DYNAMIC SEARCHABLE SYMMETRIC ENCRYPTION

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OUTLINE

INTRODUCTION

THE SCENARIO

- Rise of cloud storage.
- Outsource data storage.
- Security concerns regarding data privacy.
- Naïve solution: Encrypt data beforing uploading.

Searchable Symmetric Encryption

- Encrypt data such that it can still be searched.
- Generate search tokens to send as queries to server.
- Return appropriate encrypted files.
- Application: Cloud storage.

DEFINITIONS

Symmetric Key Encryption

- Same key for encryption and decryption.

$$c = E_K(m) \qquad\qquad m = D_K(c)$$

Homomorphic Encryption

- Permit computations on encrypted data.
- Obtaining $E_K(f(x))$ from $E_K(x)$.
- Server learns nothing about data it computed on.
- 2 types: Partially HE & Fully HE.

Psuedorandom Function

- Polynomial time function whose output is indistinguishable from a random function.

$$F\colon \{0,1\}^n \times \{0,1\}^s \to \{0,1\}^m$$

- Given F, K, $x_1, \ldots, x_a$ and $F_K(x_1), \ldots, F_K(x_a)$, $F_K(x_{a+1})$ can't be predicted for any x_{a+1}.

THE CONSTRUCTION

- A private-key encryption scheme SKE.
- 2 pseudorandom functions F and G.
- A_s - search array.
- T_s - search table.

- Collection of files $\mathbf{f} = (f_1, \ldots, f_n)$
- Each file has unique identifier $\mathrm{id}(f_i)$
- $W =$ keyword space.
- Map each file to a list of keywords from W.
- $\mathbf{f}_w =$ set of files in $\mathbf{f}$ that contain w.

- $\forall w \in W$, construct $\mathsf{L}_w = (N_1, \ldots, N_{|f_w|})$
- Each node stored at random locations in A_s
- $\mathsf{N}_i = \langle \mathrm{id}, \mathrm{addr}_s(\mathsf{N}_{i+1}) \rangle$
- K_1 and K_2 are the keys to the PRF F and G.
- $\mathsf{T}_s[F_{K_1}(w)] =$ head of L_w
- Each list encrypted using SKE under key $G_{K_2}(w)$

- Send *search array* A_s, *search table* T_s and the collection of encrypted files $\mathbf{c} = (c_1, \ldots, c_n)$ to the server.
- To search for w, send $F_{K_1}(w)$ and $G_{K_2}(w)$.
- Use $F_{K_1}(w)$ to recover the pointer to head of L_w.
- Use $G_{K_2}(w)$ to decrypt the list.
- Running time - $O(|\mathbf{f_w}|)$
- Leakage of statistical information.

- Allow addition, deletion or modification of a file.
- Difficulties:
    1. Nodes corresponding to a file f are unknown.
    2. Can't modify pointer of the previous node as it is encrypted.
    3. Free locations in search array are unknown.

1. Store list of pointers to nodes in A_s corresponding to a file f in the data structures A_d and T_d called the *deletion array* and *deletion table*.
2. Encrypt pointers with a homomorphic encryption scheme.
3. Keep track of free locations in A_s in a *free list*.

EXAMPLE

EXAMPLE

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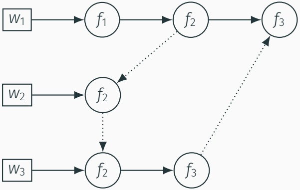


Search Table T_s

$F_{K_1}(w_1) \rightarrow 4$

$F_{K_1}(w_2) \rightarrow 0$

$F_{K_1}(w_3) \rightarrow 5$

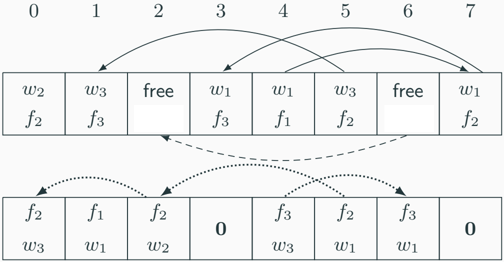
free $\rightarrow 6$

Deletion Table T_d

$F_{K_1}(f_1) \rightarrow 1$

$F_{K_1}(f_2) \rightarrow 5$

$F_{K_1}(f_3) \rightarrow 4$



Search Array $\mathtt{A}_s$

Deletion Array $\mathtt{A}_d$

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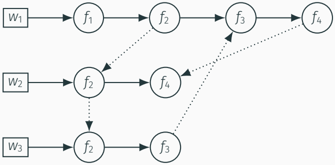


Search Table T_s

$F_{K_1}(w_1) \to 4$

$F_{K_1}(w_2) \to 0$

$F_{K_1}(w_3) \to 5$

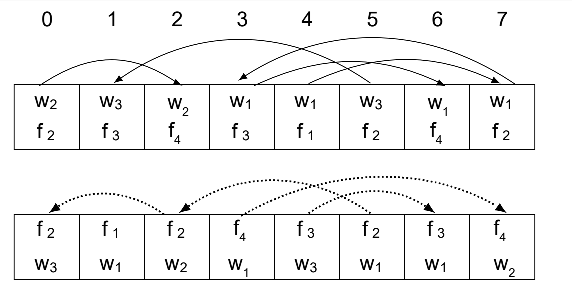
Deletion Table T_d

$F_{K_1}(f_1) \to 1$

$F_{K_1}(f_2) \to 5$

$F_{K_1}(f_3) \to 4$

$F_{K_1}(f_4) \to 3$



EXAMPLE - DELETING A FILE

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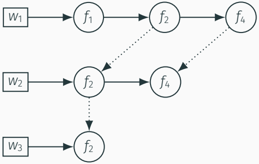


Search Table T_s

$F_{K_1}(w_1) \to 4$

$F_{K_1}(w_2) \to 0$

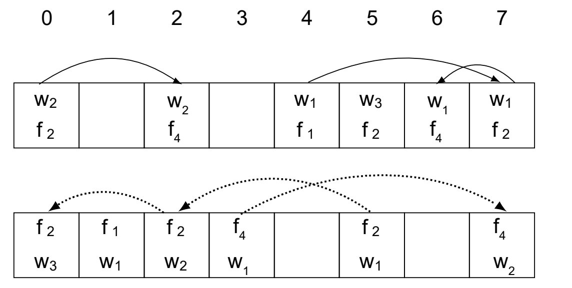
$F_{K_1}(w_3) \to 5$

Deletion Table T_d

$F_{K_1}(f_1) \to 1$

$F_{K_1}(f_2) \to 5$

$F_{K_1}(f_4) \to 3$



- Searchable encryption - important cryptographic primitive.
- Motivated by popularity of cloud storage.

Questions?

[1] C. Bösch, P. Hartel, W. Jonker, and A. Peter.
A survey of provably secure searchable encryption.
ACM Computing Surveys (CSUR), 47(2):18, 2014.

[2] S. Kamara, C. Papamanthou, and T. Roeder.
Dynamic searchable symmetric encryption.
In *Proceedings of the 2012 ACM conference on Computer and communications security*, pages 965–976. ACM, 2012.