Matrix Cryptographic Key Infrastructure

Sumner Evans

21 September 2024

Beeper (Automattic)

Why Cryptography?

Matrix uses cryptography for two main purposes:

1. **Message Security** — only the people who are part of the conversation should be allowed to view messages of the conversation.
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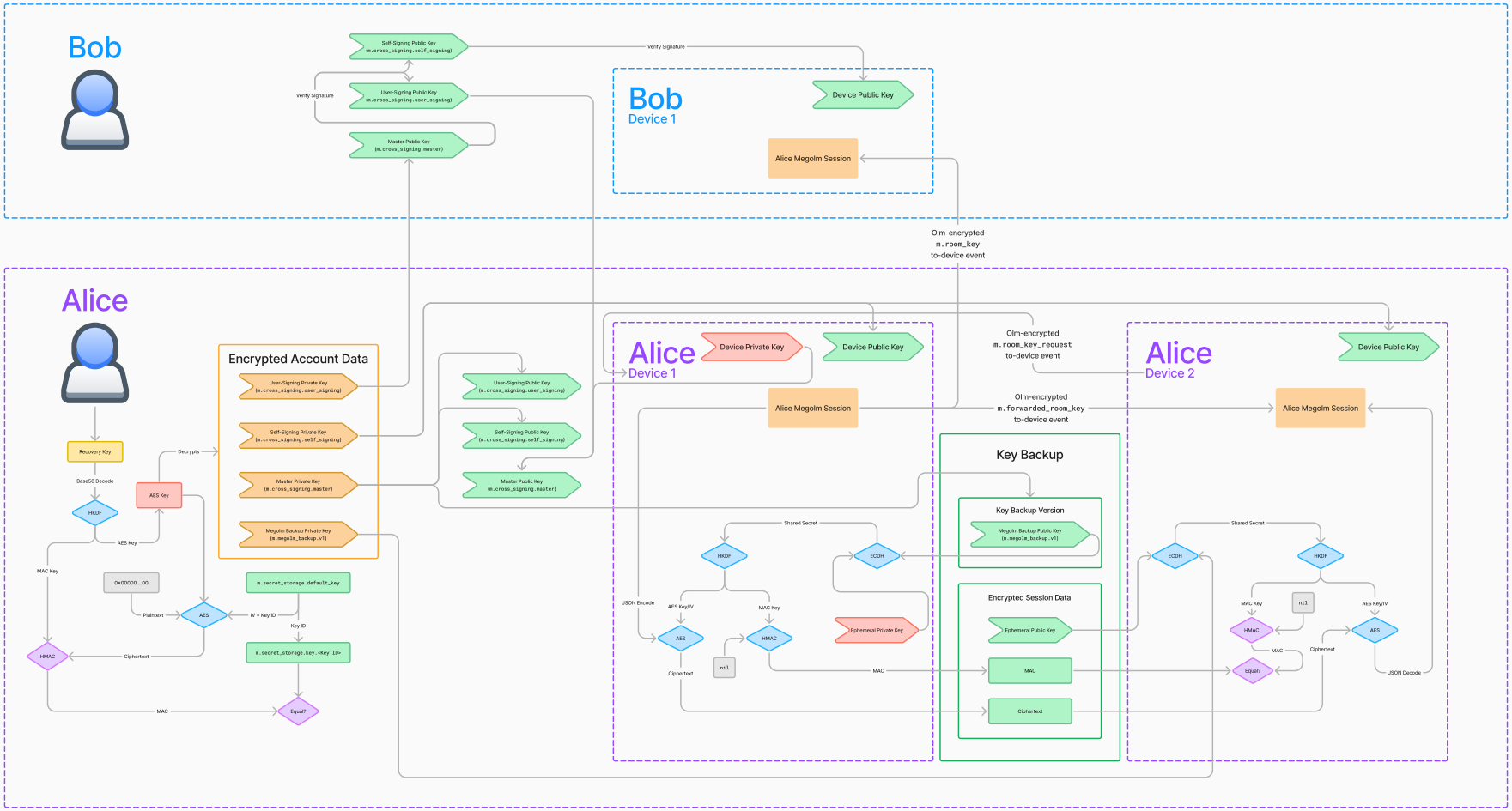
Big Picture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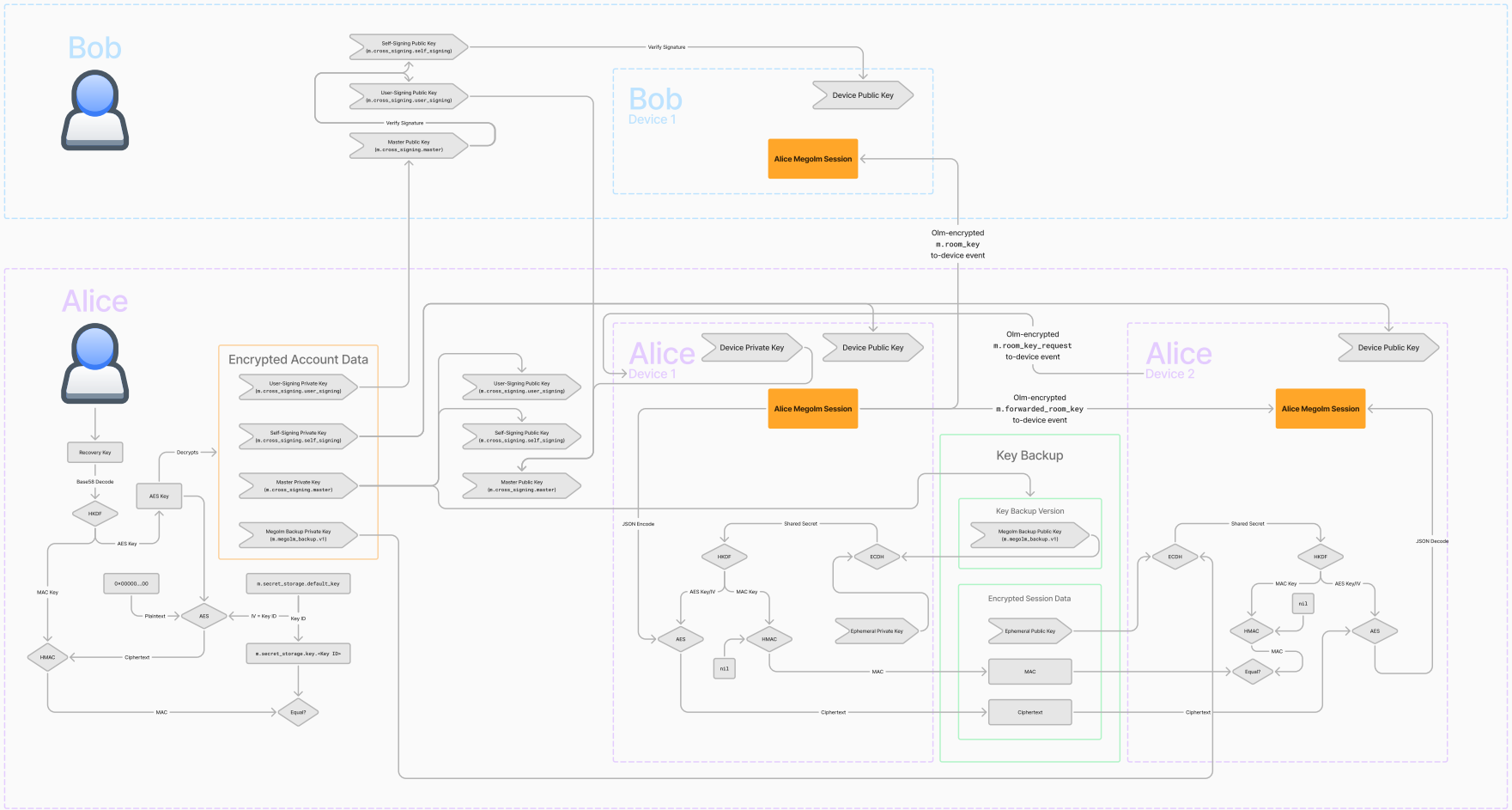
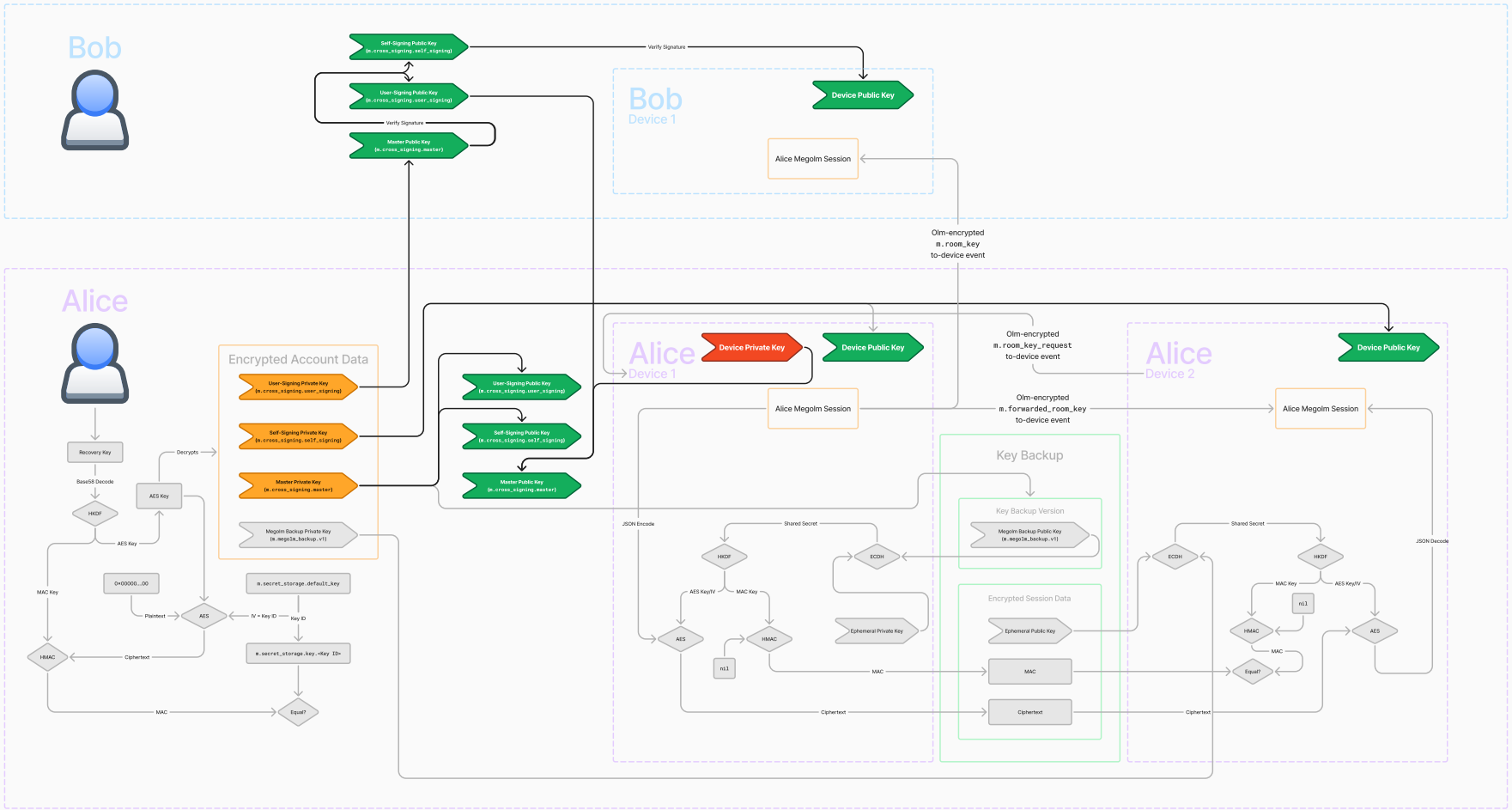
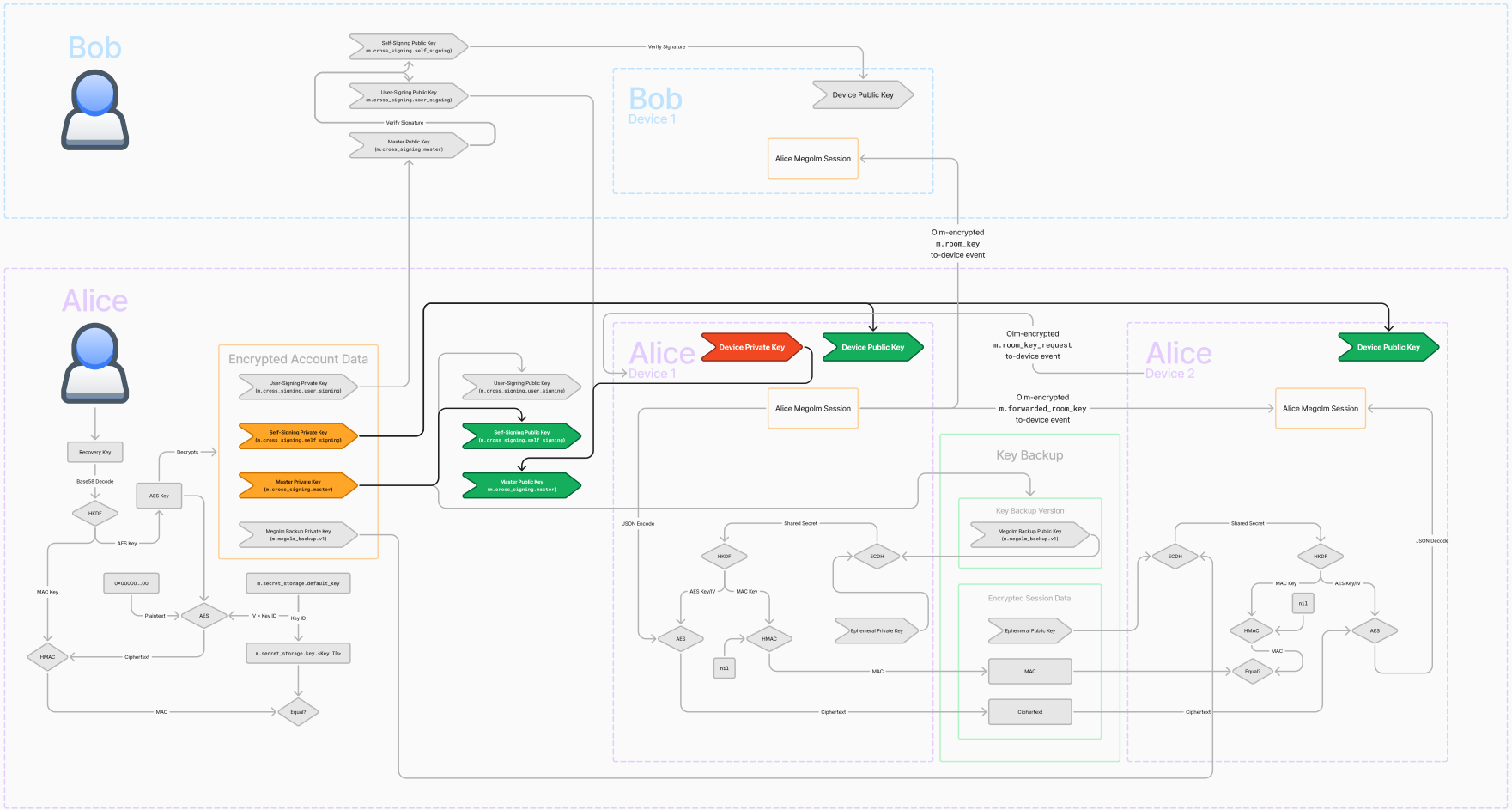
Big Picture: Message Security



