Rutgers School of Arts and Sciences — Computer Science

Compact and Anonymous Role-Based Authorization Chains

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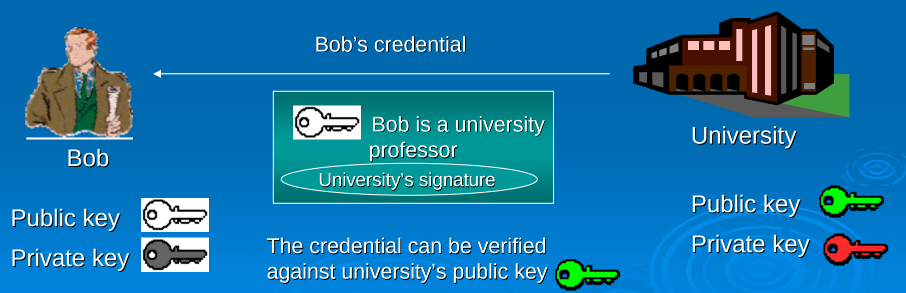
Outline

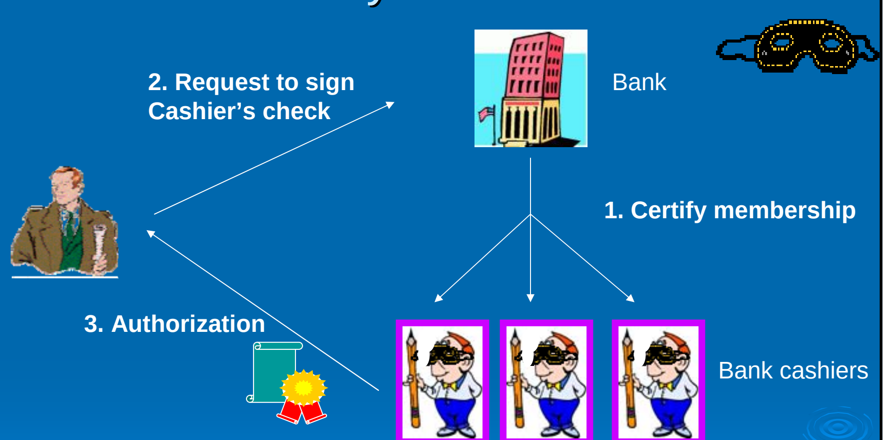
- Motivation for anonymity and aggregation
- Construction of Anonymous-Signer Aggregate Signature Scheme
- Security properties of the scheme
- Applications

Digital credential

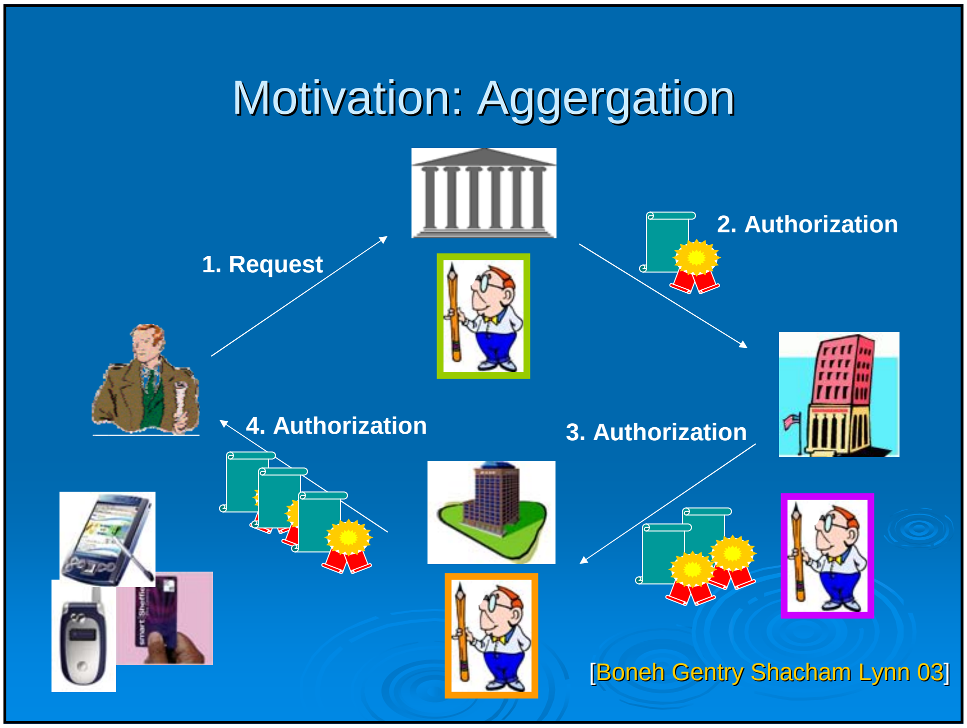
- Digital credential is signed by the issuer with a digital signature scheme
  - To certify the credential holder
- Digital signature scheme
  - Signing uses the private key
  - Verification uses the public key

