A Privacy-Preserving Infrastructure to Monitor Encrypted DNS Logs

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December 7, 2023

Introduction and Motivation

- Forensics analysis in cybersecurity

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- Encryption as a solution ?

Monitoring Encrypted Logs

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- Searchable Encryption as a solution

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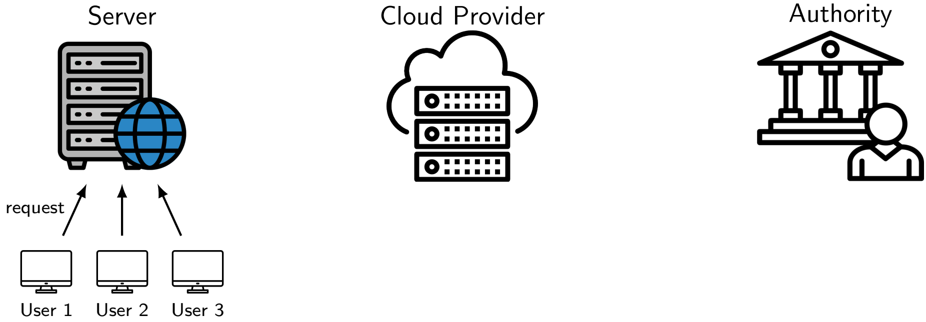

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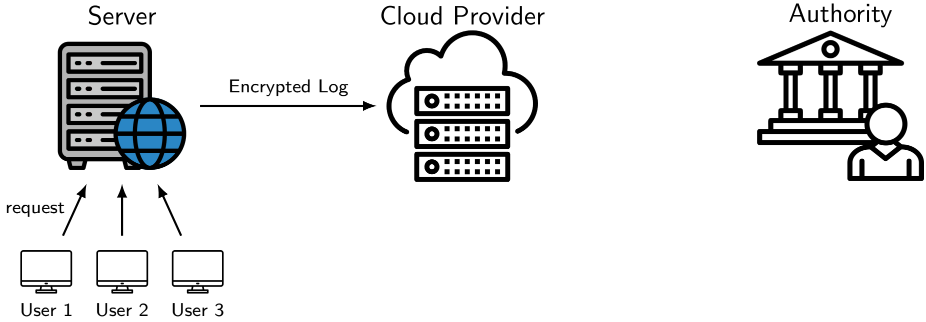

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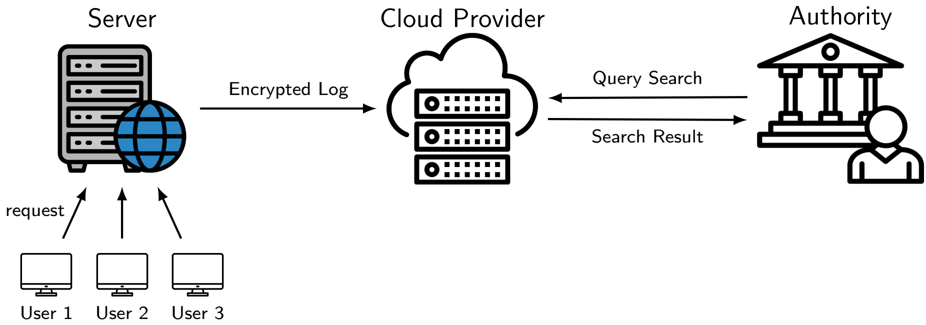
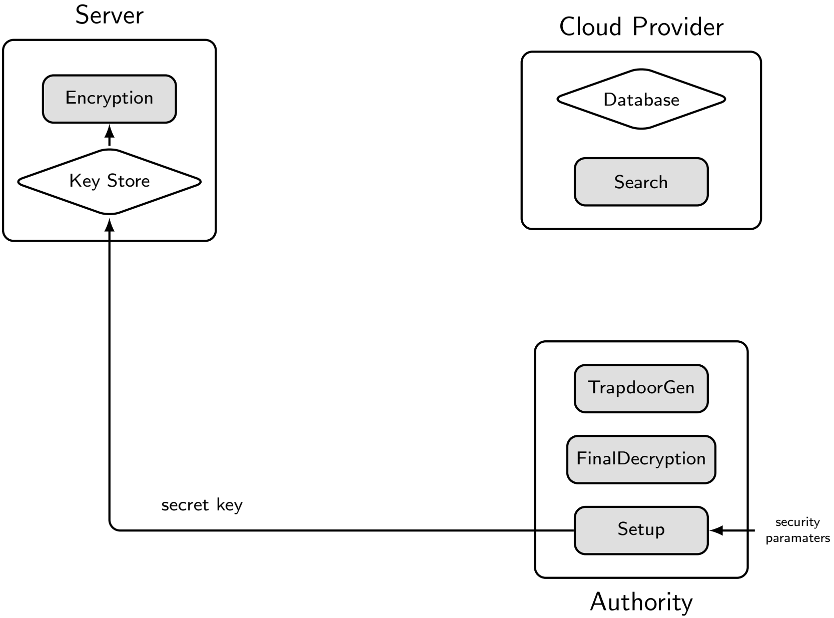


