A Secure Searcher for End-to-End Encrypted Email

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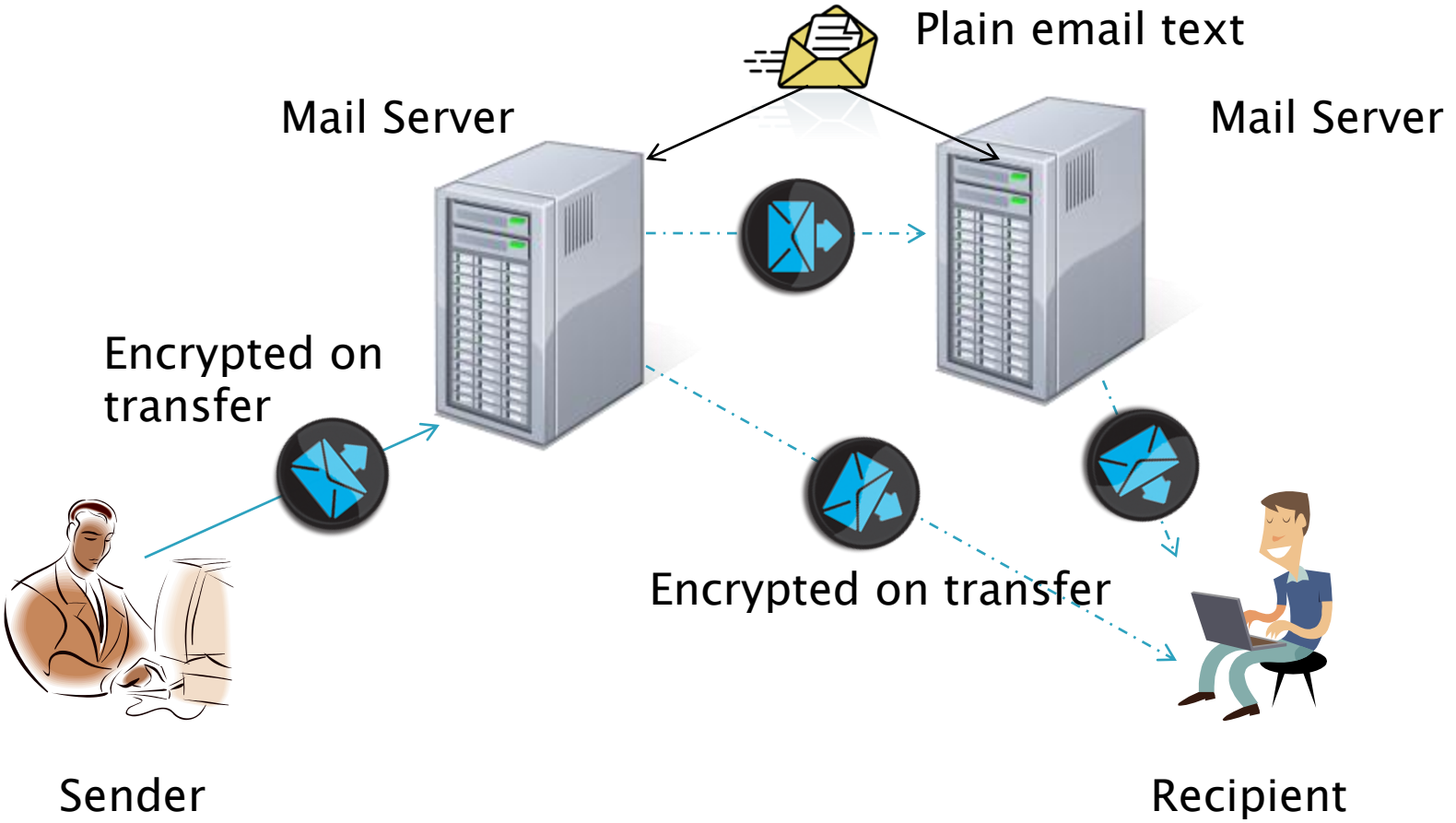
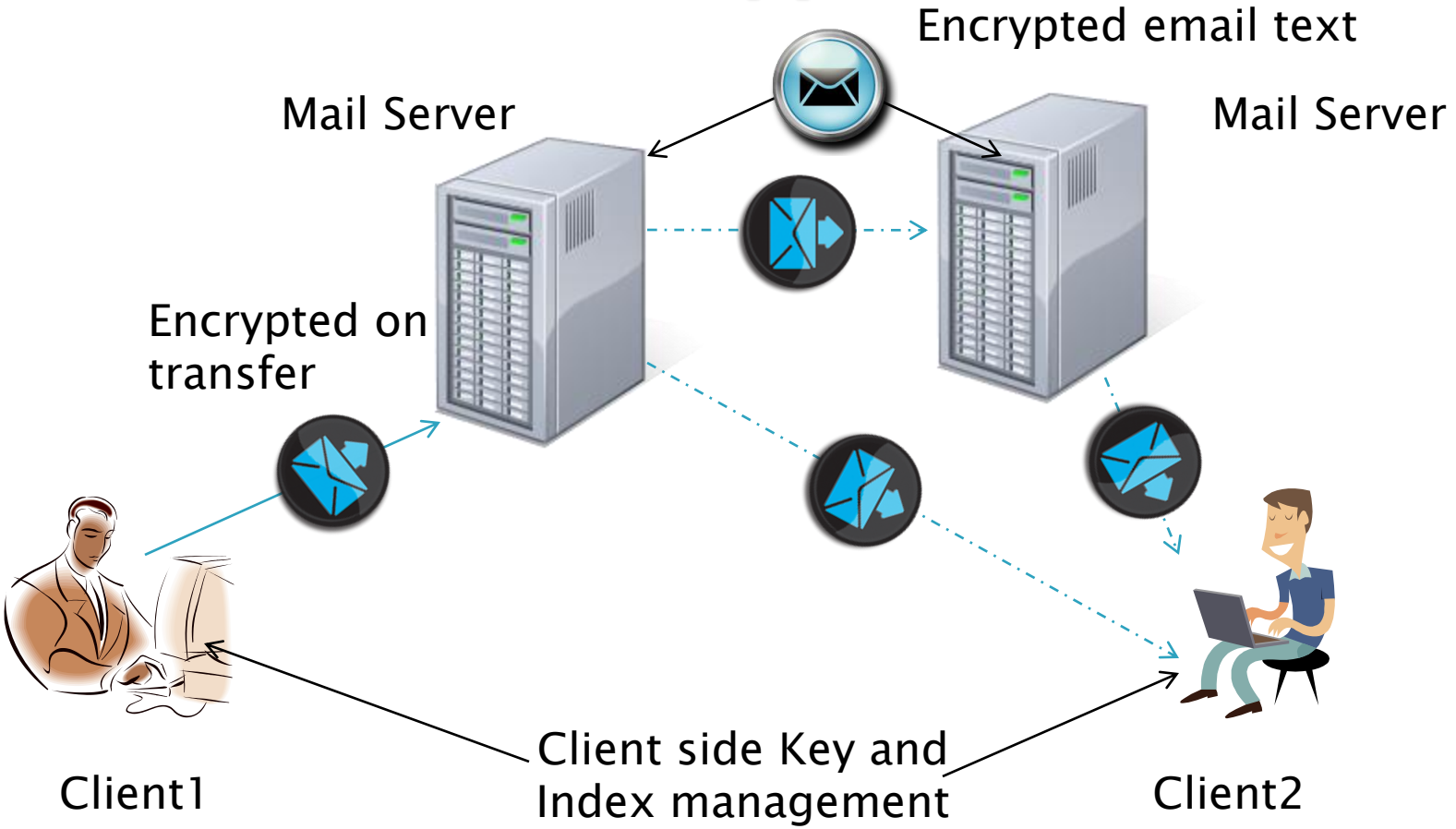
Introduction



