政大在職碩班「專題研討」

Deniable Encryption

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Who am I?

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  - National Taiwan Normal University
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- Interests:
  - Applied Cryptography
  - Network Security
  - Next Generation Network

Outline

- Introduction to Deniable Encryption.
- Shared-Key Deniable Encryption.
- Public-Key Deniable Encryption.
- Bi-Deniable Public-Key Deniable Encryption.
- Block-wise Deniable Encryption.
- Reference.

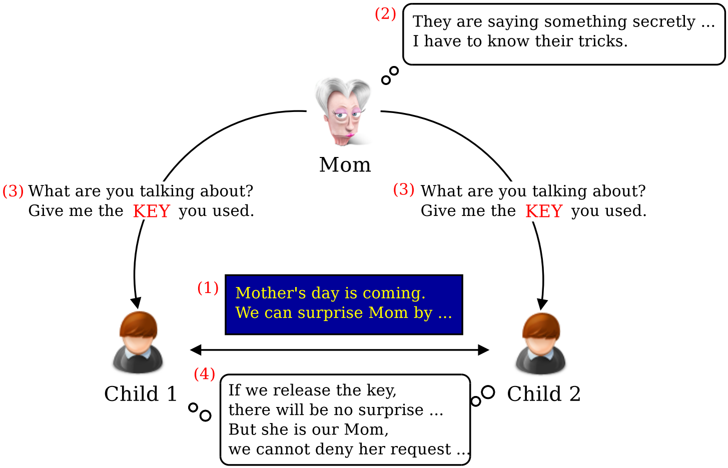
Don't Worry.

This is not a mathematic course.

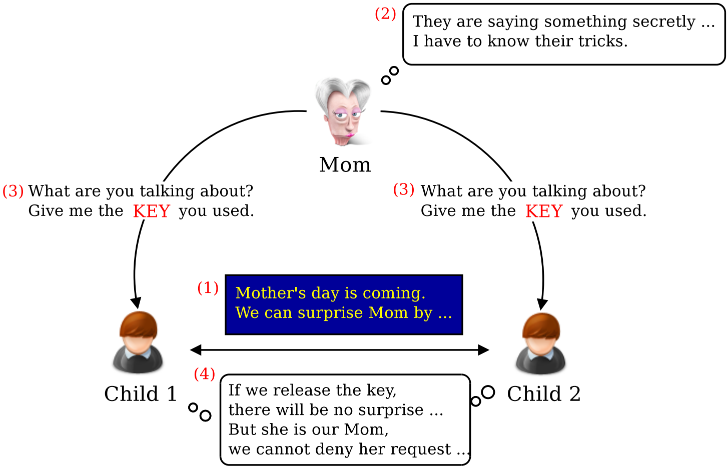
Everything will be described in plain Chinese.

Introduction to Deniable Encryption

Deniable Encryption



Deniable Encryption



Deniable Encryption!!

This is a Stupid Scenario!!

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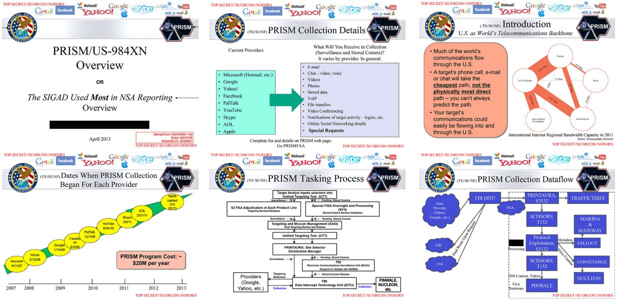

Email Service Provider

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On January 20, 2017, Lavabit owner Ladar Levison relaunched the service.

Deniable Encryption

- An encryption scheme is *deniable* if the entities can generate *plausible* keys or random coins that will satisfy the authority.
- Usage: Protect people from subpoenas or legal coercion.
  - Ex: E-Voter, Journalist, Whistle-blowers.
- Theoretical Properties:
  - Non-committing.
  - Against selective-opening attacks.
  - Incoercible multi-party computation.

Selective Opening Attack

- Given a public key encryption scheme:
  - $c = (c[1], c[2], c[3], \ldots, c[n])$.
  - $c[i] = E(pk, m[i], r[i]), 1 \leq i \leq n$.
  - All coins $r[i]$ are random and independent.
- The adversary is allowed to corrupt some subset I :
  - $r[i], i \in I$.
  - $m[i], i \in I$.
- The security requirement is that the privacy of the unopened messages is preserved.

