A decentralized approach to publishing confidential data

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Outline

1. Motivation
2. Cryptography
3. The Protocol
4. Conclusion

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Motivation

- This is Bob
- Bob hosted a party at his house yesterday
- He made some pictures to share with his friends
- How can he do that?

Motivation

- This is Alice
- Alice maintains an electronic calendar
- Some appointments should be visible
  - Only to her co-workers
  - Only to her friends
  - Only to her family
  - Only to herself
- How can she do that?

Motivation

- How can Bob share his pictures with his friends?
- How can Alice share appointments with defined groups of peers?
- **But no one else!**
  1. Social Networks / Web Applications?
  2. Just set up a server?
  3. Upload an encrypted tar archive?

The Confidential Publishing Problem

- More general: How can people share content with peers over third-party infrastructure, with
  - Confidentiality
  - Integrity
  - Authenticity
  - Decentralized structure
  - Usability
- How to achieve that?

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How to solve the confidential publishing problem

- Confidentiality
  - Exchange symmetric key using public-key crypto
  - Encrypt using symmetric crypto
  - Problem: How to encrypt for n people?
- Integrity & Authenticity
  - Hash using one-way hash function
  - Sign using public-key crypto

How to solve the confidential publishing problem

- Decentralized structure
  - Just like "traditional internet services"
  - user@server
- Usability
  - Easy to use & to try out
    - Web application
  - User friendly crypto?
    - Problem: How to verify public-key fingerprints?

How to encrypt for n people?

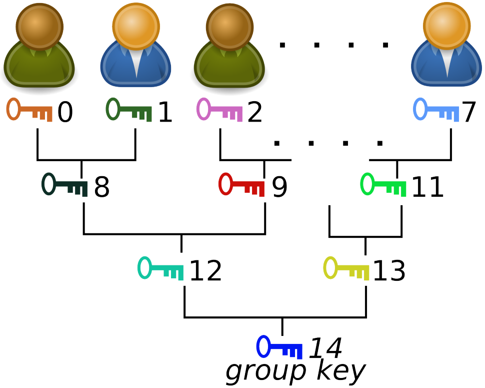
- Crypto aims at one-to-one encryption
- How to encrypt for n people?
- Naive approach
  - Generate symmetric key k
  - Share k with set of people U
  - If user u joins:
    - Give k to u
    - Constant cost
  - If user u is removed:
    - Generate new key k'
    - Share k' with $U \setminus u$
    - Linear cost

How to encrypt for n people?

- Can we do better than linear removal cost?
- Idea: Build a tree (Wallner et al. [1999], Wong et al. [2000])

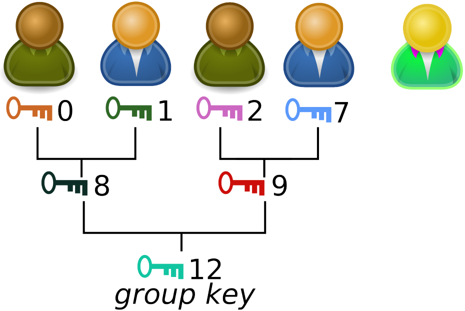
Key Trees

- User knows exactly the keys from their leaf key to the group key



Adding a user

- Create new leaf for the user, send leaf to user
- If tree is full: create new group key



