Mix&Slice: Efficient Access Revocation in the Cloud

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Scenario

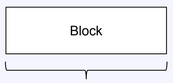
- **Encryption** is increasingly used to protect stored data from both other users and cloud providers
- In presence of multiple users, the **access policy** maps to the ability of each user to **get/derive the encryption key** for the resources she should be allowed to access
- **Problem**: enforcement of authorization revocation

Alternatives to Manage User Revocation

- The key becomes unavailable to the revoked user
  - efficient, but the user may have kept a copy of the key
- The resource is re-encrypted with a fresh key
  - inefficient, the entire resource has to be re-encrypted
  - especially inefficient in a cloud environment (download → re-encrypt → re-upload)
- The resource is protected with an additional encryption layer (i.e., over-encryption)
  - it requires support by the server
- Our solution: Mix&Slice

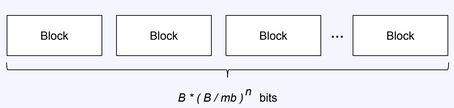
Basic Concepts

- **Block**: A sequence of bits input to a block cipher (it corresponds to the classical block concept). AES is today the most common option ($B = 128$ bits).



- **Mini-block**: A portion of a block that defines the atomic unit of information (either available in its entirety or missing). Its size must be a divisor of the size of the block.

- **Macro-block**: A sequence of blocks. It allows extending the application of the block cipher on sequences of bits larger than individual blocks.



Our approach partitions the resource in distinct, equally sized, macro-blocks. Then it performs two processes: mixing and slicing.

Mixing

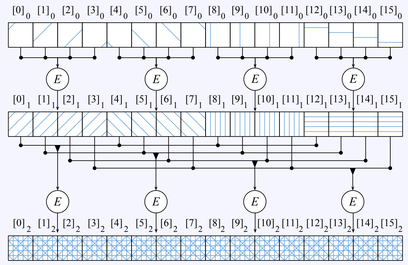


Figure: The mixing process creates the inter-dependency

A symmetric block cipher guarantees **complete dependency of the encrypted result**. This guarantee is not provided when the data to encrypt is larger than a block.

In our mixing process the content of each macro-block is processed by an **iterative application of multiple encryption rounds** together with a carefully designed **mini-block mixing**, that ensures that every mini-block of the input has had impact on each of the mini-blocks in the encrypted output.

Unmixing

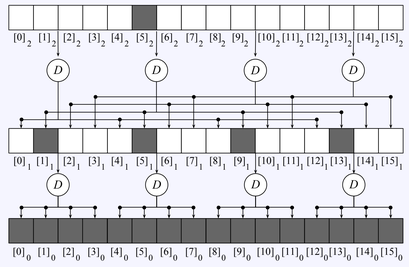
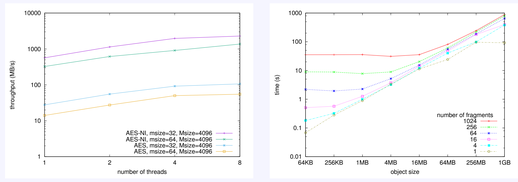


Figure: The lack of a micro-block protects the whole macro-block

If a mini-block in the encrypted representation is missing, the encryption cannot be inverted, even with knowledge of the key. This is an All-or-Nothing Transform (*AONT*).

Other AONT techniques derive a key from the encrypted representation. Storing this key permits to bypass the protection. In our scenario a revoked user must not be able to bypass the protection with a computational and local storage cost significantly lower than the cost of storing the resource itself.

Implementation



(Mixing throughput) (Fragment size impact)

Figure: Experimental results of Mix&Slice based on AES / AES-NI

- For the implementation and experimental evaluation, the components that have to be considered are the **client**, which decrypts resources to access them, and the **algorithm parameters** such as *macro-block size* and *number of fragments*, which affect the interaction between client and server.
- The client implementation has been written in C and is able to leverage hardware implementation of AES (AES-NI), with **excellent performance** (up to 2.5GB/s). Experimenting with the **Swift server**, we observed that the number of fragments has to be selected based on the resource size, as the fragmentation overhead is significant for small resources.
- `https://github.com/unibg-seclab/aesmix`

All-or-Nothing Transform for User Revocation

Use an encryption structure that slices the resource and then mixes all pieces within each slice, making **the decryption dependent on the availability of all the pieces** (i.e., All-or-Nothing Transform). When the policy changes, update the encrypted representation of a randomly chosen piece. If there are n pieces, **the resource can become unavailable with the update of $1/n$-th of the resource**.

Slicing

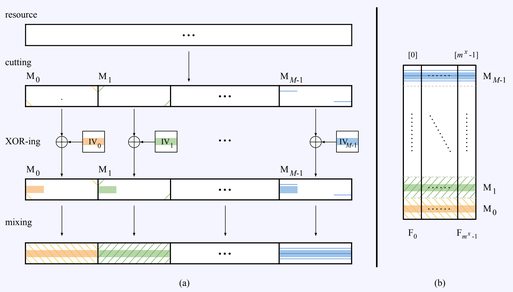


Figure: Macro-blocks can be sliced into fragments

Large macro-blocks introduce shortcomings such as: **reduction in decryption efficiency**, and **data transfer overhead** when only a small portion of the macro-block is needed.

These problems can be mitigated by limiting the macro-block size: (*a*) a resource can be split into macro-blocks, (*b*) all the mini-blocks in the same position are part of the same **fragment**. Each fragment is necessary to reconstruct the resource (*or even portions of it*).

Policy Update

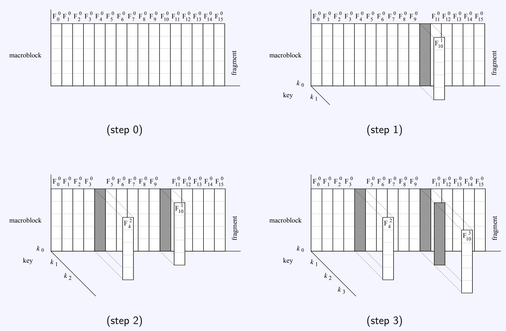


Figure: An example of fragments evolution

The base fragments F_0^i are produced by the application of Mix&Slice (step 0). When a user is revoked access to the resource, only a randomly chosen fragment needs to be re-encrypted (steps 1-3). At step j, the fragment F_0^i is replaced by fragment $F_j^i = E_{k_j}(F_0^i)$. **Only Authorized users will be able to access k_j.**

Using a *key regression* technique based on RSA, all keys k_i can be derived from $k_j, \forall i < j$, with no need to store additional information.

Conclusions

- Mix&Slice efficiently enforces access revocation on encrypted resources stored at external providers even for users locally maintaining copies of previously-used keys.
- The implementation and experimental evaluation confirm the efficiency and effectiveness of the proposal, and confirms its compatibility with current cloud storage solutions.

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Acknowledgments

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