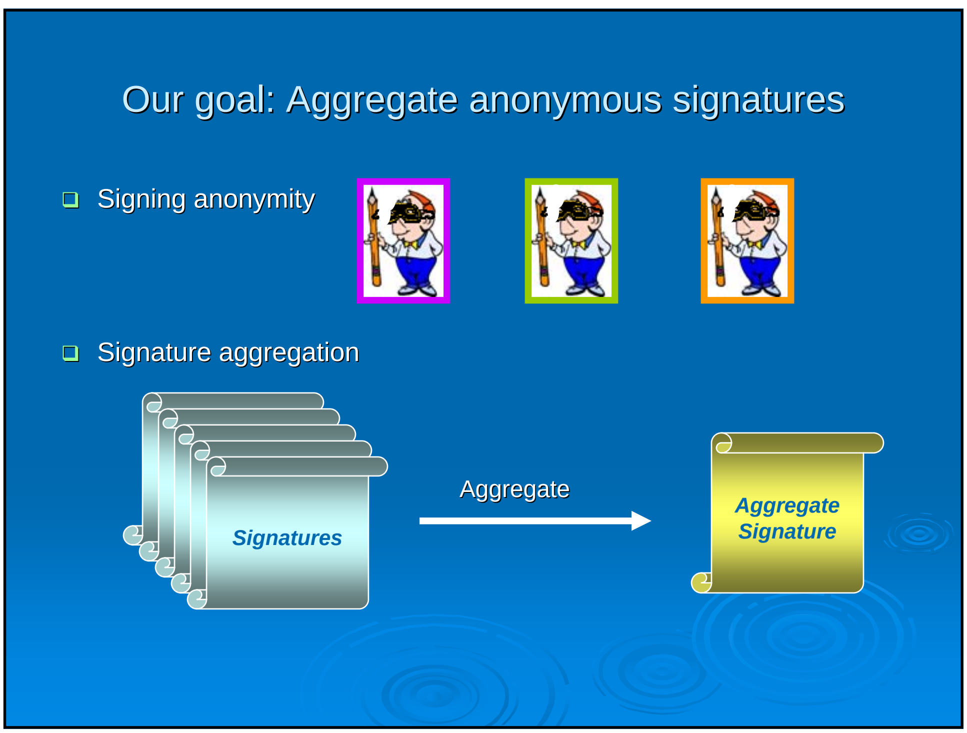


Motivation: Anonymous authorization

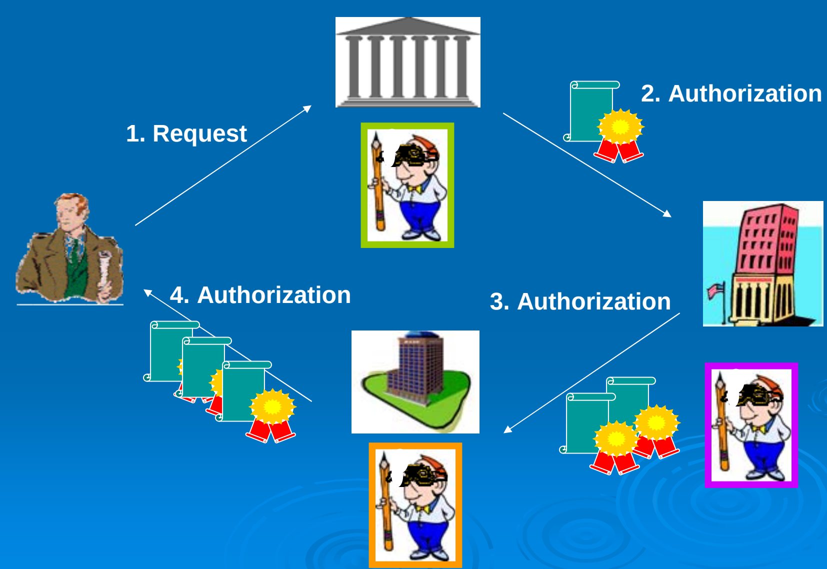


- Group signature schemes
  - [Chaum van Heijst 91, Ateniese Camenisch Joye Tsudik 00, Boneh Boyen Shacham 04, Camenisch Lysyanskaya 04]
  - Support anonymity