Email Communication
Encryption over network

End-to-End Encryption

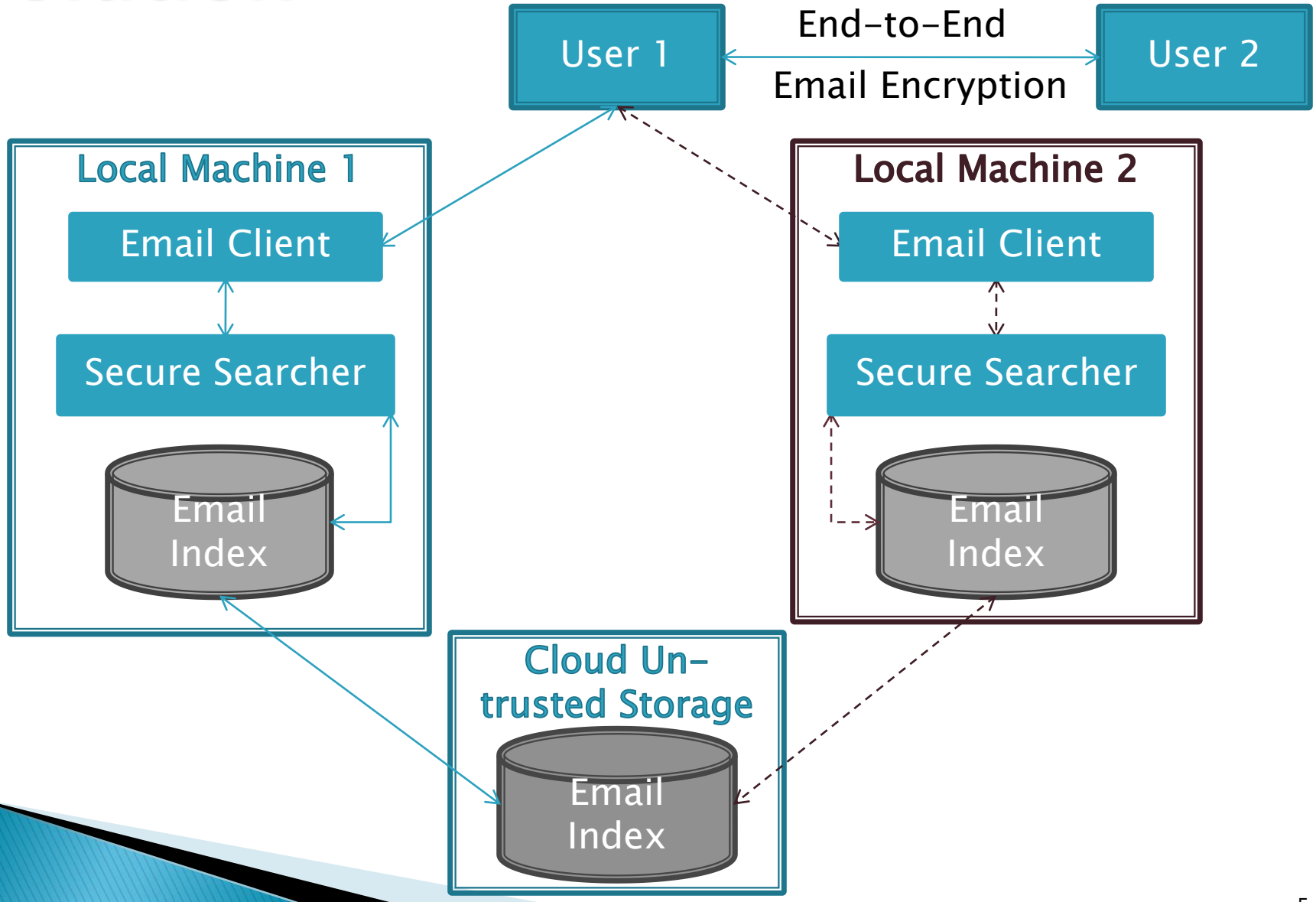


Email Communication
End-to-End Encryption

Motivation

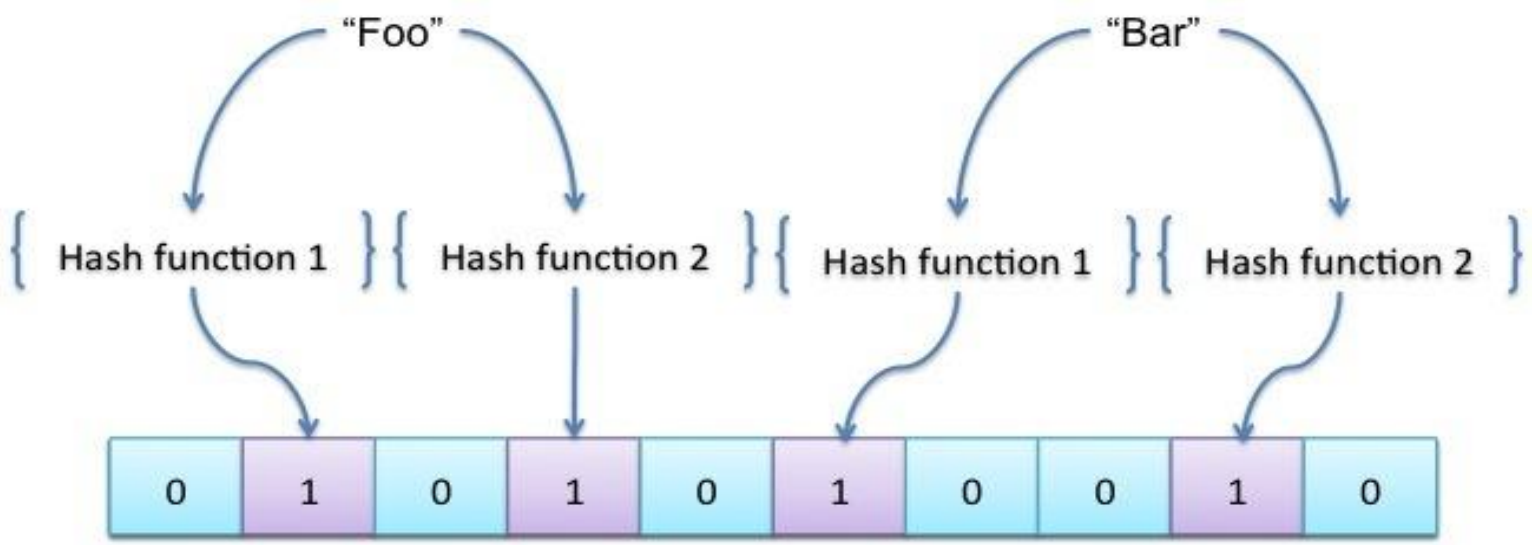
- Client side End-to-End Encrypted email is needed to ensure privacy
- Current tools or extensions that support encrypted email do not have a direct support for search
- A naive solution would be to decrypt all messages and store them on the local machine
  - Security risk if the local machine is compromised
  - Inefficient as it is not accessible from other machines

Solution


User 1
End-to-End
Email Encryption
User 2
Local Machine 1
Email Client
Secure Searcher
Email Index
Local Machine 2
Email Client
Secure Searcher
Email Index
Cloud Un-trusted Storage
Email Index

Secure Index – Technique

- Build a secure index using Goh's Bloom filter technique where Bloom filter is a data structure with bit vector as a base



- Catch: There is a false positive rate (fp = (1/2)^r where r = (ln 2)(m/n)) based on the number of elements to be mapped (n), size of the Bloom filter (m) and the number of hash functions used (r)