Definition

Computational Indistinguishable:

Let $A = \{A_n\}_{n \in N}$ and $B = \{B_n\}_{n \in N}$ be two probability distributions and $\delta : N \rightarrow [0,1]$. A and B are $\delta(n)$-close if for every polytime distinguisher D and for all large enough n,

$$|Prob(D(A_n) = 1) - Prob(D(B_n) = 1)| < \delta(n).$$

If $\delta(n)$ is negligible, A and B are *computational indistinguishable* and write $A \approx^c B$.

Definition

Correctness:

The probability that R's output is different than S's input is negligible (as a function of n).

Some Definitions

Definition

Plan-Ahead:

A somewhat *weaker* deniability property allows the encryption algorithm to have the fake messages as part of its input.

Definition

Sender Deniable:

1. Correctness.
2. Security: $E[m_1] \approx^c E[m_2]$.
3. Deniability:
   - $c = E[m_1, r_S]$.
   - A faking algorithm ϕ that $r'_S = \phi(m_1, r_S, c, m_2)$.
   - $(m_2, r'_S, c) \approx^c (m_2, r''_S, E[m_2, r''_S])$.

Definition

Receiver Deniable:

1. Correctness.
2. Security: $E[m_1] \approx^c E[m_2]$.
3. Deniability:
   - $c = E[m_1, r_R]$.
   - A faking algorithm ϕ that $r'_R = \phi(m_1, r_R, c, m_2)$.
   - $(m_2, r'_R, c) \approx^c (m_2, r''_R, E[m_2, r''_R])$.

Shared-Key Deniable Encryption

Shared-Key Deniable Encryption

- The most trivial solution is: One Time Pad, Vernam Cipher.
  - $c \leftarrow m \oplus k$.
  - $k' \leftarrow c \oplus m'$.
- m' can be chosen as late as at time of coercion.
- This scheme is not practical for most cases.

Shared-Key Deniable Encryption based on Pseudorandom Generators

- The message will be encrypted:
  - $m_1 = m_1^{(1)}, m_1^{(2)}, m_1^{(3)}, \ldots$.
  - Each block $m_1^{(j)}$ is n-bit.
- The fake messages:
  - $m_2 = m_2^{(1)}, m_2^{(2)}, m_2^{(3)}, \ldots$.
  - $\ldots$
  - $m_l = m_l^{(1)}, m_l^{(2)}, m_l^{(3)}, \ldots$.
- The shared key:
  - k_1: n-bit random key.
  - $k_2, \ldots, k_l$: $l - 1$ independent n-bit *fake* keys.
- A pseudorandom number generator G:
  - Expand n-bit input to $3n$-bit output.
  - Using G iteratively: $G(k_i^{(j-1)}) = k_i^{(j)} | a_i^{(j)} | b_i^{(j)}$.

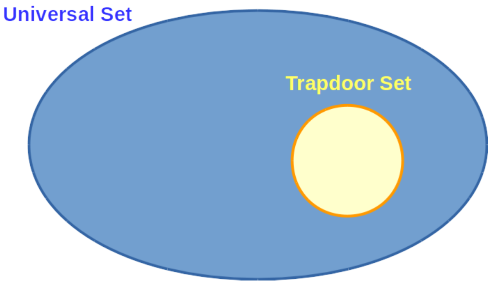
Shared-Key Deniable Encryption based on Pseudorandom Generators

- Encryption:
  - $c = c^{(1)}, c^{(2)}, c^{(3)}, \ldots$.
  - The sender finds the polynomial $Q^{(j)}$ of degree $l - 1$ such that $Q^{(j)}(a_i^{(j)}) = m_i^{(j)} + b_i^{(j)}, i = 1 \ldots l$.
  - $c^{(j)} = \langle j, Q^{(j)} \rangle$.
- Decryption:
  - $m_1^{(j)} = Q^{(j)}(a_1^{(j)}) - b_1^{(j)}$.
- Deniability:
  - Just select one of fake keys when coercion.

Public-Key Deniable Encryption

Translucent Set

- This scheme is based on the trapdoor *SPARSE sets*.
  1. A small set $S \subset \{0,1\}^t$, $|S| \leq 2^{t-k}$ for some k.
  2. It is easy to generate random element $x \in S$.
  3. Without the trapdoor d, it is infeasible to decide whether $x \in \{0,1\}^t$ was chosen from S or uniformly from $\{0,1\}^t$.



