Cryptography Engineering

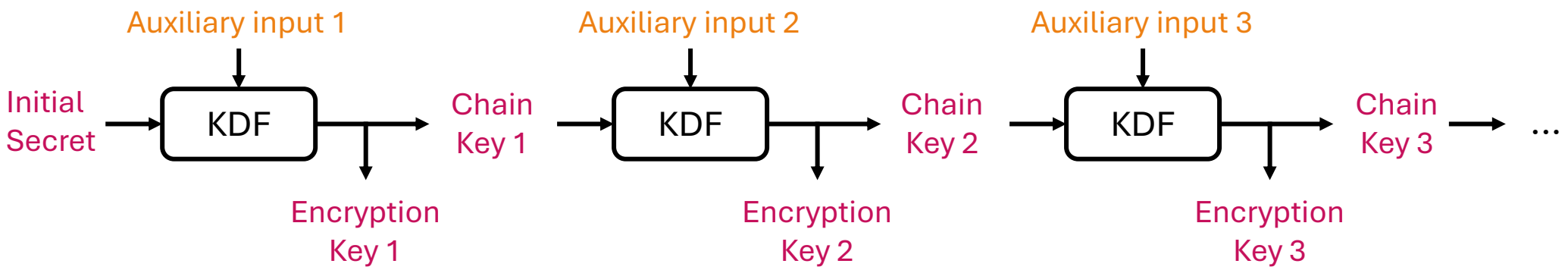
- Lecture 5 (Nov 20, 2024)

- Today's notes:
  - Symmetric-key Ratchet (Continue)
  - Forward/Backward Secrecy
  - Diffie-Hellman Ratchet

- No homework

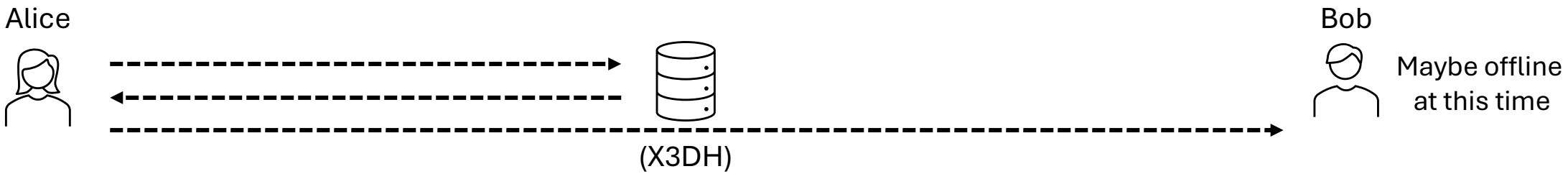
Symmetric-key Ratchet

- KDF chain
  - KDF: Key derivation function



Symmetric-key Ratchet

- A toy example of instant messaging using symmetric-key ratchet



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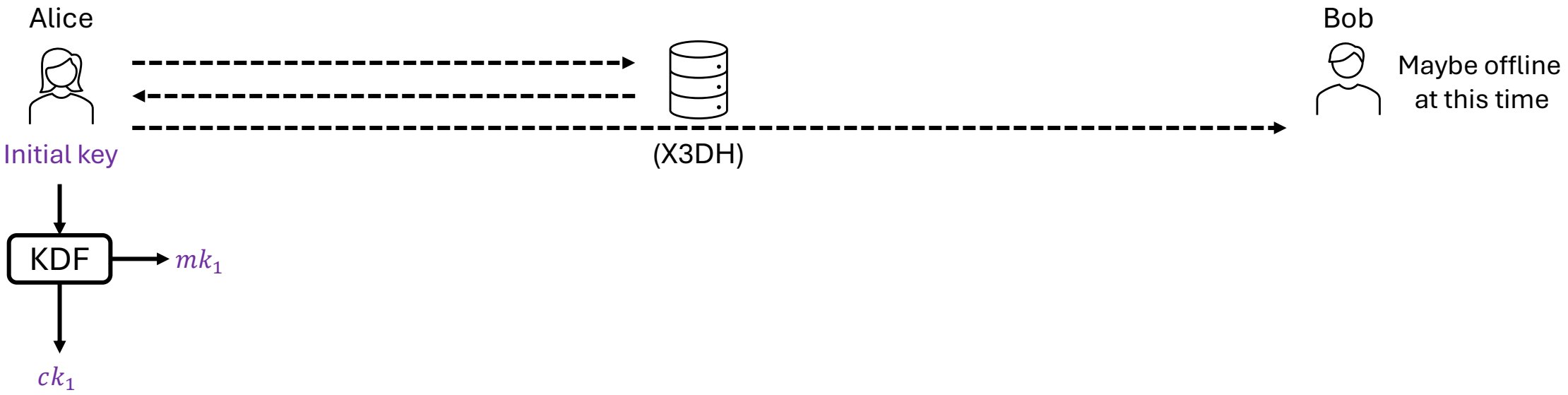

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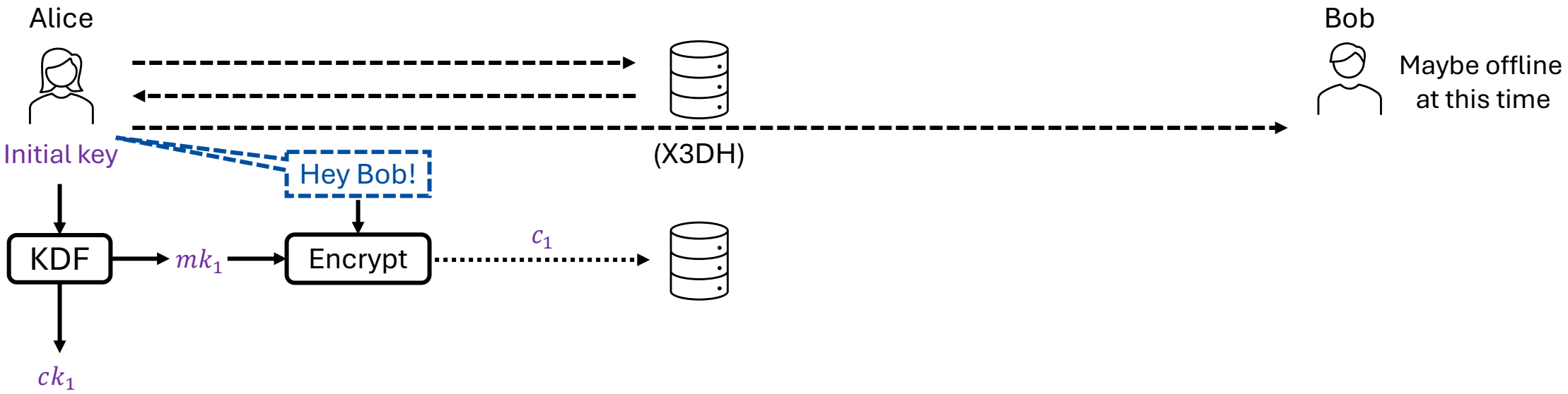