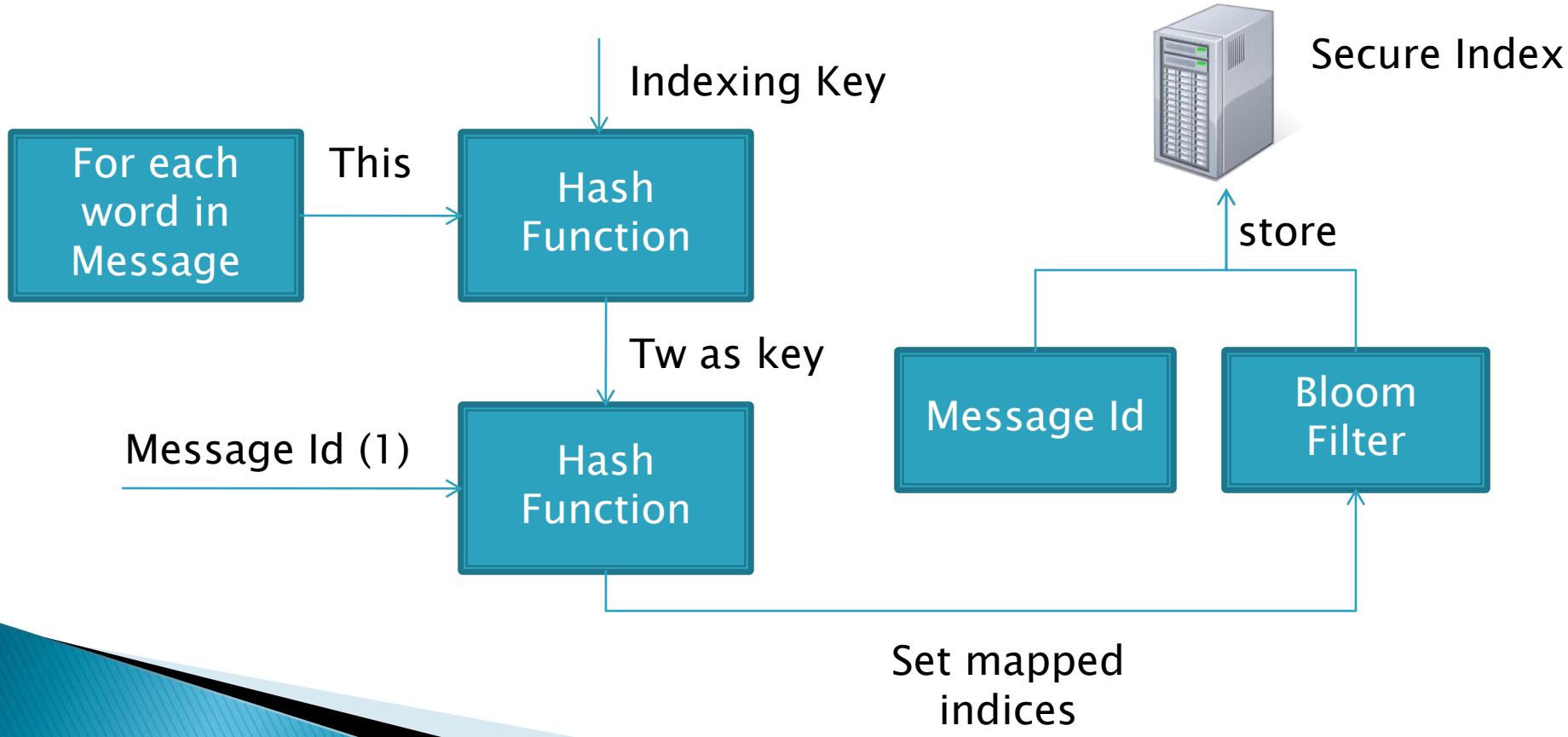
Secure Index – Indexing

-----BEGIN PGP MESSAGE-----
Version: Mailvelope v0.13.1
Comment: https://www.mailvelope.com

