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Another Nail in the Coffin: OpenPGP Key Servers Gone Rogue

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Outline

Introduction

- Use Cases for Key Servers
- SKS – Synchronising Key Servers
- OpenPGP basic structure + RSA basics
- **Why we need revocation**

Problems

- Missing Integrity Check
- Equivocation
- **The current concept and it's implementation are broken**

Solution

- Certificate Transparency Log
- PGP Revocation Bytes
- **How to design a Revocation Service**

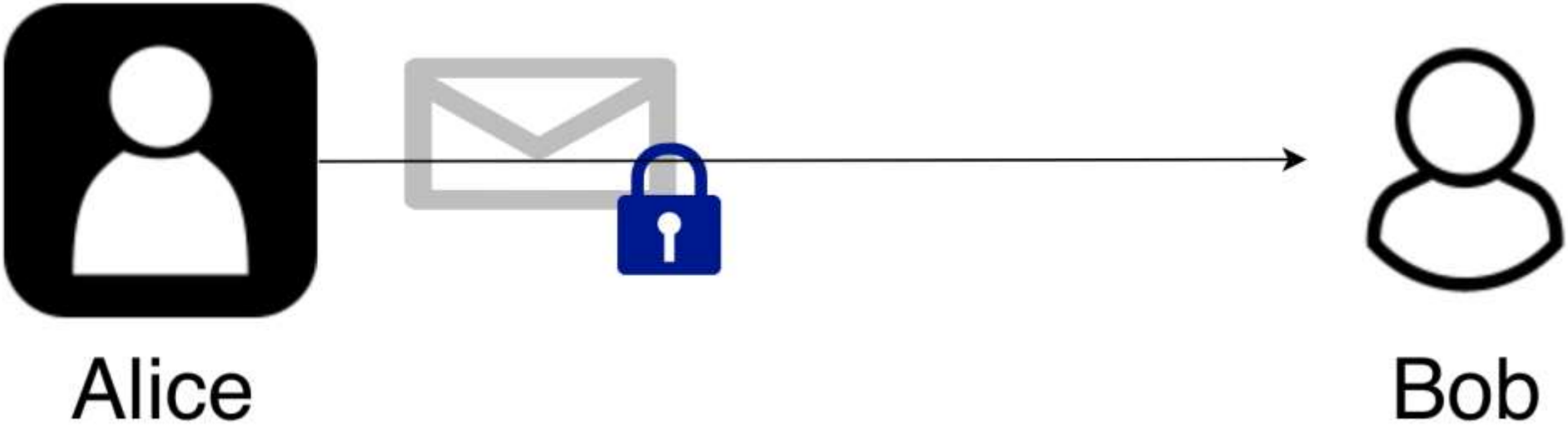
Intro

- Why do we need to exchange keys?
- What to I do when my keys got stolen?
  - Generate a Revocation Certificate beforehand
- How do PGP packets work?

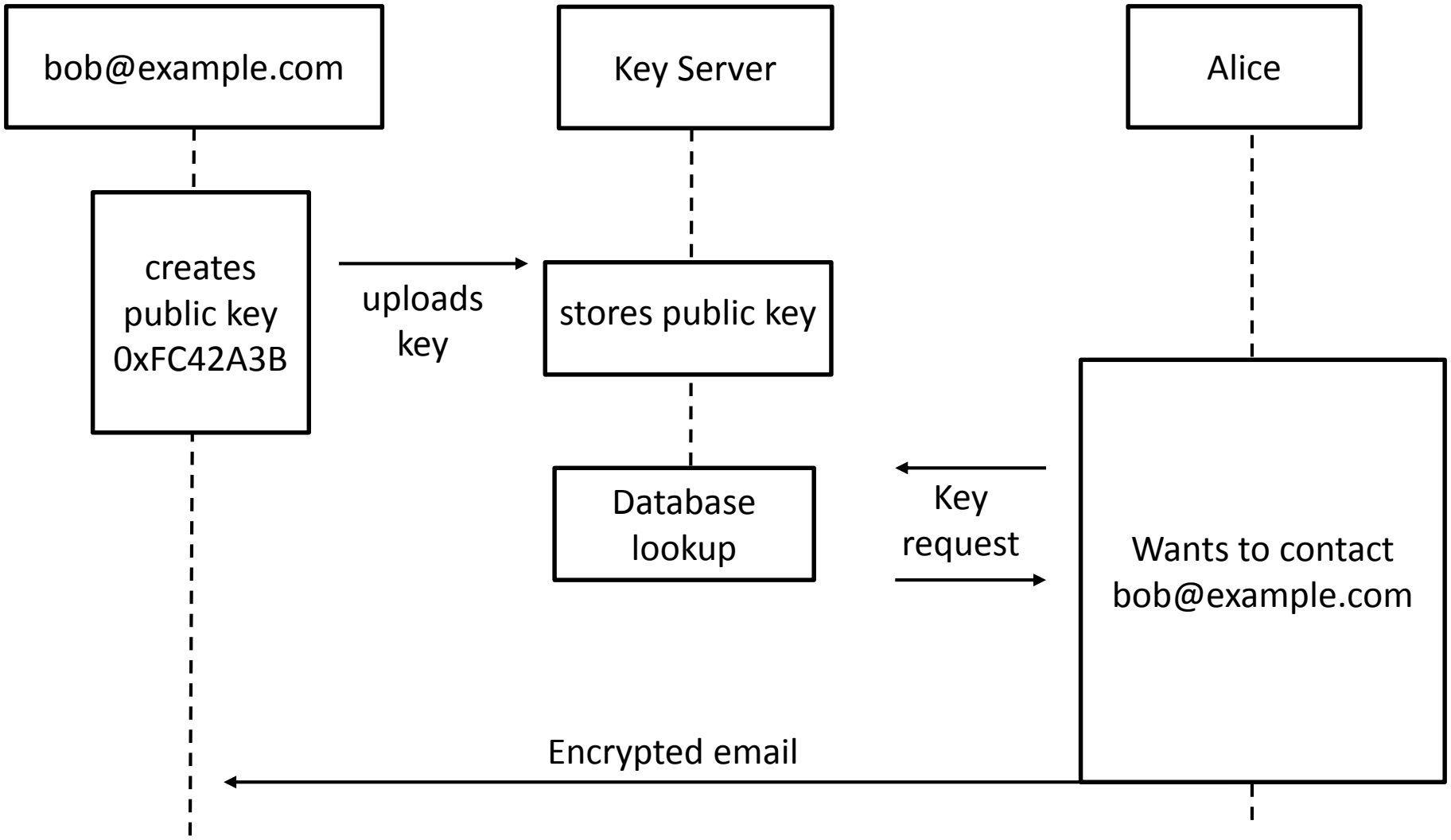
Source: xkcd.com

Sending and encrypted Email

- Alice needs a key for sending an encrypted Email to Bob



Promise: Availability without prior contact



Key Servers' promise: Availability of Cryptographic Keys

- Receiving the actual key material by UID or fingerprint
- Mitigate Deletion of Keys on one Key Server by Re-Distribution
- Update certificate, e.g. new sub-keys, new UIDs, new certifications
- **Check for revocations**