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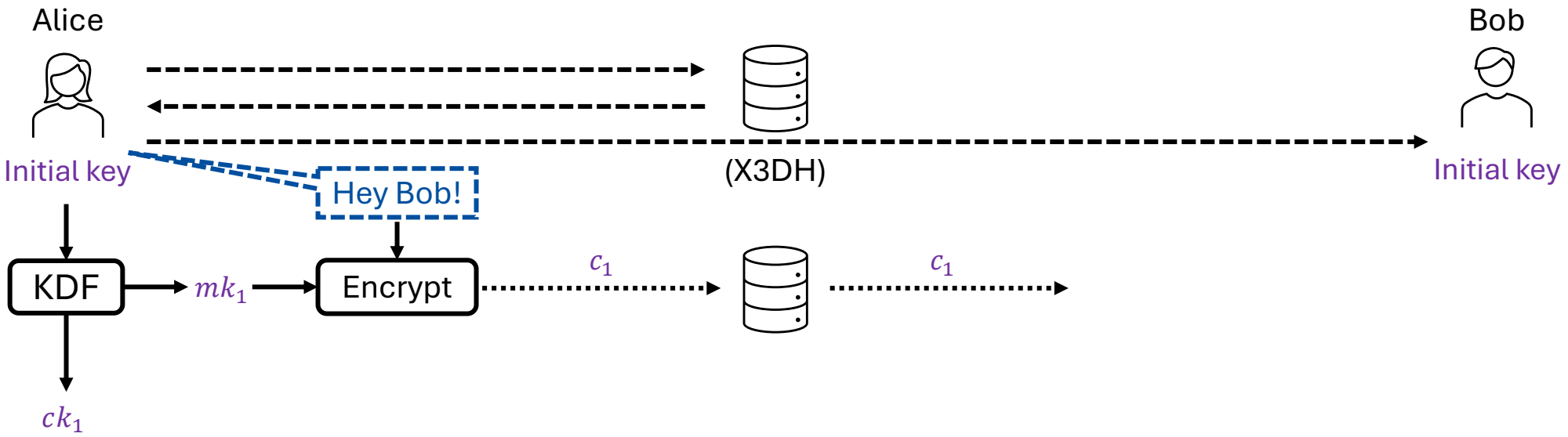

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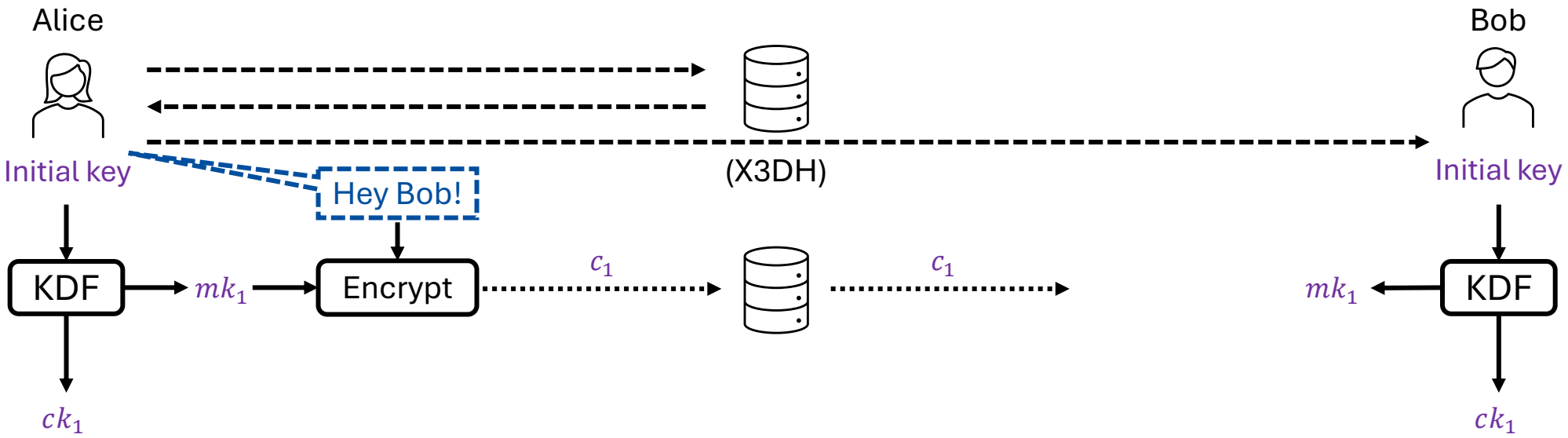

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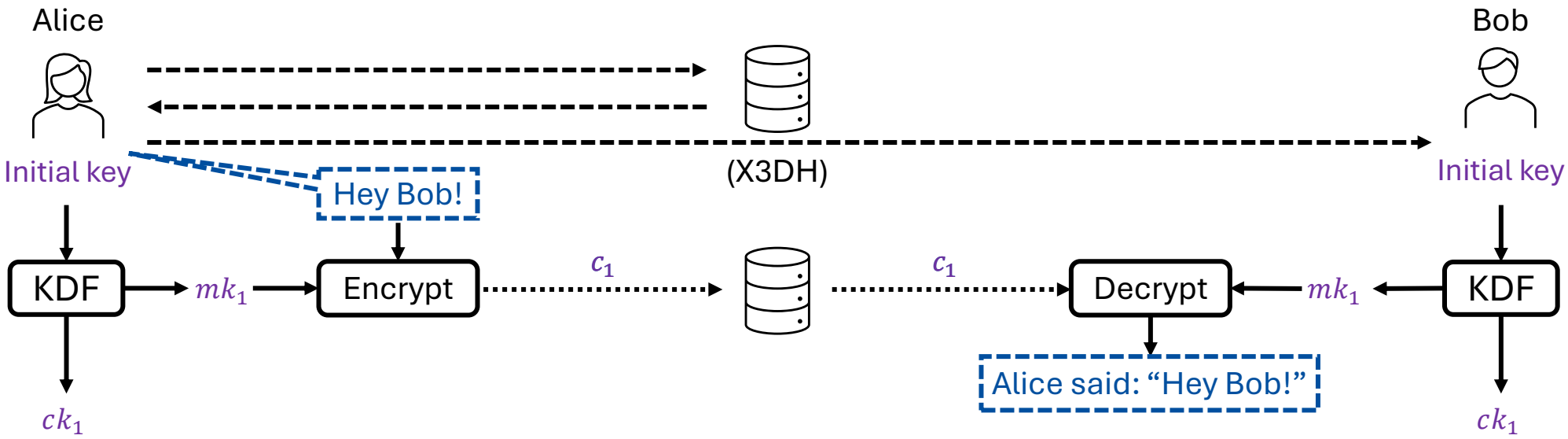

