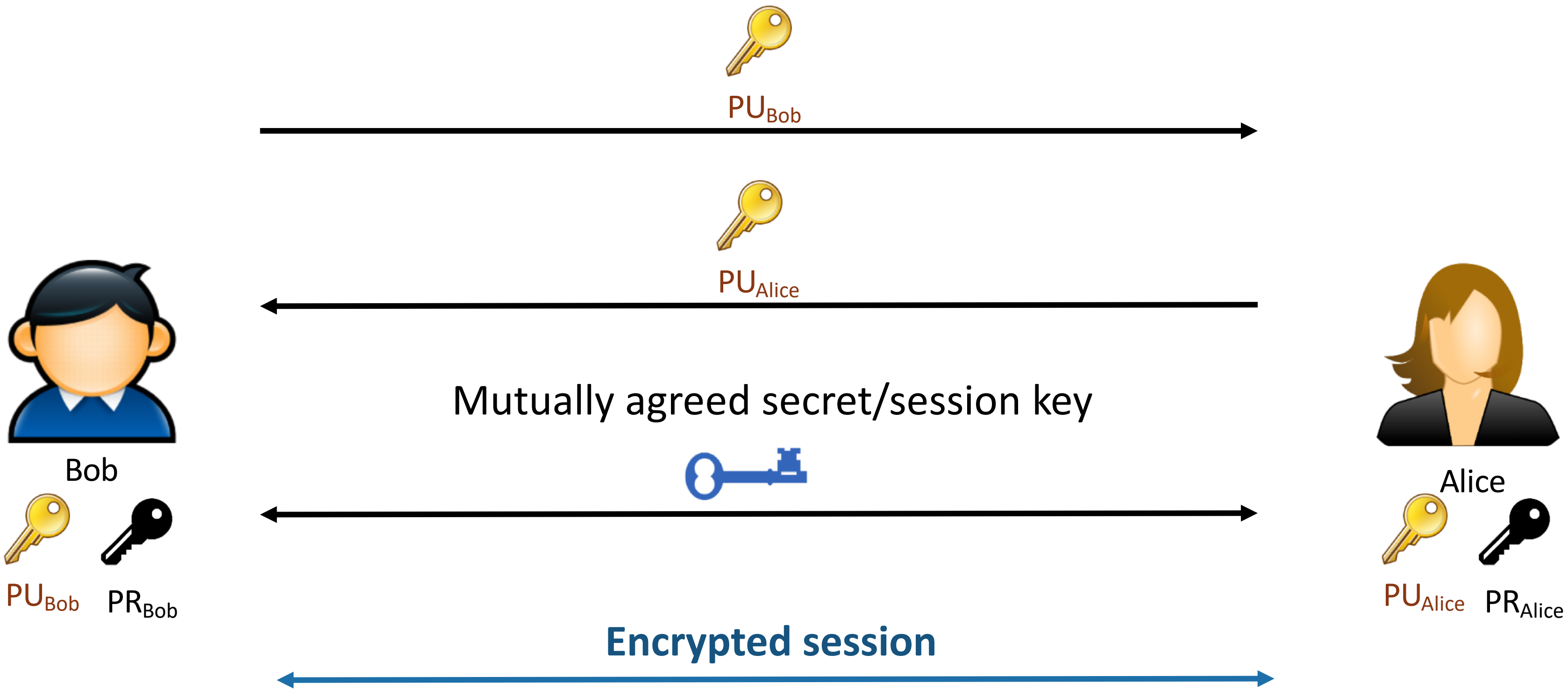
- Message integrity
- Key authentication

TLS/SSL

Certificates and certificate authorities

Attacks against SSL/TLS

# Establishing Encrypted Connections



# Types of Adversaries/Attacks

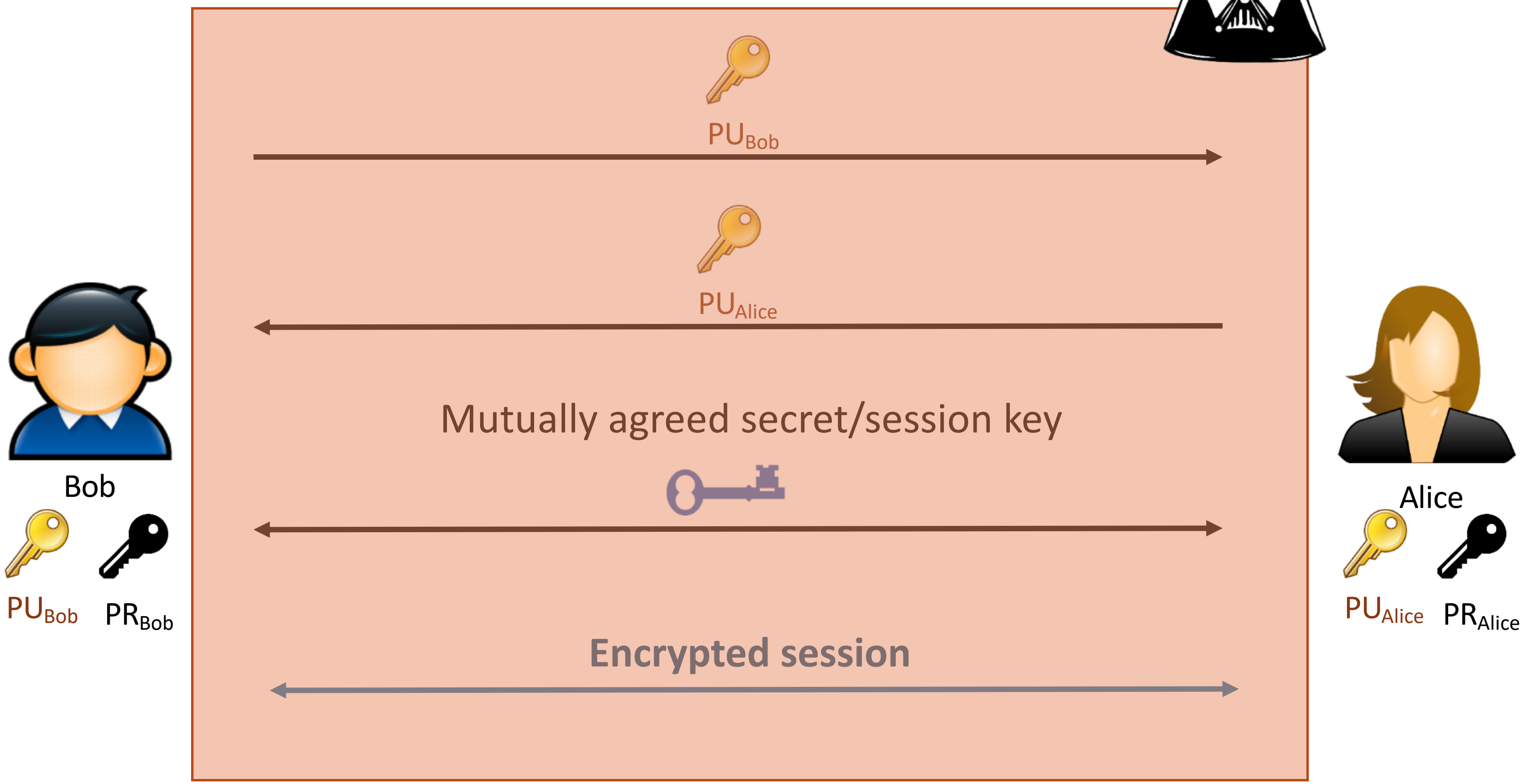
**Passive** – does not affect system resources

- Can intercept messages but not modify

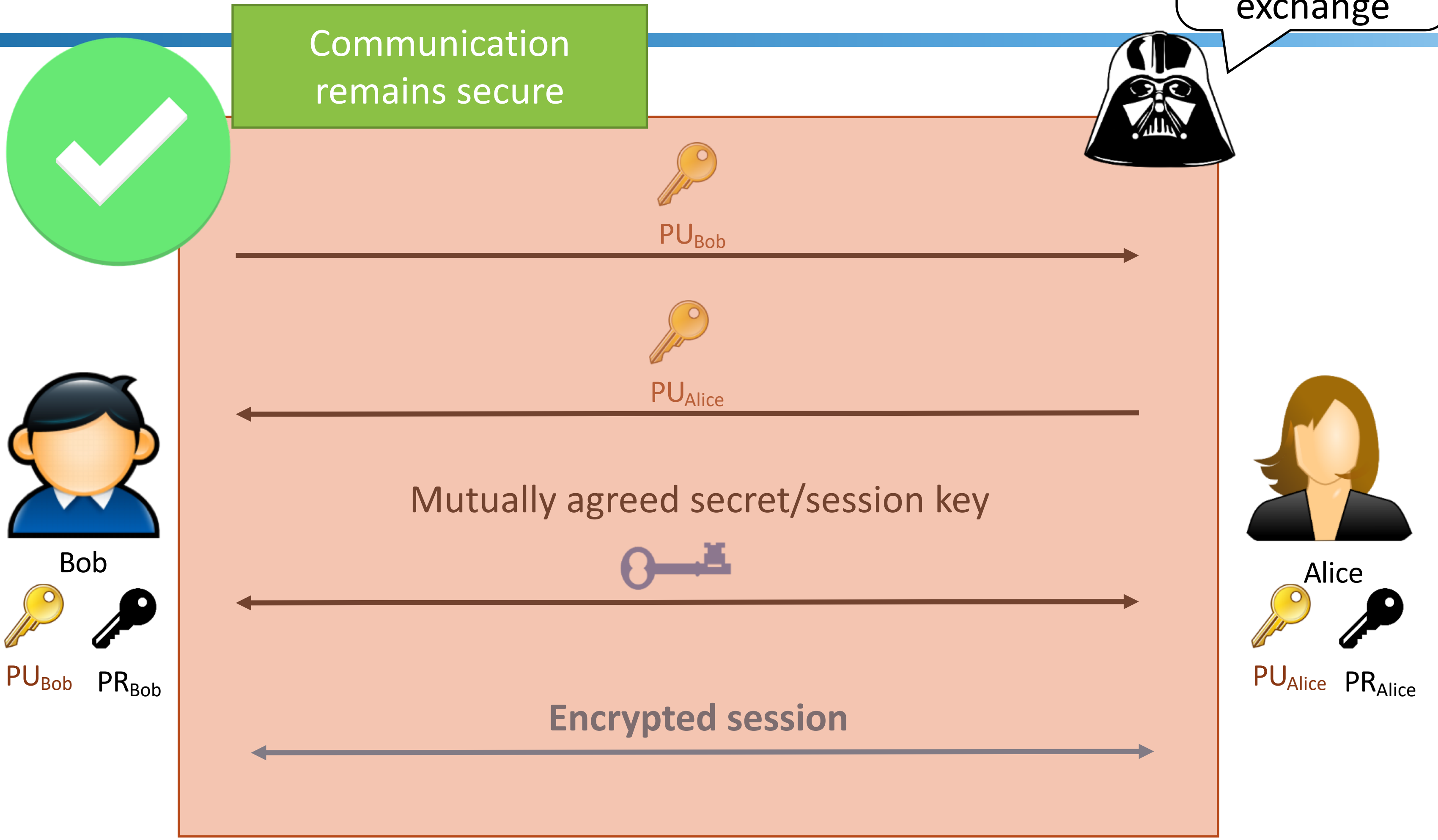
**Active** – attempt to alter system resources or affect their operation