How to Construct Sparse Sets

- A trapdoor permutation $f\colon \{0,1\}^s \to \{0,1\}^s$.
- A hard-core bit function $B : \{0,1\}^s \to \{0,1\}$.
- Construction I:
  - $t = sk$.
  - Represent $x \in \{0,1\}^t$ as a vector $x = x_1 x_2 \ldots x_k$, where $x_i \in \{0,1\}^s$.
  - $S = \{x \in \{0,1\}^{sk} | \forall i = 1 \ldots k, B(f^{-1}(x_i)) = 0\}$.
  - $|S| = 2^{(s-1)k} = 2^{t-k}$.

How to Construct Sparse Sets

- A trapdoor permutation $f\colon \{0,1\}^s \to \{0,1\}^s$.
- A hard-core bit function $B : \{0,1\}^s \to \{0,1\}$.
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  - $S = \{x \in \{0,1\}^{sk} | \forall i = 1 \dots k, B(f^{-1}(x_i)) = 0\}$.
  - $|S| = 2^{(s-1)k} = 2^{t-k}$.
- Construction II:
  - $t = s + k$.
  - Represent $x \in \{0,1\}^t$ as a vector $x = x_0, b_1 b_2 \dots b_k$, where $x_0 \in \{0,1\}^s$ and $b_i \in \{0,1\}$.
  - $S = \{x \in \{0,1\}^{s+k} | \forall i = 1 \dots k, B(f^{-i}(x_0)) = b_i\}$.
  - $|S| = 2^s = 2^{t-k}$.

Public-Key Sender-Deniable Encryption Scheme 01

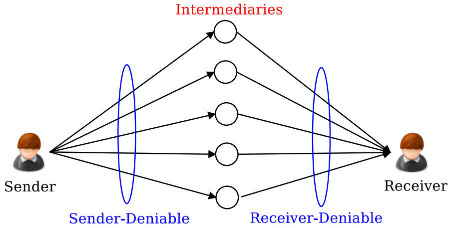
- The Basic Scheme:
  - Bitwise encryption.
  - Public key: $S \subset \{0,1\}^t$; Private key: the trapdoor d.
  - Encryption:
    - To encrypt 1, send a random element from S.
    - To encrypt 0, send a random element from $\{0,1\}^t$.
  - Decryption: Check if the cipher c is in S.
  - Dinability: If the encrypted bit is 1, claim that the cipher is chosen from $\{0,1\}^t$ instead from S.
  - Only half deniablity.
  - The probability of decryption error is $\frac{2^{t-k}}{2^t} = 2^{-k}$.

Public-Key Sender-Deniable Encryption Scheme 02

- The Parity Scheme:
  - Public key: $S \subset \{0,1\}^t$, $R = \{0,1\}^t$; Private key: the trapdoor d.
  - Use $V \in \{S,R\}^n$ to denote a length n vector.
  - Encryption:
    - To encrypt 1, send a $V \in_R \{S,R\}^n$ where V randomly contains odd S-elements.
    - To encrypt 0, send a $V \in_R \{S,R\}^n$ where V randomly contains even S-elements.
  - Decryption: Reveal the number of elements in V that belongs to S.
  - Deniability: The sender can claim V has $i-1$ S-elements rather than i.
  - The probability of decryption error is at most $n2^{-k}$.

Receiver-Deniability and Bi-Deniability

- Receiver-Deniability from Sender-Deniability:
  - If there is a Sender-Deniable scheme, the receiver first sends a deniable message r to the sender.
  - The sender sends $m \oplus r$ to the receiver.
- Bi-Deniability:
  - Sender-and-Receiver-Deniability.
  - $\oplus_i b_i = b$.
  - As long as one intermediary node is uncoerced, the sender and the receiver can deny their messages.



What is the Problem?

- We do not like bitwise encryption.
- We do not like interactive encryption.
- We do not like third-party.
- We do not like decryption error.

Bi-Deniable Public-Key Deniable Encryption

Multi-Distributional Bi-Deniable Scheme

- A. O'Neil, C. Peikert and B. Waters proposed Multi-Distributional Bi-Deniable Scheme based on Simulatable Public-Key Encryption.

Definition

Multi-Distributional:

- Multi-Distributional means the parties run alternative key-generation and encryption algorithms for equivocable communication, but claim under coercion to have run the prescribed algorithms.
- Multi-Distributional means the scheme contains normal and deniable encryption at the same time.