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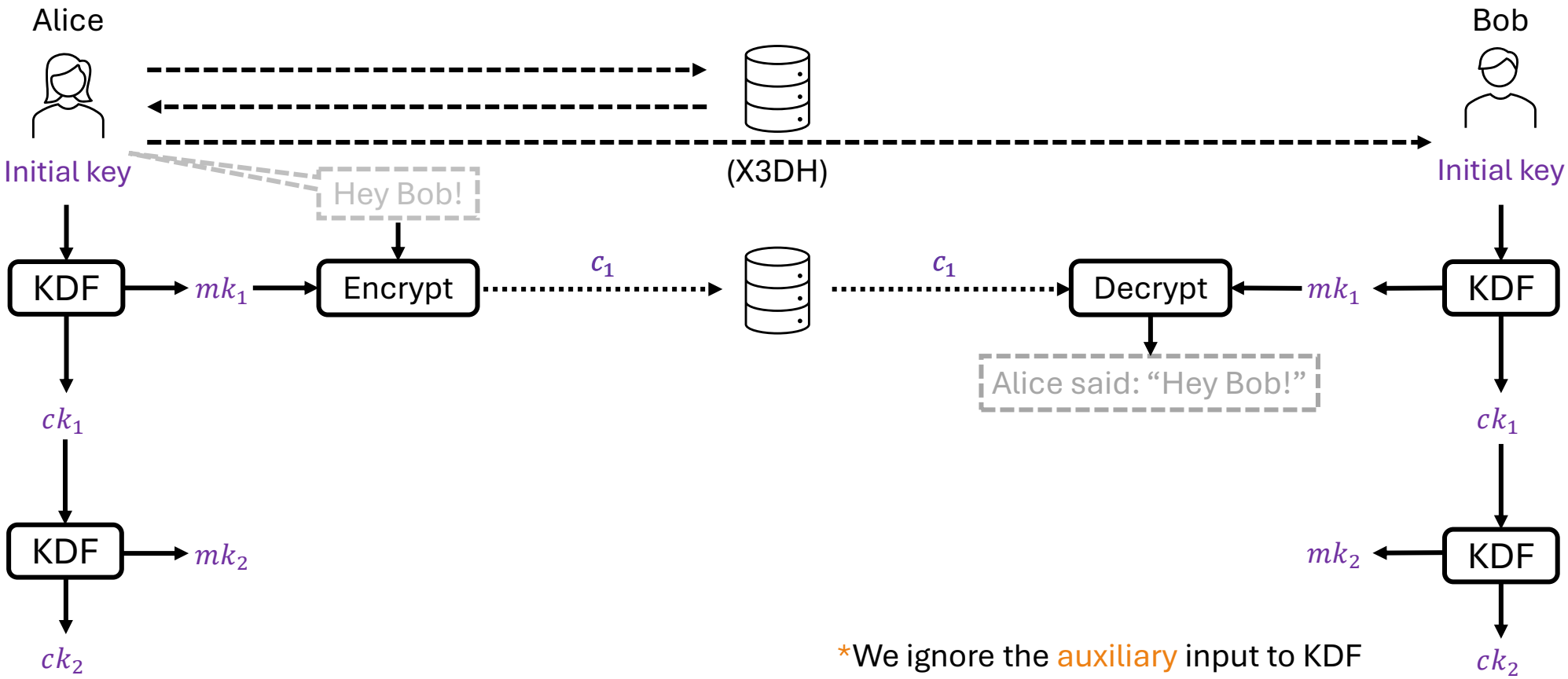

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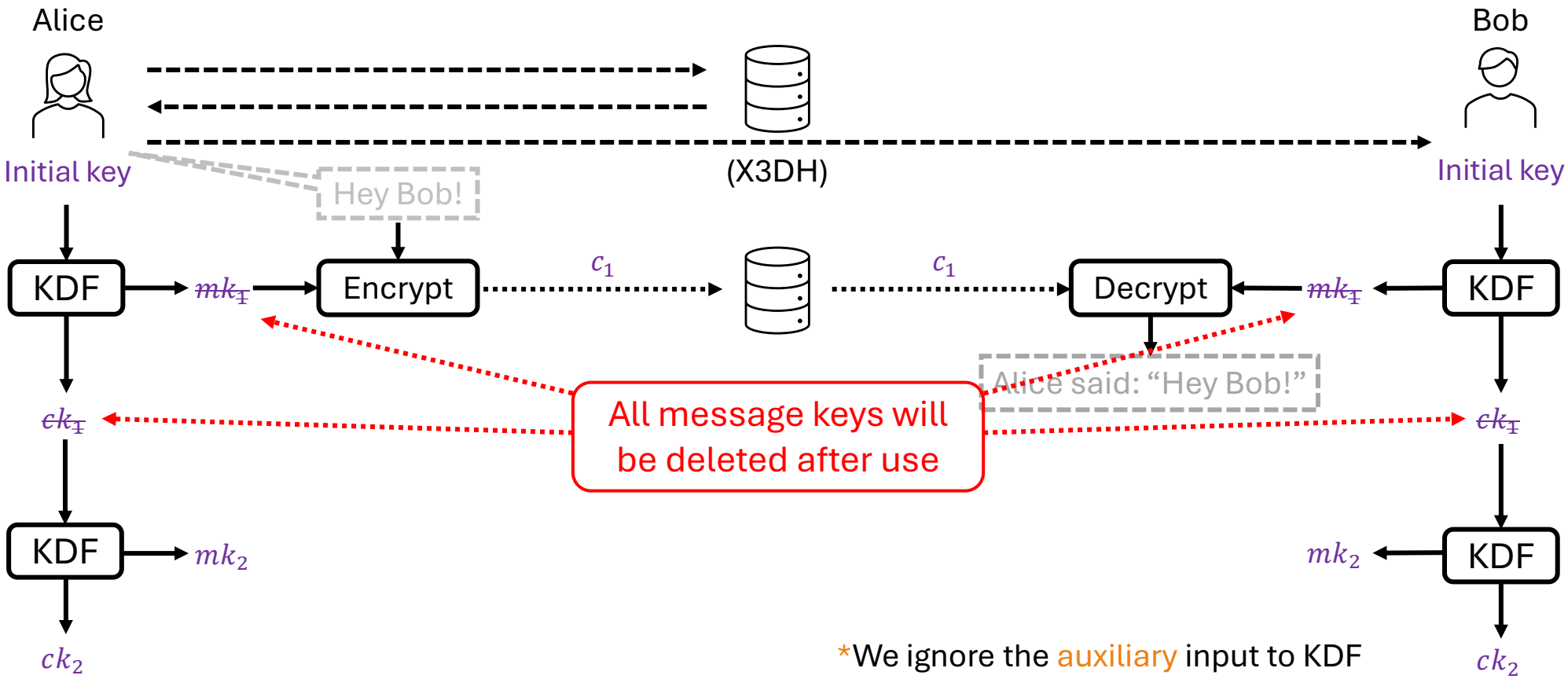