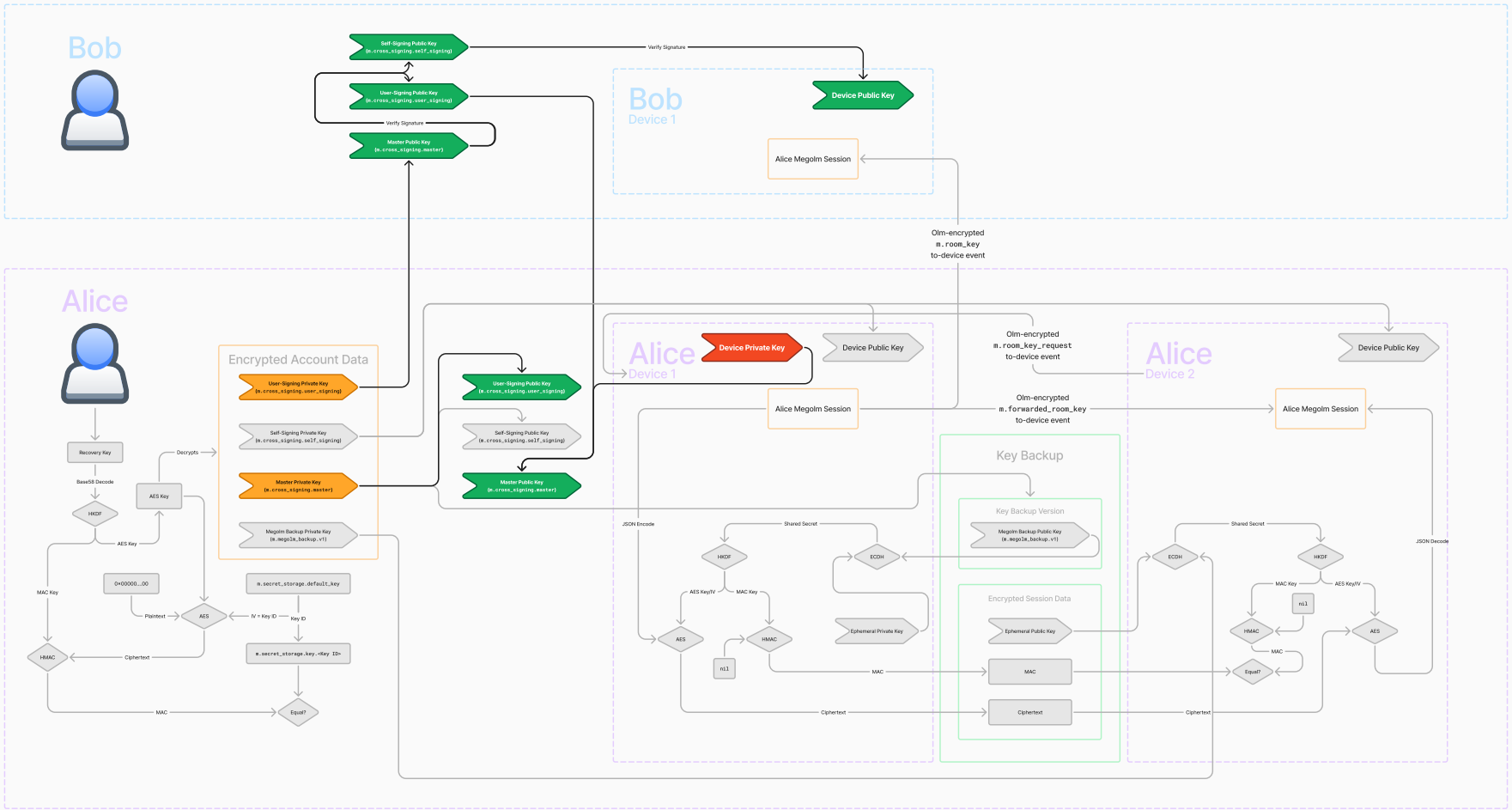
Big Picture: Identity



Big Picture: Identity: Device Verification



Big Picture: Identity: User Verification



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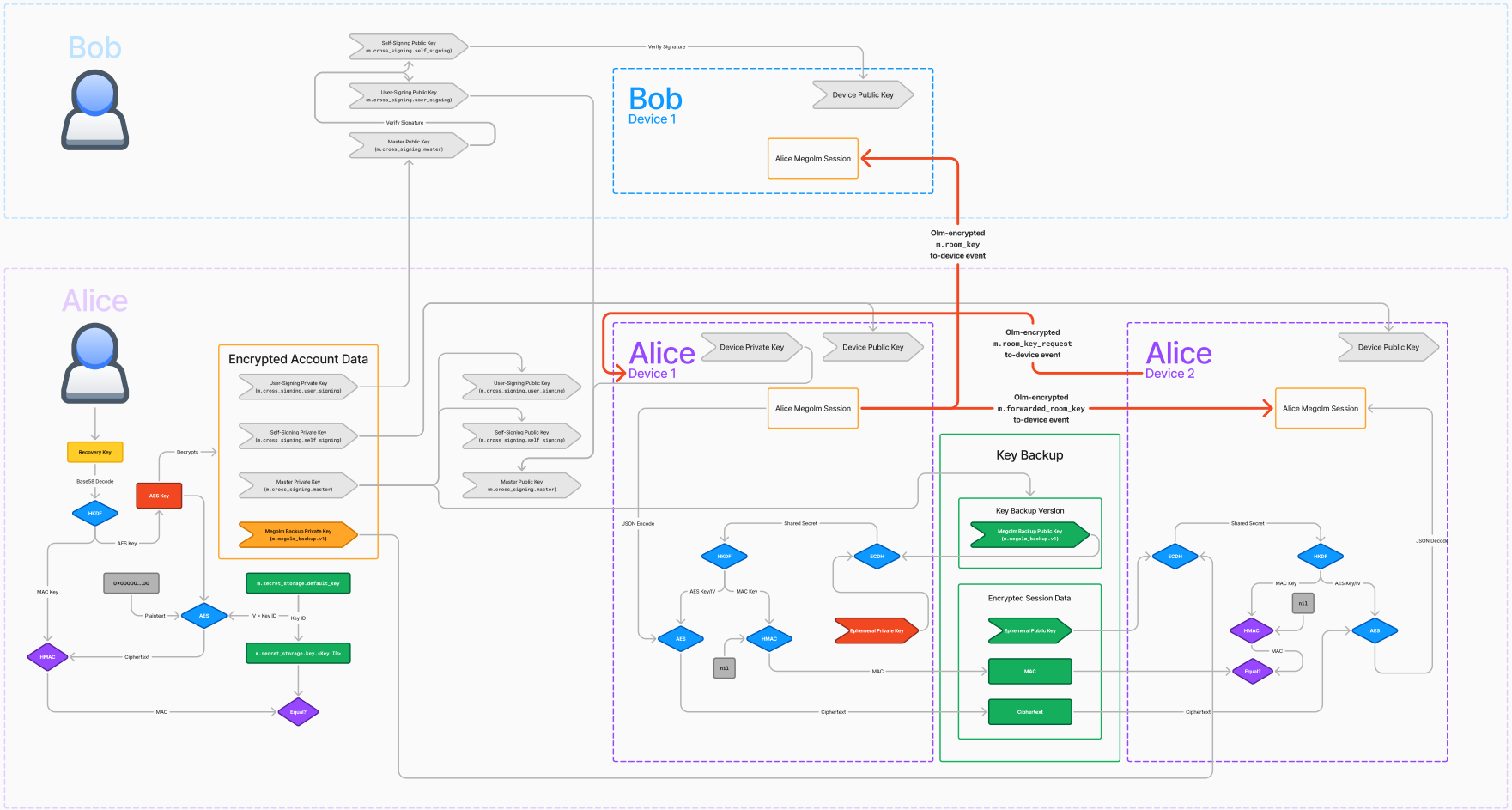
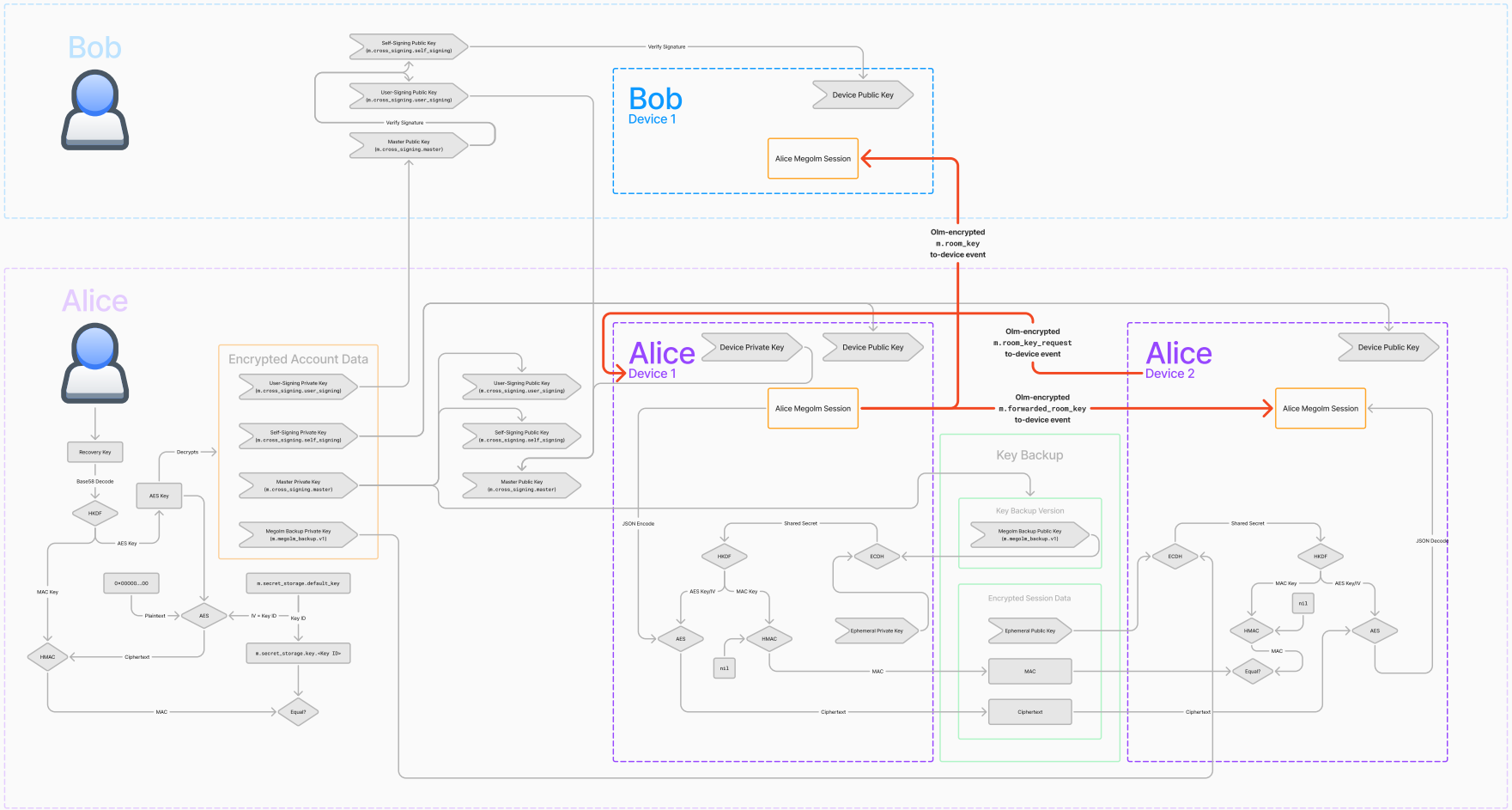
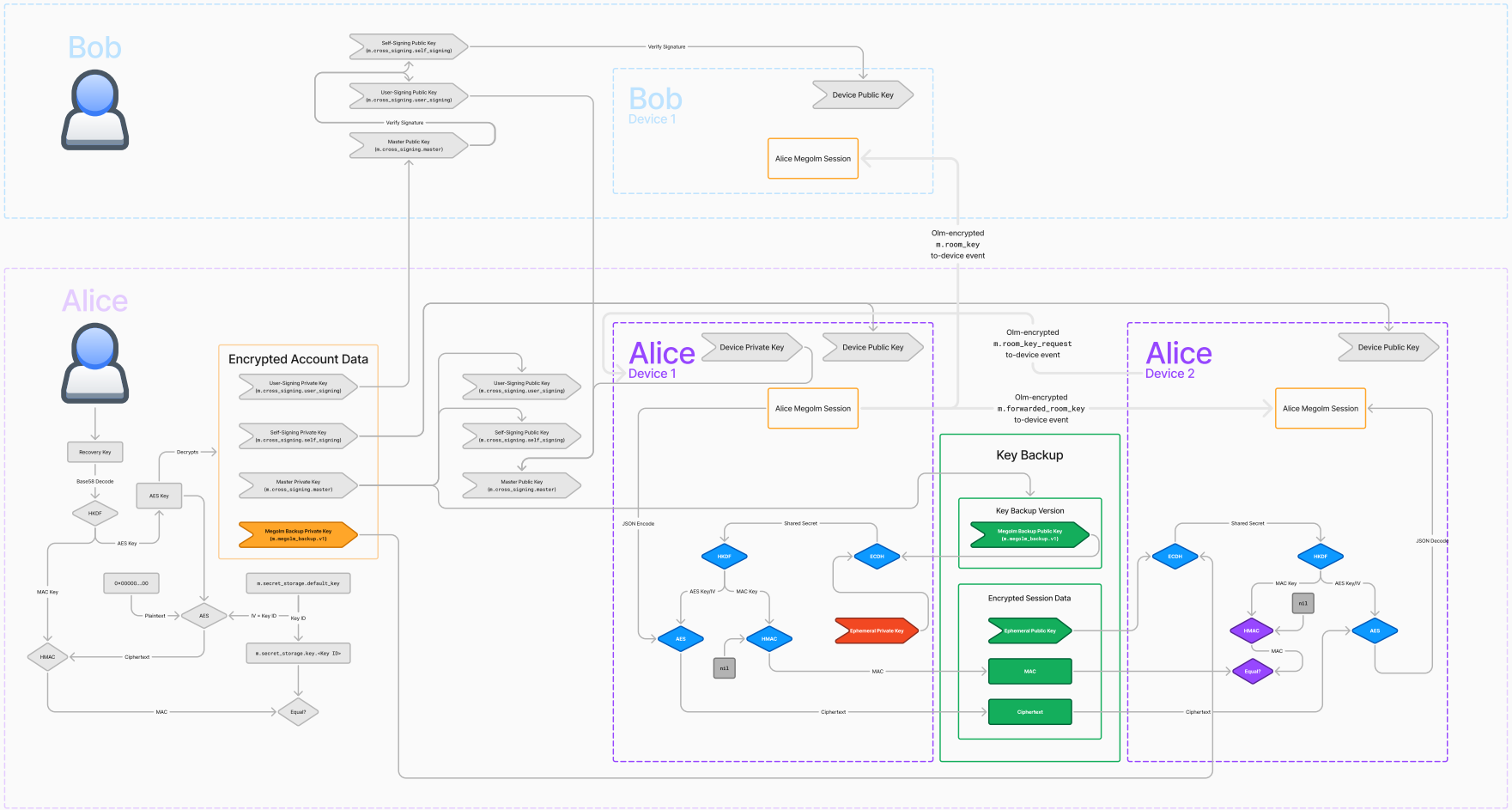