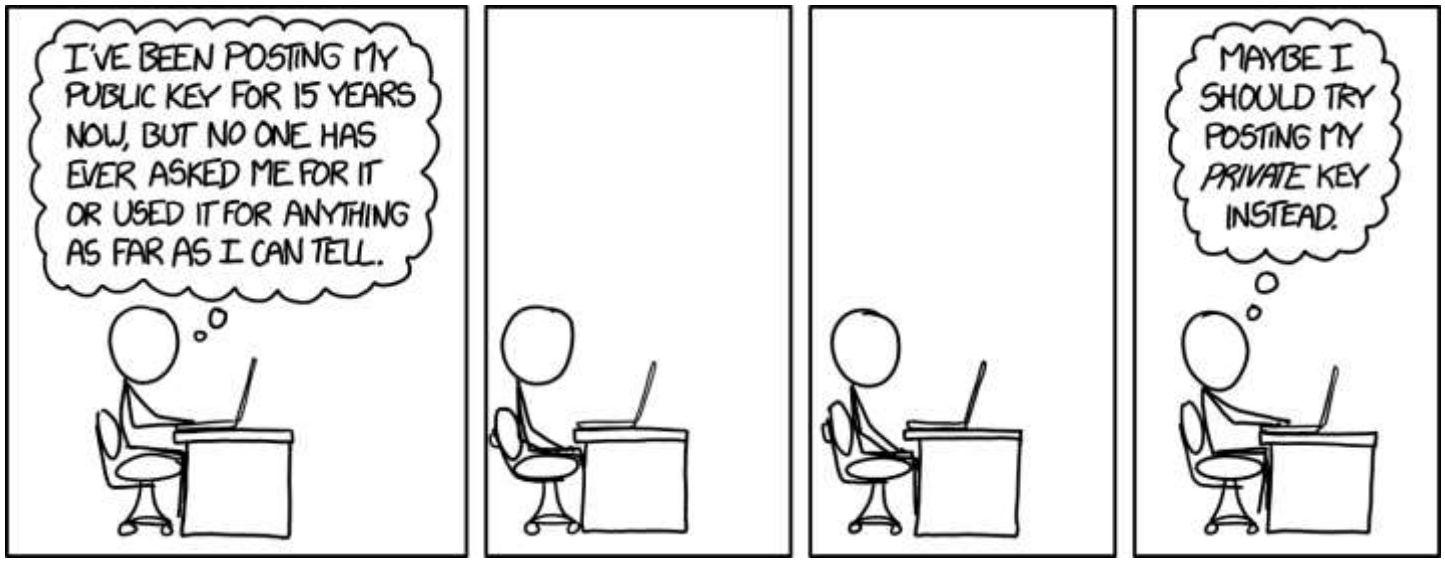
You have to check for integrity yourself

What if my **private key** gets compromised?

- When an attacker could successfully obtain the private key of Bob,

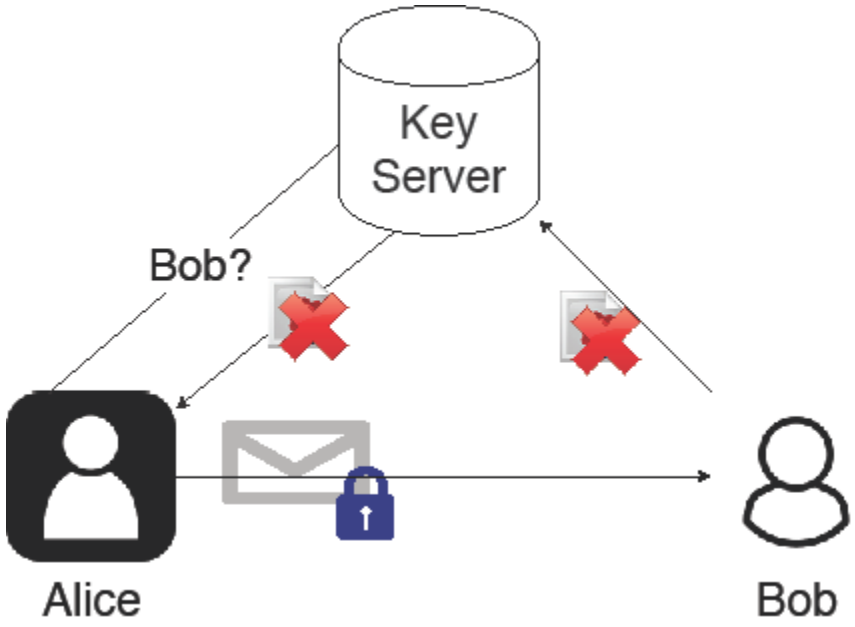
  Bob needs to **revoke** his key.