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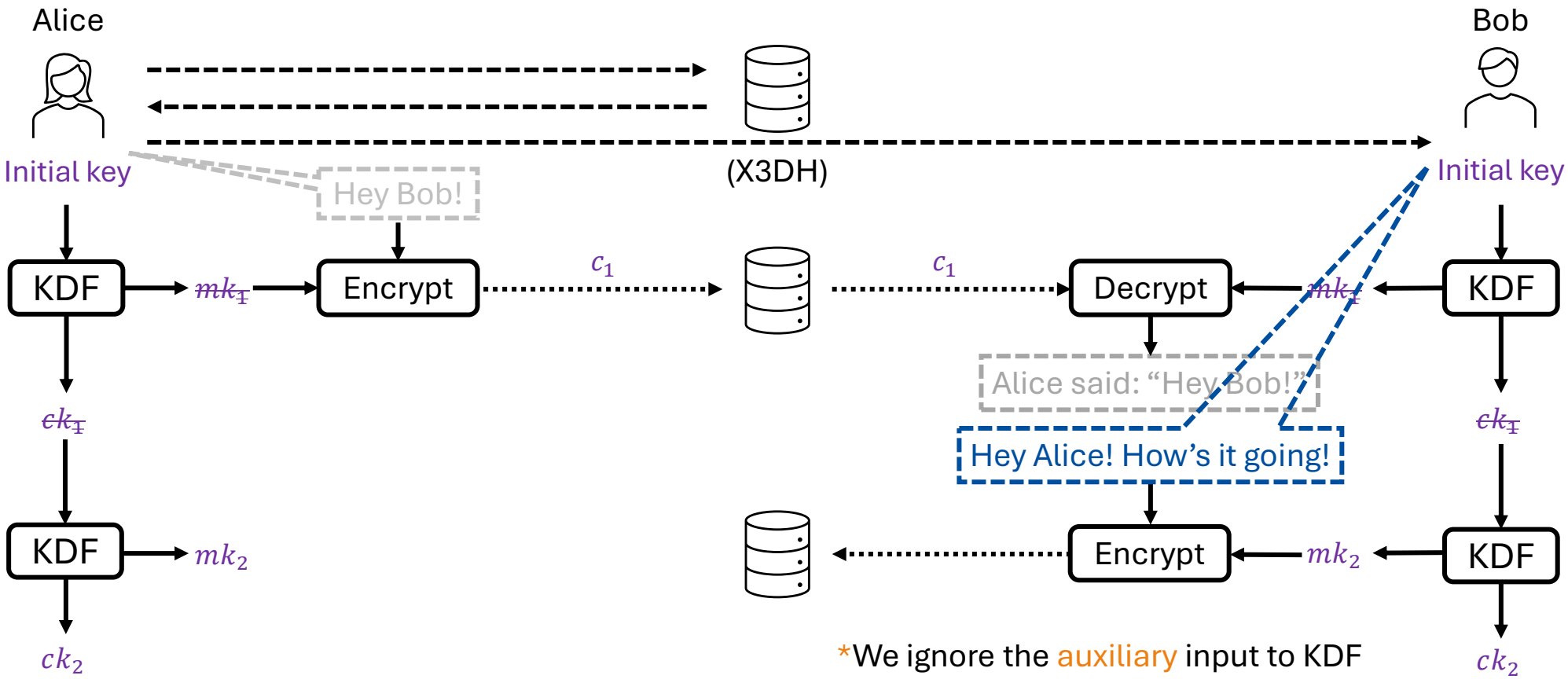

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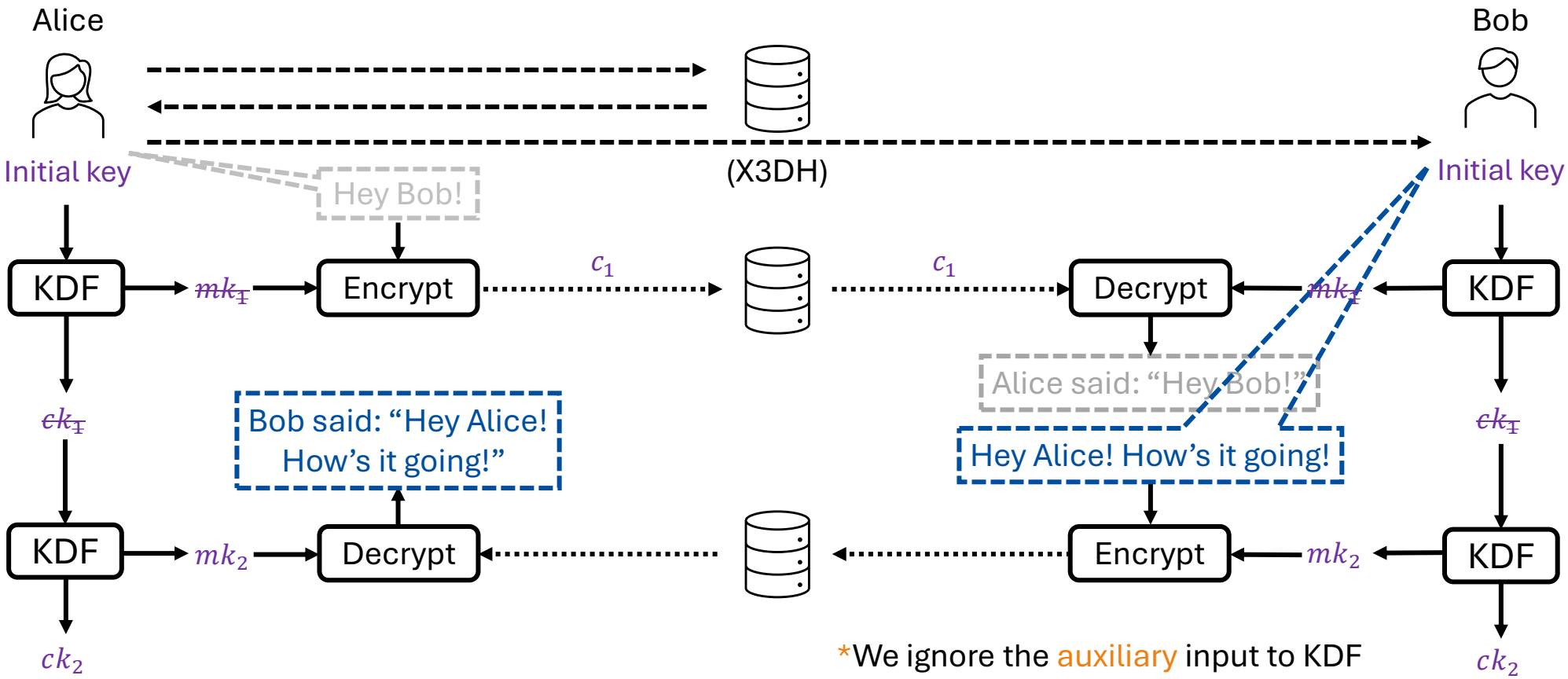