Proposed Framework



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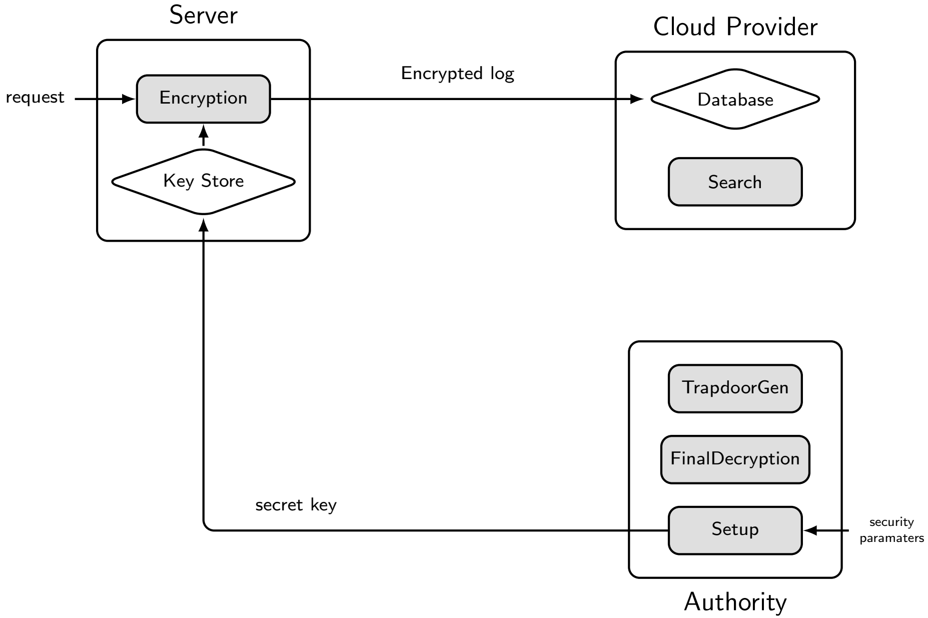

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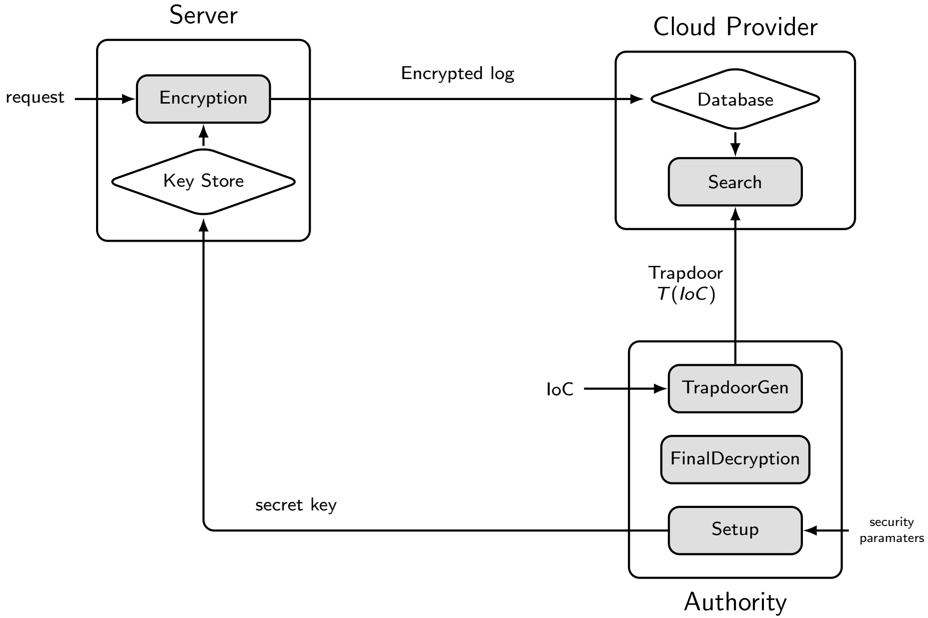