- Can intercept, re-order, and alter messages

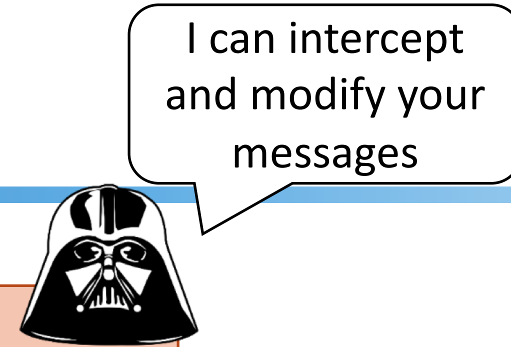
# Passive Attacker

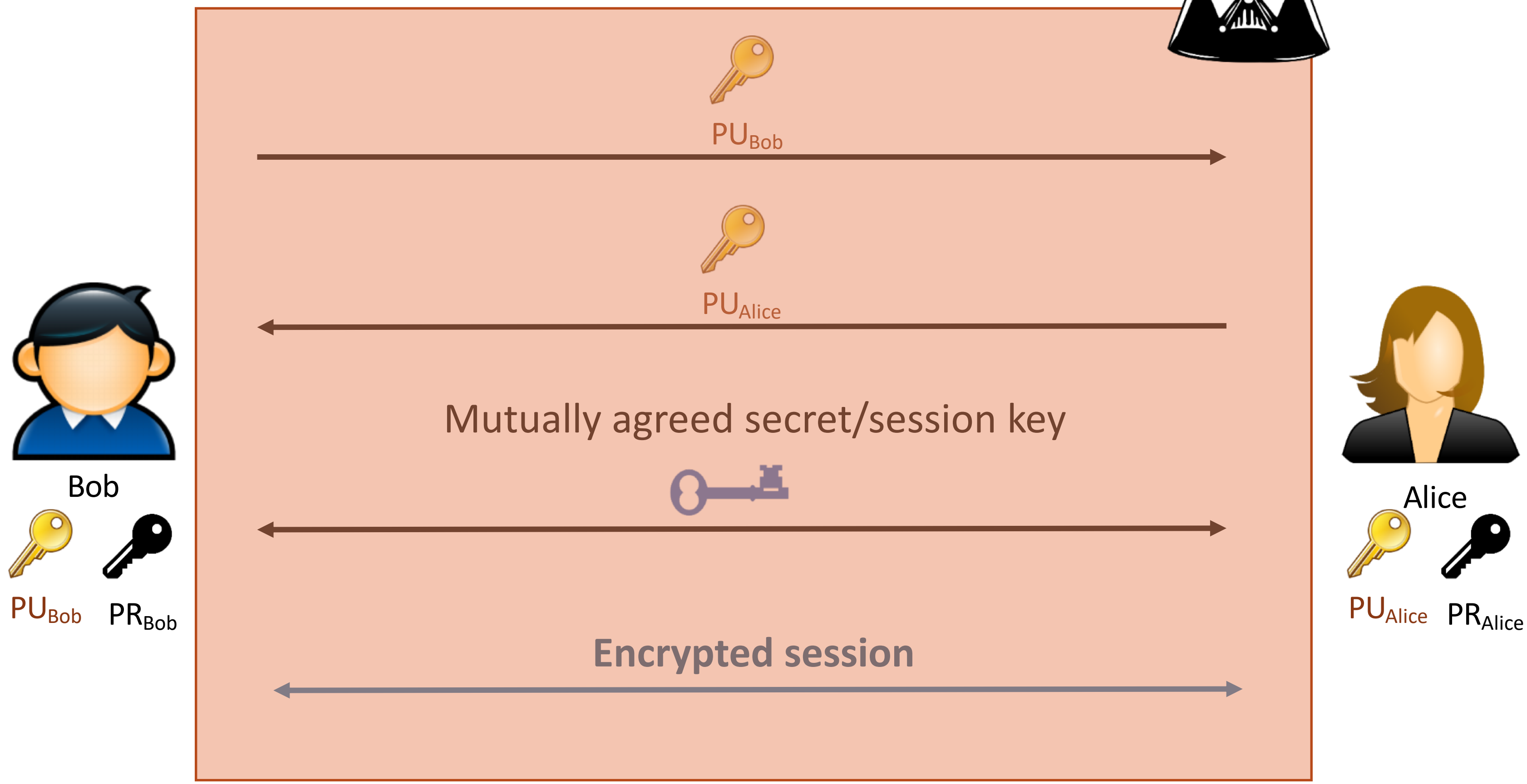



# Passive Attacker

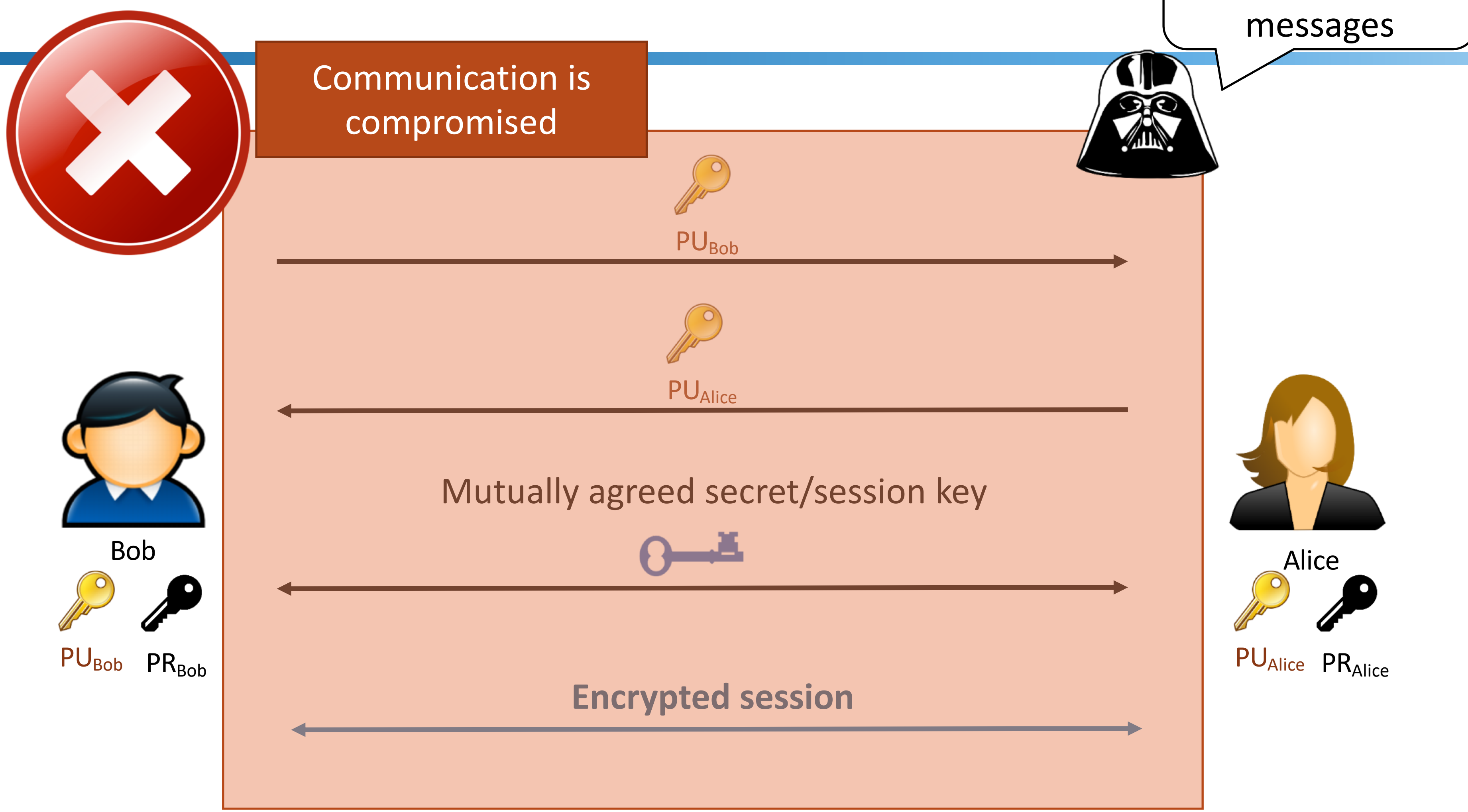


# Active Attacker

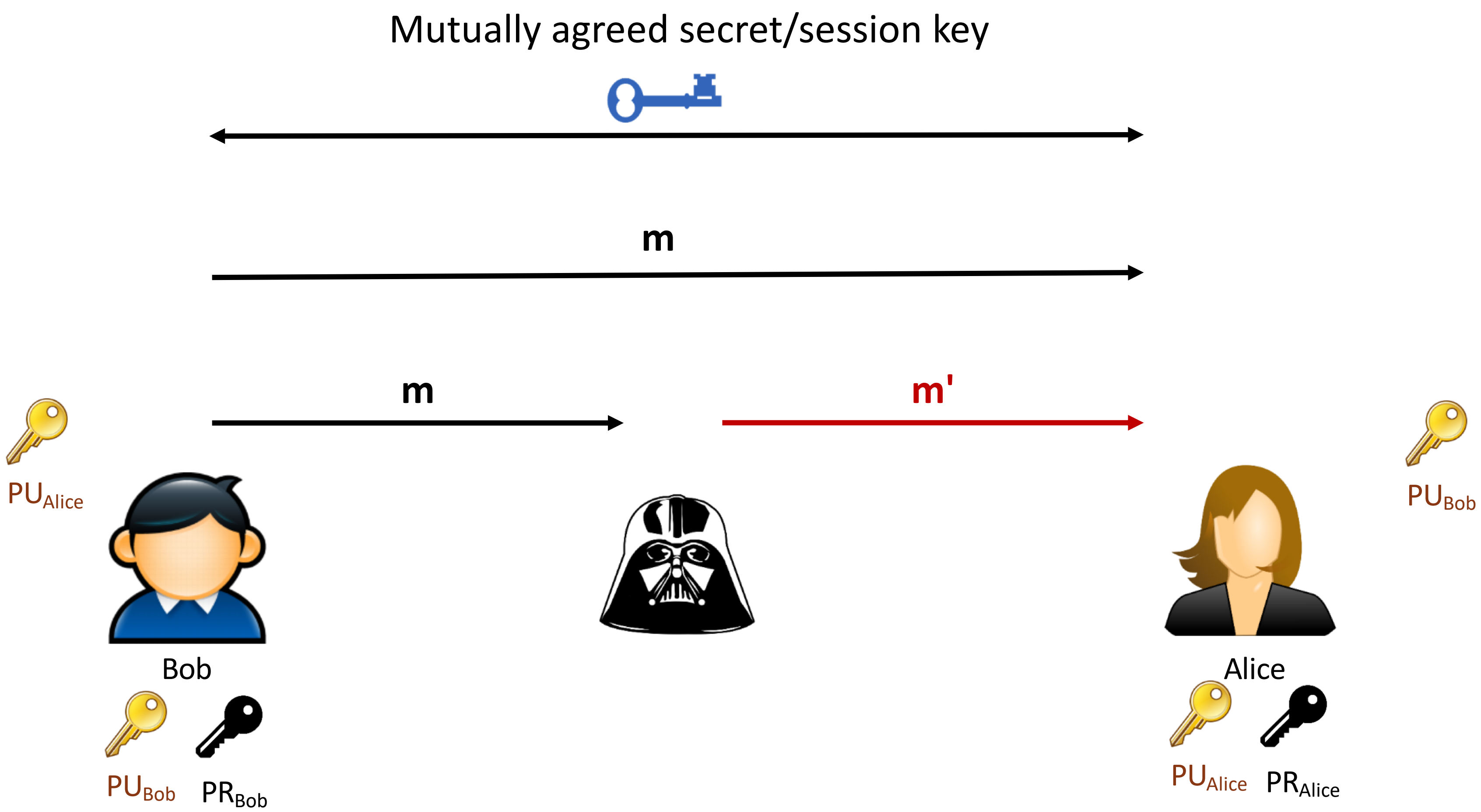


# Active Attacker



# Alteration of Messages



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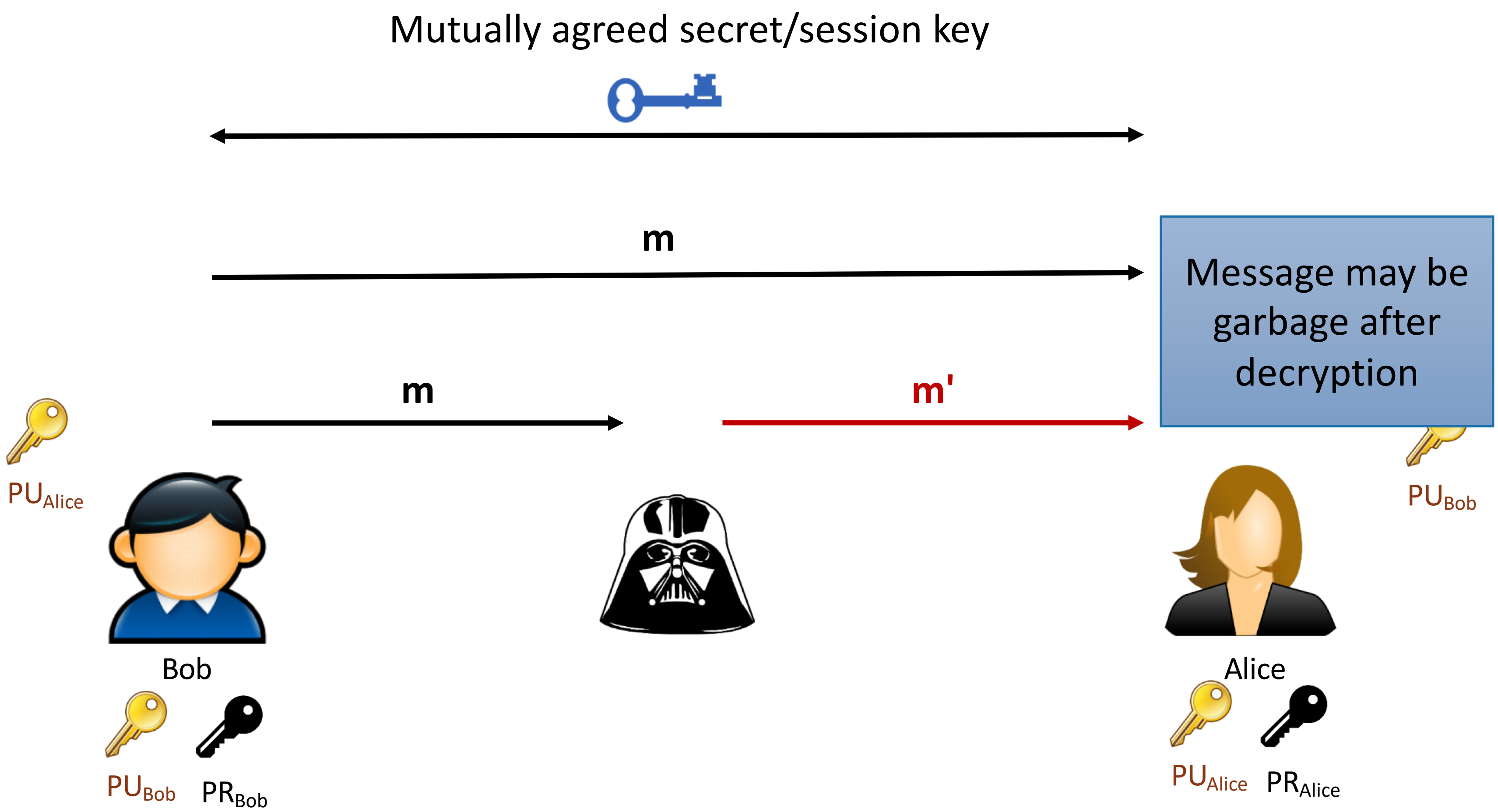


# Message Integrity with MAC

Encrypted data need to protected with MAC against active adversaries