  Notice - Bob should generate a **revocation certificate for his key in advance**

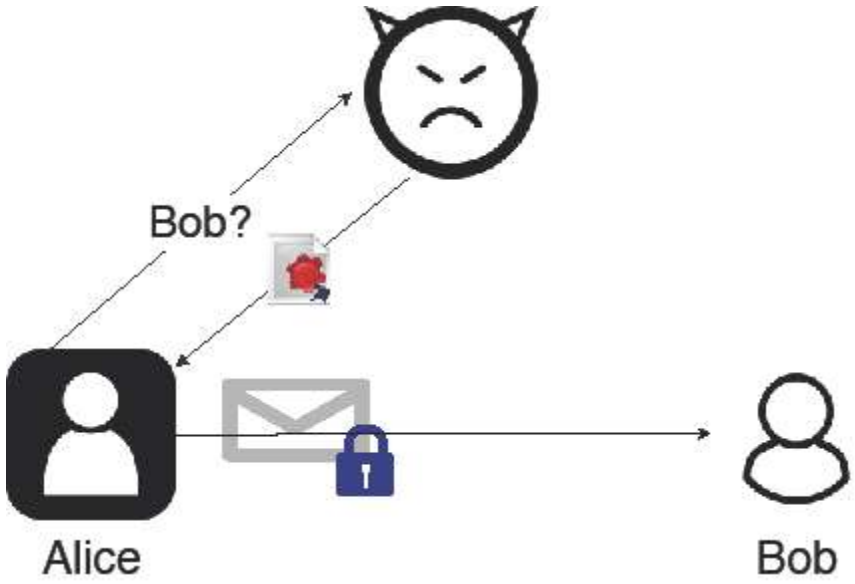


Source: xkcd.com

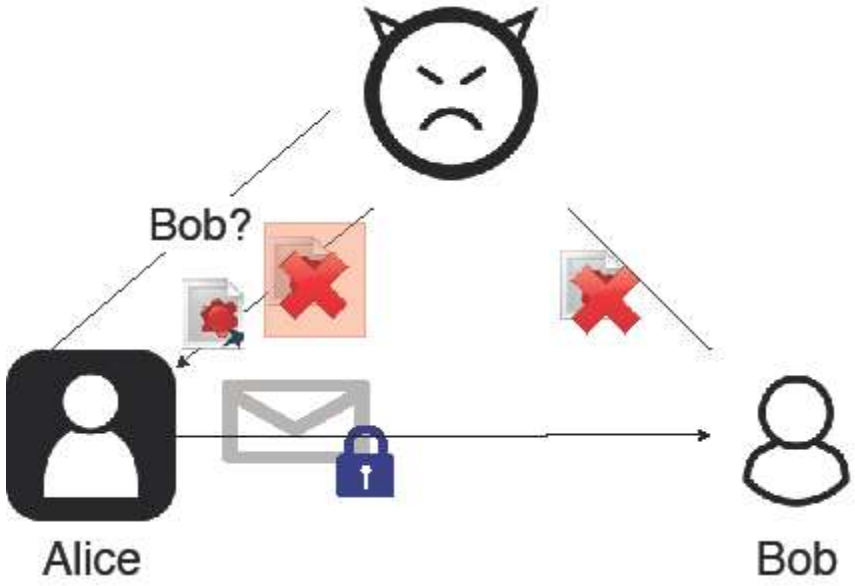
Revocation – The happy path



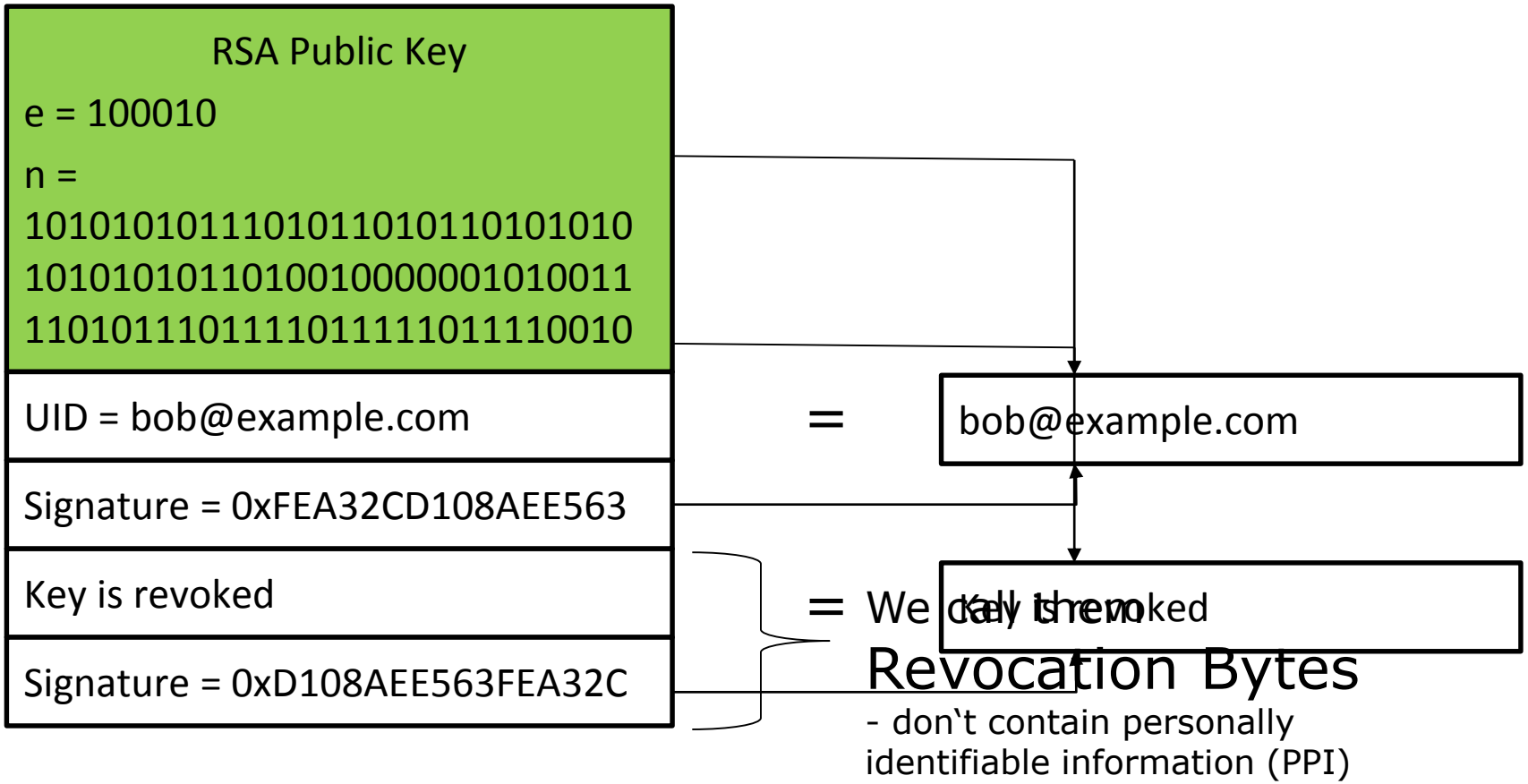
Revocation – The evil path



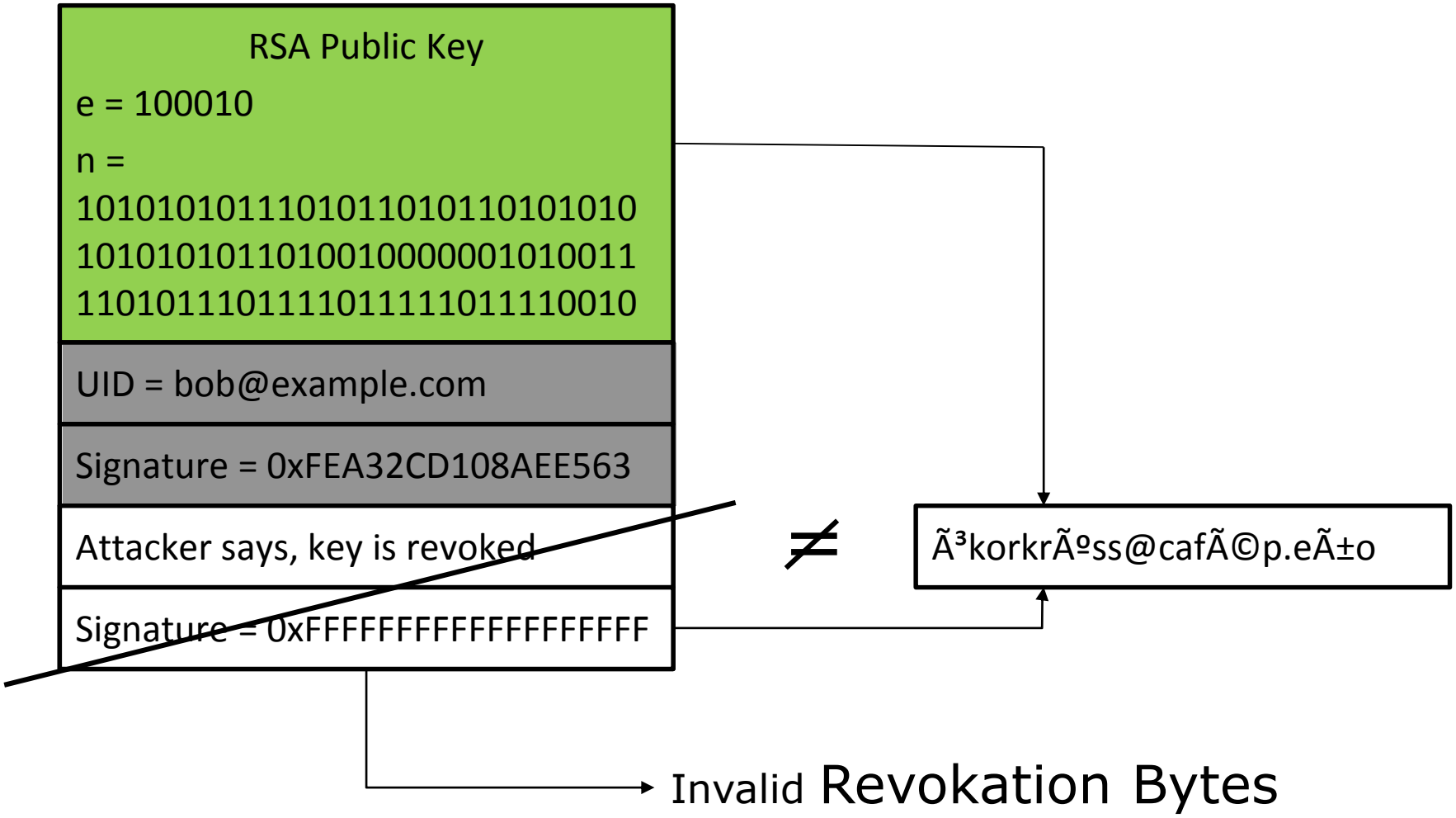
Revocation – The evil path, Equivocation