A Philosophical Question

- Why would anyone ever choose to send a message according to the non-deniable encryption algorithm?
- It is impossible to eliminate this option because the coercer would *know* that the sender is lying.
- The purpose of deniability is not at all to convince the coercer, but to *preempt coercion* in the first place.

Bi-Deniable Scheme

Sender-Deniable	Receiver-Deniable
$pk \leftarrow \mathsf{Gen}(1^n, r_R)$	$(pk, fk) \leftarrow \mathsf{DenGen}(1^n)$
$c \leftarrow \mathsf{DenEnc}(pk, m, r_S)$	$c \leftarrow \mathsf{Enc}(pk, m, r_S)$
	$r_R^* \leftarrow \mathsf{RecFake}(pk, fk, c, m')$
$r_S^* \leftarrow \mathsf{SendFake}(pk, r_S, m, m')$	
Return (pk, c, r_S^*)	(pk, c, r_R^*)

Bi-Deniable
$(pk, fk) \leftarrow \mathsf{DenGen}(1^n)$
$c \leftarrow \mathsf{DenEnc}(pk, m, r_S)$
$r_R^* \leftarrow \mathsf{RecFake}(pk, fk, c, b)$
$r_S^* \leftarrow \mathsf{SendFake}(pk, r_S, m, m')$
Return (pk, c, r_S^*, r_R^*)

Simulatable Public-Key System

Definition

Given a public-key system (K, E, D, M), where

- K: key generation algorithm; E: encryption algorithm;
- D: decryption algorithm; M: message space generator.

(K, E, D, M) is a simulatable public key system if $(\tilde{K}, \tilde{K}^{-1}, C, C^{-1})$ exists:

- **Oblivious public key generation**:

$$r \leftarrow R, (P, S) \leftarrow K(r), r' \leftarrow \tilde{K}^{-1}(P).$$

$$r'' \leftarrow R, (P'', S'') \leftarrow \tilde{K}(r'').$$

(r', P) and (r'', P'') are computationally indistinguishable.

Simulatable Public-Key System

Definition

- **Oblivious ciphertext generation**:

$$(P, S) \leftarrow K, r_1 \leftarrow R, C_1 \leftarrow C(P, r_1).$$

$$r_2 \leftarrow R, C_2 \leftarrow E_P(M, r_2), r_2' \leftarrow C^{-1}(C_2, P).$$

(P, r_1, C_1) and (P, r_2', C_2) are computationally indistinguishable.

Definition

- **Semantic security**:

$$r \leftarrow R, (P, S) \leftarrow K(r).$$

$$r_0 \leftarrow R, C_0 \leftarrow E_P(M_0, r_0);$$

$$r_1 \leftarrow R, C_1 \leftarrow E_P(M_1, r_1).$$

(P, M_0, M_1, C_0) and (P, M_0, M_1, C_1) are computationally indistinguishable.

ElGamal is Simulatable under DDH Assumption

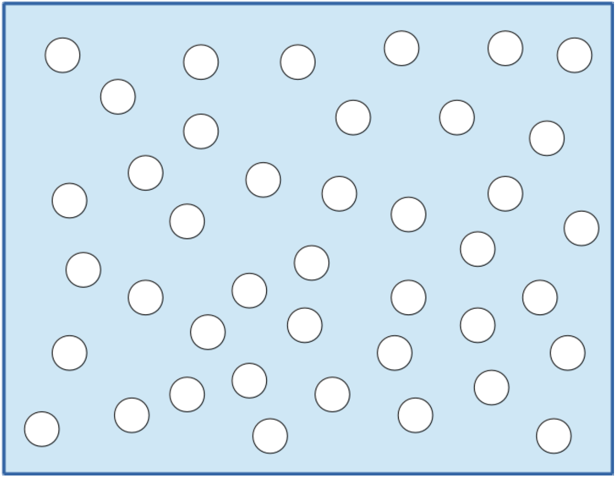
- ElGamal Encryption:
  - Public key: $h = g^x, p, g$.
  - Private key: x.
  - Encryption: (g^y, mh^y).
- Oblivious:
  - $\tilde{K} = h$.
  - $\tilde{K}^{-1}(p, g, h) = (p, g, h)$.
  - $C = (y_1, y_2)$, where $y_1 \leftarrow R, y_2 \leftarrow R$.