MAC-and-Encrypt $E(P) || M(P)$

- No integrity of the ciphertext

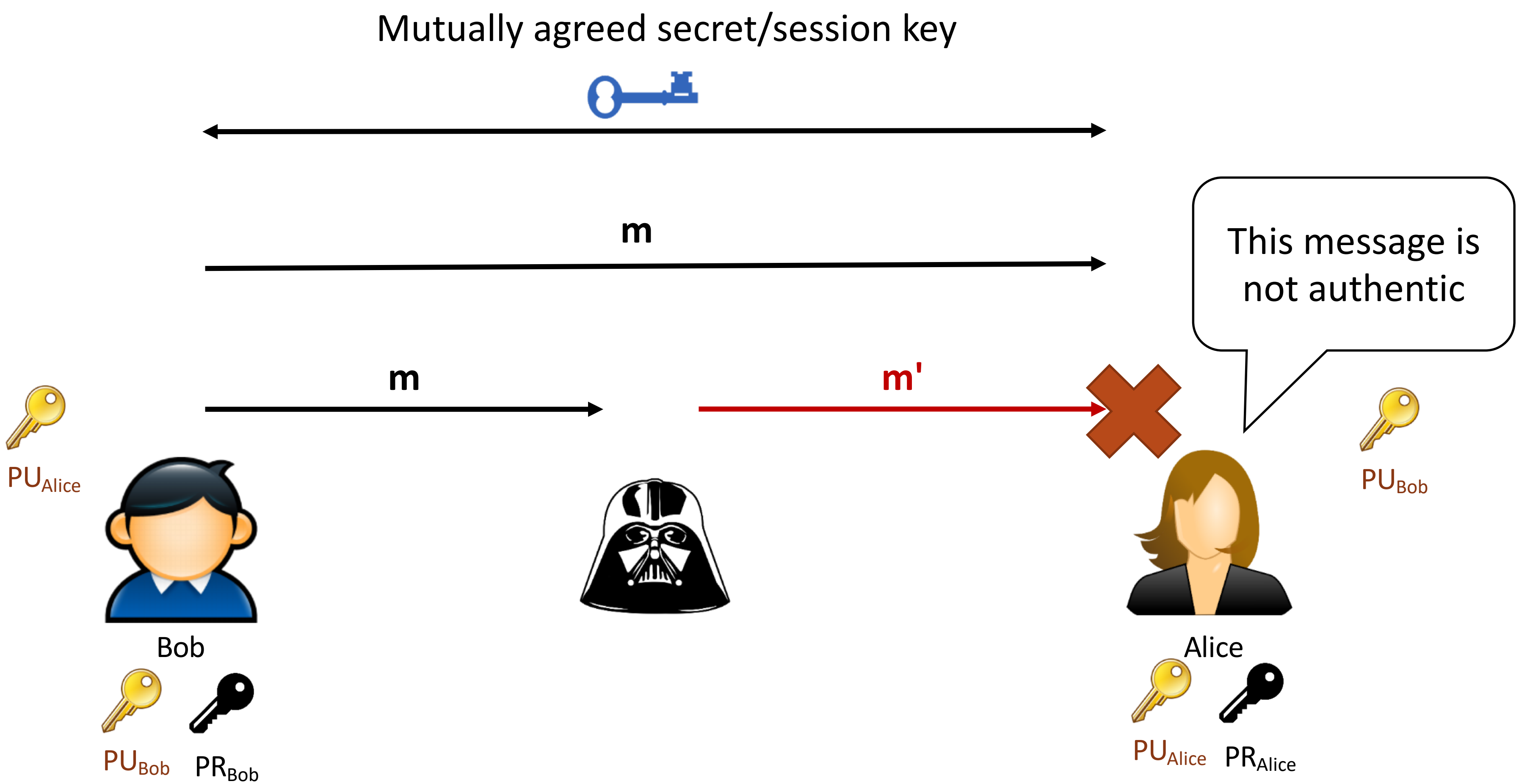
MAC-then-Encrypt $E(P || M(P))$

- No integrity of the ciphertext

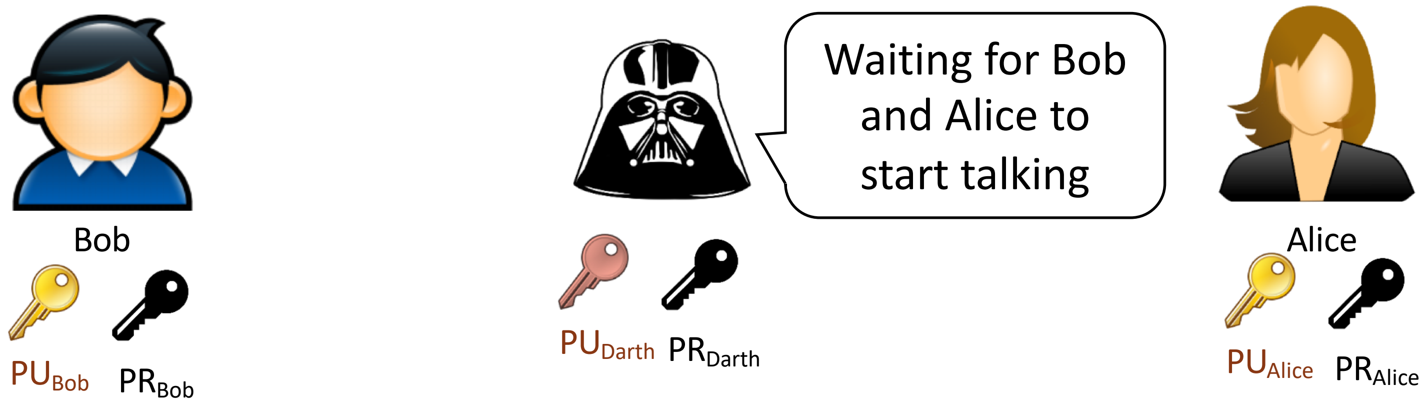
Encrypt-then-MAC $E(P) || M(E(P))$

- **The right option**

# Alteration of Messages Detected



# Man-in-the-middle (MITM)



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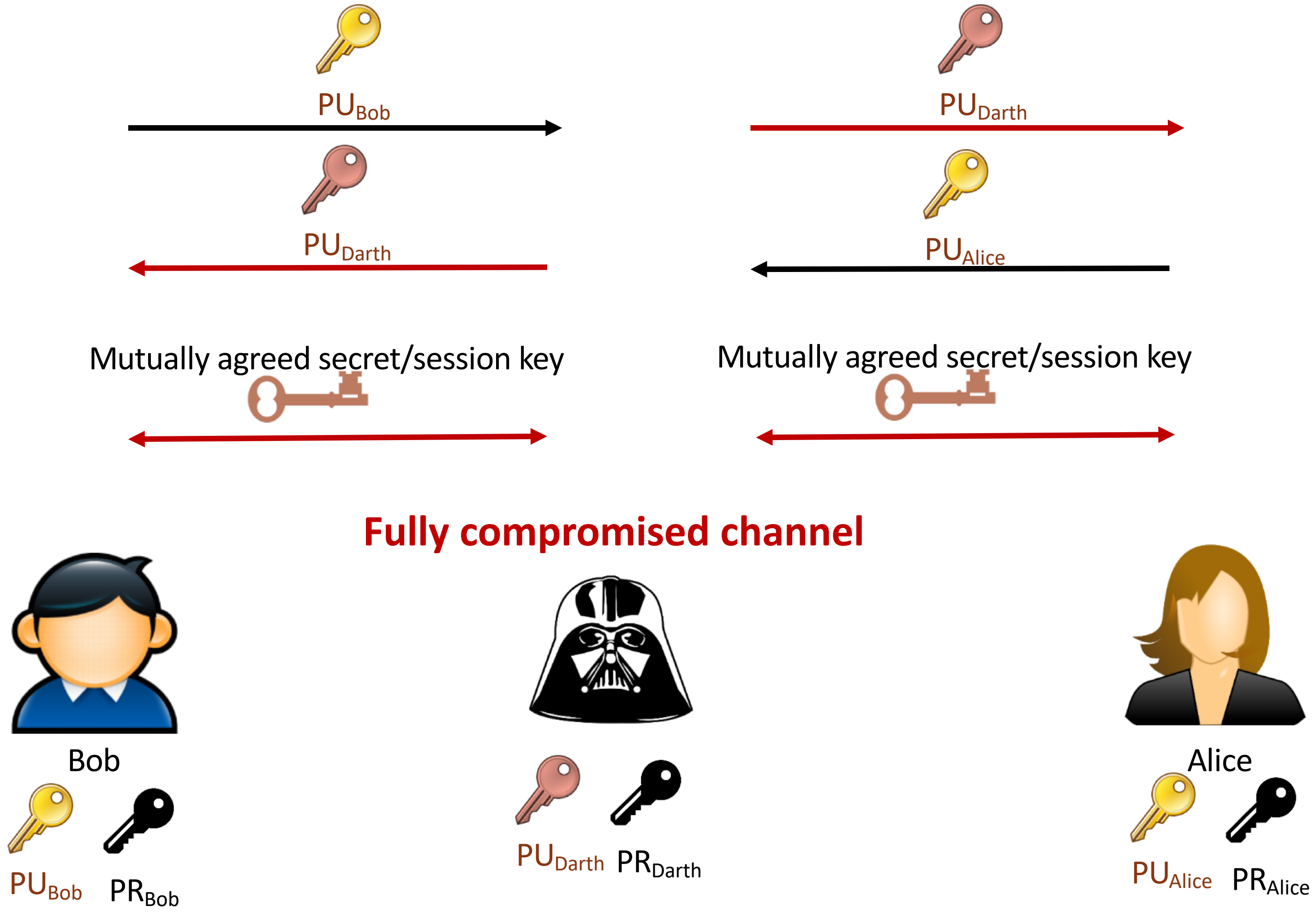