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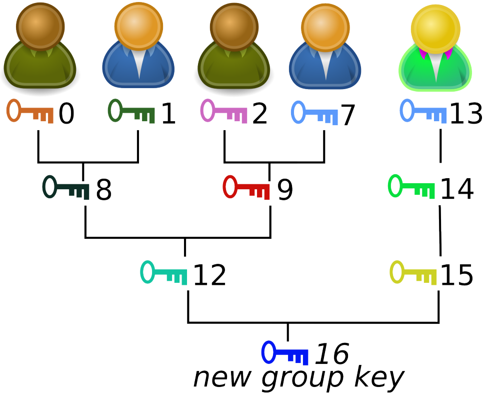
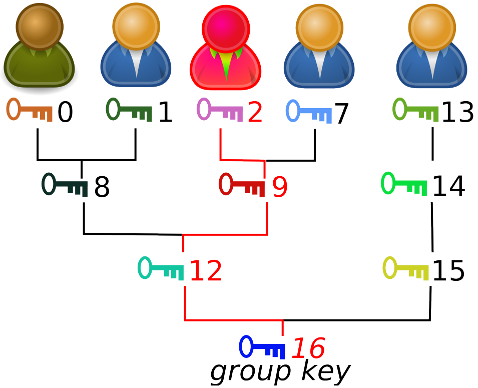


Removing a user

- All keys that the removed user knows need to be exchanged with new keys



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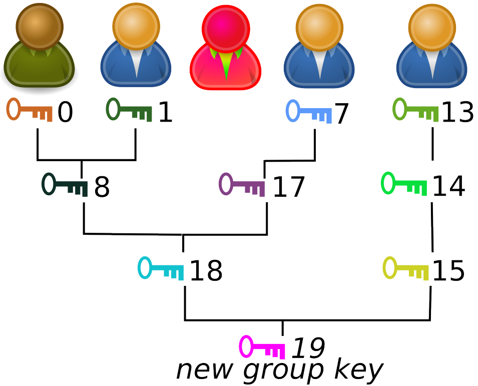

Efficiency

- Naive approach
  - Constant cost to add
  - Linear cost to remove
- Key Tree
  - Amortized constant cost to add
  - Logarithmic cost to remove

Public-key Fingerprints

- Users need to verify public-key fingerprints to detect man-in-the-middle-attacks
    - Real-life example: SSH
- Are these the same fingerprint?
  c1:b1:30:29:d7:b8:de:6c:97:77:10:d7:46:41:63:87

  c1:b1:30:29:d7:b8:de:6c:77:97:10:d7:46:41:63:87
- User friendly?

Human-Readable Fingerprints

- Introduced by Bååth and Kühn [2002], Kaminsky [2006] independently
- Generate human-readable sentences from the fingerprint
- Are these the same fingerprint?

Happy:
Lisa:chased:the cookie:
Savah:jumped over:the flower:
Chip:smiled at:the world:
Nacho:joked about:the pizza

Happy:
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The Protocol

- User should be able to publish content to a set of peers with
  - Confidentiality
  - Integrity
  - Authenticity
  - Decentralized structure
  - Usability
- We covered the cryptography that is needed
- Let's describe the protocol!

Login

- Every user has a passphrase
- Generate symmetric key from passphrase
- Private content is encrypted with that key
    - E.g. the user's private key

Short-term passphrases

- User has *one main* passphrase
  - Encrypts his long-term public key
  - Valid for e.g. 5 years
- Problem: Should the user enter that passphrase at an Internet cafe?
- Solution: *Short-term* passphrases
  - Valid for a short period of time
  - Encrypt a *short-term public key*
  - Can only access a subset of data
  - Only that data can be compromised
  - Usable?

Public keys

- Folder “/public-keys”
  - Contains all public keys
  - Publicly accessible
- Public keys have validity period
- *Key messages*
  - Signed by preceeding key:
    - Introduce new keys
    - Declare old keys compromised
  - *Not* signed:
    - Declare old keys “lost”

Content Files

- Content is organized into folders and files
- *Content files* consists of
  - Actual (encrypted) content
  - Revision number
  - Signature
  - Key to access the content
    - Encrypted for every user/group that may access the content
- One content file can consist of multiple filesystem files
  - E.g. one containing content, another containing the signature
- Folders are just a "list of files"

File names

- Problem: Files names carry potentially confidential information
  - “Bob totally drunk”
  - “Alice’s doctor appointment”
- Solution: Generate *public filename(s)* from *private name*
  - Every folder defines a *salt*
  - Public name: Hash of salt + user id + namespace + private name
  - Namespace: e.g. content, revision, ...
    - If content file is split over multiple filesystem files
    - Avoids name clashes