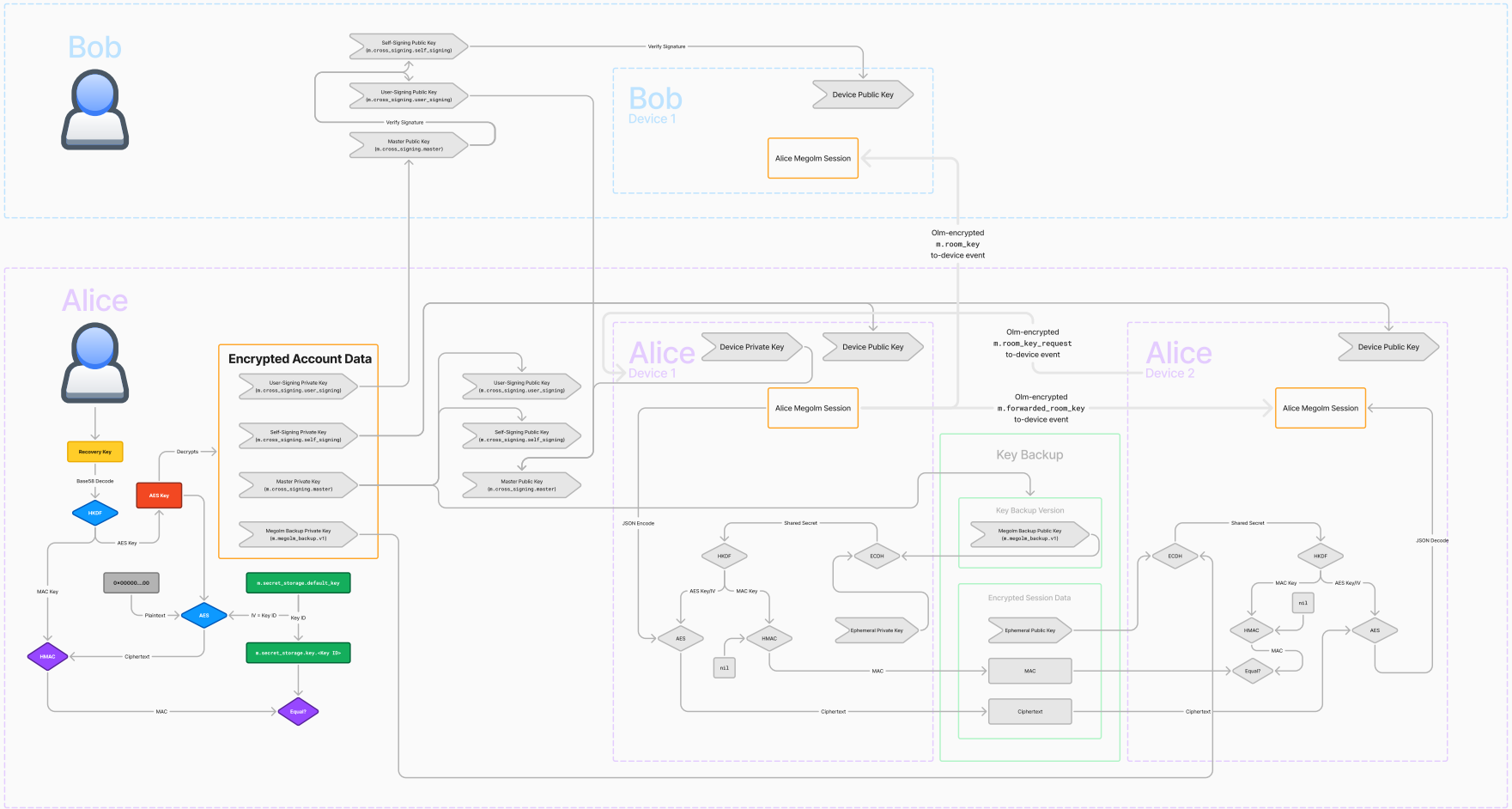
Big Picture: The Other Stuff: To-Device



Big Picture: The Other Stuff: Key Backup



Big Picture: The Other Stuff: Secure Secret Storage and Sharing



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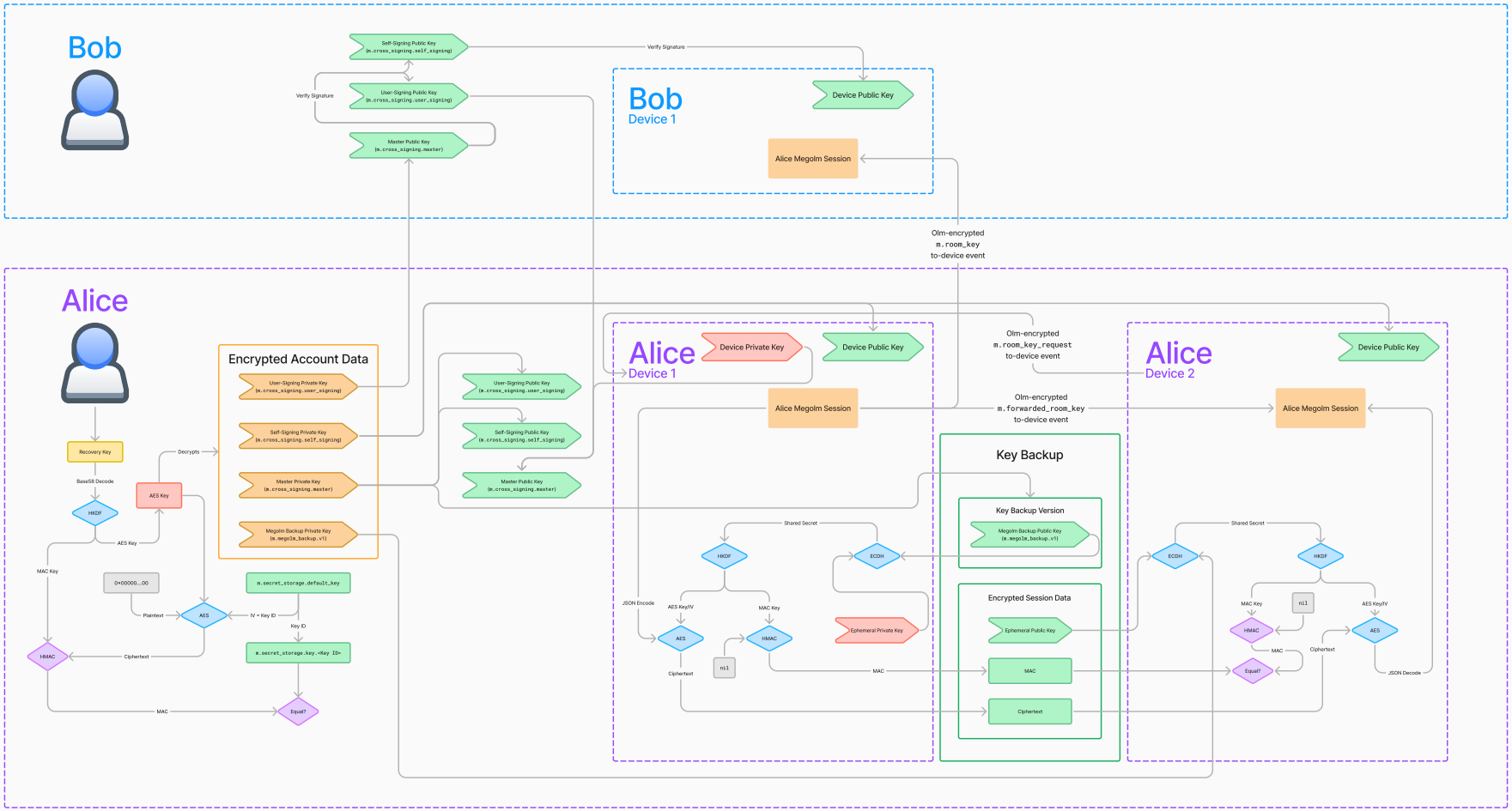
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Cryptography Crash Course

Encryption: Symmetric vs Asymmetric

There are two main categories of encryption schemes:

- **Symmetric** — both **the encryptor and the decryptor share the same key** and that key is used in both the encryption and decryption of the message
- **Asymmetric** — **the encryptor needs the public key, and the decryptor needs the private key** and the encryptor encrypts the message with the public key, and the private key is required to decrypt the message

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Asymmetric Signatures

In addition to providing encryption, asymmetric encryption schemes also provide **signatures**.

Signing uses the *private* key, and anyone who possesses the *public* key can verify the signature.

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Hashes and HMAC

A **cryptographic hash function** is a one-directional function which takes an arbitrarily large set of data and produces a unique fixed-size output (called the hash).

Given the same data, a hash function will always return the same output.

This allows us to verify that the data did not change in transit (for example, by a malicious actor).