# Public-Key Authenticity

PK encryption requires that parties can establish the authenticity of public keys

Some ways to accomplish this:

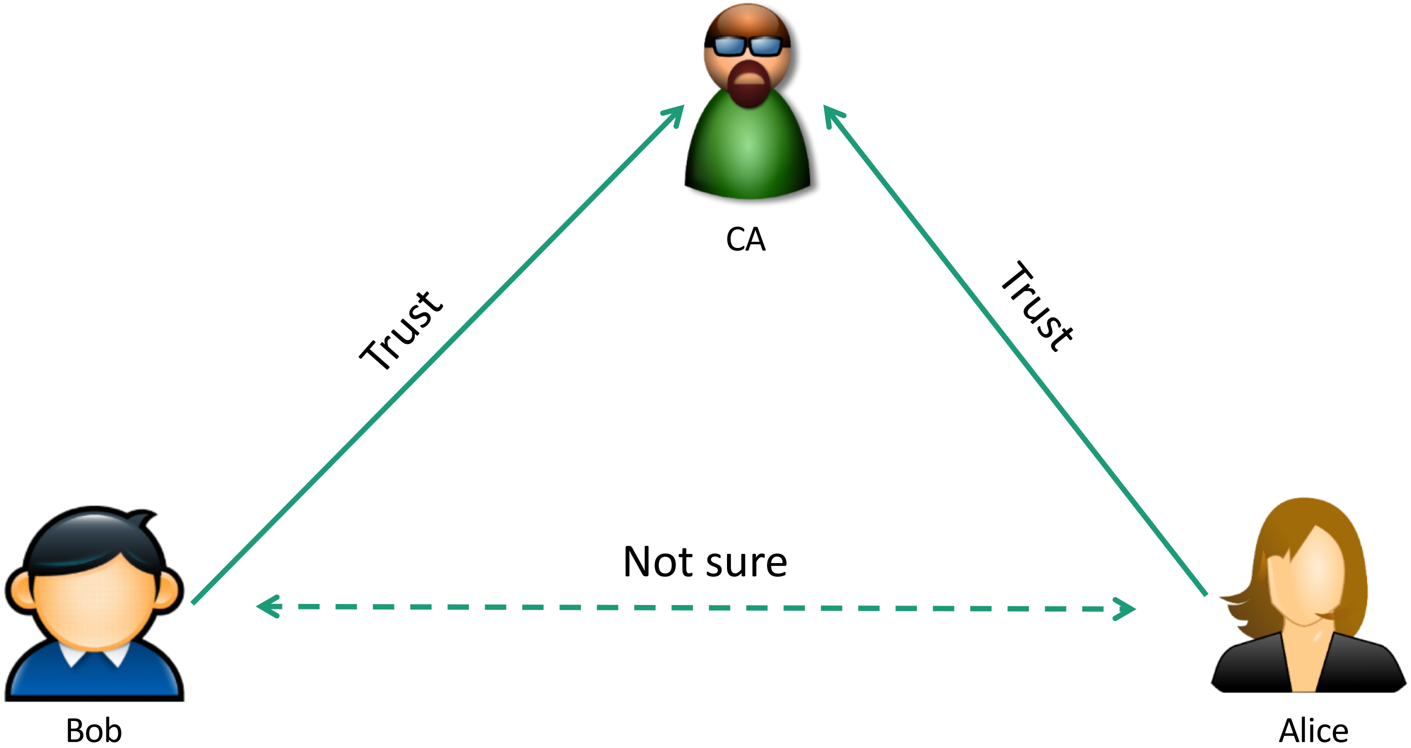
- Trust on first use (TOFU)
- Web of Trust
- **Public-key infrastructure (PKI)**

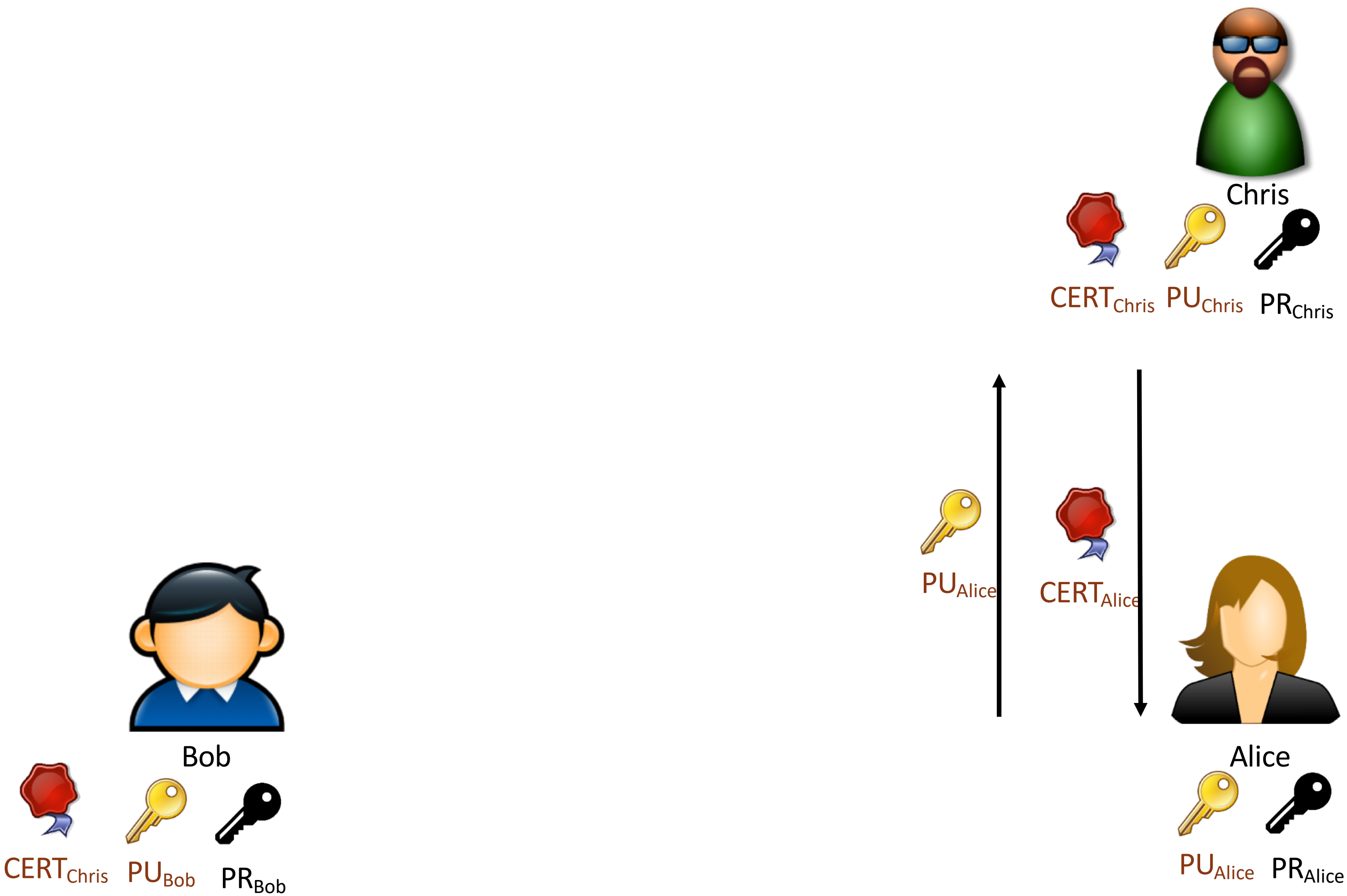
# Certificates

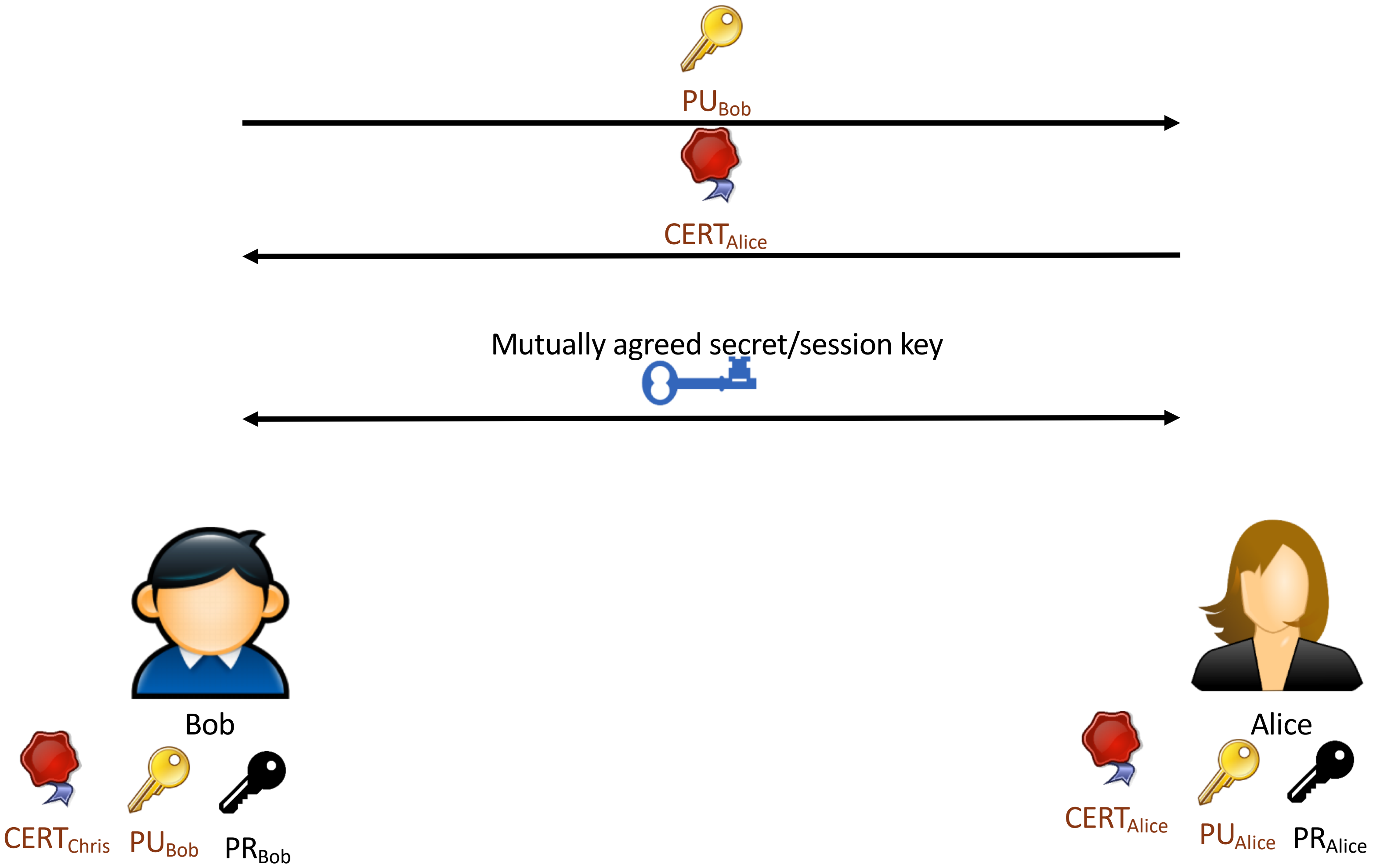
Certificates are essentially signed public keys