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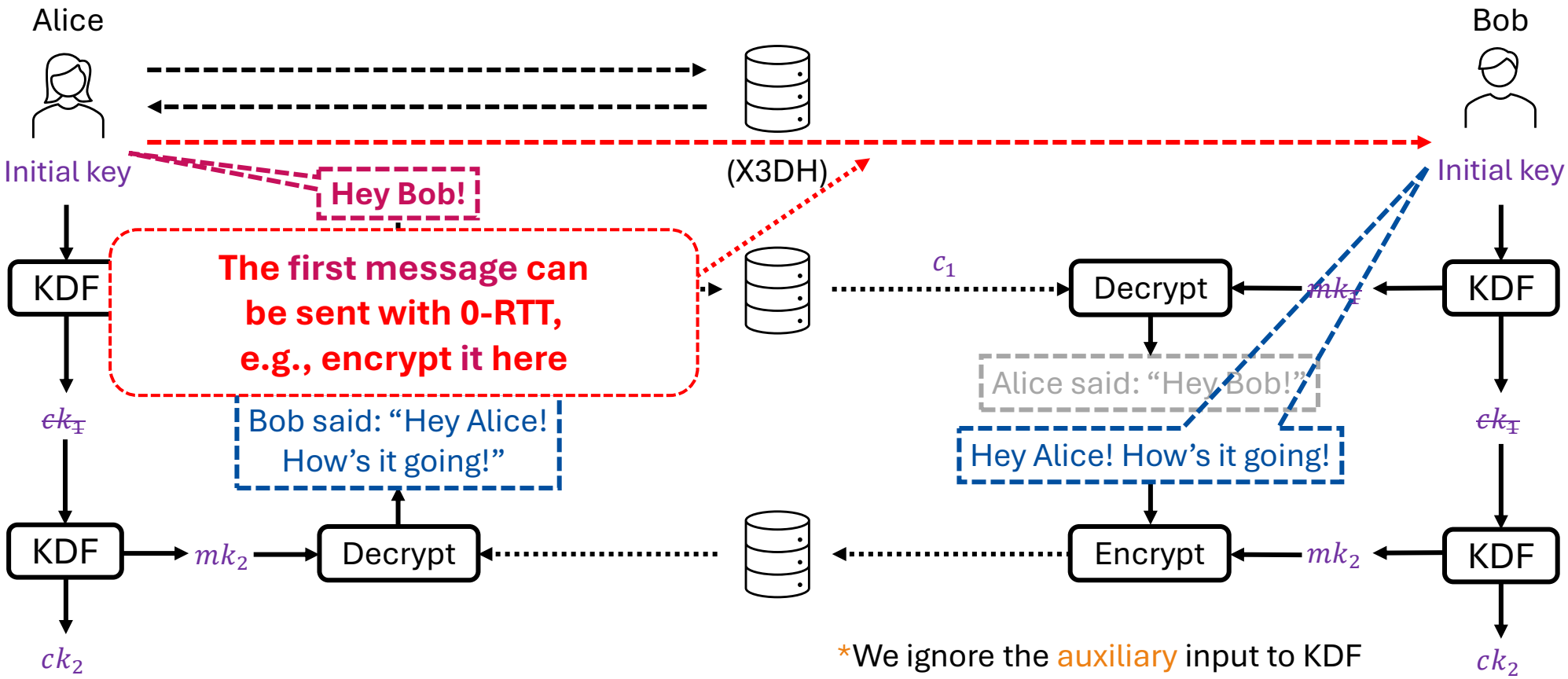

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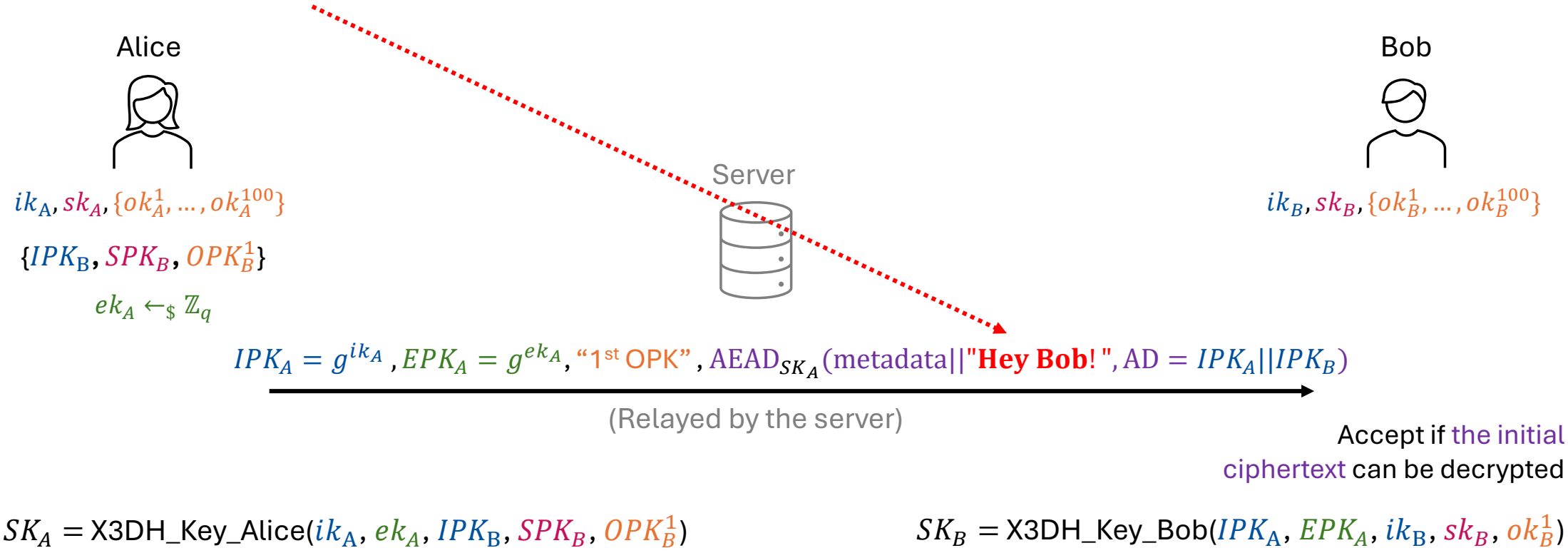
Symmetric-key Ratchet

- Make the first message 0-RTT (Zero Round Time Trip)…



Forward Secrecy

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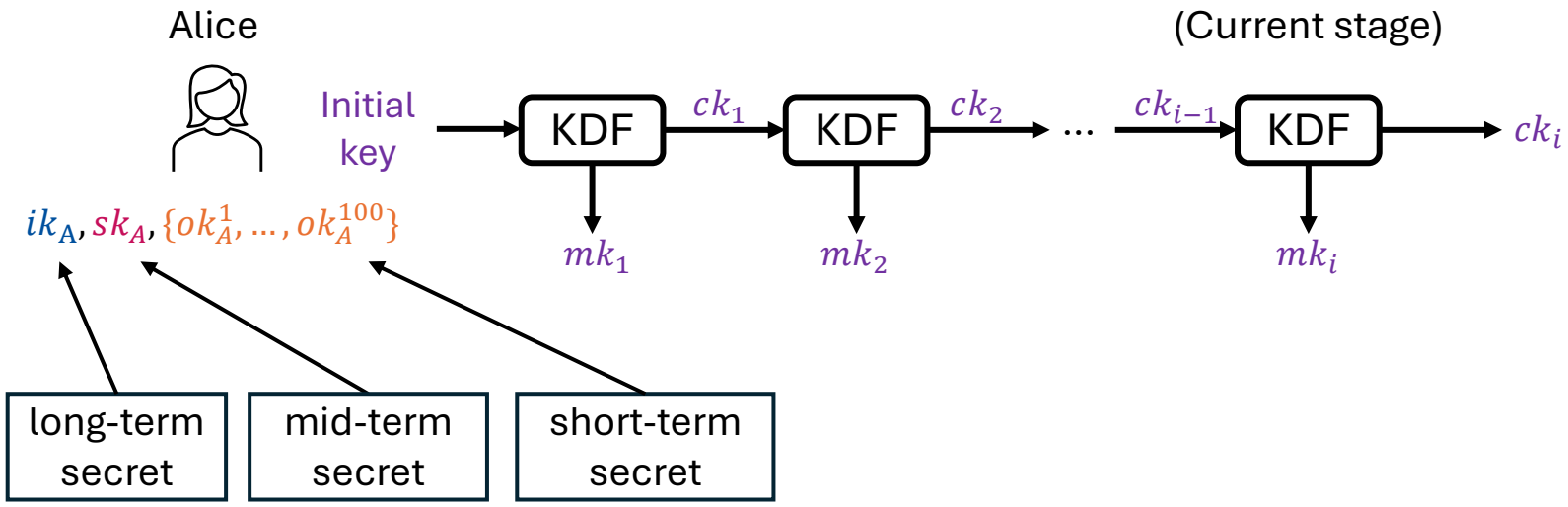