Validation


RSA Public Key
e = 100010
n =
10101010111010110101101010101
10101010110100100000010100111
11010111011110111111011110010
UID = bob@example.com
Signature = 0xFEA32CD108AEE563
Key is revoked
Signature = 0xD108AEE563FEA32C
=
bob@example.com
=
Key is revoked
Revocation Bytes
- don‘t contain personally identifiable information (PPI)

Invalid packets get discarded

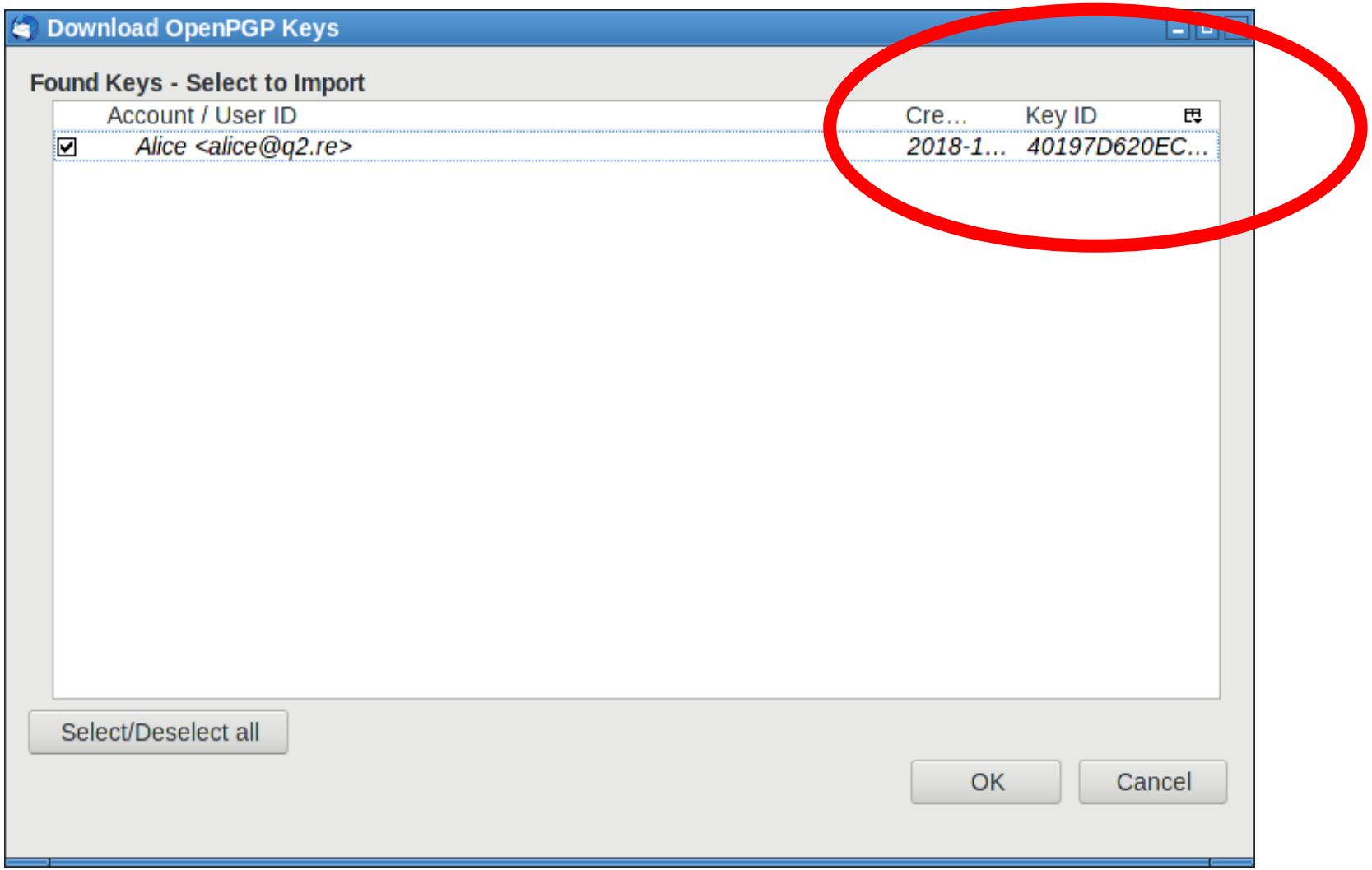


…, so what does the key server check then?

Anatomy of an OpenPGP Certificate

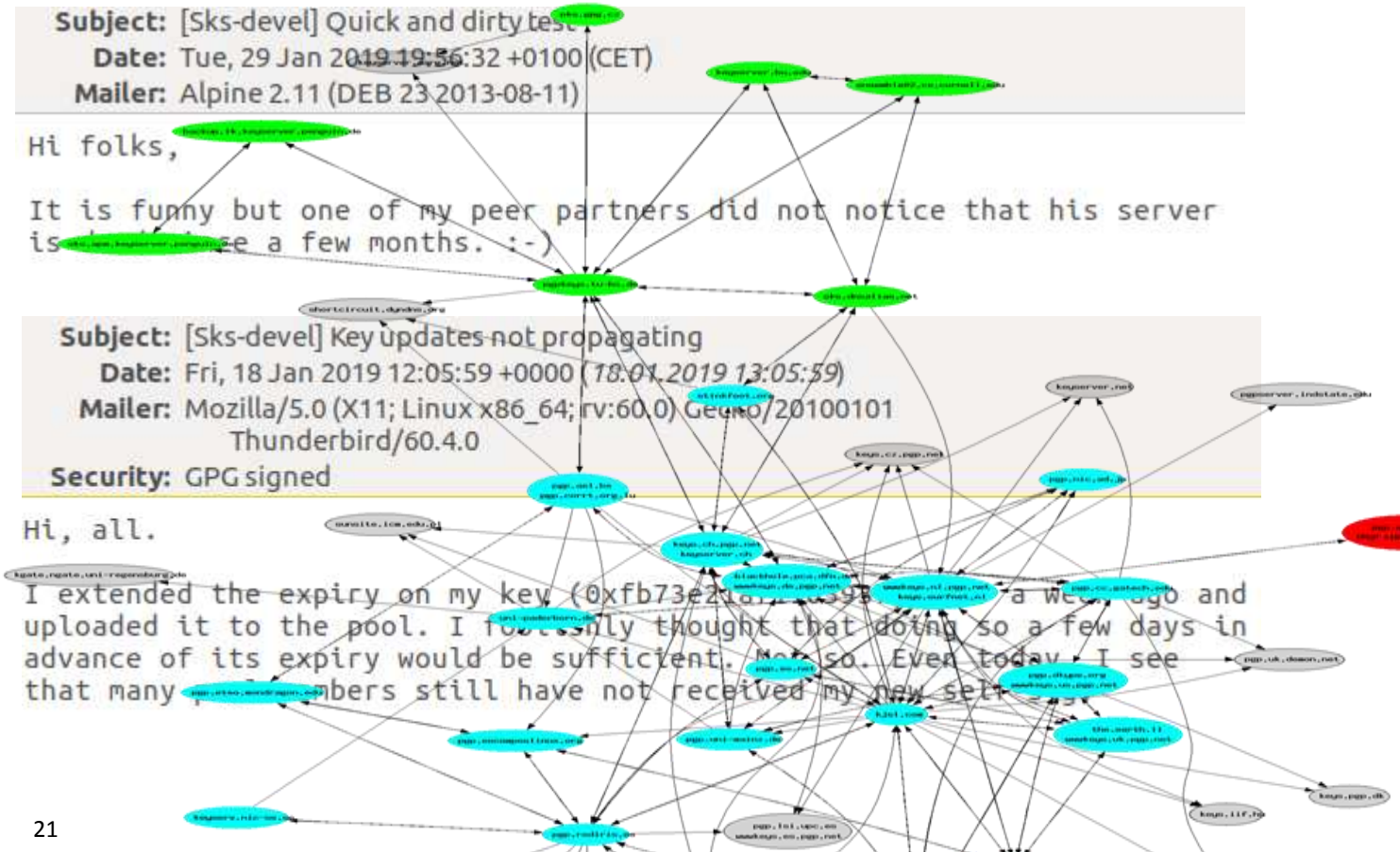
```
0000  88 78                                                 frame
0002        04                                               version
0003           20                                            sigtype
0004              16                                         pk_algo
0005                 08                                      hash_algo
0006                    00 20                                hashed_area_len
0008                          16 21 04 cd 6f 2d 93 e8        hashed_area
0010  87 0d 61 17 6a d5 c7 89  b4 a0 07 47 a2 88 70 05
0020  02 5b dd 82 a9 02 1d 00
0028                          00 0a                          unhashed_area_len
002a                                09 10 89 b4 a0 07        unhashed_area
0030  47 a2 88 70
0034              06                                         hash_prefix1
0035                 f9                                      hash_prefix2
0036                    01 00                                mpi_len
0038                          97 61 89 af 42 3d f5 e2        eddsa_signature_r
0040  eb 95 9a 50 d2 c4 20 ce  fc 2a f7 f9 1b 72 27 33
0050  0e 5a 4b 7a 2f 27 73 2a
0058                          01 00                          mpi_len
005a                                9d 3b 4a 71 c2 2f        eddsa_signature_s
0060  1e 2b 65 f4 24 20 11 3d  45 29 ee 16 fc 61 ef 3f
0070  fd 98 16 f7 98 e1 33 48  1e 07
```