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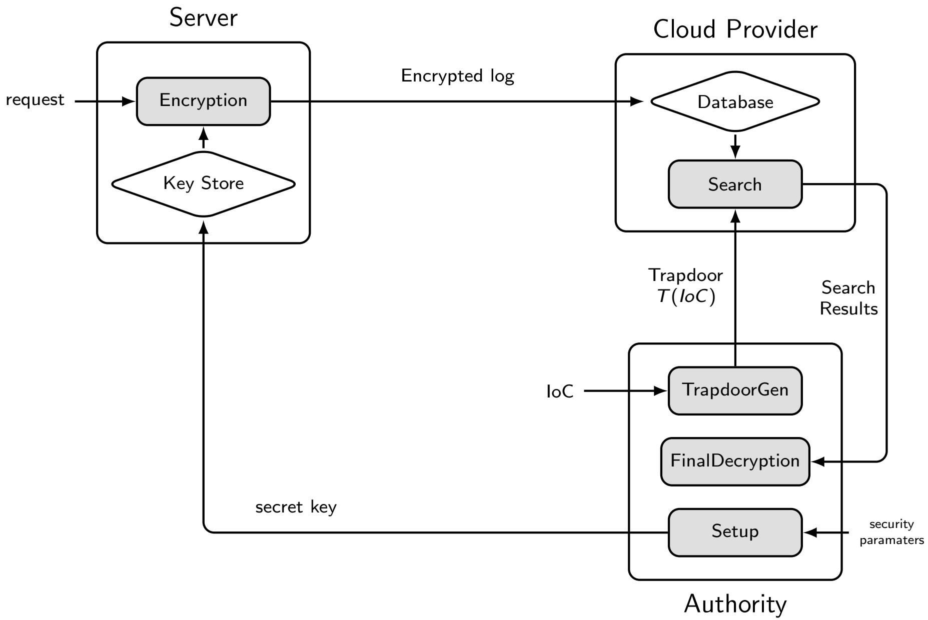

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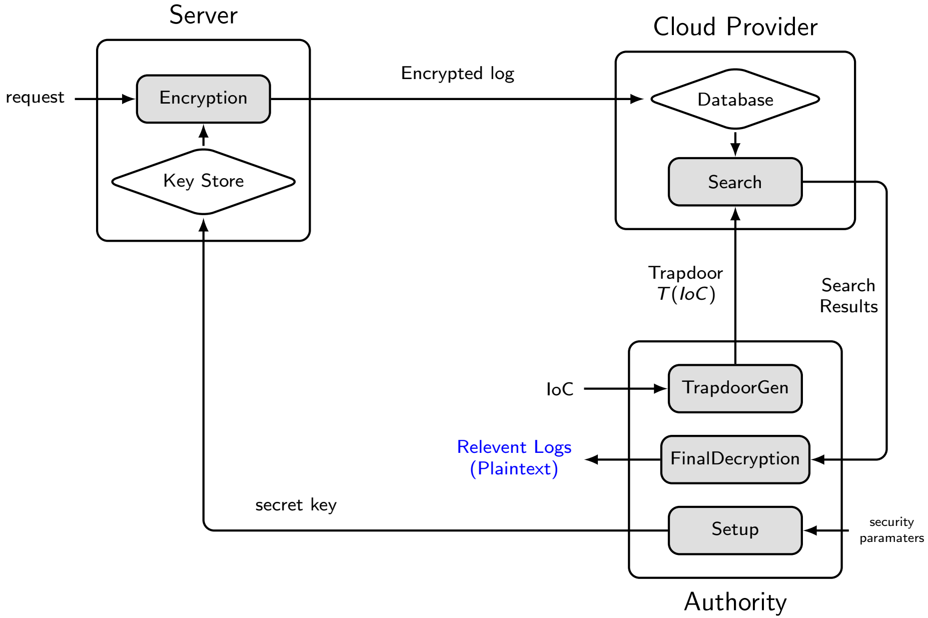