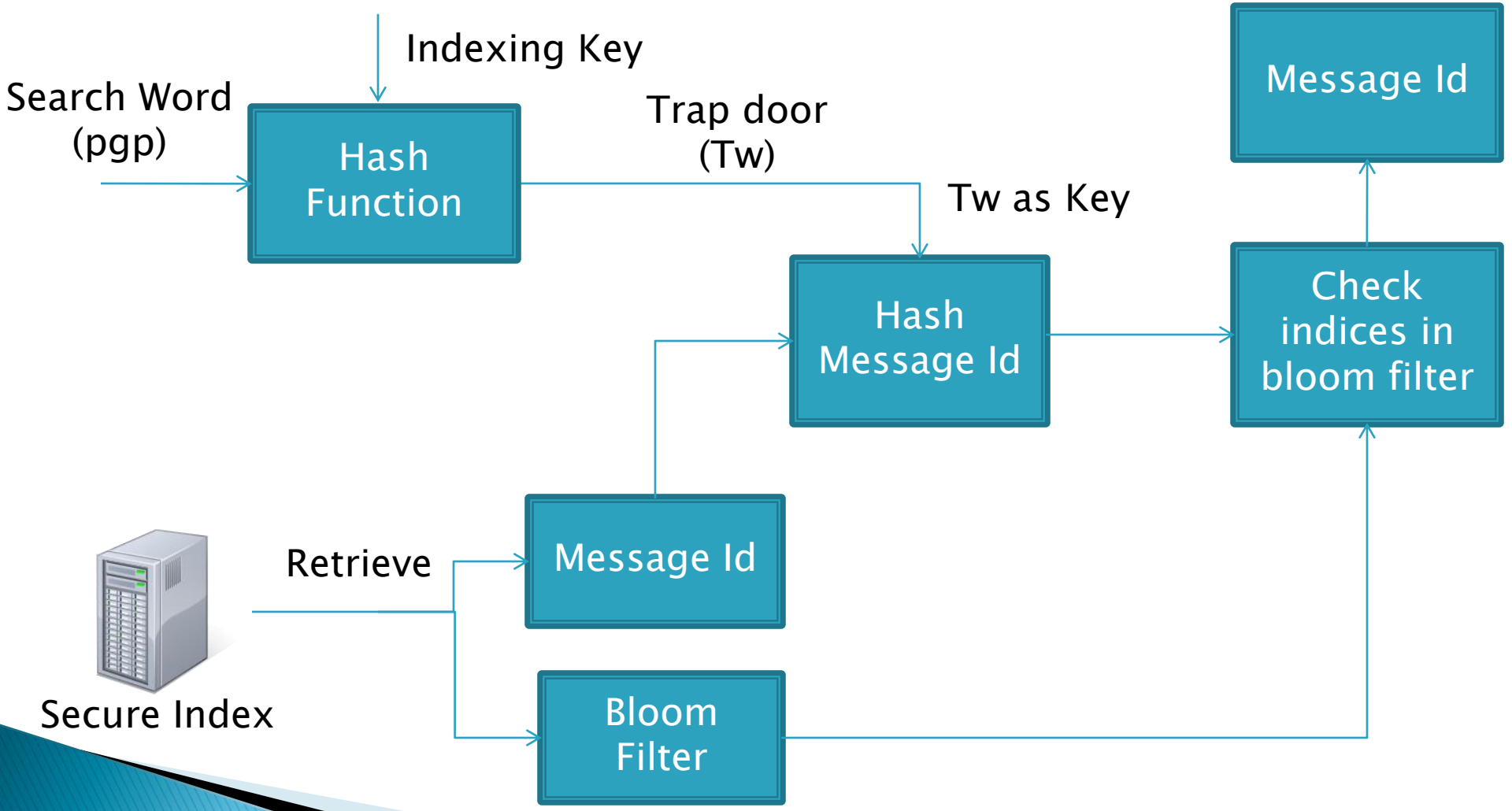
wcFMA0VxwhGntlUaAQ/+Kk7+euGZcpg1au2eOgBODBZQdMI0maLaba3g/zM9
JbwOcpX2z3nMyzz6Ba73aoBczASvXkGEwVsQVioOawgns4NSXnbQgsyJhNer
7c2ERr/MDSPjIwdVf+TfhTp5ddxqf/uOGiKVk4nXM6n0PZ1WVQBtn7GqSTkn
IKbNjZ3bMoSw4qLCPezISWXXYBwby35ZQIKz3fY0pdhsAURjPHXuYZlAWvBI
qEH5uTCeCSBhyz0yY8o+b52UCGpcdLs7BcHrXFhT8xZGhgRE1V7DflyW+55n
DIPf2tF/89KiMTBHUMKN7uE3S2T37TC3F4rmn1bYAX2tCD4Ew1lZCgx9b4ft
anvg+YuwrqTZStvgm9CDCx3wWNigqjm2GgWR+UVsoSdq0C6pDM4YjFlNVRry
nlWxmwm40fzDWekCyoGg+sEWmGaUwyhcxEtJUhmeOMuFomZkUsDlkfRfCpnn
NQGLHsk7A9iCeY7btb2H66O8kEP38VSz95aUMJfplUv5CED4csKyZx0sHSPO
Aplc7OYrLsyxKVRiNRkyKr7MxvpnB5B4Y+qYH374v46ncAnbtN+QIlPfMu3m
Aw7i2HnJDoWYY9tRV4WRXXemR6UOUTDH0iYcYeSY23TZA2S3wiOc6m6GGBZM
jxp7dYzlkF2Wkn9RED8I/LyNDX4vFoEW7c5q81yVQLDSUgFyqo0iAtCu2pxA
CF/uQGZbGXR+GiGr18lH+xtGX/uhHq/hYN9kZWE1rR6Ypo1CnAbFBUZMVlnn
7vZMGa1IzG6CzLwEzecPSfOAedJzyfCbHWI=
=Qj0J
-----END PGP MESSAGE-----