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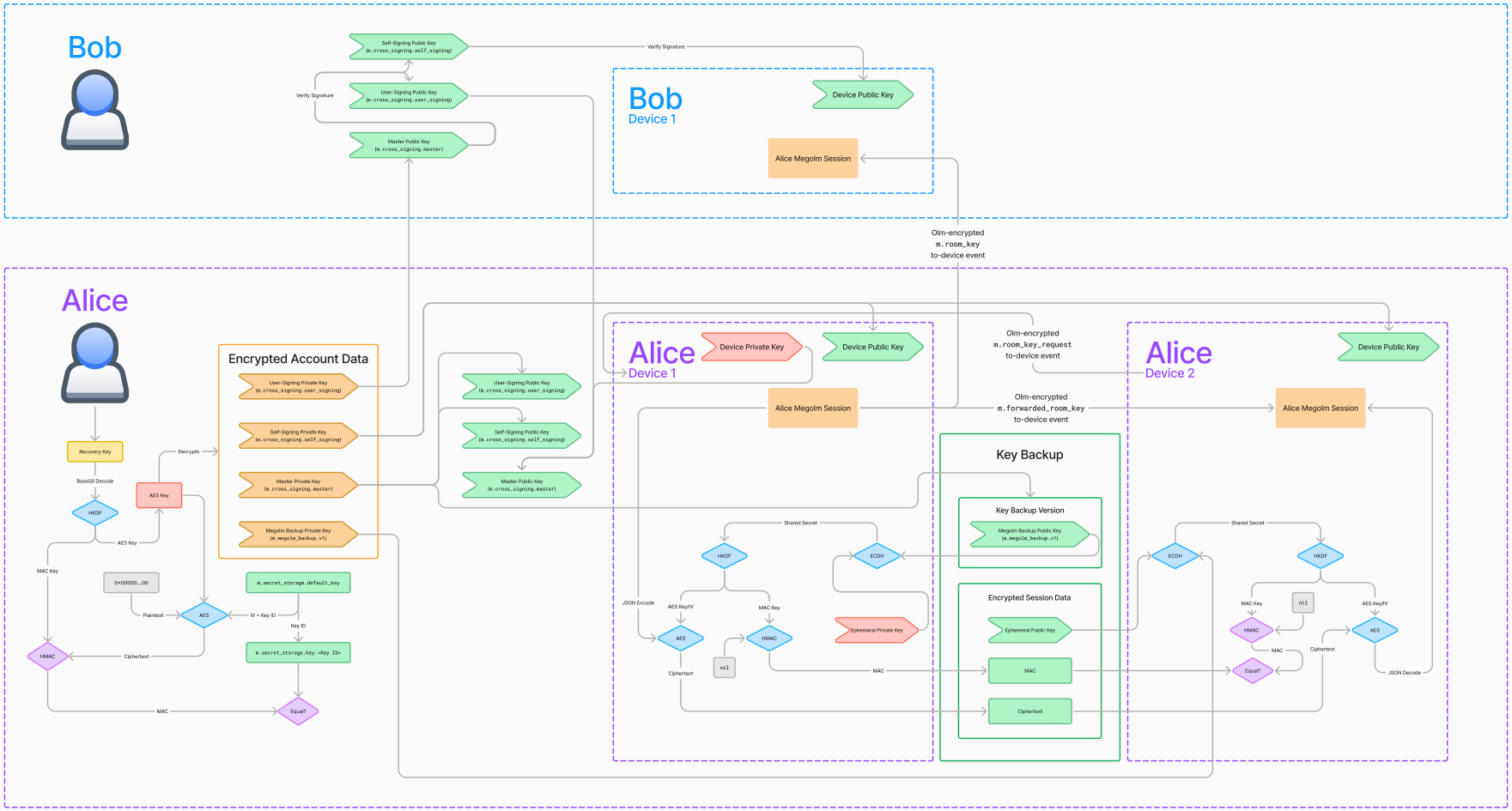
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Sharing Keys

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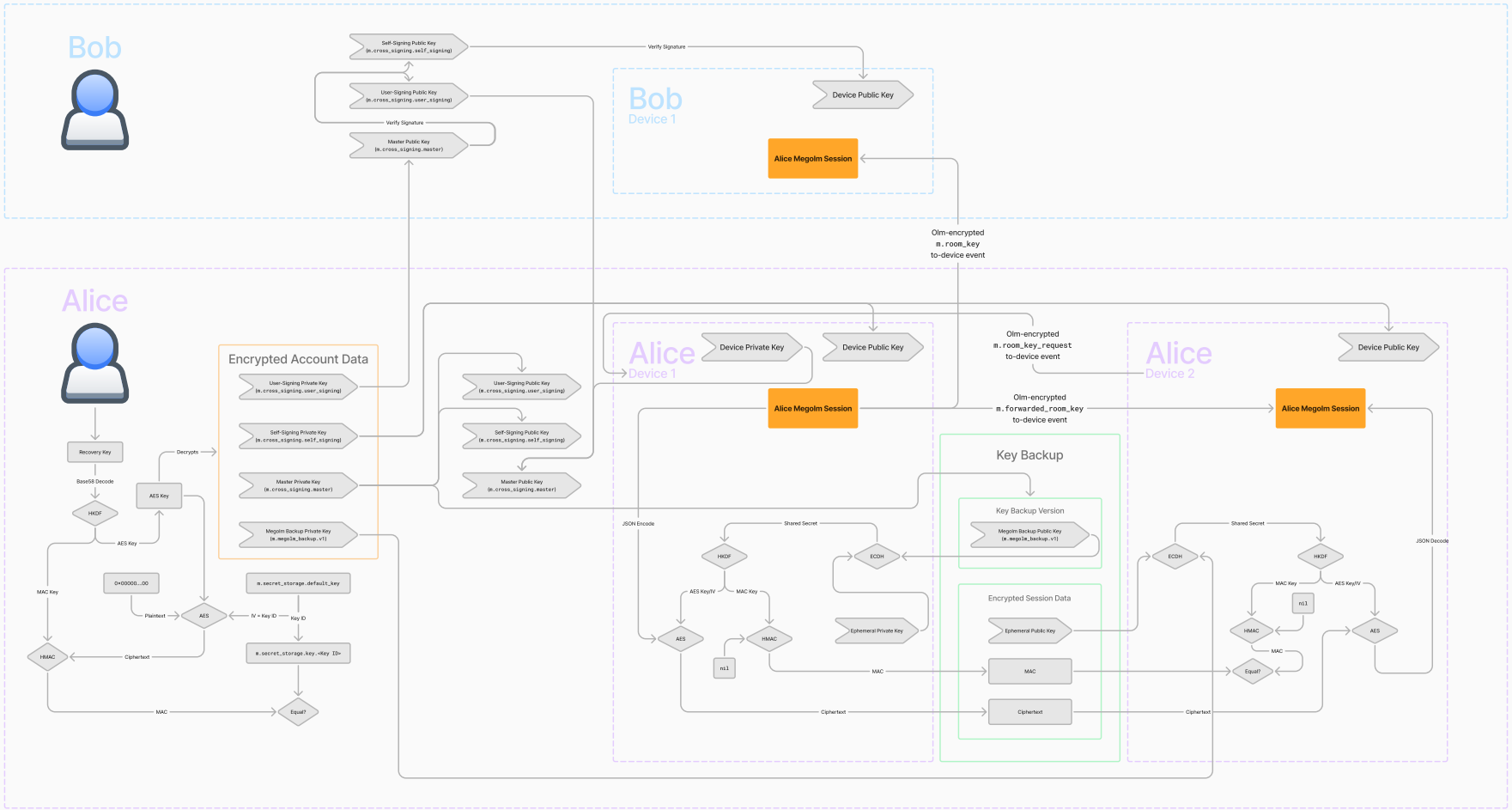
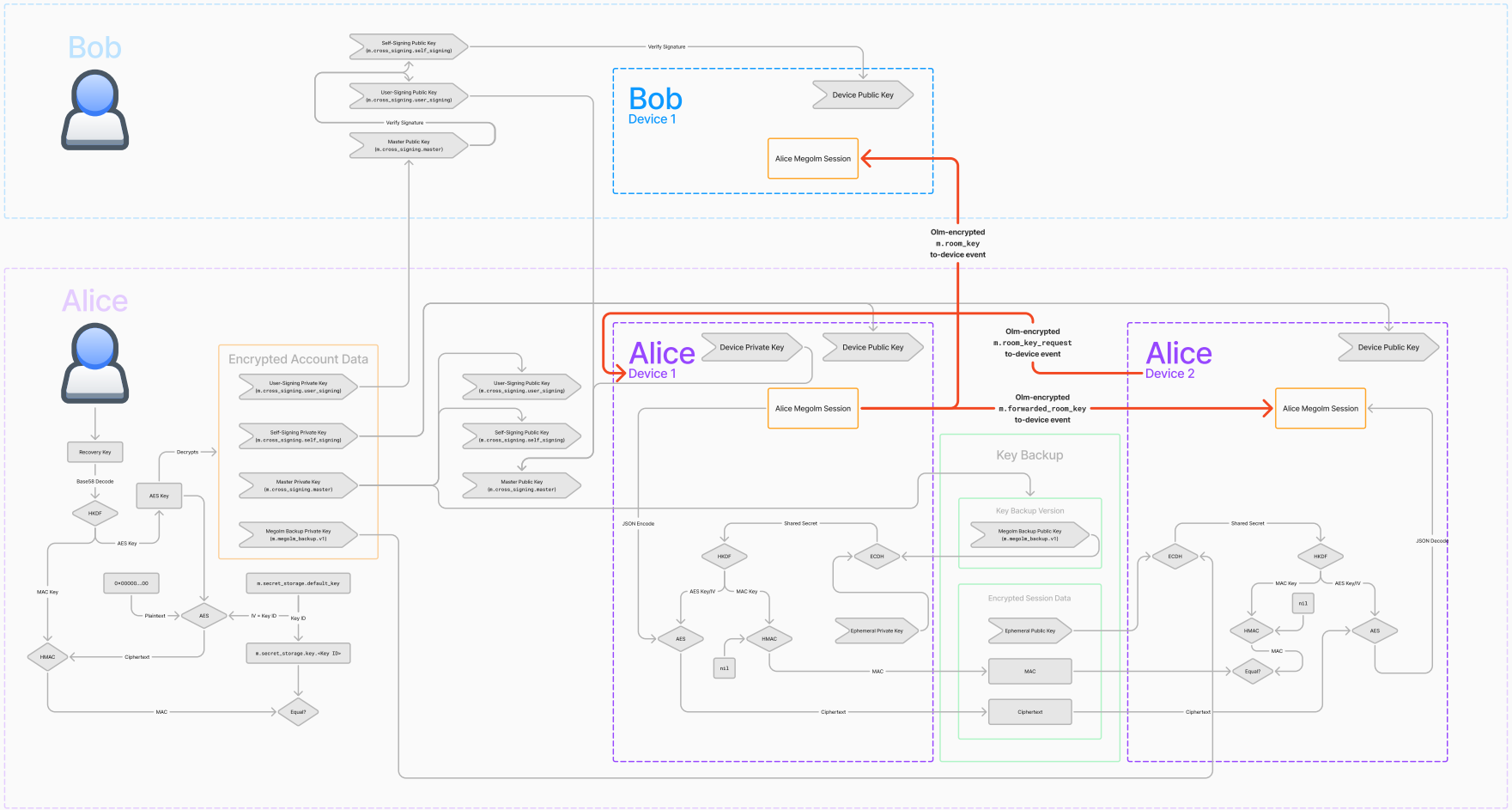


Encrypted Olm Events



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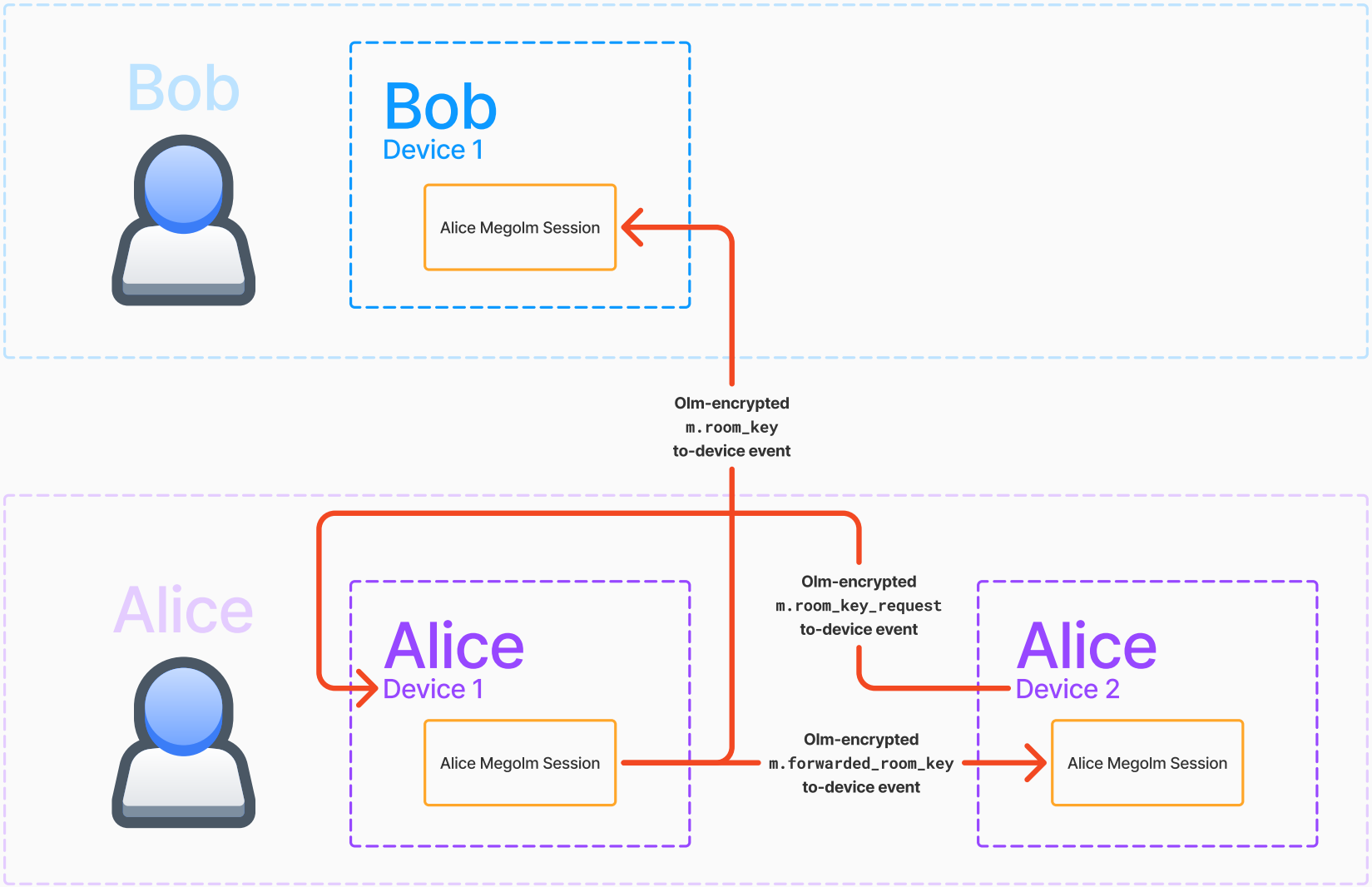