- Signed with the private key of a **certificate authority**

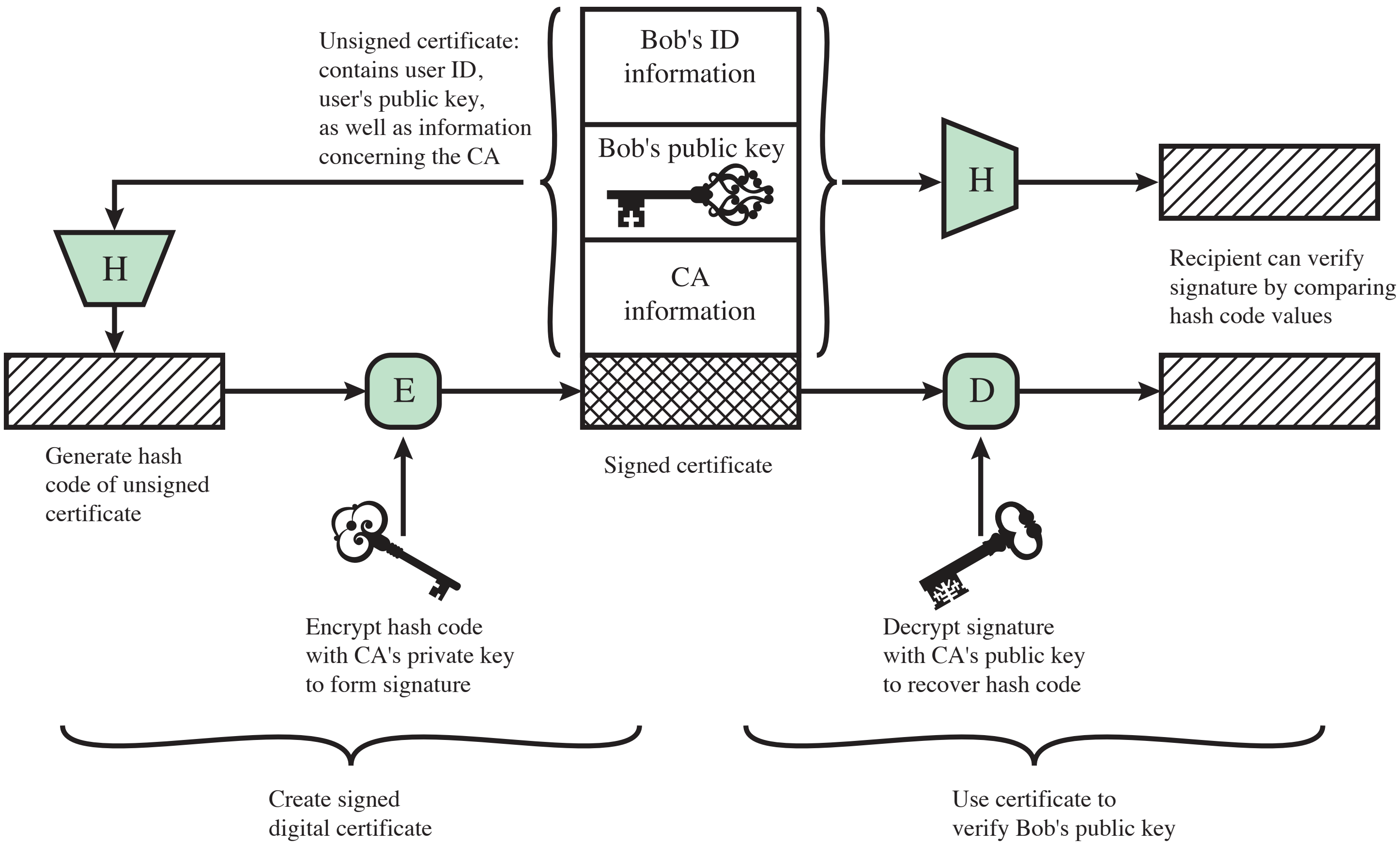
# Trusted Certificate Authorities




Chris
CERT$_{Chris}$
PU$_{Chris}$
PR$_{Chris}$
PU$_{Alice}$
CERT$_{Alice}$
Bob
CERT$_{Chris}$
PU$_{Bob}$
PR$_{Bob}$
Alice
PU$_{Alice}$
PR$_{Alice}$


PU Bob
CERT Alice
Mutually agreed secret/session key
Bob
CERT Chris
PU Bob
PR Bob
Alice
CERT Alice
PU Alice
PR Alice

# Certificates

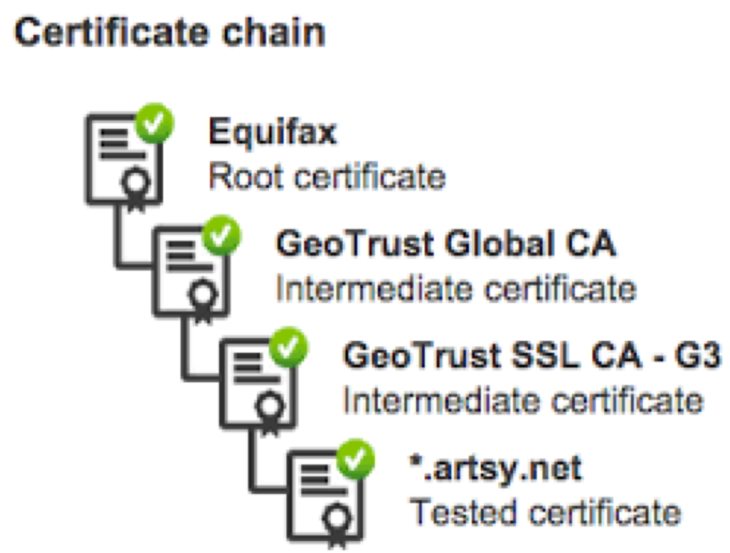


# Certificate Chains

Trust anchors: Systems are preconfigured with a list of trusted certificates

- System-wide or application-based store
- More can be added: self-signed, organization certificates, MiTM certificates, etc.

Server provides a chain of certificates




Any CA can sign certificates for any domain

- The system is as secure as the weakest CA

# TLS

Transport Layer Security (TLS) is the most widely used protocol for secure communications over TCP

Succeeds the Secure Socket Layer (SSL)

- Plagued by various security issues

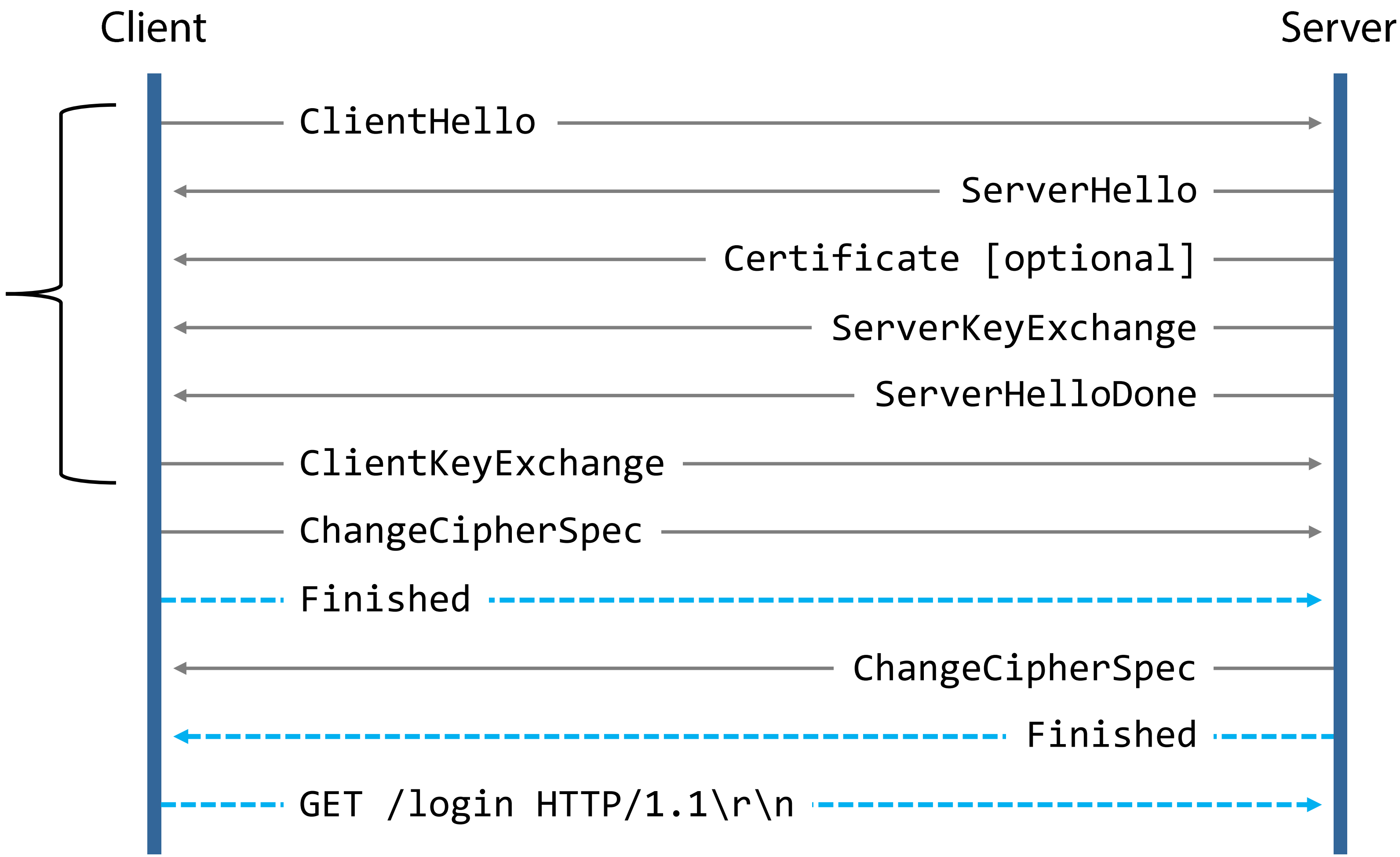
Used in HTTPS, IMAPS, SMTP, etc.