Secure Index – Indexing

- 1 (Message Id)
- This is test pgp (Decrypted Message Body)



Secure Index – Searching



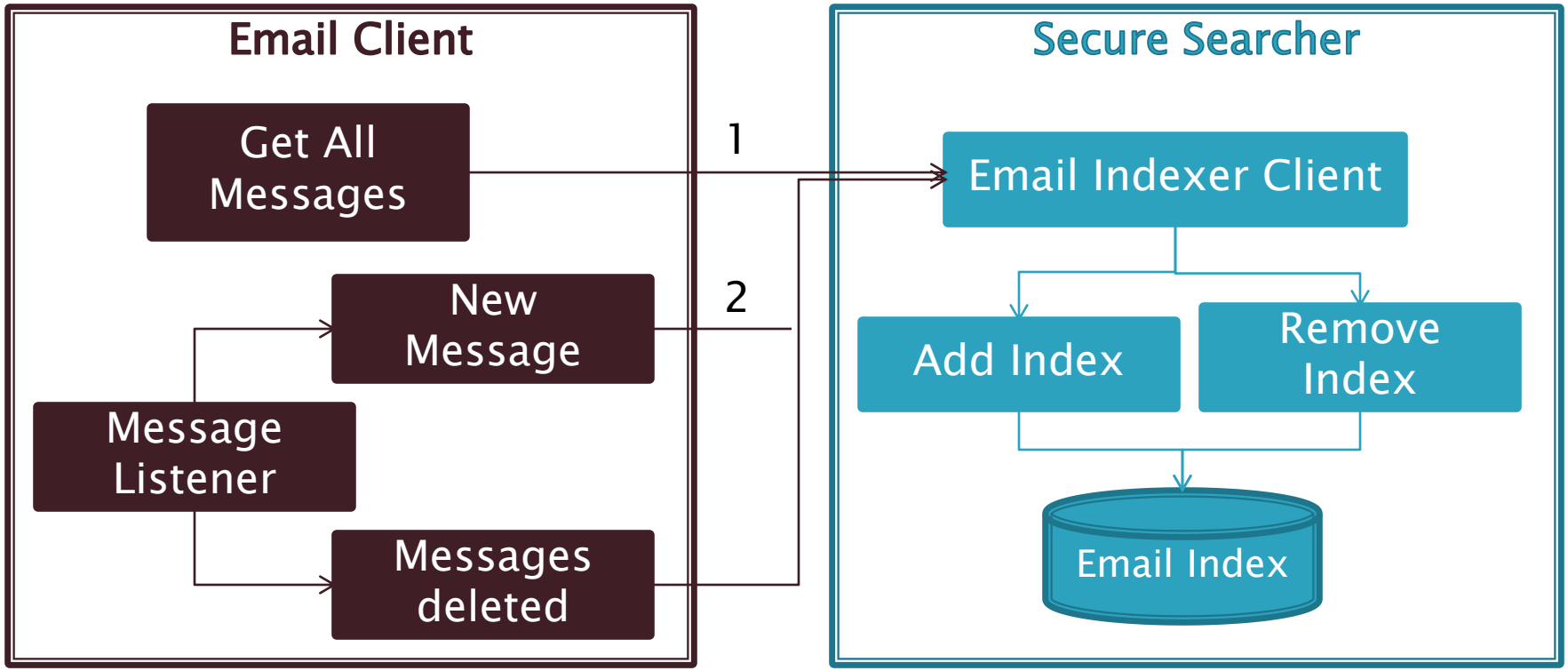
Implementation

- Implemented a library in Java using Bouncy Castle cryptographic libraries

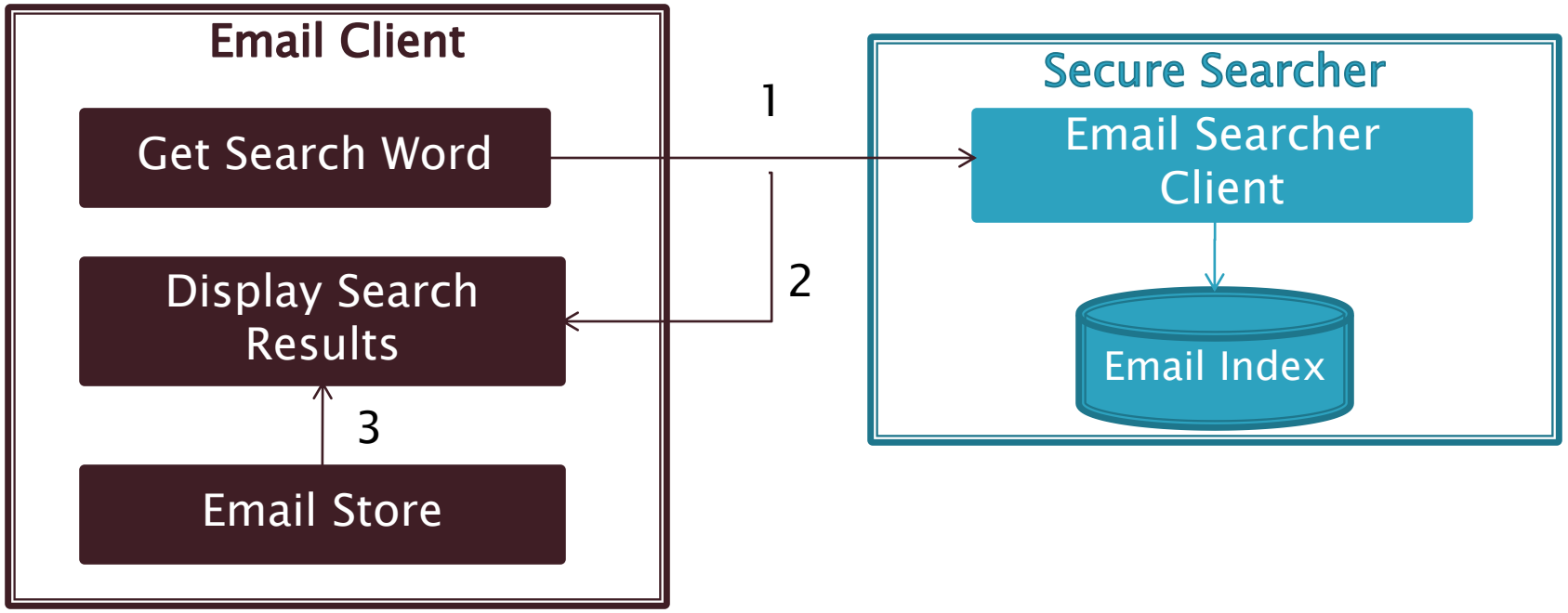
- Exposed APIs
  - Index plain/encrypted messages
  - Search for word/words in the indexed messages
  - Import Open PGP and S/MIME private keys to Key store

- Integrated the library with Columba email client to demonstrate the secure search library usage

Columba Client Integration



Columba Client Integration



Evaluation

- Security
  - Technique is IND-CKA semantically secure (Indistinguishability under Chosen Keyword Attack)
  - Security of the implementation depends on the hash function used (Default: Hmac sha256)
  - Ensures confidentiality but not integrity and authenticity
  - Not secure against in-memory attacks on client that decrypts the message
  - Encrypting the message id may provide more security at the expense of search speed

Evaluation

- Space efficiency vs False positive (Default: 2% with 6 hash functions and 8 bits per word).
  - False positives can be removed by storing all the encrypted words

- Performance – Time
  - DaCapo Benchmark suite – luindex a corpus of 1230 text documents converted to Open PGP and S/MIME encrypted email messages
  - Indexing time is approximately 1 second for indexing 3000 words up to a maximum of 5.5 seconds for 32000 words
  - Search time in terms of number of email messages indexed in the database (3.5 seconds for searching 3690 indexes)

Conclusion

- Columba email client with integrated secure searcher is available as a runnable jar
- Columba client and secure searcher library are extensible with plug-in architecture and layered architecture respectively
- Facebook enables people to add Open PGP public keys to their profile to enhance the privacy of email messages from Facebook!

Thank you