Bideniable Encryption from Simulatable System (1/3)

BI-DEN.Gen(1^n)	BI-DEN.Enc(pk, b)
$R \leftarrow P_n([5n])$	$S \leftarrow P_n([5n])$
For $i = 1$ to $5n$ do:	For $i = 1$ to $5n$ do:
If $i \in R$ then	If $i \in S$ then
$pk_i \leftarrow \mathrm{Gen}(1^n, r_{R,i})$	$c_i \leftarrow \mathrm{Enc}(pk_i, b, r_{S,i})$
Else	Else
$pk_i \leftarrow \mathrm{OGen}(1^n, r_{R,i})$	$c_i \leftarrow \mathrm{OEnc}(pk_i, r_{S,i})$
$pk \leftarrow pk_1 \| pk_2 \| \ldots \| pk_{5n}$	$c \leftarrow c_1 \| c_2 \| \ldots \| c_{5n}$
Return pk	Return c

BI-DEN.Dec$((R, r_R), c)$
For $i \in R$ do:
$d_i \leftarrow \mathrm{Dec}(r_{R,i}, c_i)$
If most d_i's are 1 then Return 1
Else Return 0

Encryption.



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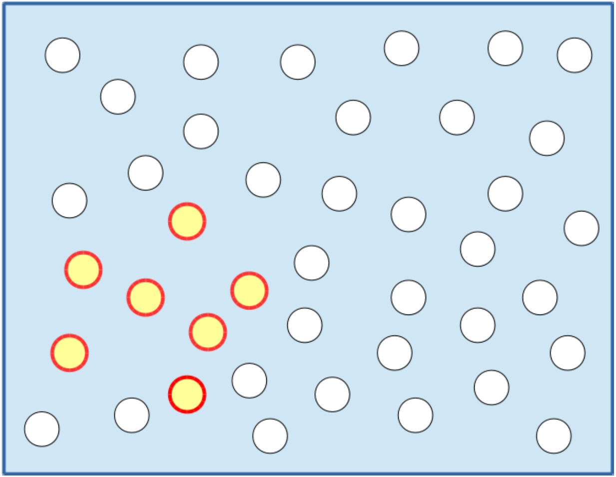
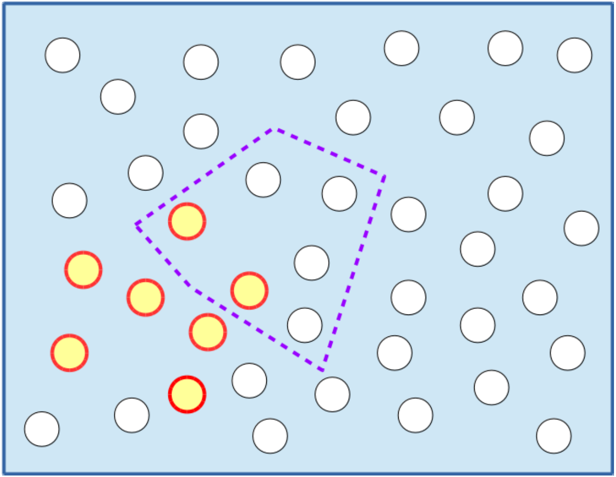


Decryption.



Proof of Correctness

- BI-DEN.Enc should be correct.
- The tail of the hypergeometric distribution:

$$Pr[X \leq E[X] - ty = y(\frac{M}{N} - t)] \leq e^{-2t^2 y}$$

$$Pr[X \leq E[X] + ty = y(\frac{M}{N} + t)] \leq e^{-2t^2 y}$$

- BI-DEN.Enc:
  - Let I be $|S \cap R|$ and D be $R \setminus S$ and $d_i = b$.
  - Decryption error: $D + I < \frac{n}{2}$.
  - If $\frac{n}{10} < I \leq \frac{n}{2}$,

$$Pr[D \leq \frac{n - I}{2} - \frac{I}{2}] \leq Pr[D \leq (1 - \frac{1}{9})E[D]] \leq e^{-\frac{n-I}{324}} \leq e^{-\frac{n}{648}}$$

Bideniable Encryption from Simulatable System (2/3)