Enigmail showing a revoked certificate (but it has not been revoked!)



SKS – Synchronising Keyserver

- Main implementation of HKP enabled daemon
- Set-reconciliation with near optimal communication
- Loosely connected set of servers in the pool



SKS – Synchronising Keyserver – inherent problems

- Cannot delete keys
  - GDPR concerns
  - Poison keys

> the pool of SKS keyservers: as anyone can upload anybody's key, and
> it does not allow to delete keys, it's IMHO by not compatible with GDPR.

- Equivocation
  - Strip packets

Subject: Re: [Sks-devel] Unusual traffic for key 0x69D2EAD9 and 0xB33B4659
Date: Mon, 04 Feb 2019 10:49:30 +0100
Mailer: Roundcube Webmail/1.2.3

Hi,

Don't get me wrong, but within three days I've got 450G traffic which can be assigned to sks by 99.9%. Estimated to 30 days this means 4.5T (which is in good agreement of your 2+T/Key for these two poison keys).

SKS – Synchronising Keyserver – operational problems

- Single threaded Ocaml
  - Arcane architecture for high performance pools
  - Maintenance
  - Pool size
- No integrity validation
  - No semantic checks, i.e. identity
  - No cryptographic checks, e.g. Invalid signatures
  - Only rudimentary validation against the OpenPGP spec

> And how do we tell sks to use more than ONE instance for the SAME
> database?!

You don't. SKS just isn't built that way. To get concurrency, you need to run multiple separate instances of SKS and configure them to gossip between each other. Then you can put a load balancing reverse proxy in front to simulate a multi-threaded server. Kristian and a few others have been operating this way for a while now.

> Any chance that sks will be fixed some day?

Short answer, no. SKS is effectively running as end-of-life software at this point. It gets emergency bugfixes but little else. The improvements you are talking about would require an enormous refactoring of the codebase, likely requiring migration to a different database engine. Given that there are fundamental design flaws (poison keys) that aren't getting fixed, performance issues just aren't on the radar. Sorry.

1. Future updates for the key will be denied, including legitimate ones by key holder (FreePBX team). 2. DoS is still possible just by accessing/fetching the key. To fix that, you'll have to remove the DoS packets (large user packets with random gibberish, not valid per OpenPGP packet spec, does not validate cryptographically) or the whole key. 3. Anyone can create another poison key at any time and there's no way to fix that without breaking compat, it's a fundamental flaw :-(

The final breath of SKS
(*2002 - †2019)

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> I have not been running a keyserver myself since the first poison-key incident. Given the ongoing poison-key problems I am unlikely now to ever run one again, unless the entire codebase is overhauled. I have neither the time, energy nor skillset to perform this task, and it is becoming clear that nobody else does either.
>
> This is not anyone's fault. It is just an unfortunate reality that we have to accept. SKS is end-of-life.

What can we do?

Requirements for a Revocation Service

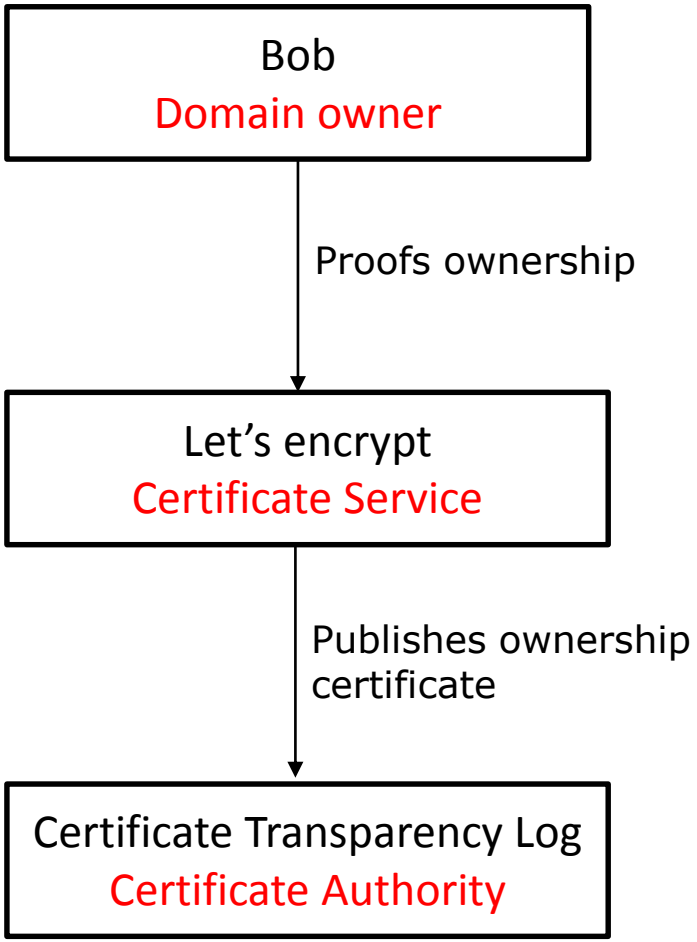
- Integrity
  - A key server must not be able to alter data it has received.
- Non-Repudiation
  - The key server must be held accountable for serving manipulated data.
- Privacy
  - The key server must not learn who a client wishes to communicate with.
  - The uploaded data must not contain Personally Identifiable Data (PII).
- Offline-Capability
  - The store and forward architecture of the email ecosystem does not require the recipients to be online at the same time.
- Timeliness
  - Once a packet has been uploaded to a key server, it must serve it to clients requesting it.
- Equivocation-resistance
  - A key server must provide the same answer regardless of the identity of the client.