# TLS Protocols

Handshake protocol

- Negotiate sessions keys
- Authenticate server and (optionally) client

# TLS Handshake



# TLS Protocols

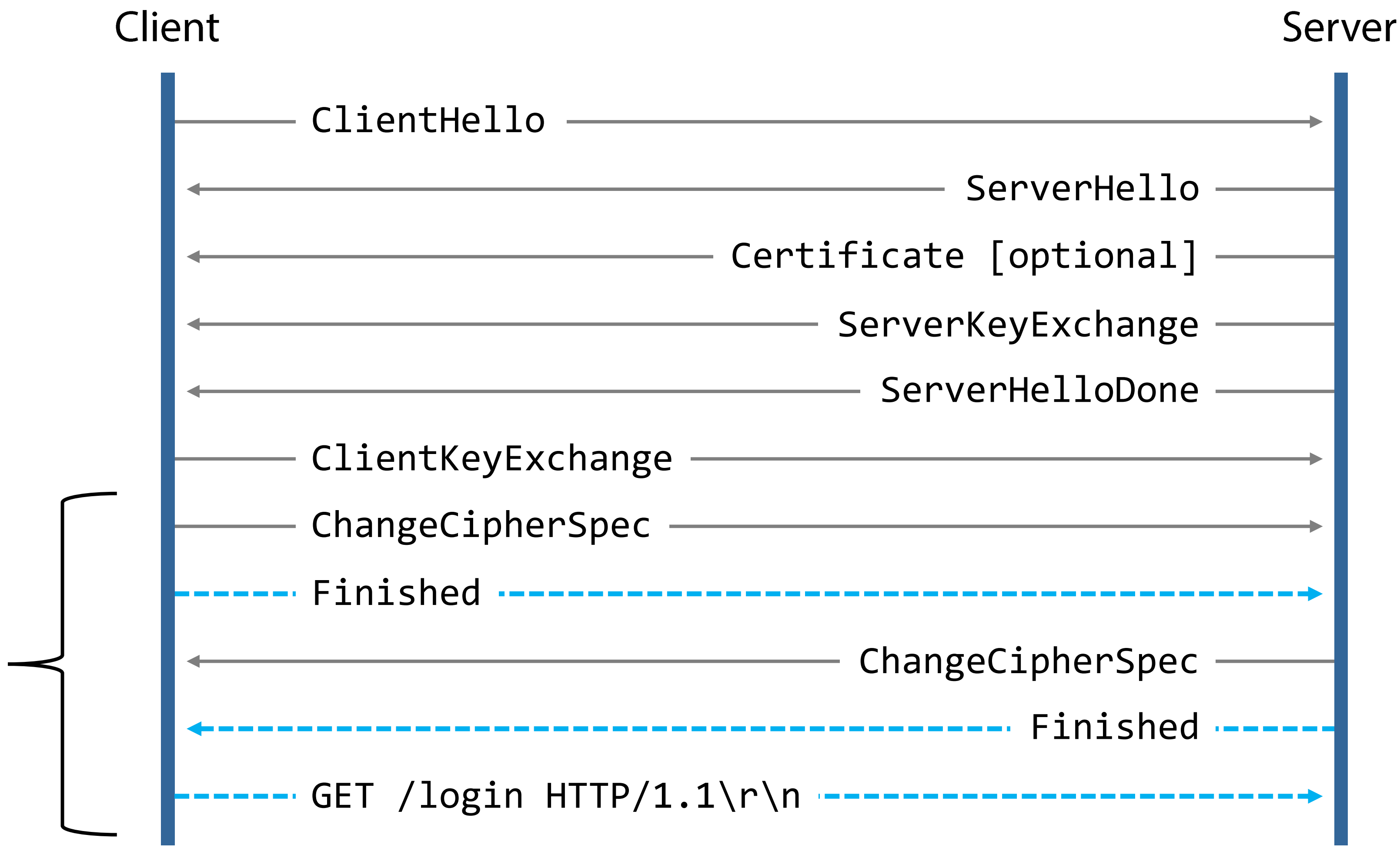
Handshake protocol

- Negotiate sessions keys
- Authenticate server and (optionally) client

Record protocol

- Exchange messages encrypted and MACed with established session key
- Compression before encryption
  - **Don't do it**
- Extensible sub-protocols
  - For example, **change the cipher suit used**

# TLS Records



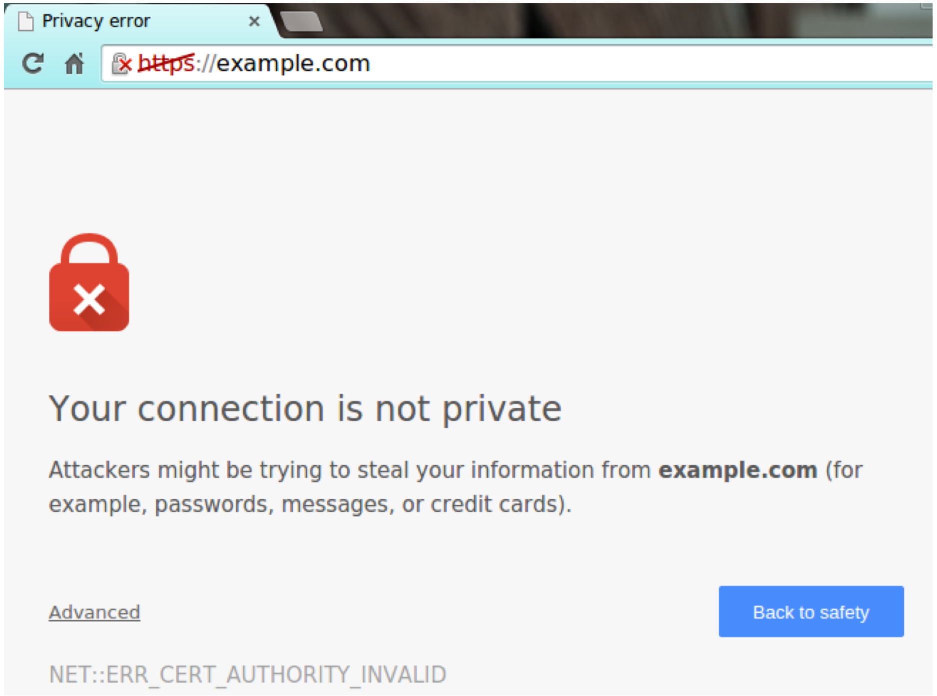
Client
Server
ClientHello
ServerHello
Certificate [optional]
ServerKeyExchange
ServerHelloDone
ClientKeyExchange
ChangeCipherSpec
Finished
ChangeCipherSpec
Finished
GET /login HTTP/1.1\r\n

# Problems with CAs

CAs are businesses doing this for profit

- Certificates are expensive
  Self-signed certs cost nothing

Despite the warnings users tend to keep going




Now you can a cert for free

- https://letsencrypt.org/

# Problems with CAs

## CAs issuing invalid certs

Google Security Blog

The latest news and insights from Google on security and safety on the Internet

### Chrome's Plan to Distrust Symantec Certificates

September 11, 2017

Posted by Devon O'Brien, Ryan Sleevi, Andrew Whalley, Chrome Security

*This post is a broader announcement of plans already finalized on the blink-dev mailing list.*

*Update, 1/31/18: Post was updated to further clarify 13 month validity limitations*

# Problems with CAs

Misplaced “CA” keys

ars TECHNICA

BIZ & IT TECH SCIENCE POLICY CARS GAMING & CULTURE FORU

*DUST UP —*

## 23,000 HTTPS certificates axed after CEO emails private keys

Flap that goes public renews troubling questions about issuance of certificates.

DAN GOODIN - 3/1/2018, 8:36 AM

unrequited life

Enlarge

# Problems with CAs

Why is this root cert in my browser?

ars TECHNICA    BIZ & IT    TECH    SCIENCE    POLICY    CARS    GAMING & CULTURE    FOR

*NOTHING "DISHONEST"? —*

## Turkish government agency spoofed Google certificate "accidentally"

**CA mistakenly gave Ankara's transit authority even more authority.**

SEAN GALLAGHER - 1/4/2013, 3:44 PM

Microsoft has released a security advisory concerning a fraudulent digital certificate for all Google domains apparently created by the Turkish government. The certificate, which was created by a subsidiary Certificate Authority issued to the transportation directorate of the city government of Ankara, could have been used to intercept SSL traffic as part of a "man in the middle" attack to spoof Google's encryption certificate and decrypt secure Web sessions to Google Plus and GMail.

According to a statement from the Turkish certificate authority Turktrust, the organization mistakenly issued two organizations subsidiary CA certificates in 2011—created during testing of Turktrust's certificate production system—instead of the standard SSL certificates they were supposed to receive. Subsidiary CA certificates give the holder the ability to issue SSL certificates with the original CA's authority.

# Downgrade Attacks

Goal: force the use of a weak cipher suite

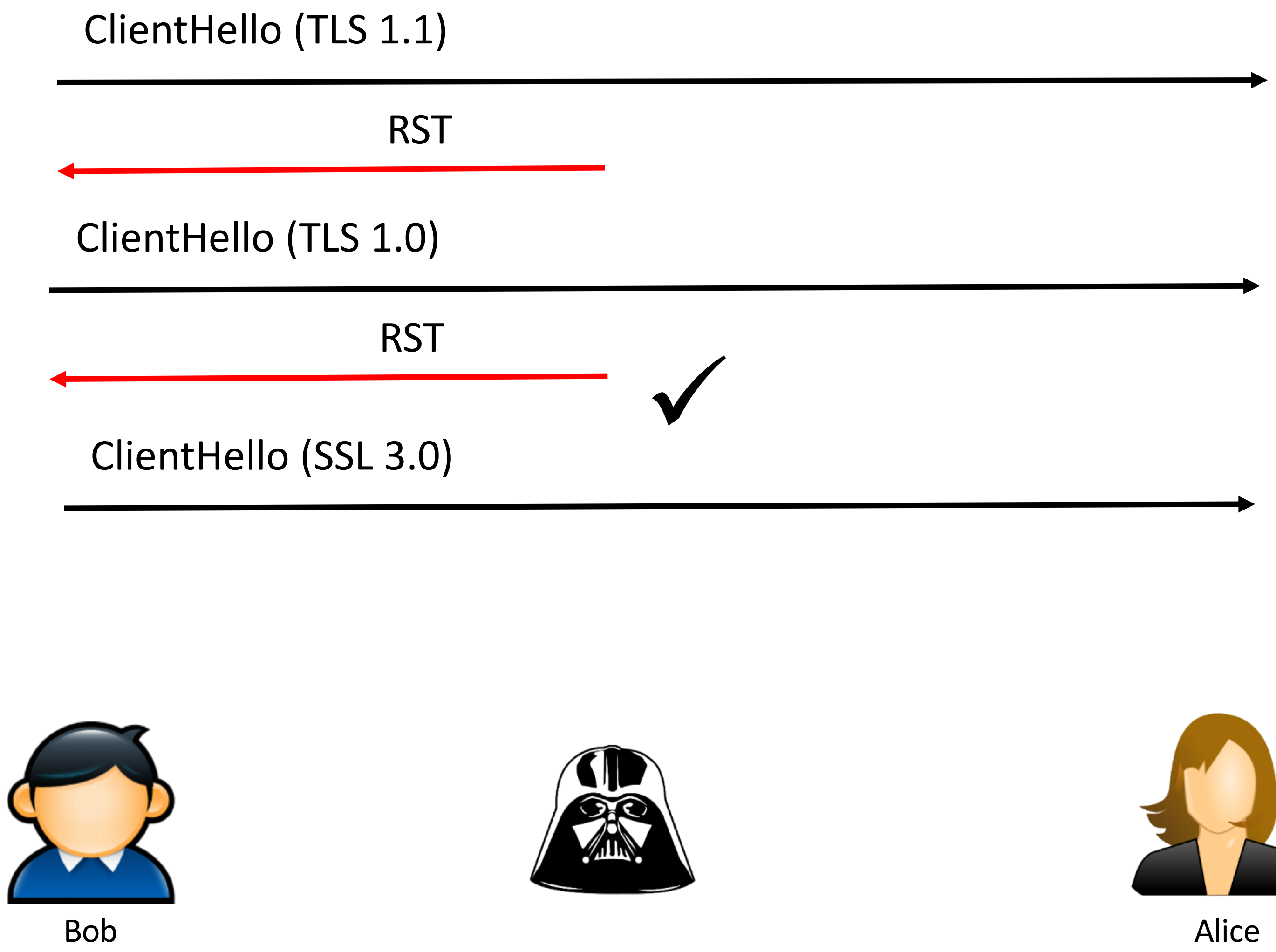
Possible because browsers voluntarily downgrade the protocol upon handshake failure