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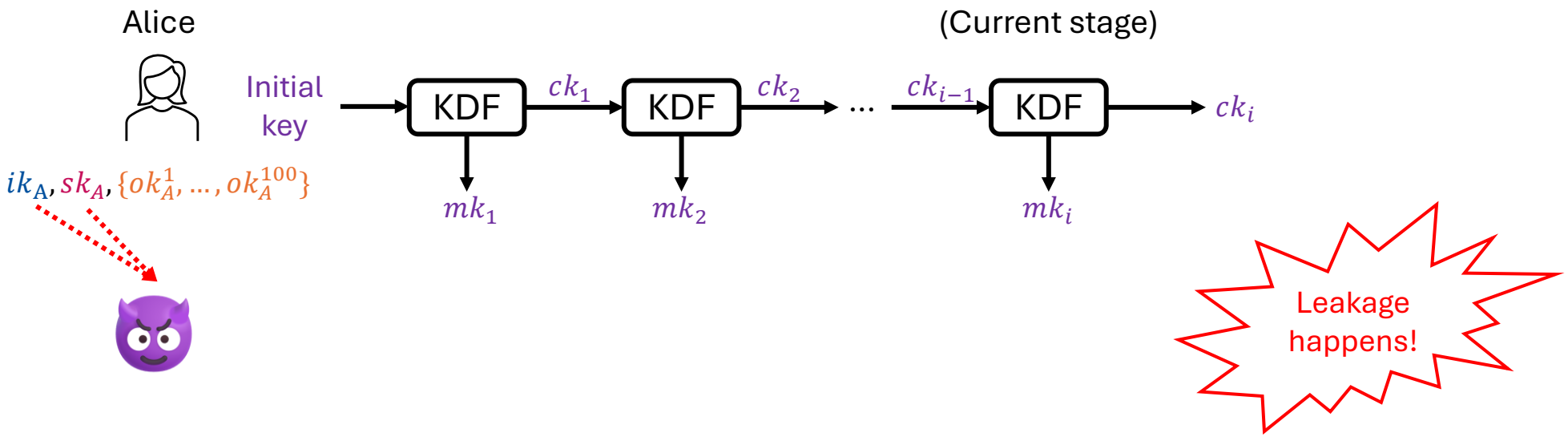

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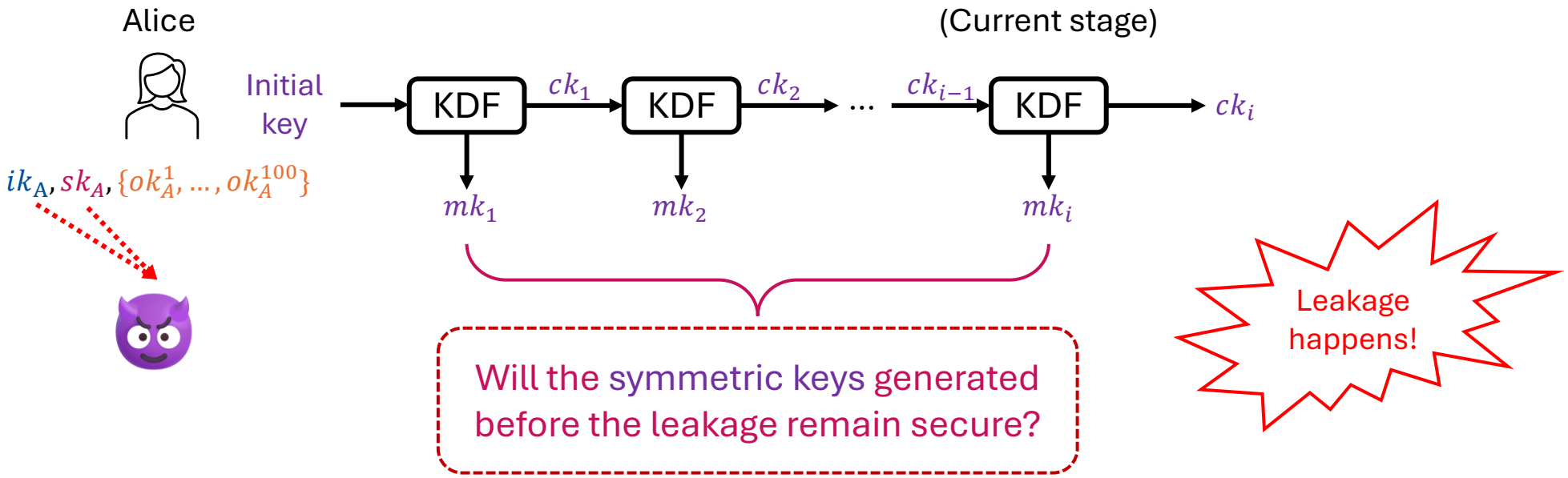

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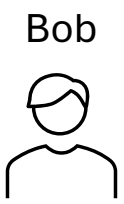

$ik_B, sk_B, \{ok_B^1, \dots, ok_B^{100}\}$

$SK_A = \text{X3DH\_Key\_Alice}(ik_A, ek_A, IPK_B, SPK_B, OPK_B)$

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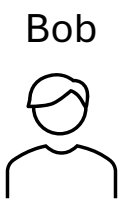

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ek_A is not a long-term secret

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Leakage!