Let’s encrypt?

- A public service
- Fully automated
- Objective: Hands-out certificates for your domain, e.g. bobswebsite.de
- Runs as a script on your server
- You have to provide proof of access
  - e.g. by putting downloadable files somewhere
- Then you get a certificate for you domain
- And all major browsers accept it

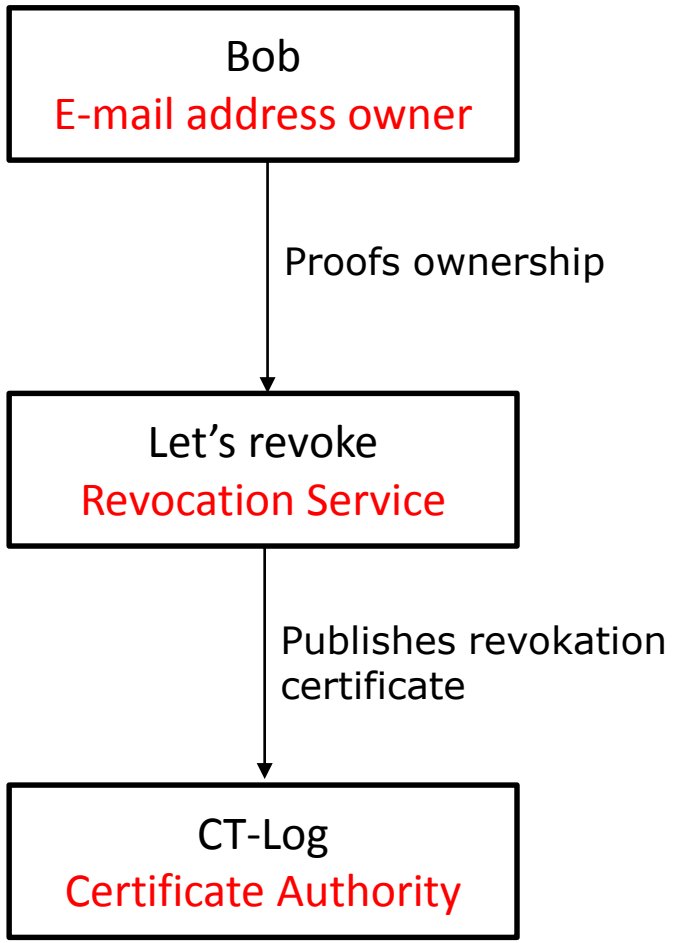
- It is possible to **verify** automatically **before** publishing!

- Why not try this for emails?



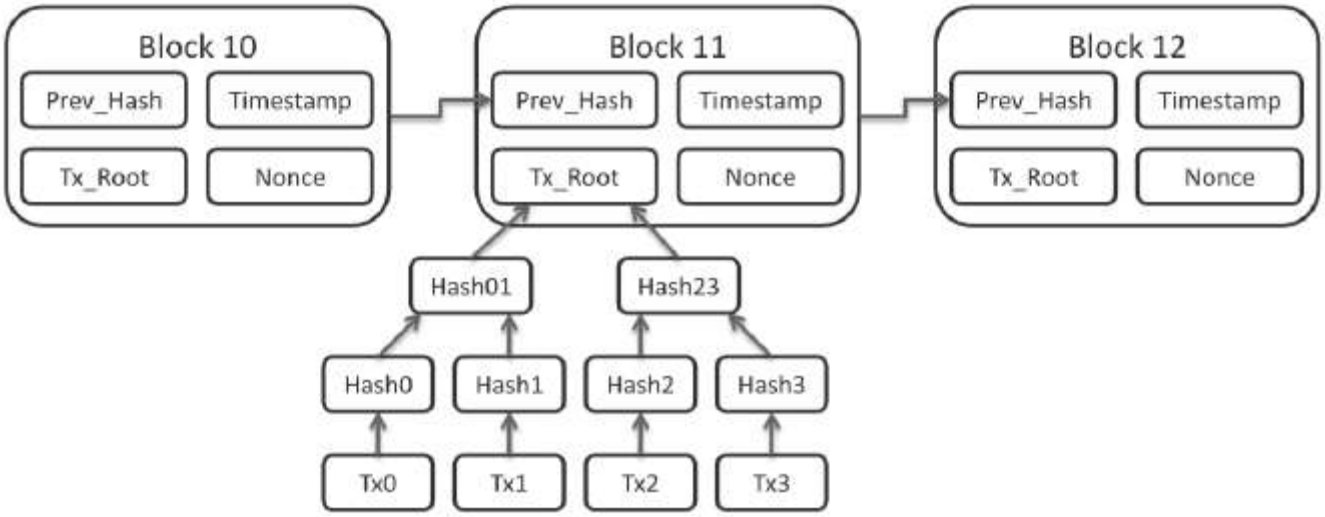
What do we need?

Let's revoke!



Towards an Equivocation resistant key revocation scheme

- Publicly Verifiable Append-only Data Structure
- Expensive to operate



CT-log-based Revocation Protocols

- WebPKI does not have an effective revocation scheme
- WebPKI uses Certificate Transparency to uncover wrongly issued certificates
- Google, Cloudflare, and others operate CT logs