- For interoperability reasons
- Due to server bugs
- Due to protocol weaknesses

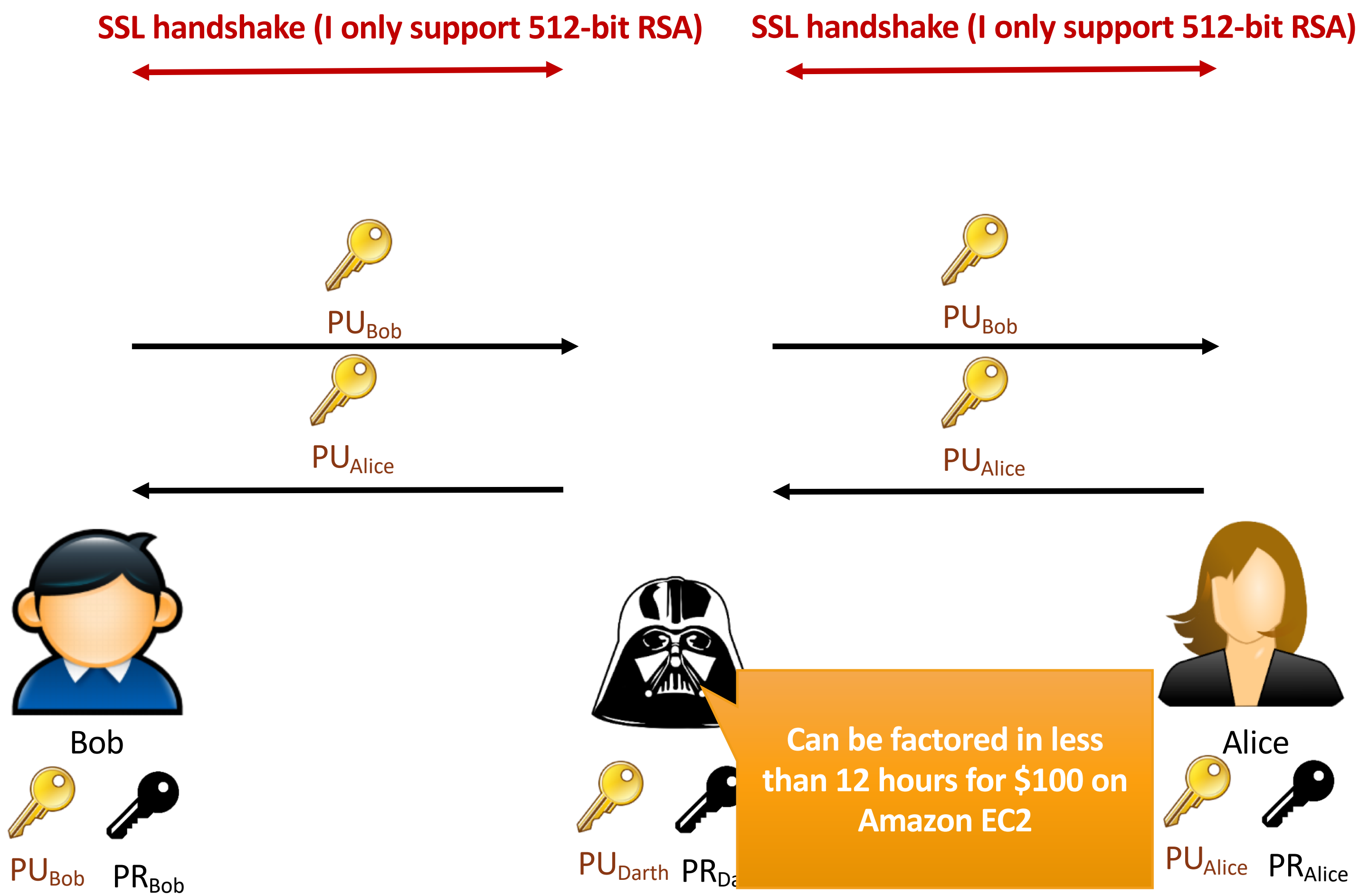
Methods:

- Close connections until retry with lower SSL/TLS version
- Modify list of supported ciphers sent from the client

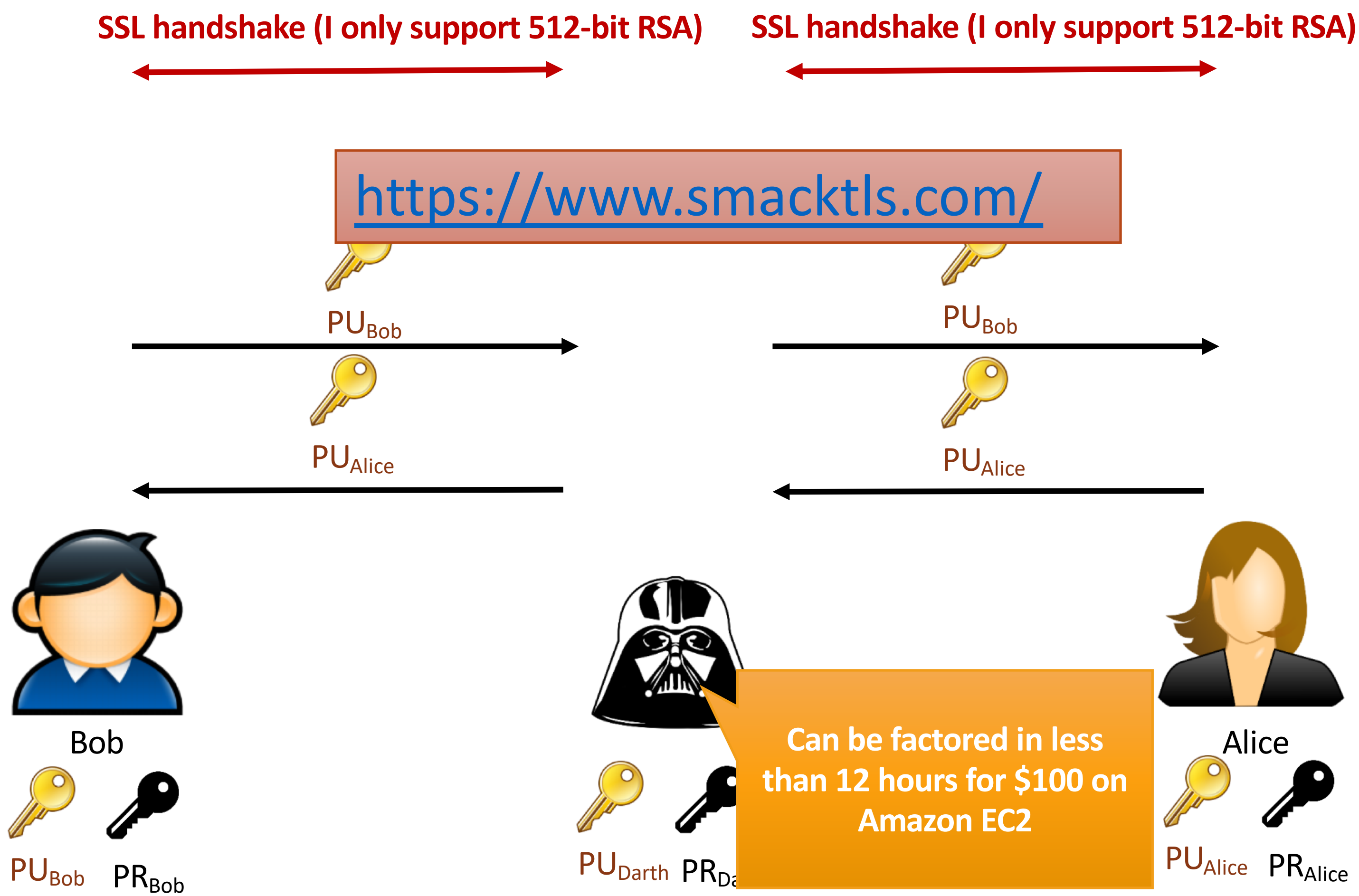
# Downgrading TLS Connection



# Downgrade Cipher Suite



# Downgrade Cipher Suite



# SSL Stripping


```
Location: http://…                  Location: https://…
  <a href="http://…">                  <a href="https://…">
<form action="http://…">            <form action="https://…">
```

# HSTS

HTTP Strict Transport Security protects against SSL stripping and other attacks

- Convert any insecure links to https
- Treat all errors as fatal

Implemented through an HTTP header

- `Strict-Transport-Security: max-age=31536000`

You may need to safely load the site once

- Trust-on-first use

Browsers now also do HSTS-preloading

# Other Mitigations

HTTP Public Key Pinning

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

Online Certificate Status Protocol

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

# Apple Fail (https://gotofail.com/)

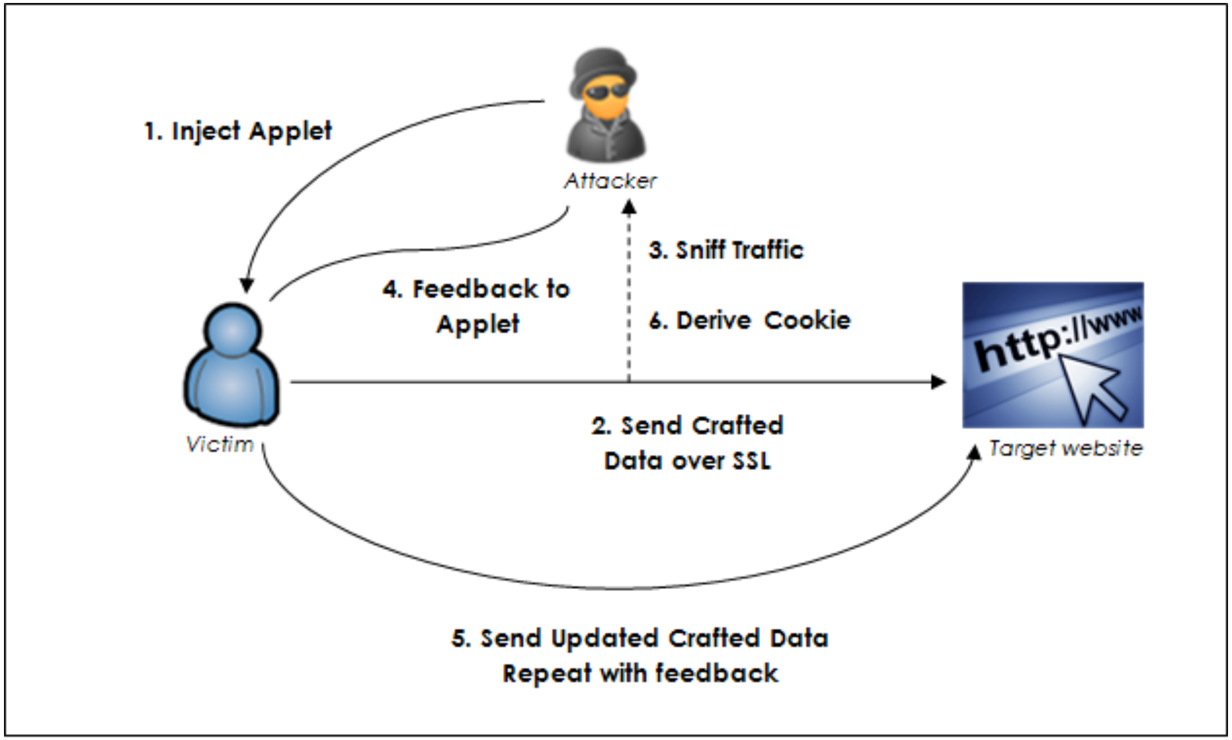
```
static OSStatus
SSLVerifySignedServerKeyExchange(SSLContext *ctx, bool isRsa, SSLBuffer signedParams,
                                 uint8_t *signature, UInt16 signatureLen)
{
    OSStatus        err;
    SSLBuffer       hashOut, hashCtx, clientRandom, serverRandom;
    uint8_t         hashes[SSL_SHA1_DIGEST_LEN + SSL_MD5_DIGEST_LEN];
    SSLBuffer       signedHashes;
    uint8_t         *dataToSign;
    size_t          dataToSignLen;

    ...
    if ((err = ReadyHash(&SSLHashSHA1, &hashCtx)) != 0)
        goto fail;
    if ((err = SSLHashSHA1.update(&hashCtx, &clientRandom)) != 0)
        goto fail;
    if ((err = SSLHashSHA1.update(&hashCtx, &serverRandom)) != 0)
        goto fail;
    if ((err = SSLHashSHA1.update(&hashCtx, &signedParams)) != 0)
        goto fail;
        goto fail;
    if ((err = SSLHashSHA1.final(&hashCtx, &hashOut)) != 0)
        goto fail;

    err = sslRawVerify(ctx,
                       ctx->peerPubKey,
                       dataToSign,                /* plaintext */
                       dataToSignLen,             /* plaintext length */
                       signature,
                       signatureLen);
    if(err) {
        sslErrorLog("SSLDecodeSignedServerKeyExchange: sslRawVerify "
                    "returned %d\n", (int)err);
        goto fail;
    }
```