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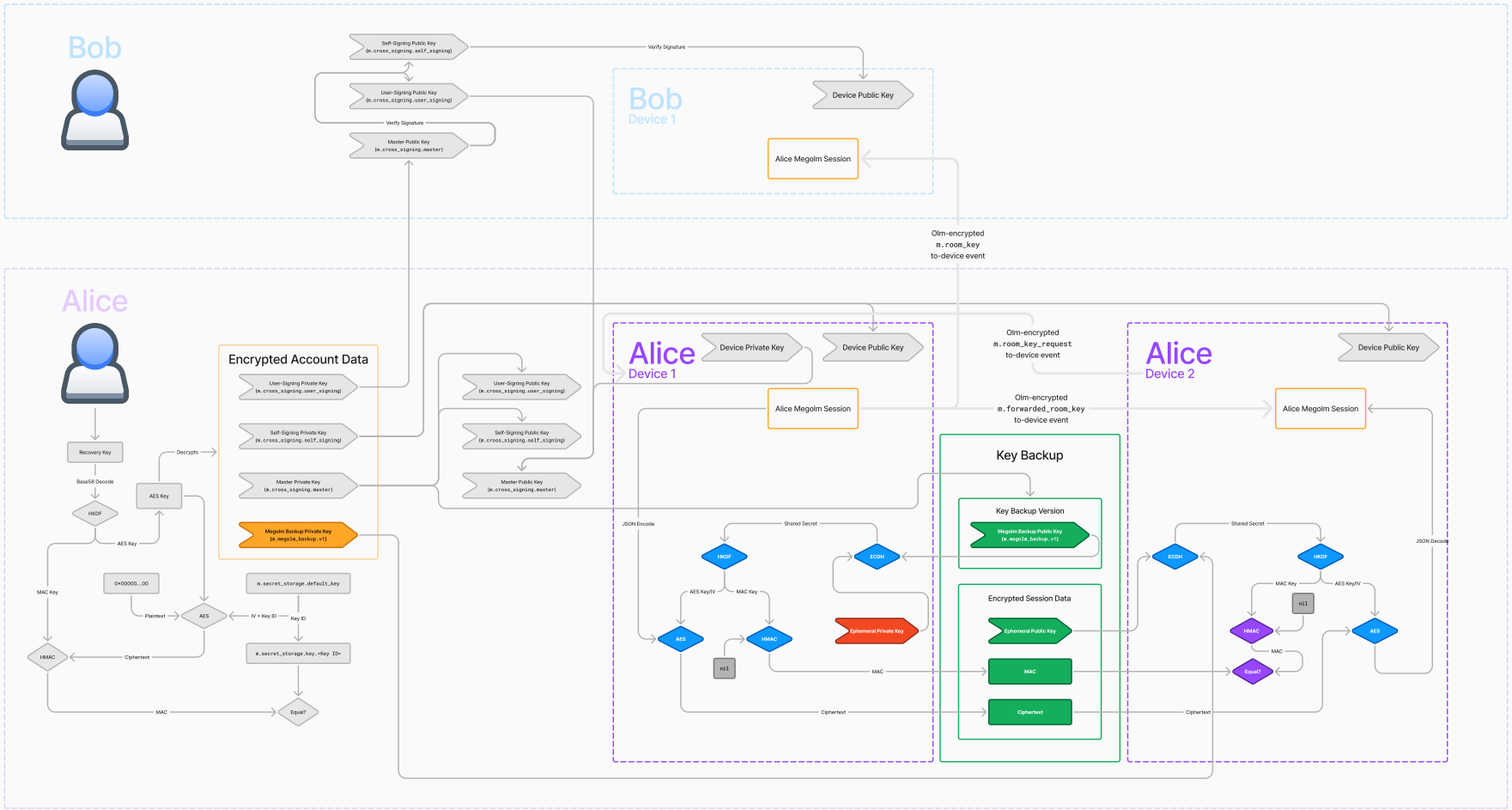
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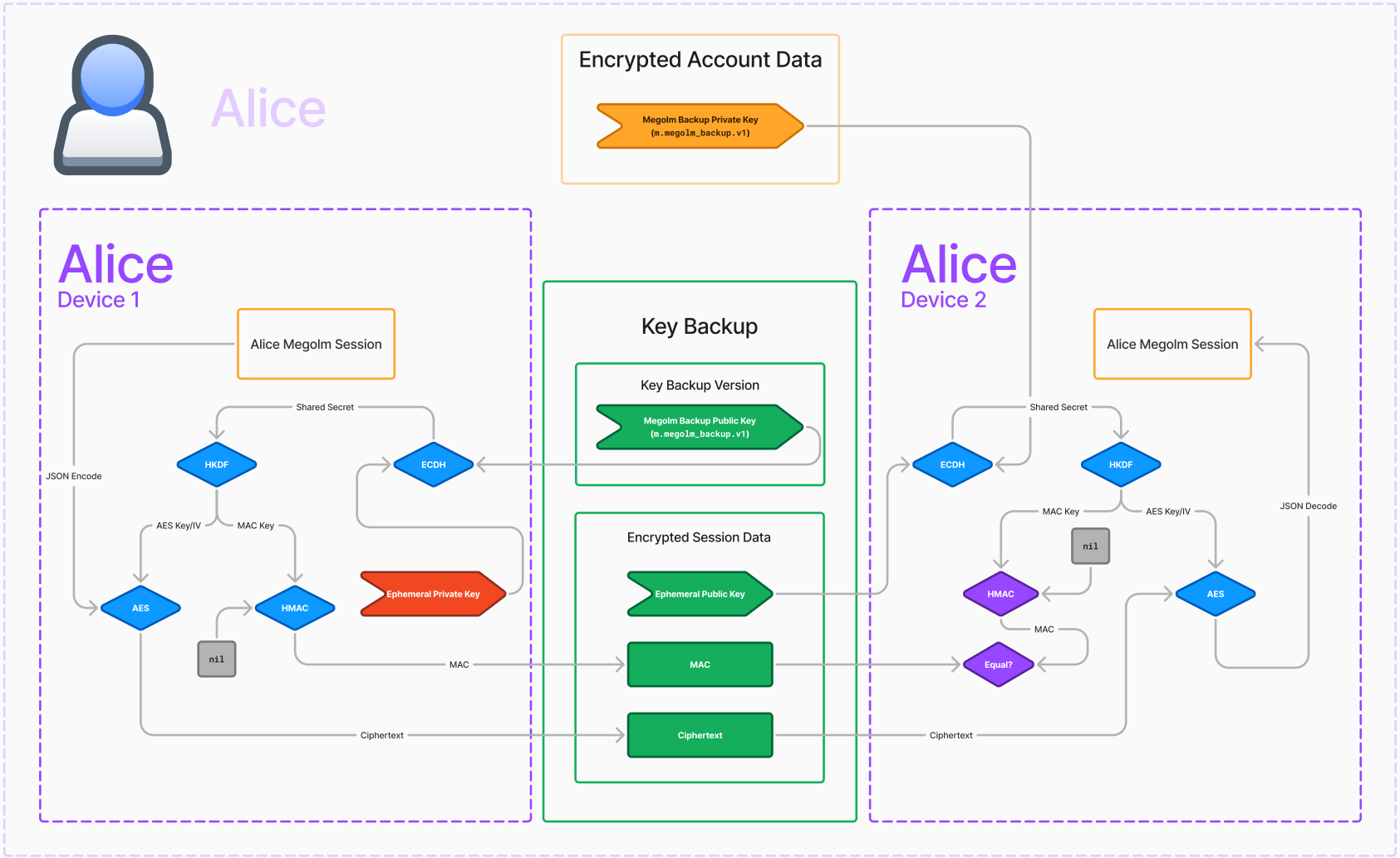
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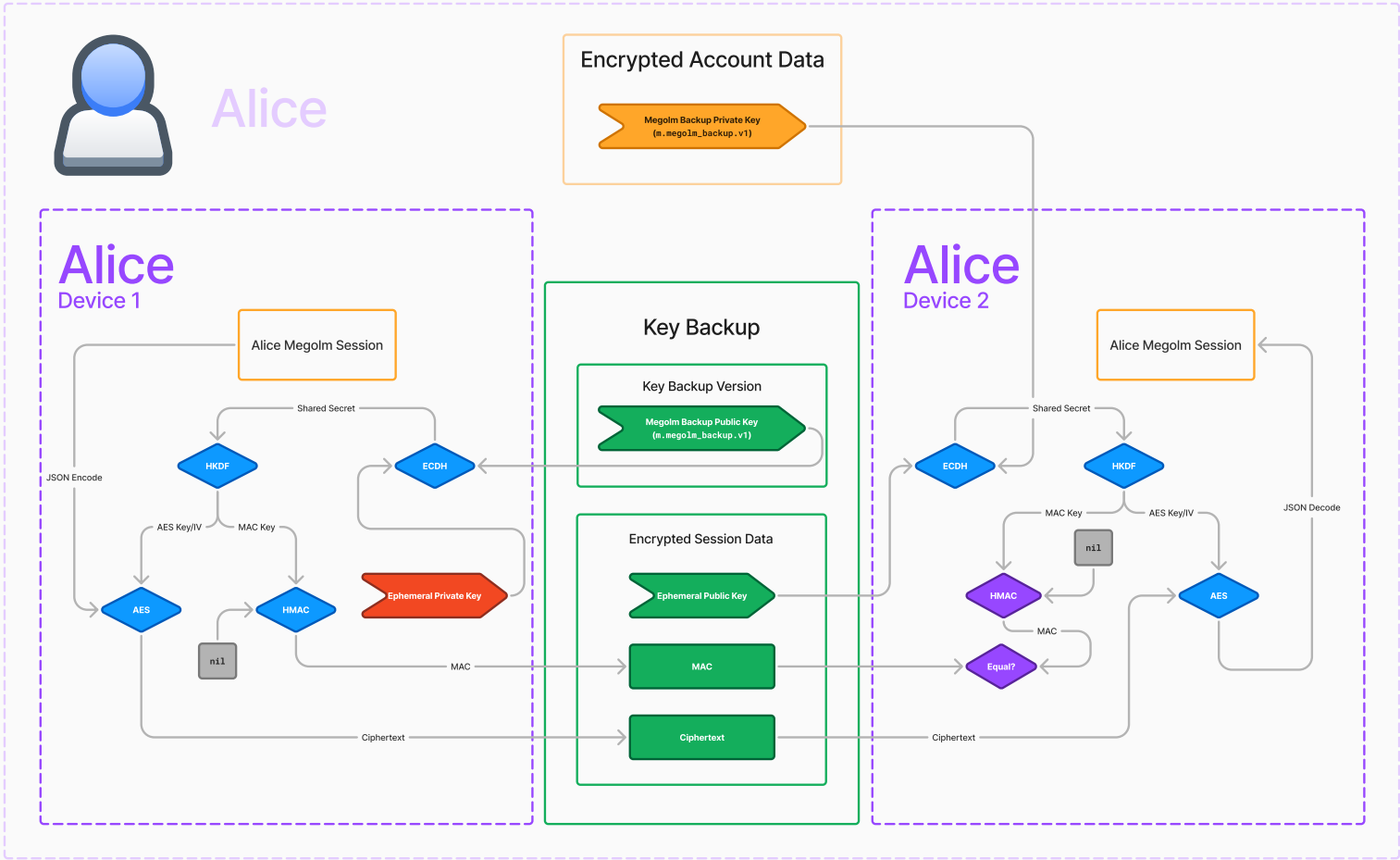