BI-DEN.DenGen(1^n)	BI-DEN.DenEnc(pk, b)
$R \leftarrow P_n([5n])$	$S_0 \leftarrow P_n([5n])$
For $i = 1$ to $5n$ do:	$S_1 \leftarrow P_n([5n] \setminus S_0)$
$\quad pk_i \leftarrow \mathsf{Gen}(1^n, r_{R,i})$	$Y \leftarrow P_n([5n] \setminus (S_0 \cup S_1))$
$pk \leftarrow pk_1 \Vert pk_2 \Vert \ldots \Vert pk_{5n}$	For $i = 1$ to $5n$ do:
$r \leftarrow r_{R,1} \Vert r_{R,2} \Vert \ldots \Vert r_{R,5n}$	$\quad$ If $i \in S_0$ then $c_i \leftarrow \mathsf{Enc}(pk_i, 0, r_{S,i})$
	$\quad$ If $i \in S_1$ then $c_i \leftarrow \mathsf{Enc}(pk_i, 1, r_{S,i})$
	$\quad$ If $i \in Y$ then $c_i \leftarrow \mathsf{Enc}(pk_i, b, r_{S,i})$
Return $(pk, (R, r))$	$\quad$ Else $c_i \leftarrow \mathsf{OEnc}(pk_i, r_{S,i})$
	$c \leftarrow c_1 \Vert c_2 \Vert \ldots \Vert c_{5n}$
	Return c

Bideniable Encryption from Simulatable System (3/3)

$\underline{\text{BI-DEN.FakeCoins}(pk, fk, r_S, b, b')}$

$c \leftarrow \text{BI-DEN.Enc}(pk, b, r_S)$

$z \leftarrow \text{HGD}(5n, n, n)$

$Z \leftarrow P_z(S_{b'})$

$Z' \leftarrow P_{n-z}([5n] \setminus (S_0 \cup S_1 \cup Y))$

$R^* \leftarrow Z \cup Z'$

$S^* \leftarrow S_{b'}$

For $i = 1$ to $5n$ do:

  If $i \in S^*$, then $r^*_{S,i} \leftarrow r_{S,i}$

  Else $r^*_{S,i} \leftarrow I_{OEnc}(pk_i, c_i)$

  If $i \in R^*$, then $r^*_{R,i} \leftarrow r_{R,i}$

  Else $r^*_{R,i} \leftarrow I_{OGen}(pk_i)$

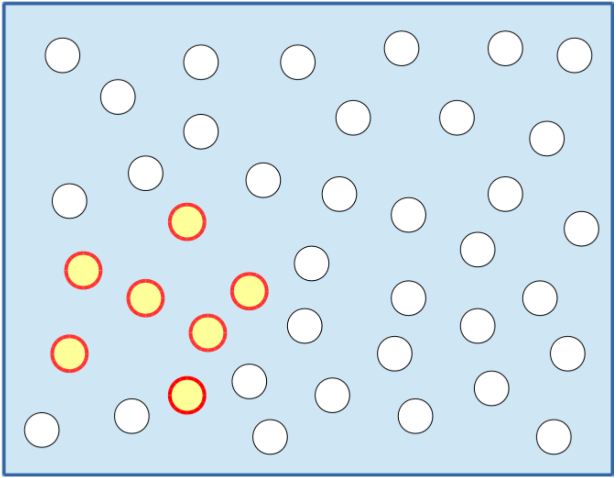
$r^*_S \leftarrow r^*_{S,1} \| r^*_{S,2} \| \ldots \| r^*_{S,5n}$

$r^*_R \leftarrow r^*_{R,1} \| r^*_{R,2} \| \ldots \| r^*_{R,5n}$

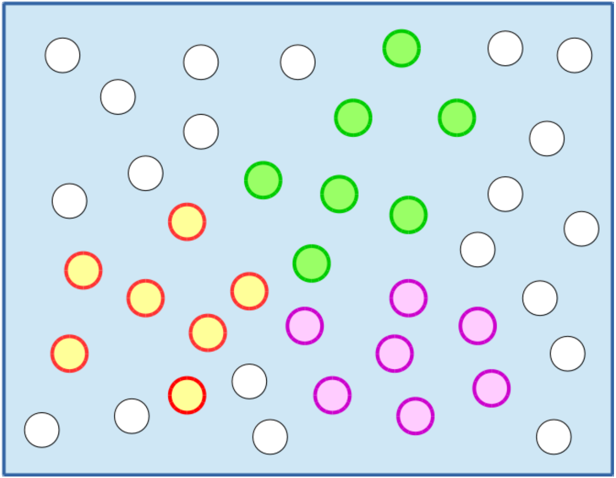
Return (r^*_S, r^*_R)

- Hypergeometric Distribution:
  - $P_{\text{HGD}}(x, N, M, y) = \frac{C_x^M C_{y-x}^{N-M}}{C_y^N}$.
  - $\text{HGD}(N, M, y)$ is the expectation.