Certificate Transparency - Merkle Tree

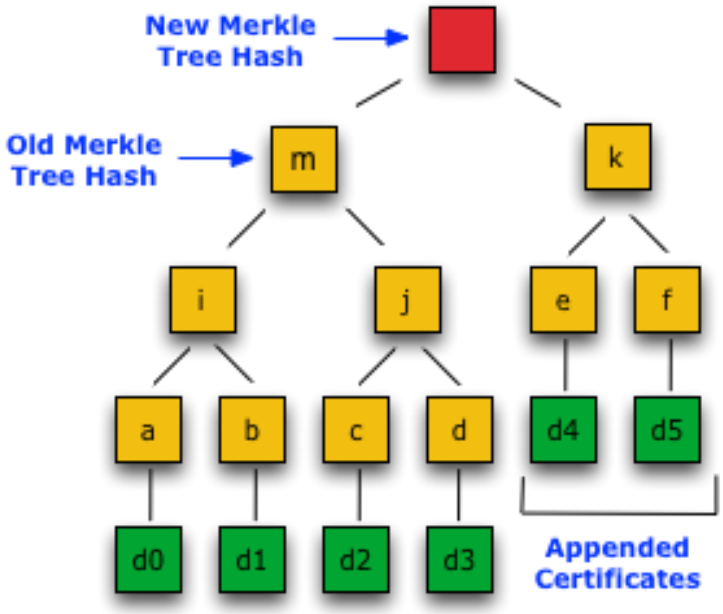


Figure 2

Certificate Transparency – Audit Proof

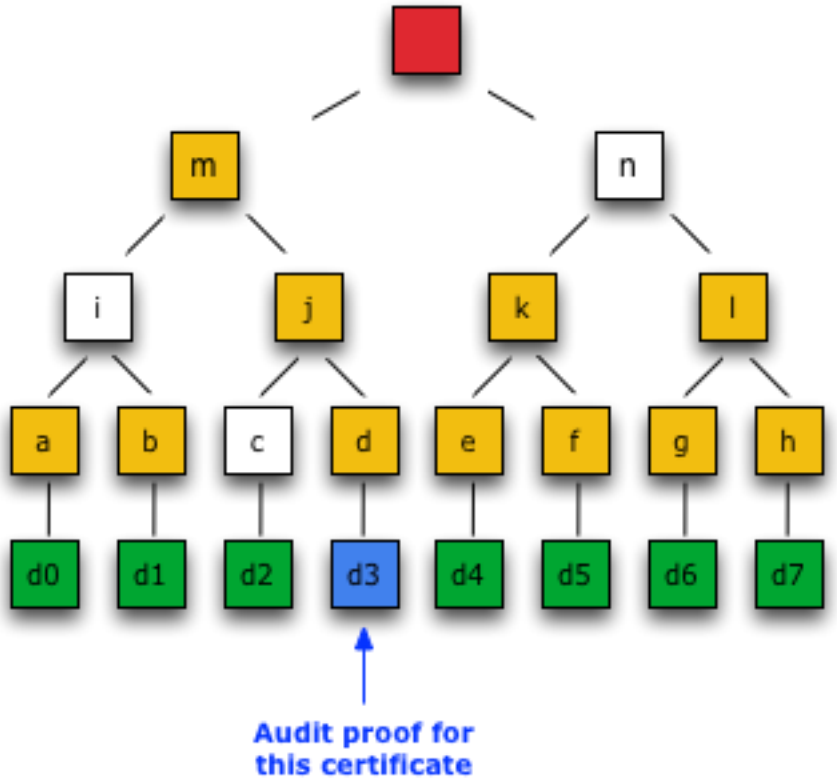
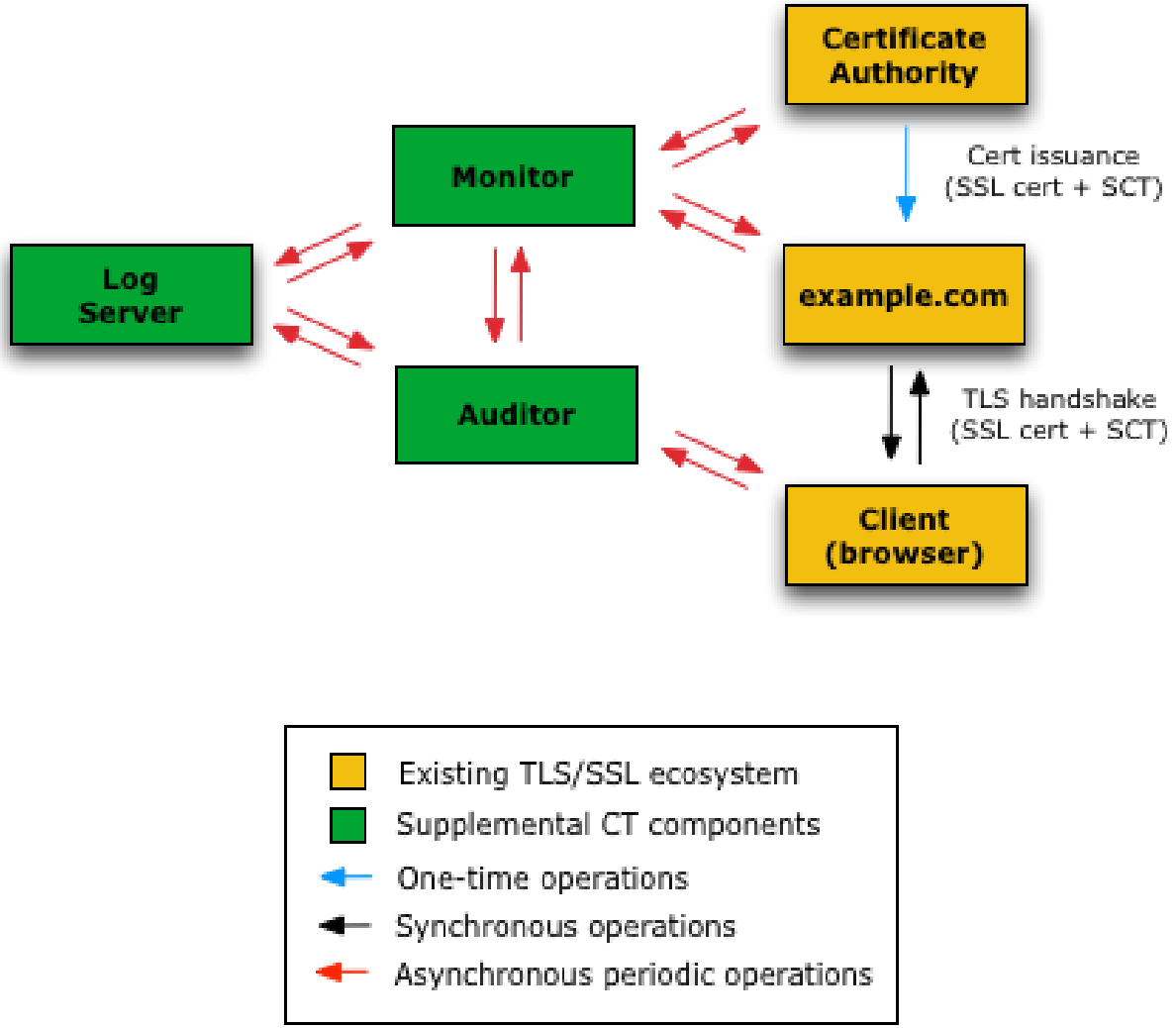