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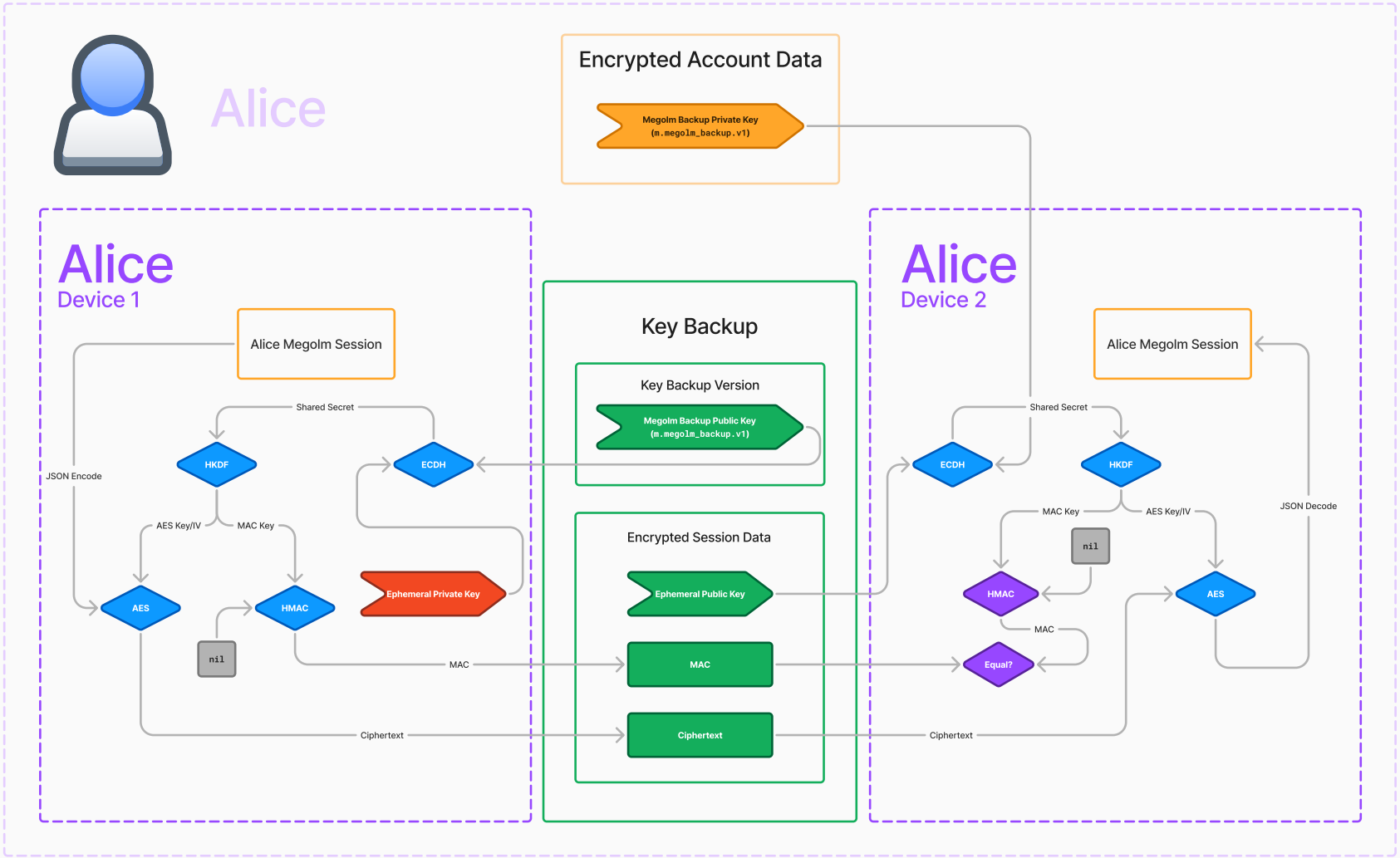
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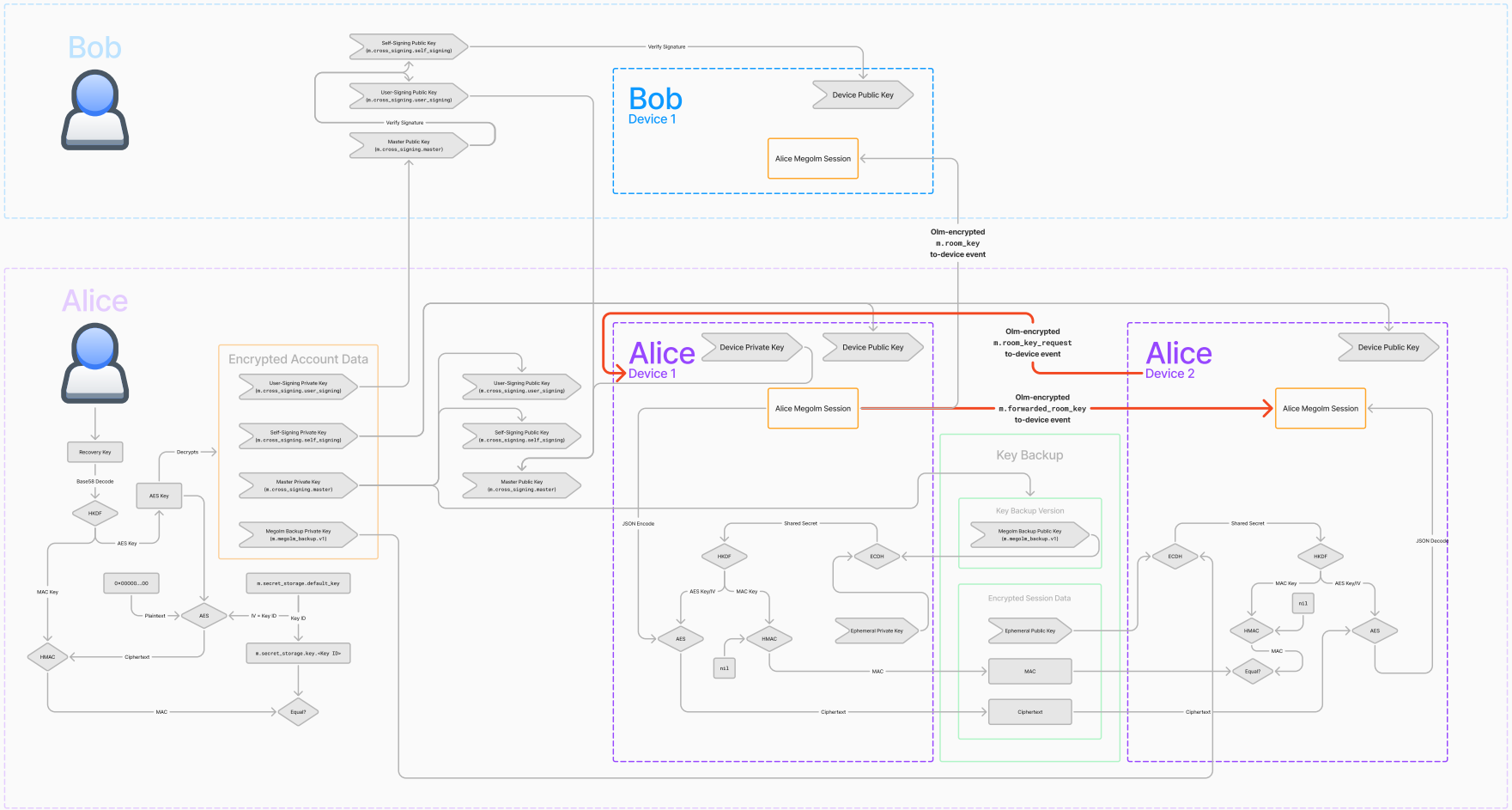
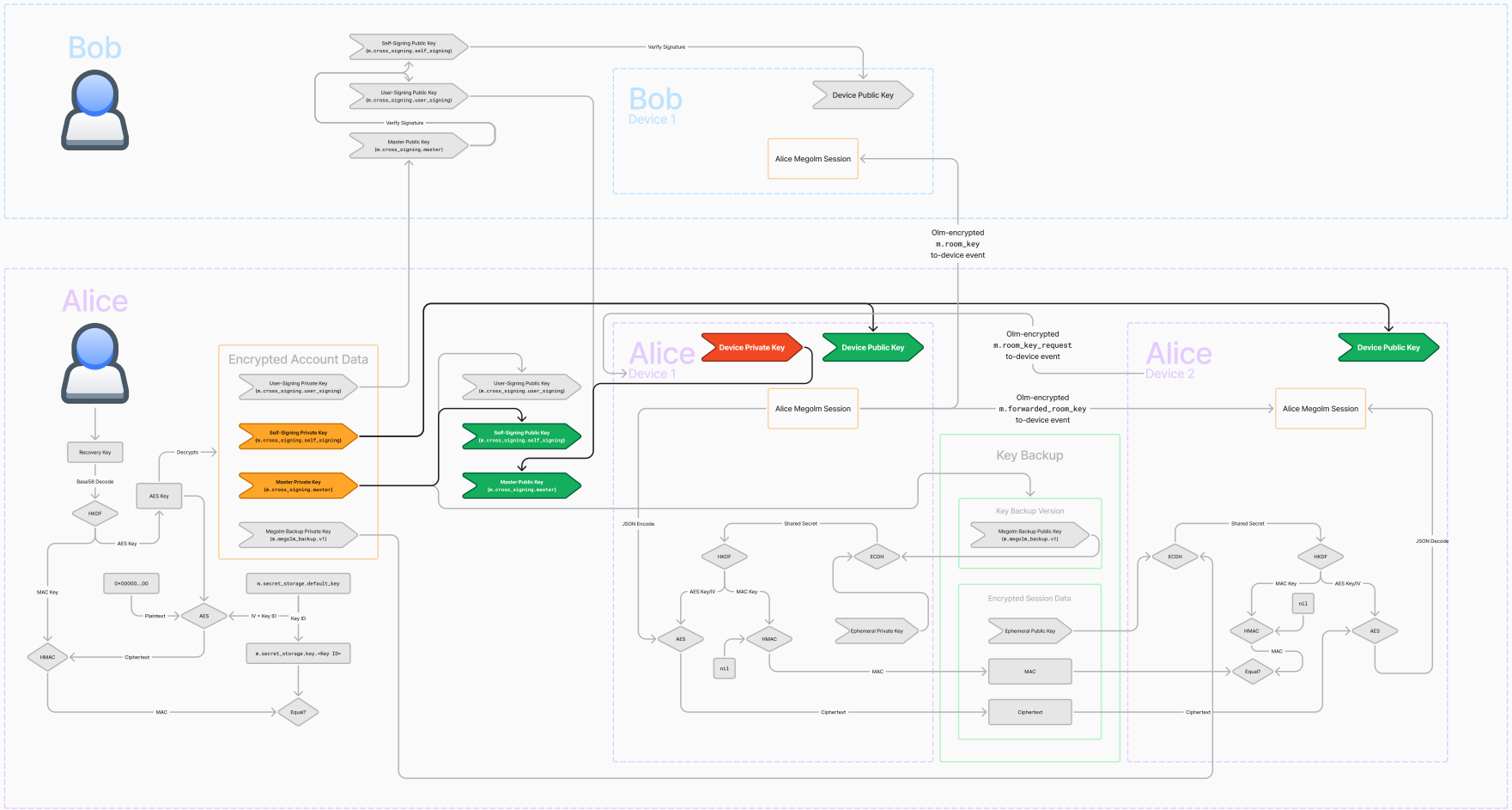
Device Verification

Who Can We Send Keys To?