File names

- Example:
  - Salt: “ssssssssssssssssssssssssssssssss”
  - Public name: “Alice’s doctor appointment”
  - Namespace: “content”
  - Private name:
    SHA-256(“ssssssssssssssssssssssssssssssss”
    + “alice@crypto.uni-freiburg.de:”
    + “content:/”)
    + “Alice’s doctor appointment”) =

`1afac6c112b4b5a1a9f43ff8445fdebc43e00c41078edfbad3b6d533e5efc15f`

- Hard to guess private name from public name

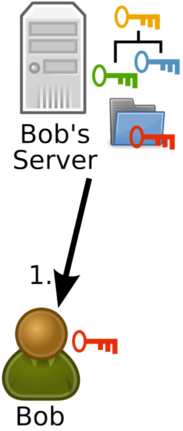
Publishing Content

- Users organize their contacts into groups
    - Every group = one key tree
- When publishing a content file, user can set which users/groups have read access

Social Network?

- *Privacy-respecting* social network becomes possible
- User maintain groups of contacts
  - Only visible to the group
- User publishes content
  - Select target audience
  - Not visible to service provider
    - Or any third party
- Also possible:
  - Messaging
  - “Wall”
  - Discussion groups
  - Tagging

Example



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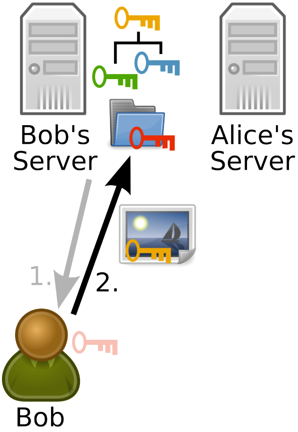

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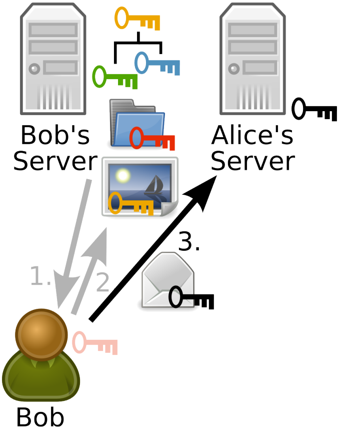

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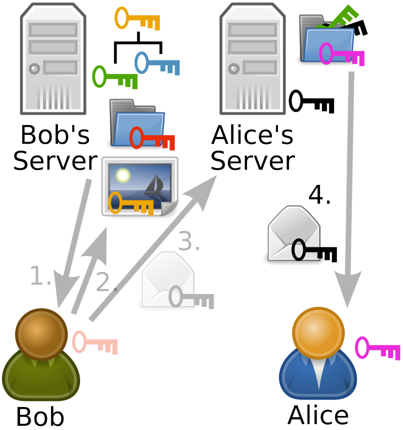

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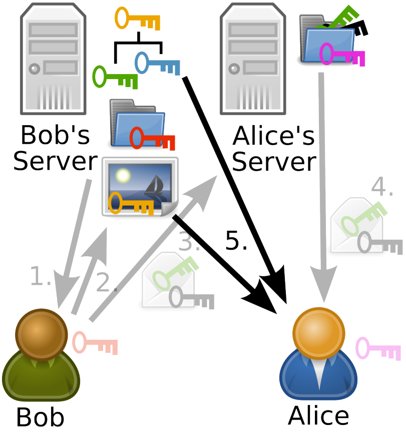

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Conclusion

- Protocol solves confidential publishing problem
- Users can publish data over third-party infrastructure
  - Without revealing the data to the infrastructure
  - One-to-many encryption is cruicial
- Web application prototype
  - Incomplete (only single-user)

That's all folks!

Thank you for your attention!

Do you have any questions?

... & Demo