# CRIME Attack

Leverage compression to leak HTTP cookies

Need to be able to inject a script in a webpage

Issue multiple requests to target website to brute force cookie



# Compression

Header sent with every request

POST /target HTTP/1.1
Host: example.com
User-Agent: Mozilla/5.0 (Windows NT 6.1; WOW64; rv:14.0) Gecko/20100101 Firefox/14.0.1
Cookie: sessionid=d8e8fca2dc0f896fd7cb4cb0031ba249

POST data

Slkgloirskjdal3irjlndfsdnvlsidjsdp91jnflijdsf;9jas;ofdas;dqlnds

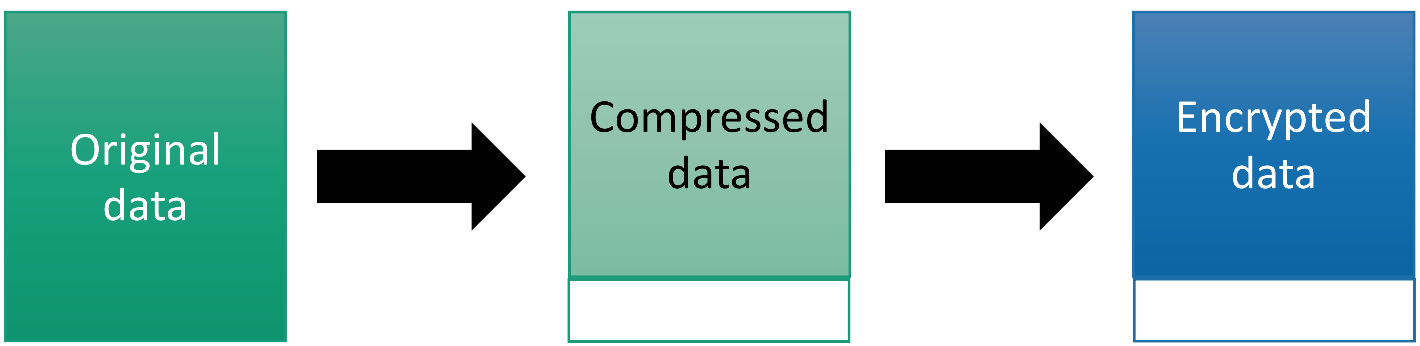
# Compression

Header sent with every request

POST /target HTTP/1.1
Host: example.com
User-Agent: Mozilla/5.0 (Windows NT 6.1; WOW64; rv:14.0) Gecko/20100101 Firefox/14.0.1
Cookie: sessionid=d8e8fca2dc0f896fd7cb4cb0031ba249

POST data

Cookie: sessionid=a




Saved transmission bandwidth due to compression

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Header sent with every request

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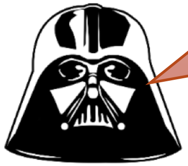
Host: example.com
User-Agent: Mozilla/5.0 (Windows NT 6.1; WOW64; rv:14.0) Gecko/20100101 Firefox/14.0.1
Cookie: sessionid=d8e8fca2dc0f896fd7cb4cb0031ba249

POST data

Cookie: sessionid=d

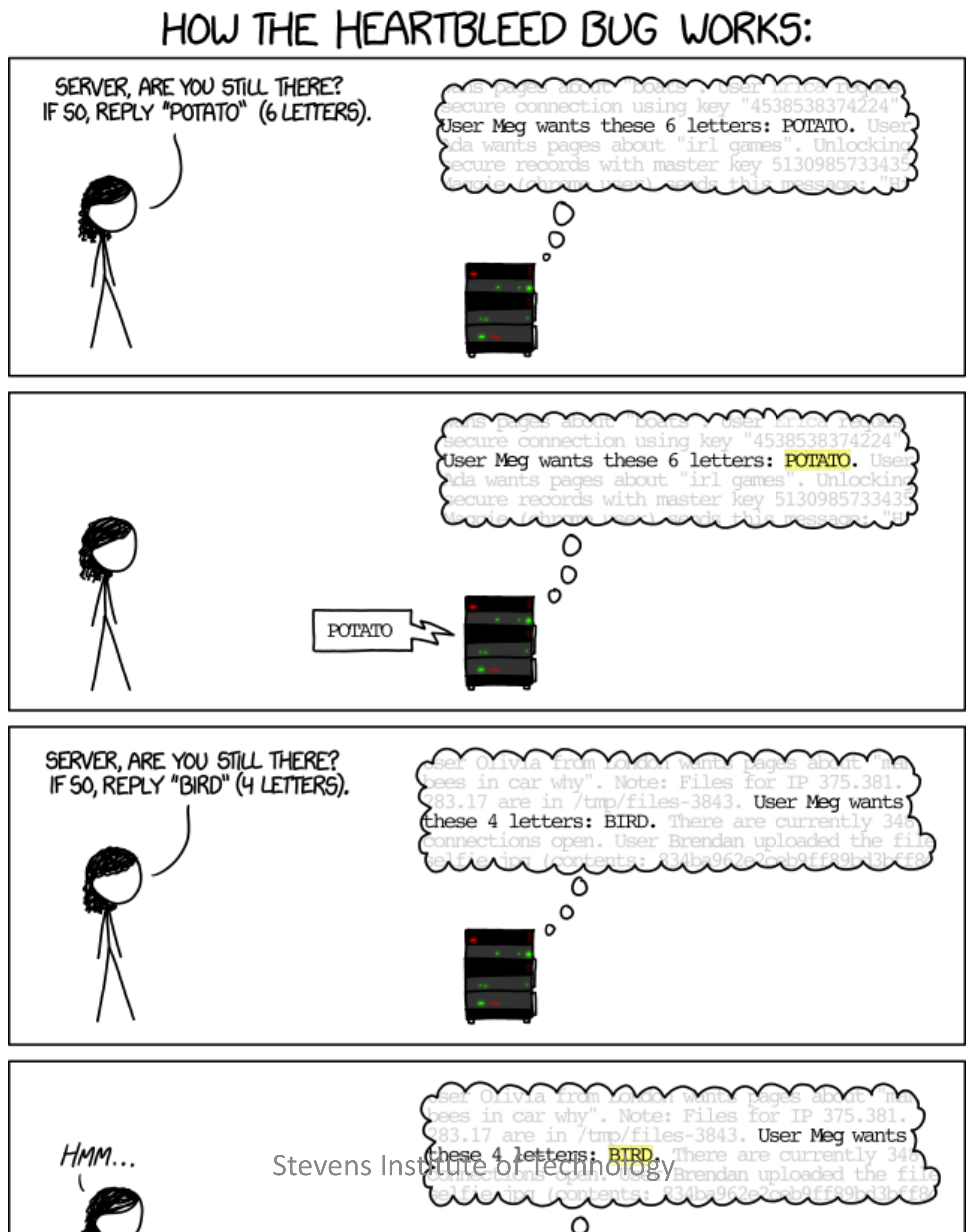
Observing the amount of data transmitted tells me when I get a match in the POST data

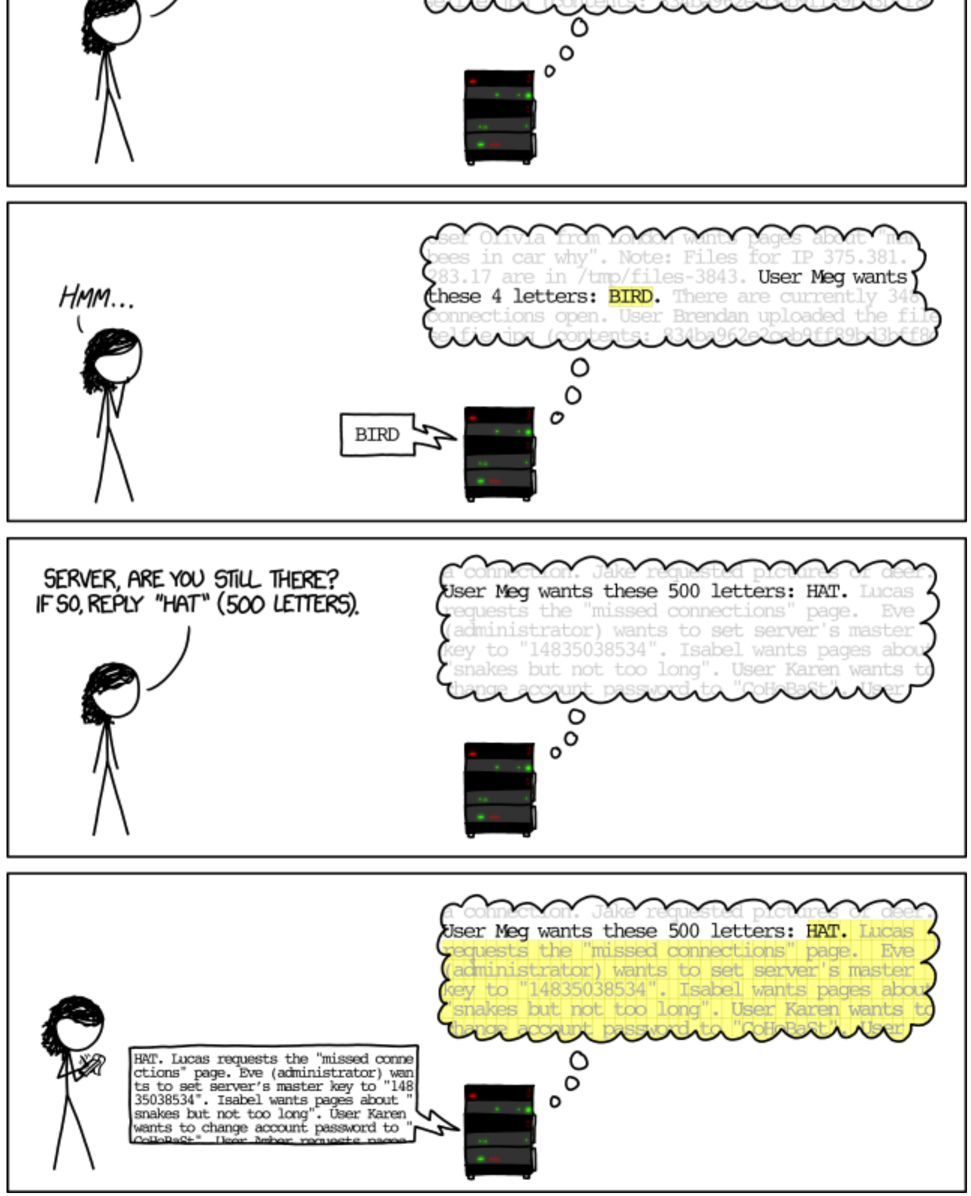


Original data → Compressed data → Encrypted data

Saved transmission bandwidth due to compression

# Heartbleed


HOW THE HEARTBLEED BUG WORKS:
SERVER, ARE YOU STILL THERE? IF SO, REPLY "POTATO" (6 LETTERS).
User Meg wants these 6 letters: POTATO.
POTATO
SERVER, ARE YOU STILL THERE? IF SO, REPLY "BIRD" (4 LETTERS).
User Meg wants these 4 letters: BIRD.
HMM...



HMM...
User Meg wants these 4 letters: BIRD.
BIRD
SERVER, ARE YOU STILL THERE? IF SO, REPLY "HAT" (500 LETTERS).
User Meg wants these 500 letters: HAT.
HAT. Lucas requests the "missed connections" page. Eve (administrator) wants to set server's master key to "14835038534". Isabel wants pages about "snakes but not too long". User Karen wants to change account password to "