Use Case Application

Domain Name System (DNS)

Why DNS ?

- DNS as a security keystone
- Cybersecurity implications of DNS monitoring

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DNS Logs

- $\texttt{log} = \{\texttt{Timestamp}; \texttt{IP\_client}; \texttt{domain\_name}; \texttt{qtype}; \texttt{rcode}; \texttt{IP\_results}\}$
- $KW = \{\texttt{domain\_name}, \texttt{IP\_results}\} = \{kw_1, \ldots, kw_t\}$

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Goal: Finding IoCs in encrypted DNS logs

- IoC may be domain name or IP address of C&C server
- Query on encrypted logs :
  - The DNS request for a given domain name
  - The DNS response producing a given IP address

Privacy Requirements

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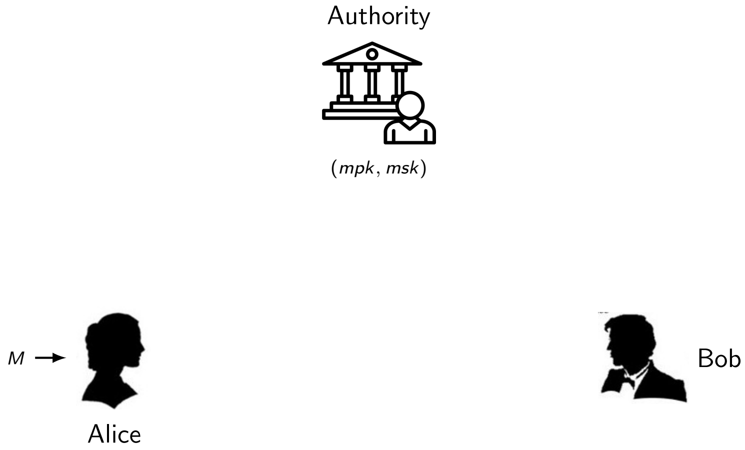
Proposed Solutions

- Asymmetric Searchable Encryption (ASE)
  - using Identity-Based Encryption (IBE)
- Symmetric Searchable Encryption (SSE)
  - using Pseudo-Random Function (PRF)

Cryptographic Primitives – Recall

Identity-Based Encryption (IBE)



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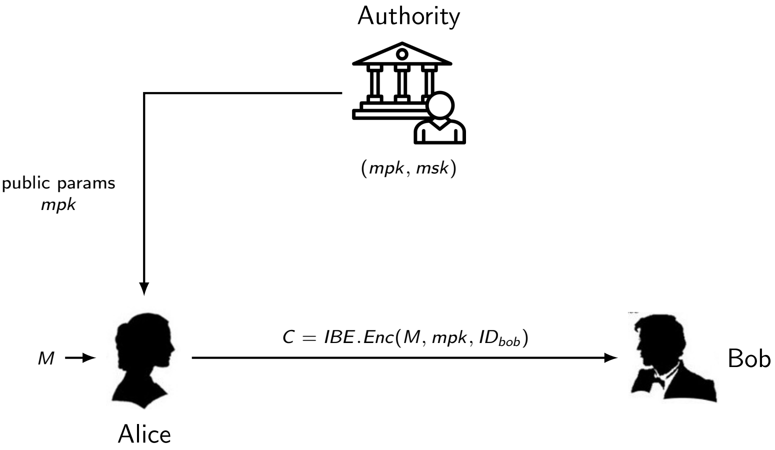