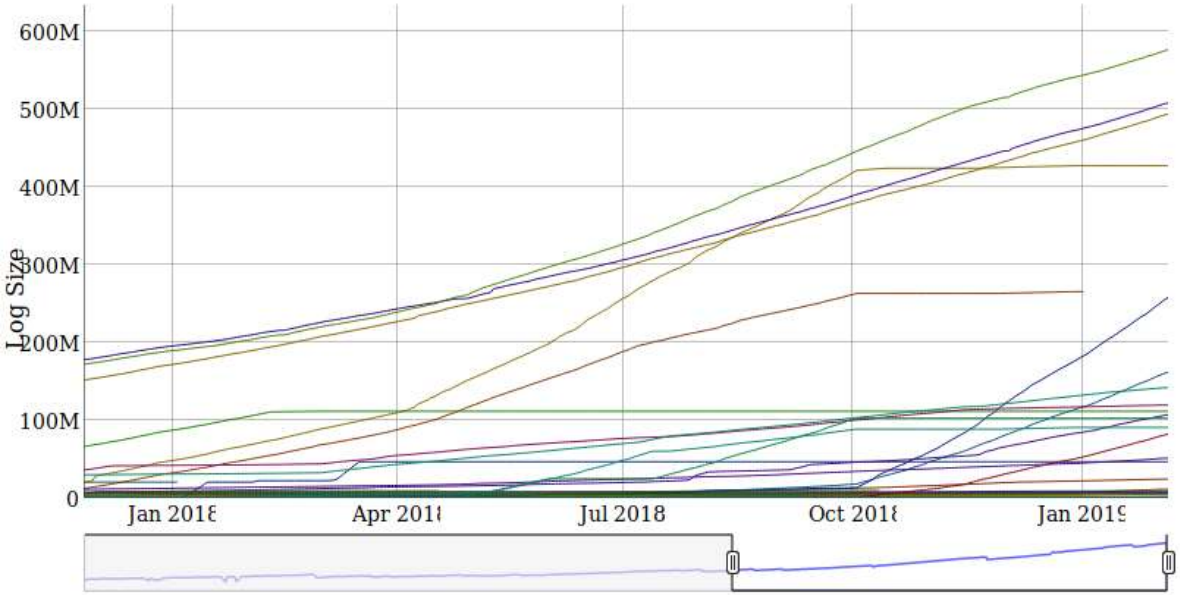
Figure 5

Certificate Transparency - Infrastructure

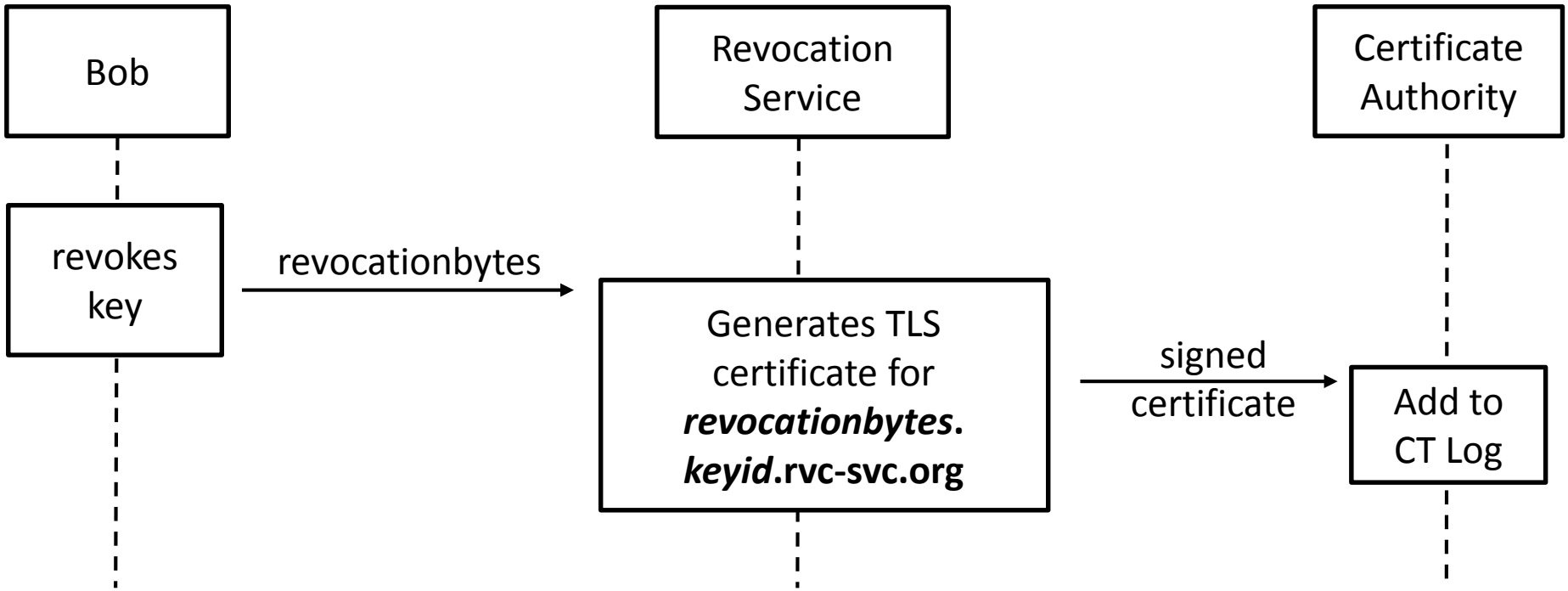


Revocation Service

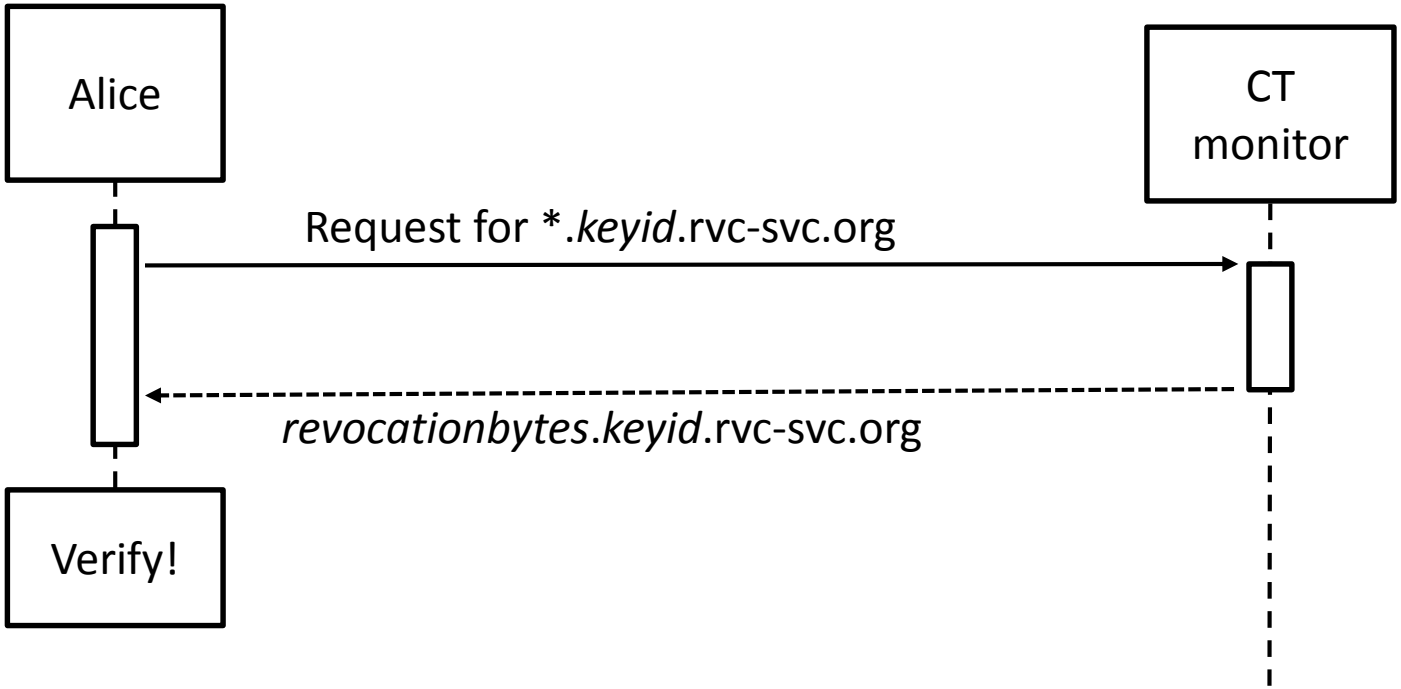
- Naively, clients store their revocation as specially encoded hostname
  - E.g. for foo@bar.com as *revocationbytes*.foo.at.bar.com
  - Then request a certificate for the hostname
- Clients can then inspect the log for those hostnames
- CT log is huge (~600MB)
- Optimise:
  - Provide well-known suffix, i.e. rvc-svc.org



Revocation Publishing Protocol



Revocation Querying Protocol



Evaluation

- \+ No PII
- \+ Same security as CT

- o DNS label length
- o CT logs cease to exist

- \- searching the log leaks recipient

Thanks!

- Running SKS incurs legal and operational risks
- Users can be equivocated on or served malicious data
- Blockchain-based revocation scheme for OpenPGP certificates

- Contact
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    - 5887 4C3C CB21 3B1B F1A4 4A46 47D5 016C 42FF 7C2C