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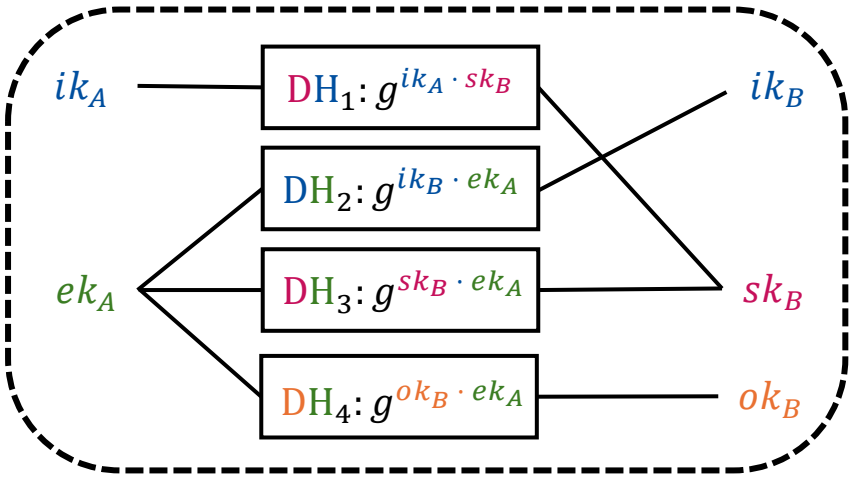
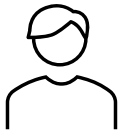


Bob



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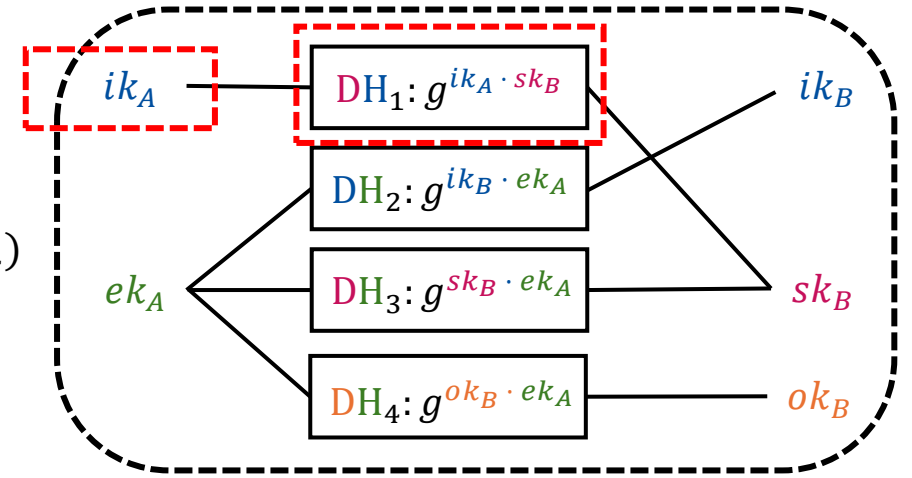

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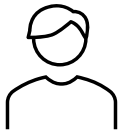

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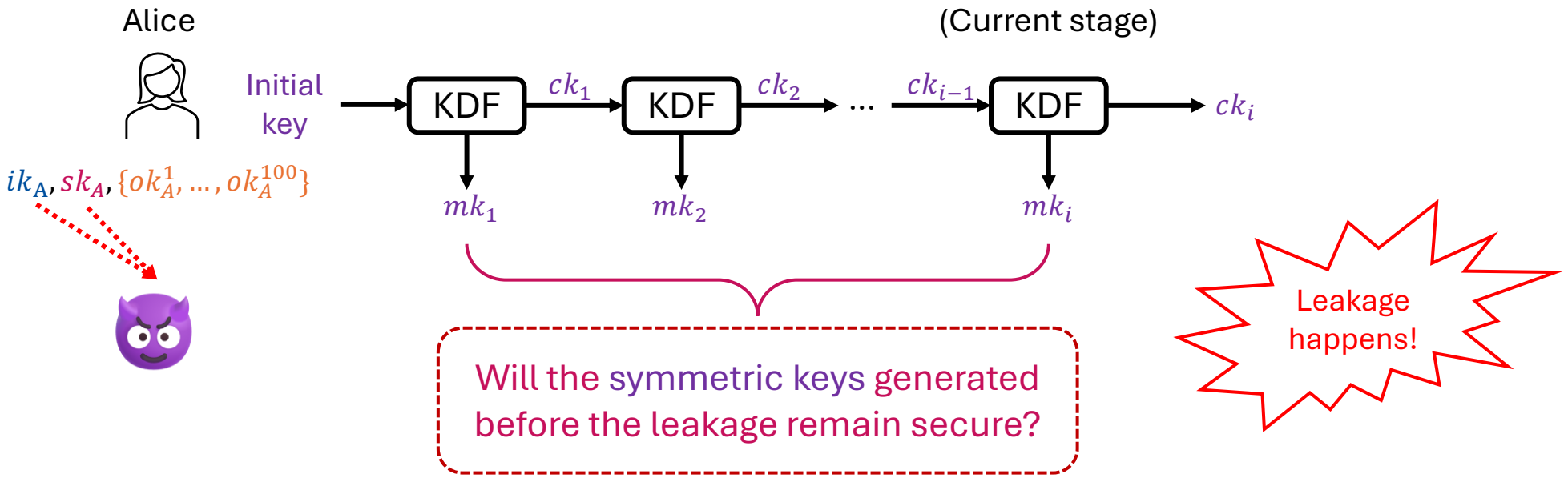

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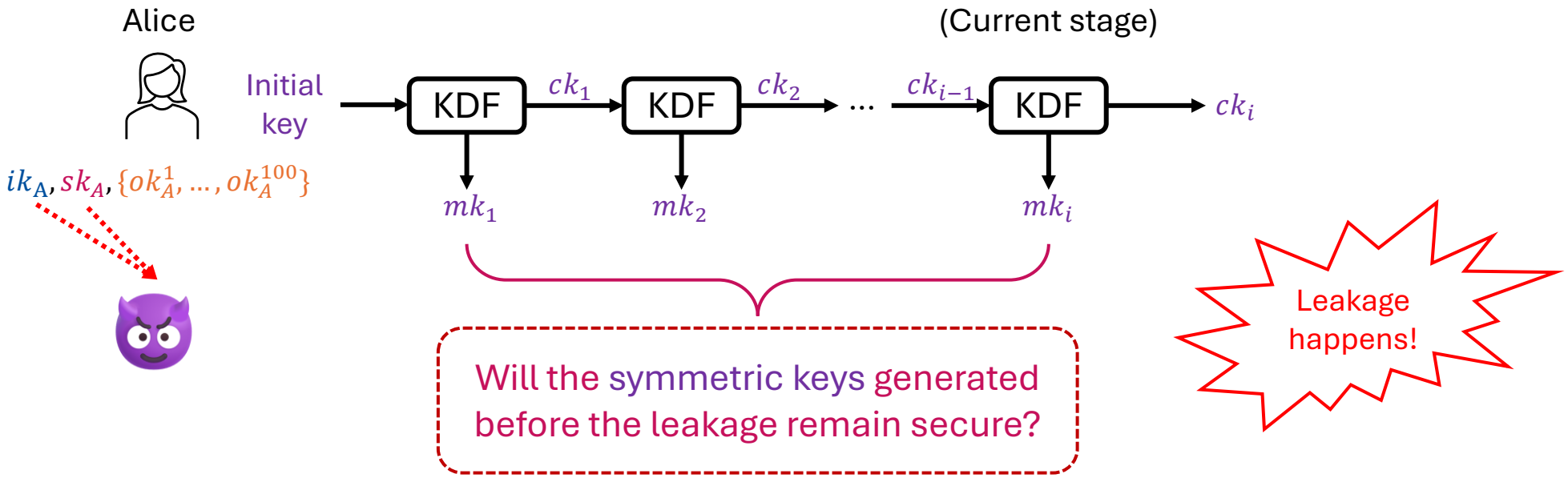