Signatures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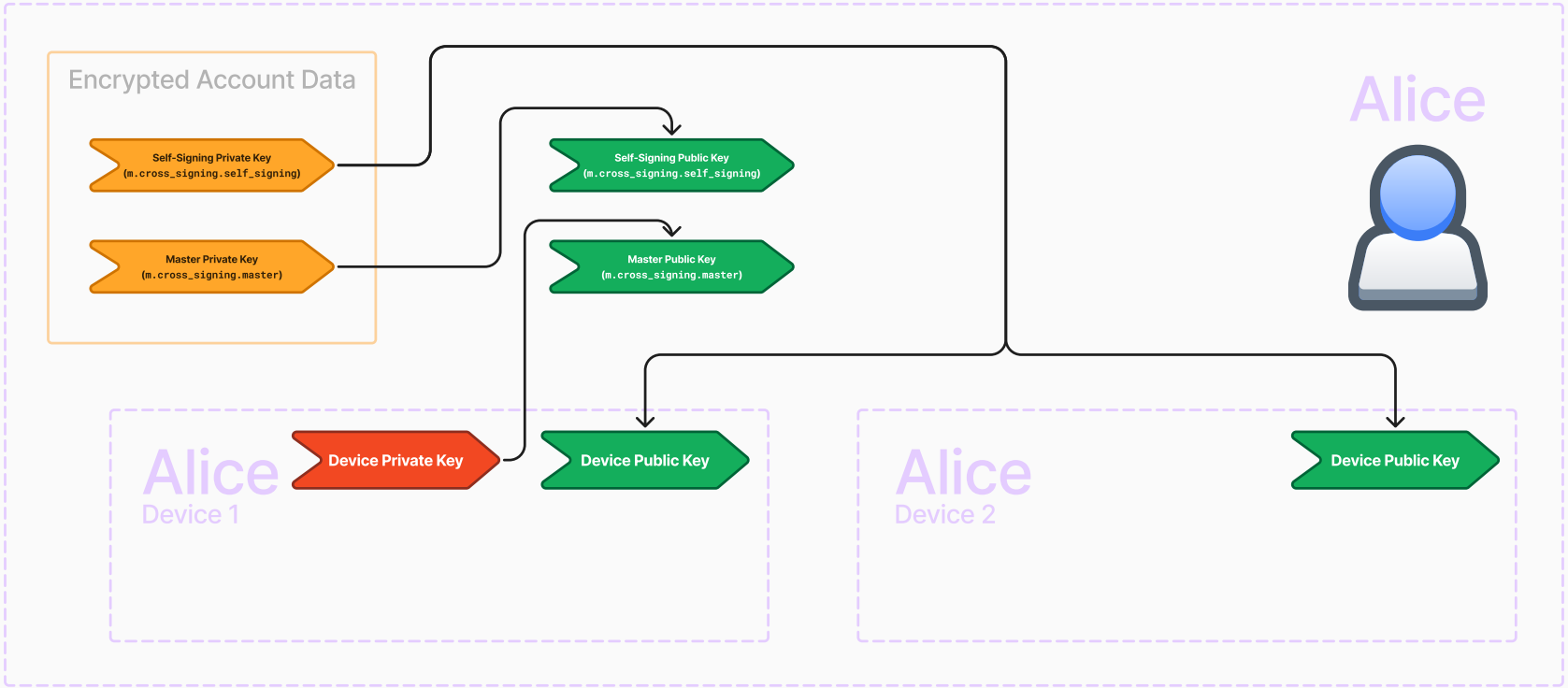
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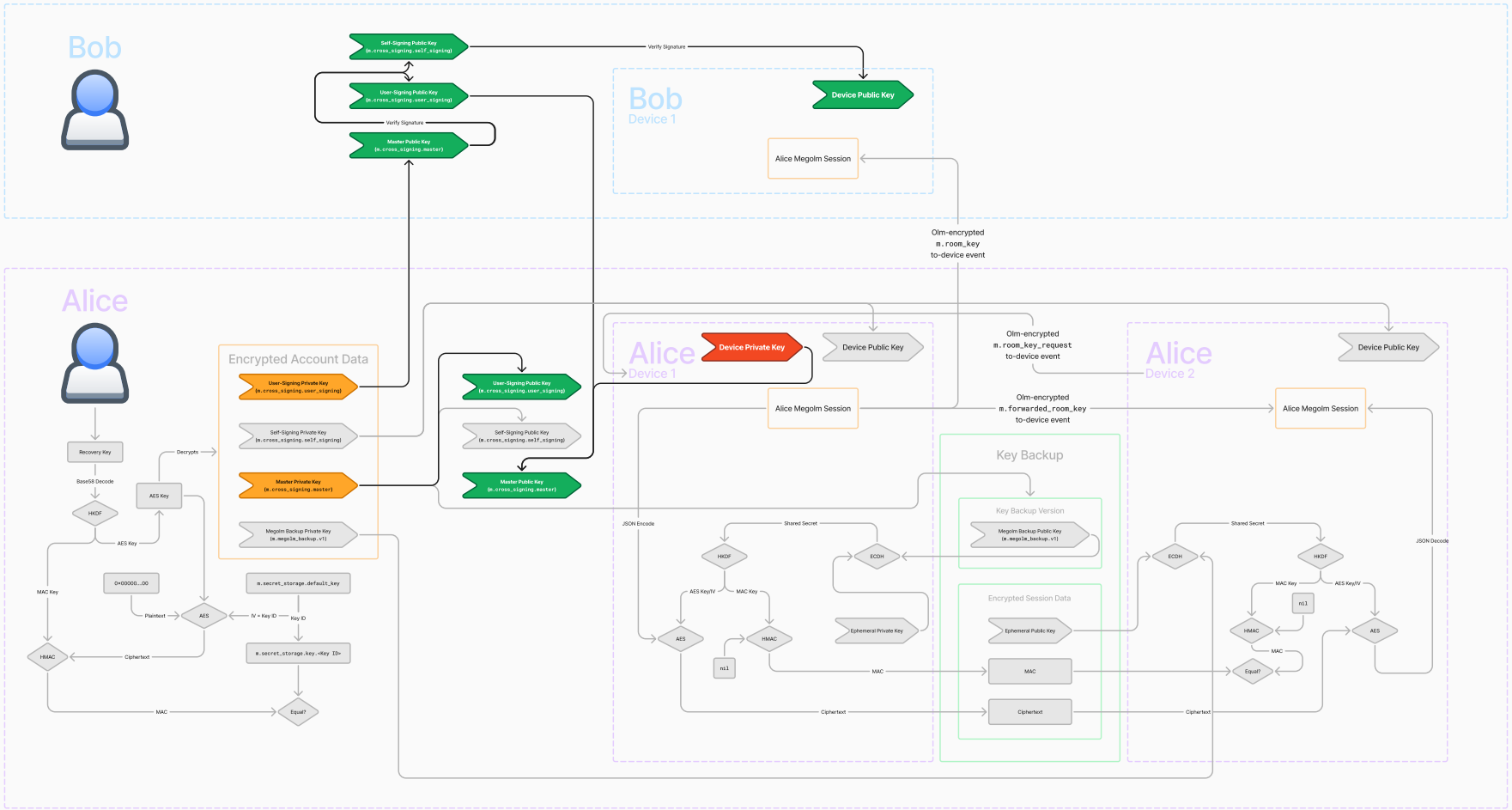
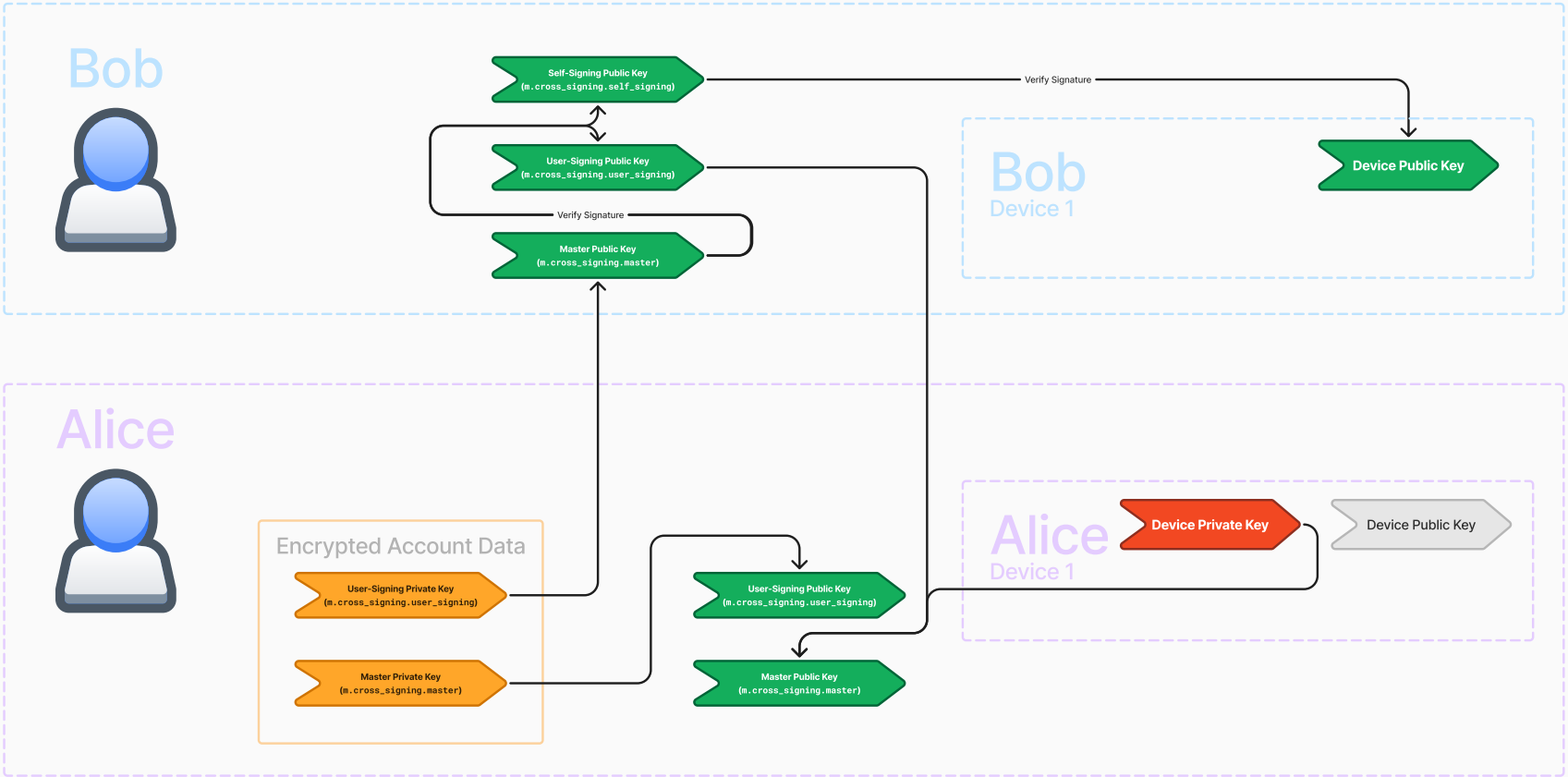
Device Private Key
Device Public Key
Alice
Device 2
Device Public Key

User Verification

Additional Identity Verification

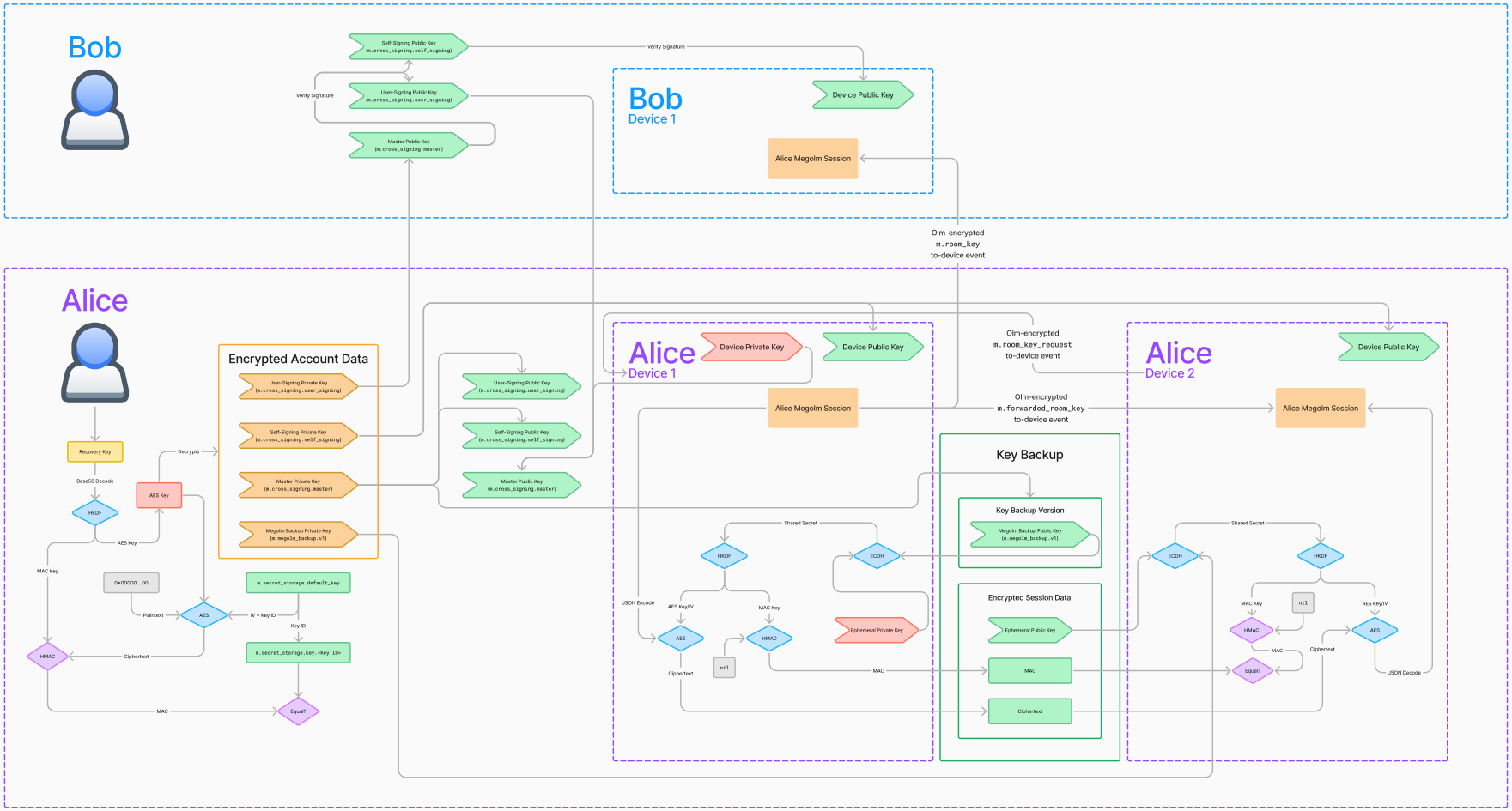


Additional Identity Verification

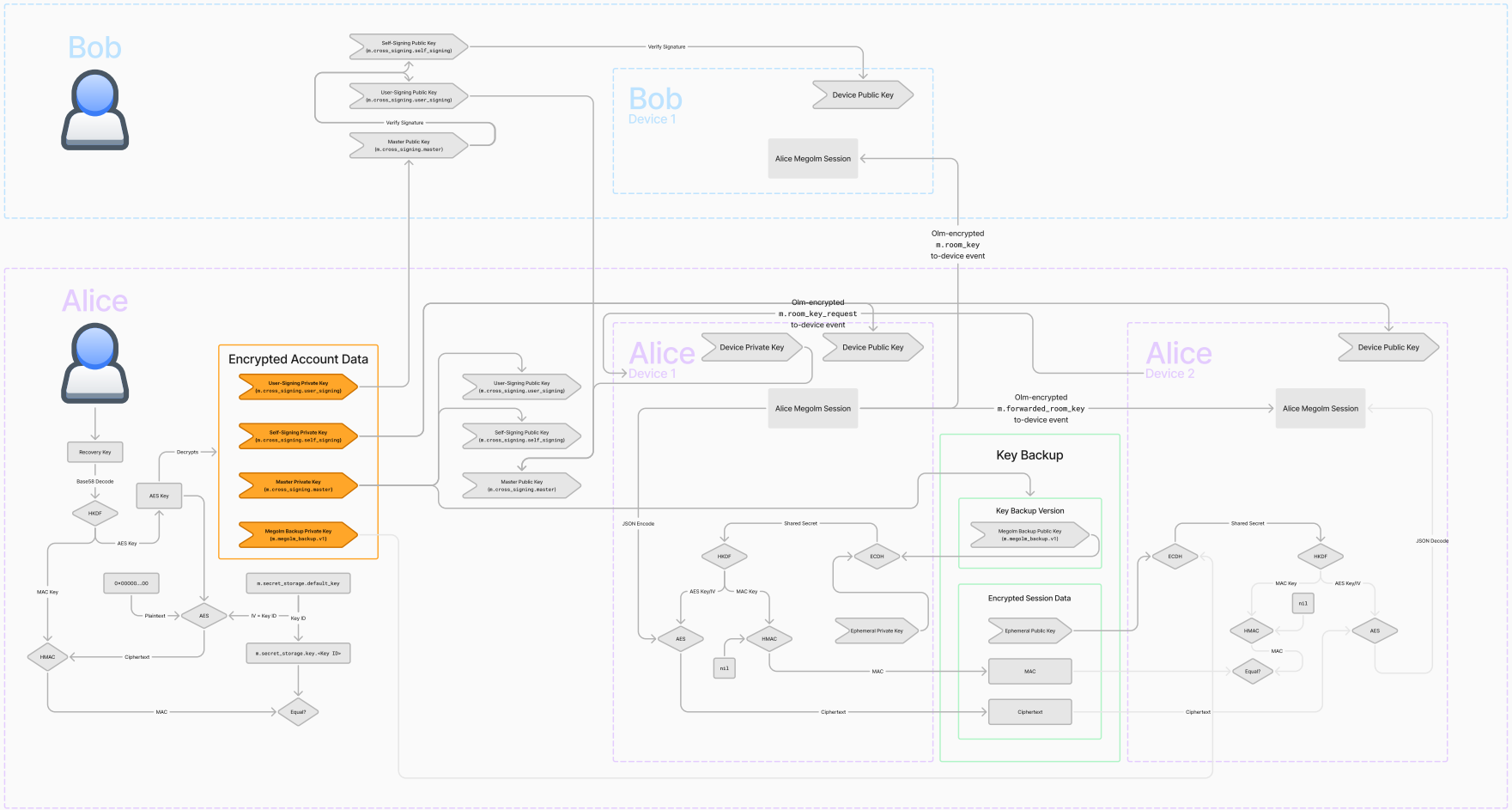


Secure Secret Storage and Sharing (SSSS)