Motivation: Aggergation
1. Request
2. Authorization
3. Authorization
4. Authorization
[Boneh Gentry Shacham Lynn 03]


Our goal: Aggregate anonymous signatures
Signing anonymity
Signature aggregation
Signatures
Aggregate
Aggregate Signature

Anonymous authorization chain

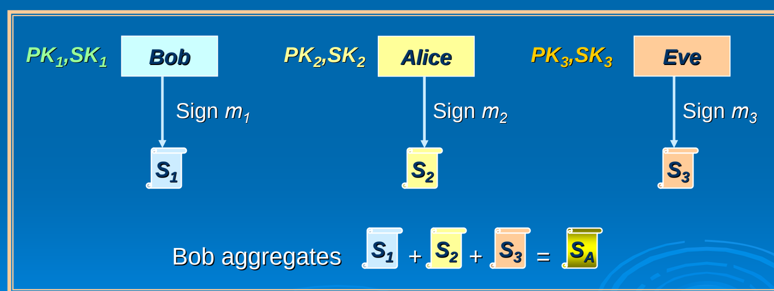


Our anonymous-signer aggregate (ASA) signature scheme

- Goals: (1) role member signs anonymously (2) signature aggregation
- Properties
  - *Aggregation*: Bob's signature can be added with Alice's
  - *Unforgeability*: No one can forge a valid signature without being a role member
  - *Anonymity*: No one can tell that a signature is signed by Bob
  - *Unlinkability*: No one can tell that two signatures are from the same signer
  - *Exculpability (non-framing)*: No one can sign on behalf of Bob
  - *Traceability*: The role manager can revoke Bob's anonymity
  - *Collusion-resistance*: Collusion does not affect the security
- Our approach: one-time signing key of Bob is a randomized long-term private key of his
  - Based on BGLS aggregate signature [Boneh Gentry Shacham Lynn 03]

Aggregate signature scheme

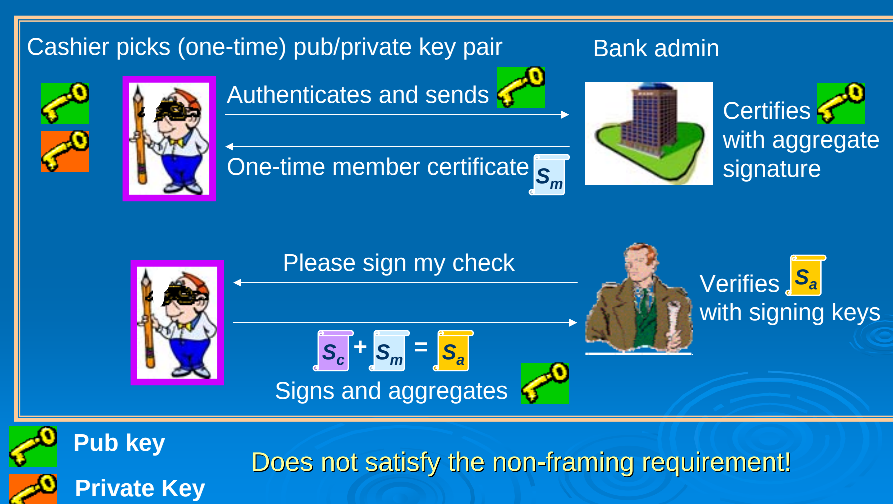
- Aggregate signature scheme [Boneh Gentry Shacham Lynn 03]
  - The size of signatures and public keys 170 bits with security comparable to 1024 bit RSA and 320 bit DSA schemes
- Verification is linear in the number of individual signatures



How to make the aggregate signature scheme support anonymity?

