Step-out Ring Signatures

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 - Signature Creation
 - Confession Procedure
 - Step-out





Procedures:

- key setup:
 - private key for creating a signature
 - public key for verifying a signature
- creating a signature
- signature verification





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Verifying signature *s* of *M*:

Bob takes the public key p_{Alice} and checks if

$$test(s, M, p_{Alice}) = true$$



Properties:

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So

```
if test(s, M, p_{Alice}) = true, then only the holder of k_{Alice} (i.e. Alice) could produce s for message M.
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- the signer uses his own private key and the public keys of the other ring members to create a signature,
- of for verification the public keys of the ring members are used,
- it is infeasible to detect which ring member created a signature.
- the signer is perfectly hidden in the ring.
- one cannot prevent being a member of a ring.





Malicious Application of Ring Signatures

Leaking information

A member of a group (i.e. a parliament commission) can leak a secret information to the press.

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- one can easily check that some commission member has signed it, and so the information is authentic,
- 2 no investigation can reveal the information source.

As soon as public keys (e.g. RSA keys) of the commission members are published, nothing can prevent this scenario!





Step-out Signatures - Target Applications

Electronic auction

Requirements:

- strong authentication and anonymity of the bids (also against the auction manager),
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Ring signatures?

- a ring signature authentication and anonymity,
- 2 however, there is no way to force the winner to reveal himself!

a useless solution ...





Step-out Signatures

Properties

Anonymity: ring type signature: identity of the signer(s) is

hidden among identities of non-signers in a ring.

Confession procedure: the real signer can prove that he has participated in signature creation.

Step-out procedure: a non-signer can prove that he has not participated in signature creation.





Step-out Signatures

Properties for auction protocol

Strong anonymity: necessary for fairness of e-auctions.

Confession procedure: the real signer of the winning bid can reveal himself against the auction.

Step-out procedure: a non-signer of the highest bid can step out during the auction and withdraw the deposit.





Discrete Logarithm

DL hardness

we use a cyclic group G such that

- computing g^x is easy for each g, x
- given a random y, it is infeasible to find x such that $y = g^x$.

Secret keys

Each user U has its private key x_U selected at random the corresponding public key is $y_U = g^{x_U}$, where g is a fixed generator of G.





Preliminaries
Signature Creation
Confession Procedure
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Non-interactive Zero Knowledge Proofs

Proof of knowledge of discrete logarithm

A signer with a private key *x* and a public key *y* can prove that he knows discrete logarithm of *y* (i.e. *x*) in a non-interactive protocol that reveals no information on *x*.





Non-interactive Zero Knowledge Proofs

Proof of equality of discrete logarithms

A signer with a private key x and a public key y can prove for $y_1 = g_1^x$ that

$$\log_g y = \log_{g_1} y_1$$

in a non-interactive protocol that reveals no information on x.

Proof of equality of discrete logarithms, 1 out of *n*

• Given $(y_1, g_1), \dots, (y_n, g_n)$ prove that

$$\log_g y = \log_{g_i} y_i$$
 for some unrevealed i

• the proof can be uniquely bound to a message m





Signature Creation

Setup

- generators g and \hat{g} ,
- ring members with public keys y₁,..., y_k
- the signer holds y_i and the private key x_i

Signature

proof of equality of discrete logarithms depending on m and created with x_i





Signature Creation

Details

- 0 r_1, \ldots, r_n chosen at random,
- $w_i \leftarrow g^{r_i}$, for $i = 1, \ldots, n^a$
- 4 the signature is a non-interactive zero knowledge proof (depending on m) that

$$\log_{\hat{g}} \hat{y} \hat{w}$$

equals one of the logarithms

$$\log_g(y_1w_1),\ldots,\log_g(y_nw_n)$$



Signature Verification

Idea

Simply checking the non-interactive zero knowledge proof provided by the signature





Revealing the Signer

Idea

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- 2 the same parameters $\hat{w}\hat{y}$ and w_1, \dots, w_n are used in both proofs—this enforces that $\log_{\hat{q}}(\hat{w}\hat{y})$ occurs on both lists:

$$\log_g(y_1 w_1), \log_g(y_2 w_2) \dots, \log_g(y_n w_n)$$

 $\log_g(y_1 w_1), \log_g(y_2' w_2') \dots, \log_g(y_n' w_n')$

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o recall that the element of the same discrete logarithm has been created by the signer!





Step out

Idea of stepping out of the ring

- a signature s contains $\hat{y}\hat{w}$ and w_1, \dots, w_n ,
- a non-signer A provides two step-out signatures for the message "I have not signed m",
- these two signatures are obtained in the same way as in the confession procedure - so they point to A!





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- \bullet the same strings w_i are used, ...
- **1** but with $\hat{y}'\hat{w}'$ instead of $\hat{y}\hat{w}$.



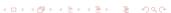


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- **1** but with $\hat{y'}\hat{w'}$ instead of $\hat{y}\hat{w}$.
- however, ŷŵ is uniquely determined by w_i, if y_i corresponds to the signer!
 So the signer cannot create these additional signatures.





Thank you for your attention