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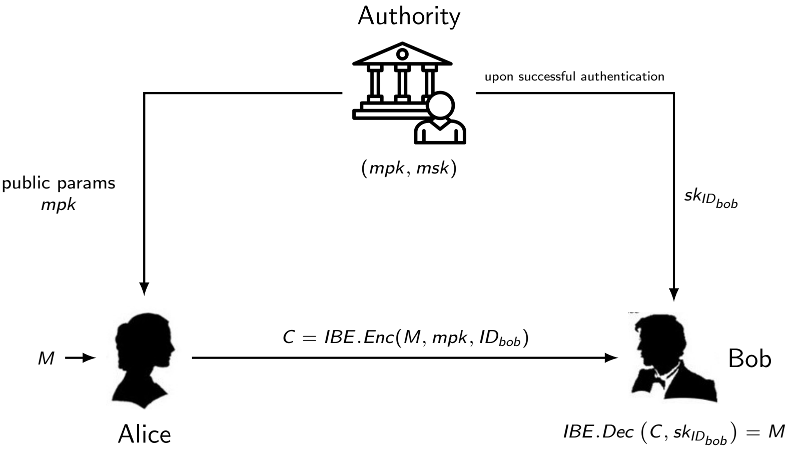

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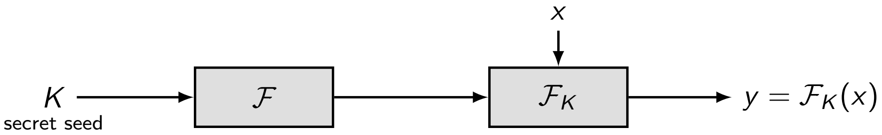
Pseudo-Random Function (PRF)



Proposed Solutions – ASE

Log Encryption

DNS Logs (Reminder)

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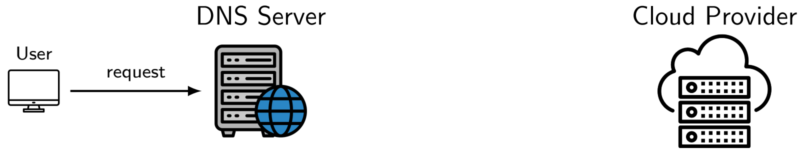

$$K \xleftarrow{\$} \{0,1\}^n, K' = \mathcal{F}_{K_R}(K)$$

$$C_i \leftarrow IBE.Enc(K, kw_i), \forall kw_i \in KW$$

$$\texttt{enc\_log} \leftarrow Sym.Enc(log, K')$$

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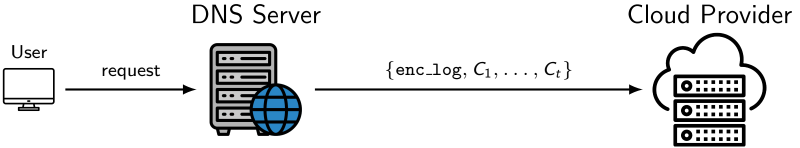

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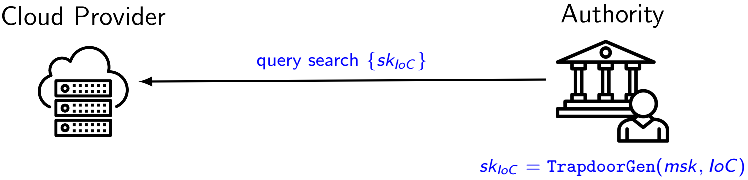
Search on Encrypted Logs



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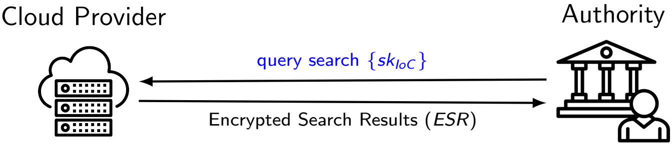

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$ESR \leftarrow \{\}$

For each $\{\texttt{enc\_log}, C_1, \ldots, C_t\}$

if $\exists i, s.t.\ IBE.Dec(C_i, sk_{IoC}) =: K$ *success*

Add $\{\texttt{enc\_log}, K\}$ to ESR

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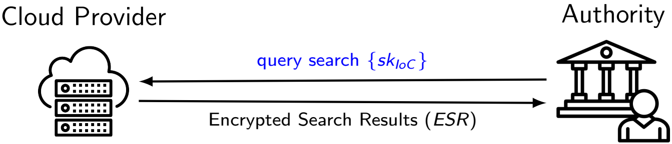