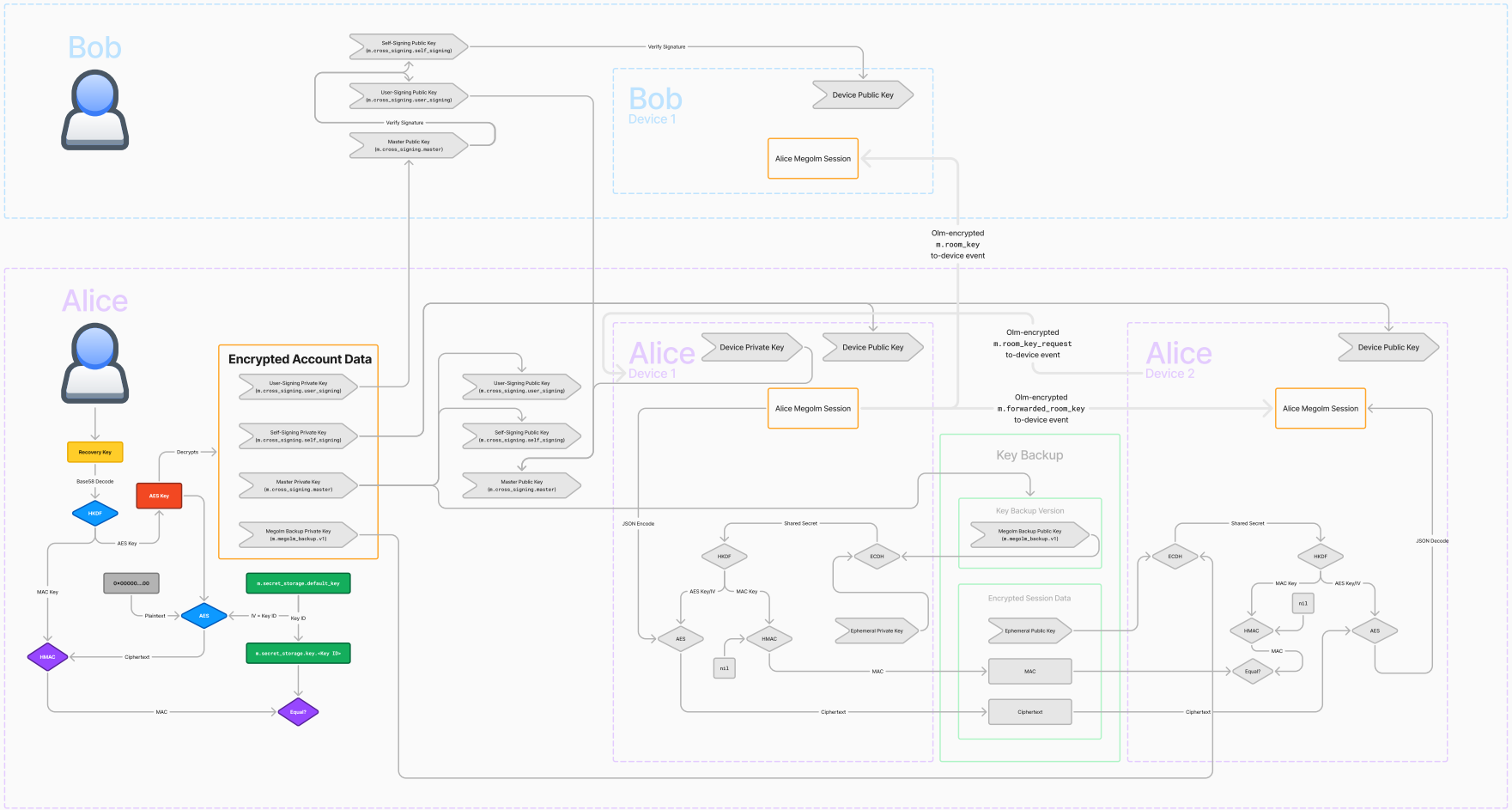
Don’t Forget Your Keys



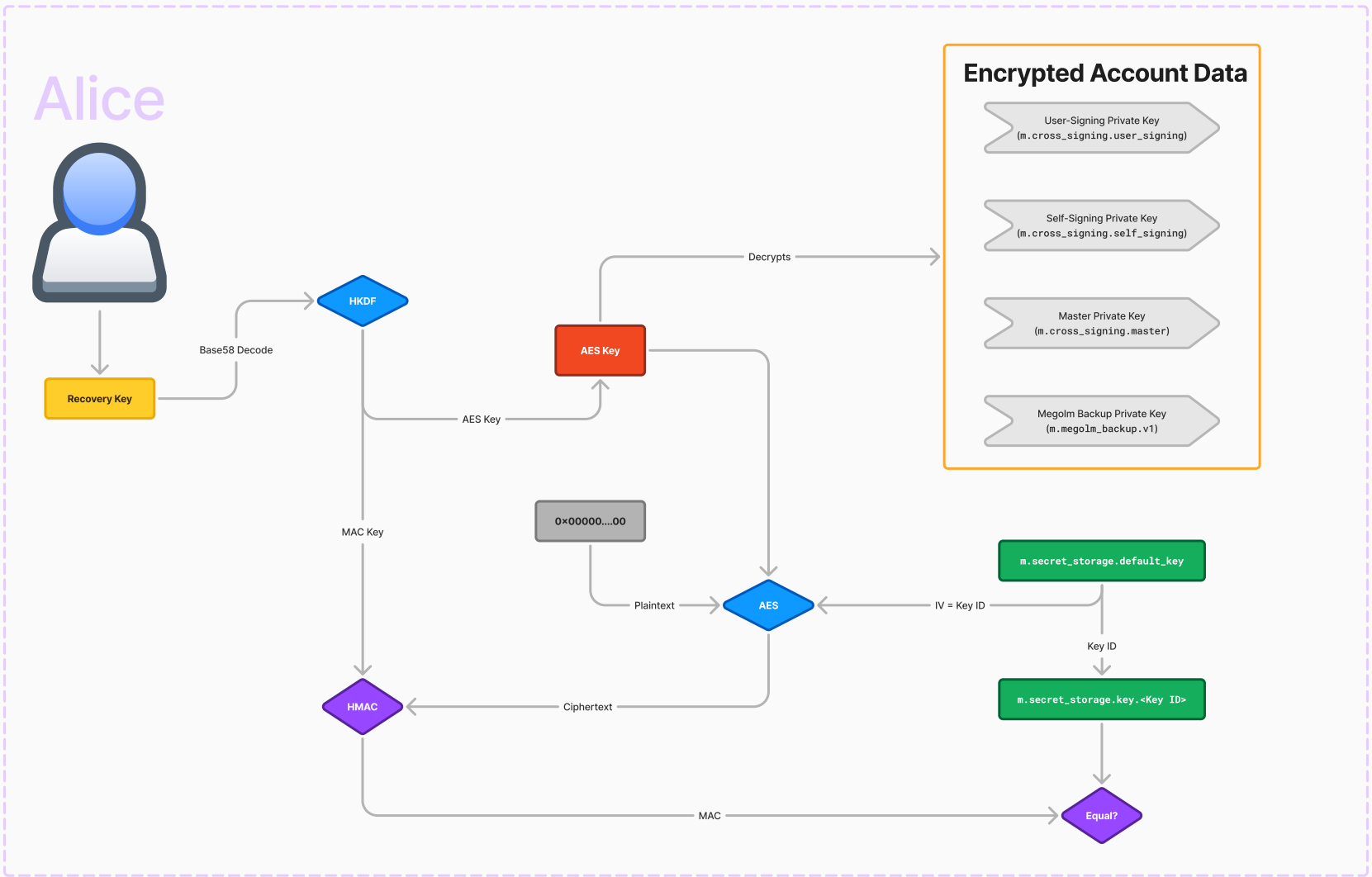
Don’t Forget Your Keys



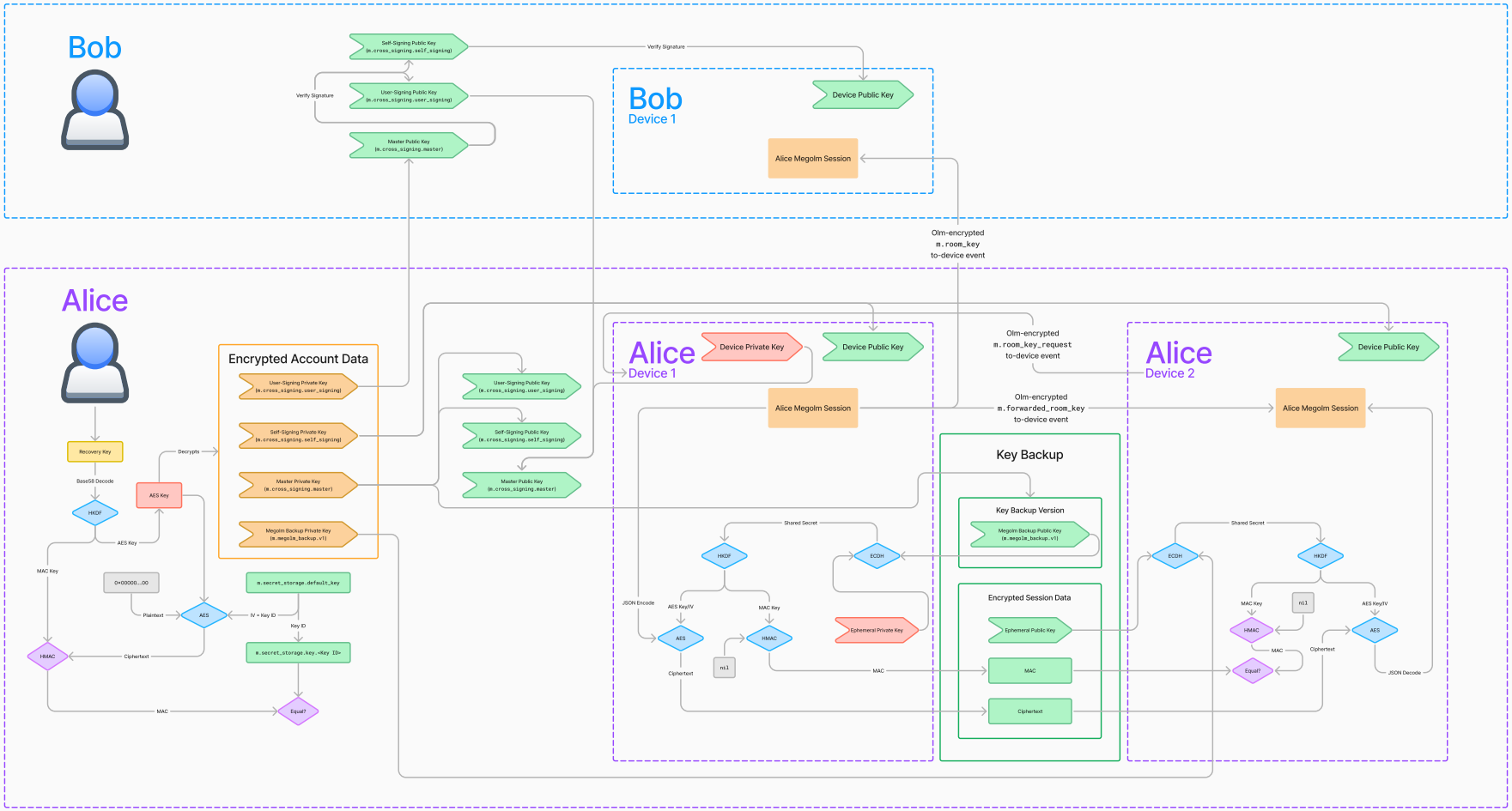
Don’t Forget Your Keys



Don’t Forget Your Keys



Big Picture


Bob
Self-Signing Public Key
(m.cross_signing.self_signing)
Verify Signature
User-Signing Public Key
(m.cross_signing.user_signing)
Verify Signature
Master Public Key
(m.cross_signing.master)
Bob
Device 1
Device Public Key
Alice Megolm Session
Olm-encrypted
m.room_key
to-device event
Alice
Encrypted Account Data
User-Signing Private Key
(m.cross_signing.user_signing)
Self-Signing Private Key
(m.cross_signing.self_signing)
Master Private Key
(m.cross_signing.master)
Megolm Backup Private Key
(m.megolm_backup.v1)
Recovery Key
Decrypts
Base58 Decode
HKDF
AES Key
AES Key
MAC Key
0x00000...00
Plaintext
AES
IV = Key ID
Key ID
m.secret_storage.default_key
m.secret_storage.key.<Key ID>
HMAC
Ciphertext
MAC
Equal?
User-Signing Public Key
(m.cross_signing.user_signing)
Self-Signing Public Key
(m.cross_signing.self_signing)
Master Public Key
(m.cross_signing.master)
Alice
Device 1
Device Private Key
Device Public Key
Alice Megolm Session
Olm-encrypted
m.room_key_request
to-device event
Olm-encrypted
m.forwarded_room_key
to-device event
Alice
Device 2
Device Public Key
Alice Megolm Session
Key Backup
Key Backup Version
Megolm Backup Public Key
(m.megolm_backup.v1)
Encrypted Session Data
Ephemeral Public Key
MAC
Ciphertext
Shared Secret
HKDF
ECDH
JSON Encode
AES Key/IV
MAC Key
AES
HMAC
nil
Ciphertext
Ephemeral Private Key
MAC
Shared Secret
ECDH
HKDF
MAC Key
nil
AES Key/IV
HMAC
AES
MAC
Ciphertext
Equal?
JSON Decode

Thank You for Listening!

Questions?

sumnerevans.com/posts/matrix/cryptographic-key-infrastructure