Claim.



In fact.



Proof of Deniability (1/3)

Experiment G_0	Experiment G_1
$S_b \leftarrow P_n([5n])$	$S_b \leftarrow P_n([5n])$
$R \leftarrow P_n([5n])$	$z \leftarrow HGD(5n, n, n)$
$S_{1-b} \leftarrow P_n([5n] \setminus (S_b \cup R))$	$Z \leftarrow P_z(S_b)$
$Y \leftarrow P_n([5n] \setminus (S_b \cup S_{1-b} \cup R))$	$Z' \leftarrow P_{n-z}([5n] \setminus S_b)$
	$R \leftarrow Z \cup Z'$
	$S_{1-b} \leftarrow P_n([5n] \setminus (S_b \cup R))$
	$Y \leftarrow P_n([5n] \setminus (S_b \cup S_{1-b} \cup R))$
For $i = 1$ to $5n$ do:	For $i = 1$ to $5n$ do:
If $i \in R$, $pk_i \leftarrow \mathrm{Gen}(1^n, r_{R,i})$	If $i \in R$, $pk_i \leftarrow \mathrm{Gen}(1^n, r_{R,i})$
Else $pk_i \leftarrow \mathrm{OGen}(1^n, r_{R,i})$	Else $pk_i \leftarrow \mathrm{OGen}(1^n, r_{R,i})$
If $i \in S_b$, $c_i \leftarrow \mathrm{Enc}(pk_i, b, r_{S,i})$	If $i \in S_b$, $c_i \leftarrow \mathrm{Enc}(pk_i, b, r_{S,i})$
Else $c_i \leftarrow \mathrm{OEnc}(pk_i, r_{S,i})$	Else $c_i \leftarrow \mathrm{OEnc}(pk_i, r_{S,i})$
Return $(pk, c, (R, r_R), (S_b, r_S))$	Return $(pk, c, (R, r_R), (S_b, r_S))$

Proof of Deniability (2/3)

Experiment G_1	Experiment G_2
$S_b \leftarrow P_n([5n])$	$S_b \leftarrow P_n([5n])$
$z \leftarrow HGD(5n, n, n)$	$S_{1-b} \leftarrow P_n([5n] \setminus S_b)$
$Z \leftarrow P_z(S_b)$	$Y \leftarrow P_n([5n] \setminus (S_b \cup S_{1-b}))$
$Z' \leftarrow P_{n-z}([5n] \setminus S_b)$	$z \leftarrow HGD(5n, n, n)$
$R \leftarrow Z \cup Z'$	$Z \leftarrow P_z(S_b)$
$S_{1-b} \leftarrow P_n([5n] \setminus (S_b \cup R))$	$Z' \leftarrow P_{n-z}([5n] \setminus (S_b \cup S_{1-b} \cup Y)$
$Y \leftarrow P_n([5n] \setminus (S_b \cup S_{1-b} \cup R))$	$R \leftarrow Z \cup Z'$
For $i = 1$ to $5n$ do:	For $i = 1$ to $5n$ do:
If $i \in R$, $pk_i \leftarrow \mathrm{Gen}(1^n, r_{R,i})$	If $i \in R$, $pk_i \leftarrow \mathrm{Gen}(1^n, r_{R,i})$
Else $pk_i \leftarrow \mathrm{OGen}(1^n, r_{R,i})$	Else $pk_i \leftarrow \mathrm{OGen}(1^n, r_{R,i})$
If $i \in S_b$, $c_i \leftarrow \mathrm{Enc}(pk_i, b, r_{S,i})$	If $i \in S_b$, $c_i \leftarrow \mathrm{Enc}(pk_i, b, r_{S,i})$
Else $c_i \leftarrow \mathrm{OEnc}(pk_i, r_{S,i})$	Else $c_i \leftarrow \mathrm{OEnc}(pk_i, r_{S,i})$
Return $(pk, c, (R, r_R), (S_b, r_S))$	Return $(pk, c, (R, r_R), (S_b, r_S))$