An attempt to support anonymity using the existing aggregate signatures

- Signers sign with certified one-time signing keys

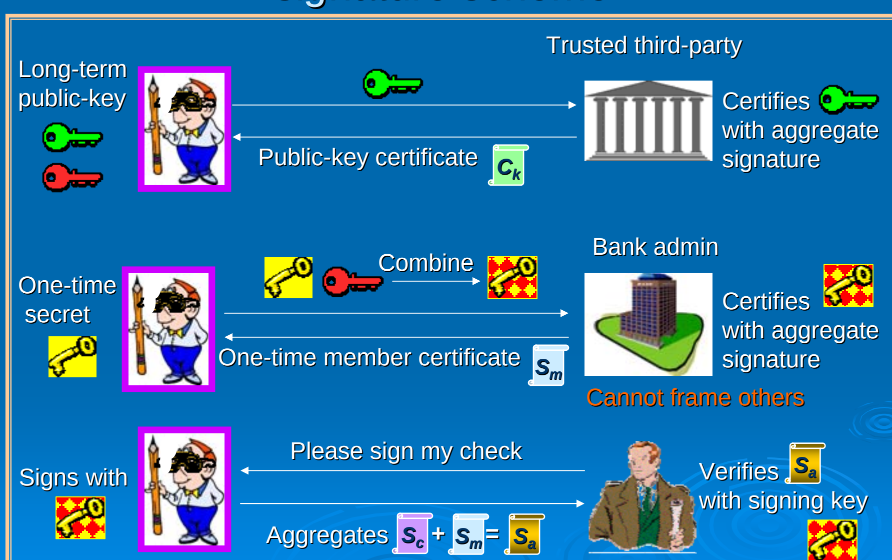


Does not satisfy the non-framing requirement!

Our solution: anonymous-signer aggregate signature scheme

- Signing key has two parts
  - Long-term public key certified by CA
  - Random one-time secret
  - Combined to become the signing key
- Supports
  - Signature aggregation
  - Anonymous authorization
- Based on the aggregate signature scheme [Boneh Gentry Shacham Lynn 03]
- Standard assumptions for pairing-based cryptography

Overview: Anonymous-signer aggregate signature scheme



Entities and Operations in Our Scheme

- Entities
  - Role manager (cashier in this talk)
  - Role member (bank admin in this talk)
- Setup: Each entity chooses long-term public/private key pair
- Join: A user becomes a role member
  - Obtains *membership certificates*
- Sign: An entity signs on behalf of the role
  - Operation Sign produces a *role signature*
- Aggregate: Multiple role signatures are aggregated
- Verify: Aggregate role signatures are verified
- Open: A role manager revokes the anonymity of a signer by revealing his or her identity

Some math about the operations

π Public parameter

Private key s_u

Public key $P_u = s_u\pi$

One-time signing secret x_u

One-time signing public key $s_u x_u \pi$

Private key s_a

Public key $P_a = s_a\pi$

S_m Certifies $s_a H( )$

S_c Signature $s_u x_u H(m)$

$S_c + S_m = S_a$ Aggregates

S_a Role signature; may be aggregated further with others

Obtains

Verifies S_a

Framing is hard – equivalent to computational Diffie-Hellman Problem

Security

Our anonymous-signer aggregate signature scheme satisfies the following requirements:

correctness,
unforgeability,
anonymity,
unlinkability,
traceability,
non-framing,
coalition-resistance,
and aggregation

assuming

random oracle model, bilinear map, and gap groups.

Non-framing property

- Our scheme protects a cashier from being framed by anyone including bank admin
- Consider a simple attack by an admin
  - Picks random x^* and s^* and uses x^*s^* to sign
- Admin cannot misattribute a signature to a cashier u
  - u with pub key $P_u = s_u\pi$
  - $e(s^*x^*\pi, \pi) \neq e(P_u, x^*\pi)$
- In general, framing is equivalent to
  - Computing $b\pi$, given q, $a\pi$, and $c\pi$ such that

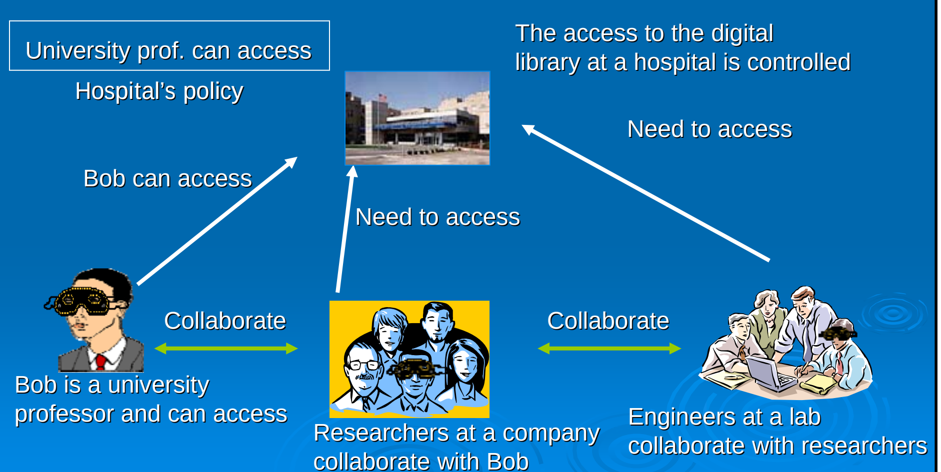
$$ab = c \bmod q$$

known equivalence to CDH problem [Chen Zhang Kim 03]