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For each $\{\texttt{enc\_log}, K\}$ in ESR

    $K' = \mathcal{F}_{K_R}(K)$

    $log = Sym.Dec(\texttt{enc\_log}, K')$

    Add log to Plaintext Logs

Proposed Solutions – SSE

Log Encryption

Core idea

$\texttt{enc\_rec} = \{Sym.Enc(log, K'), C_1, \ldots, C_t\}, \quad K' = \mathcal{F}_{K_R}(K)$ and $C_i = IBE.Enc(K, kw_i)$

Build secure index on encrypted logs

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\begin{aligned}
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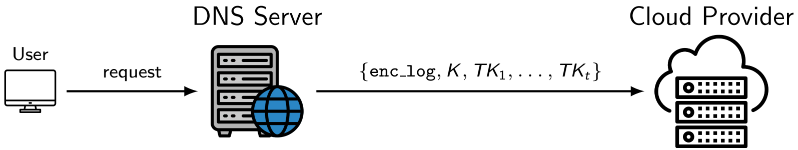

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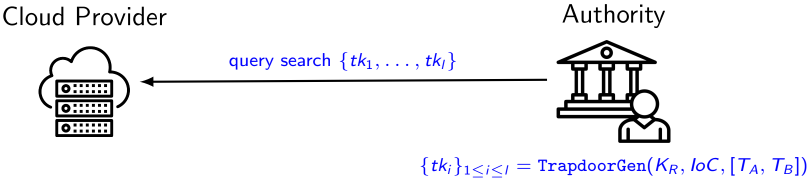

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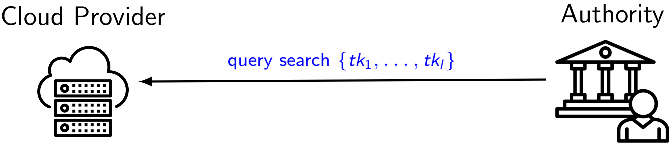

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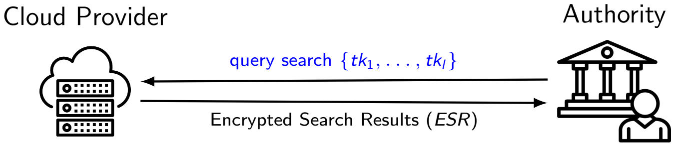

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$\texttt{log} = Sym.Dec(\texttt{enc\_log}, K')$

Add $\texttt{log}$ to Plaintext Logs

Implementation and Evaluation

Implemented schemes

- Plaintext & Plaintext + DB, DB for Database
- WBDS–SSE : SSE scheme of Waters et al.
- our SSE scheme
- SSE + DB : our SSE scheme with a database
- our ASE scheme using IBE

Implementation and Evaluation

Implementation details

- Symmetric primitives : AES, HMAC
- Asymmetric setting : elliptic curve BLS12-381 & RELIC library
- Dataset : TI-2016 DNS dataset, 2019 $\longrightarrow$ 21 million logs

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	Encryption Time (μs/log)	Ciphertext size	Search Time[1] (s/IoC)
Plaintext	2.7	1.0	0.4
Plaintext + DB[2]	2.7	2.4	< 0.01
WBDS–SSE	22.4	2.3	2.2
Our SSE	28.9	1.3	9.97
Our SSE + DB	28.9	3.3	0.02
Our ASE	5569.0	4.7	2189.28

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Discussion and Limitations

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	Log Unforgeability	Predicate Privacy	Correlation Privacy	Token Collisions	Search Efficiency
WBDS–SSE	✗	✓	✗	if $\|r\| \ll l$	$+$
Our SSE	✓	✓	✓	Within the truncation window	$++$
Our ASE	✓	✓	✓	No	$--$

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Contributions

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Perspectives

- Extension to other log types
- Improve query expressiveness
- Build an efficient SSE with no token collisions ?

Questions ?

Thank you !

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