Experiment G_2	Experiment G_3
For $i = 1$ to $5n$ do:	For $i = 1$ to $5n$ do:
	$pk_i \leftarrow \mathsf{Gen}(1^n, r_{R,i})$
If $i \in R$, $pk_i \leftarrow \mathsf{Gen}(1^n, r_{R,i})$	If $i \in R$, $r^*_{R,i} \leftarrow r_{R,i}$
Else $pk_i \leftarrow \mathsf{OGen}(1^n, r_{R,i})$	Else $r^*_{R,i} \leftarrow \mathsf{I}_{\mathsf{OGen}}(pk_i)$
If $i \in S_b$, $c_i \leftarrow \mathsf{Enc}(pk_i, b, r_{S,i})$	If $i \in S_b$
Else $c_i \leftarrow \mathsf{OEnc}(pk_i, r_{S,i})$	$c_i \leftarrow \mathsf{Enc}(pk_i, b, r_{S,i})$, $r^*_{S,i} \leftarrow r_{S,i}$
	Else if $i \in S_{1-b}$
	$c_i \leftarrow \mathsf{Enc}(pk_i, 1-b, r_{S,i})$
	$r^*_{S,i} \leftarrow \mathsf{I}_{\mathsf{OEnc}}(pk_i, c_i)$
	Else if $i \in Y$
	$c_i \leftarrow \mathsf{Enc}(pk_i, b', r_{S,i})$
	$r^*_{S,i} \leftarrow \mathsf{I}_{\mathsf{OEnc}}(pk_i, c_i)$
	Else
	$c_i \leftarrow \mathsf{OEnc}(pk_i, r_{S,i})$, $r^*_{S,i} \leftarrow r_{S,i}$

Question

How does the receiver know S_0, S_1, Y ?

Block-wise Deniable Encryption

Problems

- The proposed schemes are bitwise.
- Cost too much.
- Consistency issue.

Plan-Ahead Bi-Deniable Encryption (1/3)

$\mathsf{Gen}(1^n)$:	$\mathsf{Enc}(pk, m)$:
$(pk, sk) \leftarrow \mathsf{Gen}'(1^n)$	$K_0 \leftarrow \{0,1\}^n, b \leftarrow \{0,1\}$
Return (pk, sk)	$c_{asym} \leftarrow \mathsf{Enc}'(pk, K_0 \parallel 0^n \parallel b)$
	$c_0 \leftarrow E(K_0, m)$
	$c_1 \leftarrow \{0,1\}^{\lvert c_b \rvert}$
	Return $c_{asym} \parallel c_b \parallel c_{1-b}$

Plan-Ahead Bi-Deniable Encryption (2/3)

DenGen(1^n):	PADenEnc(pk, m_0, m_1):
$(pk, sk, fk) \leftarrow \mathsf{Gen}'(1^n)$	$K_0, K_1 \leftarrow \{0,1\}^n, b \leftarrow \{0,1\}$
Return (pk, sk, fk)	$c_{asym} \leftarrow \mathsf{DenEnc}'(pk, K_0 \parallel K_1 \parallel b)$
	$c_0 \leftarrow E(K_0, m_0)$
	$c_1 \leftarrow E(K_1, m_1)$
	Return $c_{asym} \parallel c_b \parallel c_{1-b}$

Plan-Ahead Bi-Deniable Encryption (3/3)

$\mathsf{PARecFake}(fk, c, K_0 \parallel K_1 \parallel b, b')$:	$\mathsf{PASendFake}(pk, c, r_S, b')$:
$c \leftarrow c_{asym} \parallel c_0 \parallel c_1$	$c \leftarrow c_{asym} \parallel c_0 \parallel c_1$
	$K_0 \parallel K_1 \parallel b \parallel r \leftarrow r_S$
$x \leftarrow K_0 \parallel K_1 \parallel b$	$x \leftarrow K_0 \parallel K_1 \parallel b$
$y \leftarrow K_{b'} \parallel 0^n \parallel b'$	$y \leftarrow K_{b'} \parallel 0^n \parallel b'$
$r_R^* \leftarrow \mathsf{RecFake}'(fk, c_{asym}, x, y)$	$r_S^* \leftarrow \mathsf{SendFake}'(pk, c_{asym}, r, x, y)$
Return r_R^*	Return r_S^*

Chameleon Hash

Chameleon Hash is a trapdoor one-way function with three requirements:

1. Semantic Security.
2. Collision Resistance.
3. Collision Forgery with the trapdoor.

Most trapdoor pseudo random permutation functions can be used as chameleon hash functions.

Ciphertext Pattern

- Normal Ciphertext: $V = CH(t_b, M)$.
- Deniable Ciphertext: $V = CH(t_b, M) = CH(t_{1-b}, M^*)$.

Note: b can be used as a sender proof.

Reference

Reference

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Q and A