Anonymous-signer aggregate (ASA) signature summary

- Assumptions: computation Diffie-Hellman problem is hard, decision Diffie-Hellman problem is easy; existence of an admissible pairing.
- Theorem Join takes O(k), where k is the number of one-time signing keys certified. Verify takes O(n), where n is the number of signatures aggregated.
- Theorem Our ASA signature scheme is as secure as the BGLS aggregate signature scheme against existential forgery attacks.
- Theorem Our ASA signature scheme from bilinear pairings in gap groups preserves anonymity, traceability, and exculpability in the random oracle model.
- Unlinkability and collusion-resistance follow as corollaries.

An application: Anonymous role-based delegation



Another application: Protecting whistleblower

- Protects the identity of whistleblowers
  - The verifier only knows that the whistleblower is a certified FBI agent or a New York Times reporter
- Supports efficiently certification of a series of reports

Signed reports of whistleblower(s)

Enron scandal: day 101 S_1

Enron scandal: day 102 S_2

Enron scandal: day 103 S_3

Aggregated signature S_A

…

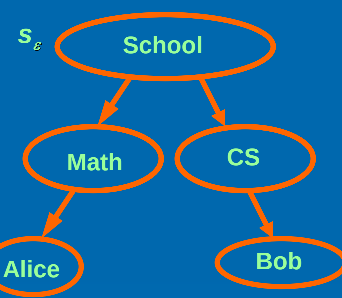
Some other IBE-related work that I did:

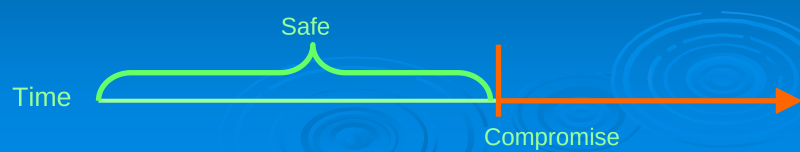
Forward-Secure Hierarchical ID-Based Encryption Scheme

Joint work with Nelly Fazio (IBM Research), Yevgeniy Dodis (NYU), Anna Lysyanskaya (Brown University)

Why need forward-secure Hierarchical IBE?

- In HIBE, exposure of parent private keys compromises children's keys
- Forward-secure HIBE mitigates key exposure
- Forward security
  - [Gunther 89] [Diffie Oorschot Wiener 92] [Anderson 97] [Bellare Miner 99] [Abdalla Reyzin 00] [Malkin Micciancio Miner 02] [Canetti Halevi Katz 03]
  - Secret keys are evolved with time
  - Compromising current key does NOT compromise past communications





Overview of our fs-HIBE scheme

- Based on HIBE [Gentry Silverberg 02] and fs-PKE [Canetti Halevi Katz 03] schemes
- Scalable, efficient, and provable secure
  - Forward security
  - Dynamic joins
  - Joining-time obliviousness
  - Collusion resistance
- Security based on Bilinear Diffie-Hellman assumption [BF 01] and random oracle model [Bellare Rogaway 93]
  - Chosen-ciphertext secure against adaptive-chosen-(ID-tuple, time) adversary

Security of fs-HIBE

- "Security definitions"
  - Secure for past communications of compromised nodes
  - Secure for ancestor nodes
  - Secure for sibling nodes
- Security based on hardness of BDH problem and random oracle model
- **Theorem** *Suppose there is an adaptive adversary A*
  - ε: *advantage against one-way secure fs-HIBE*
  - h: *level of some target ID-tuple*
  - $l = \log_2 N$ *and* N *is the total number of time periods*
  - H_1, H_2: *random oracles*
  - q_{H2}: *number of hash queries made to hash function* H_2
  - q_E: *number of hash queries made to lower-level setup queries*
  - *then there exists an algorithm B that solves BDH problem with advantage*

$$\varepsilon\left(\left(\frac{h+l}{e(2lq_E+h+l)}\right)^{(h+l)/2} - \frac{1}{2^n}\right)/q_{H2}$$

References

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