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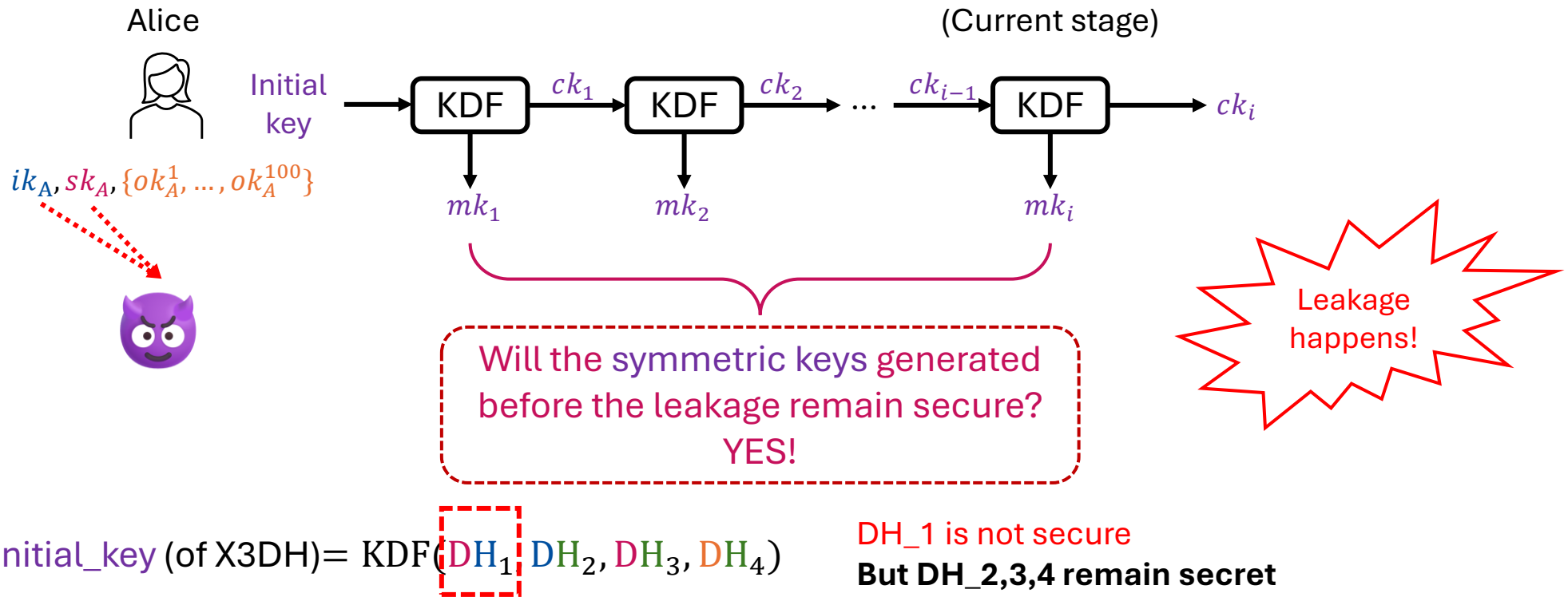

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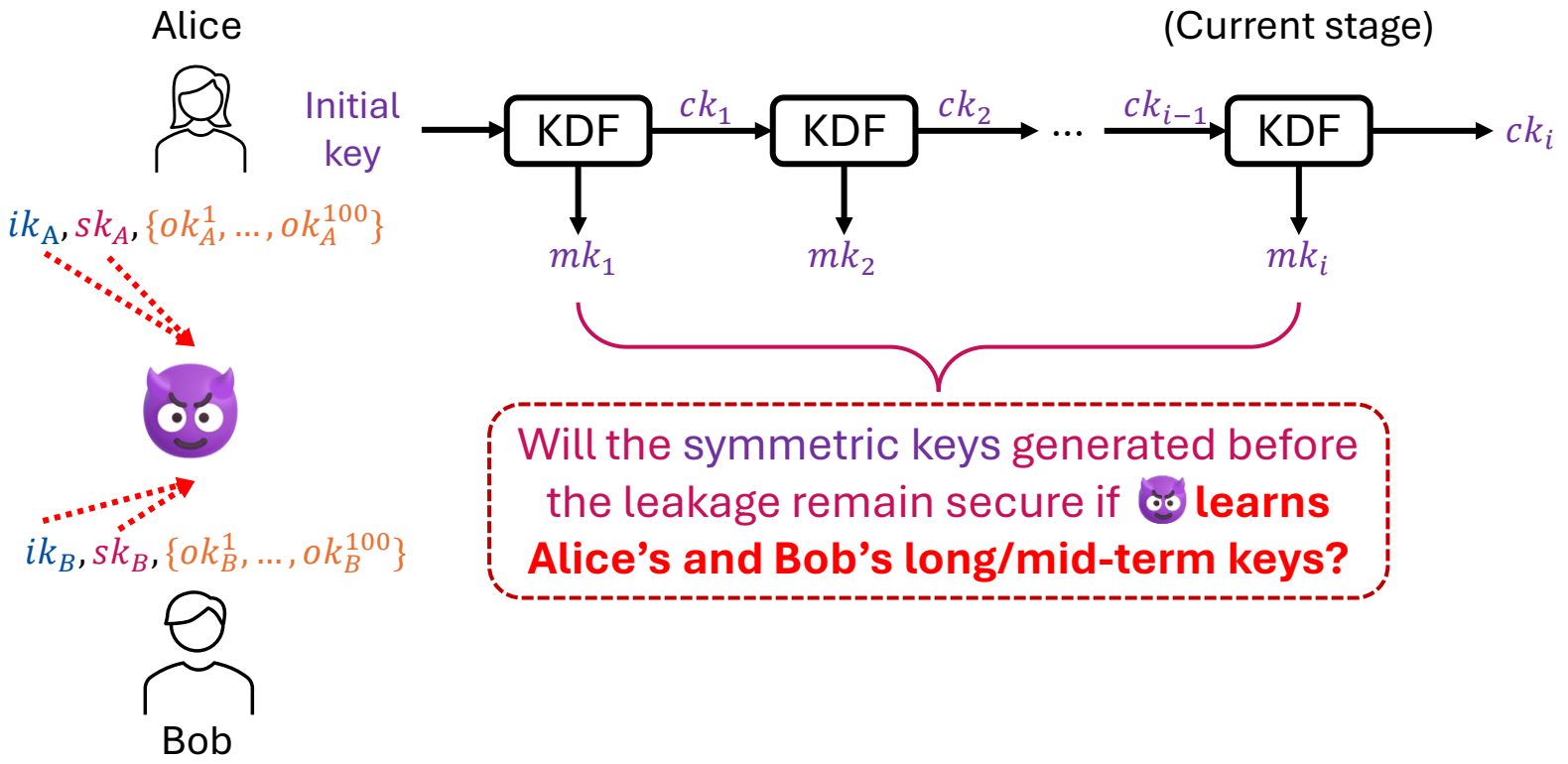

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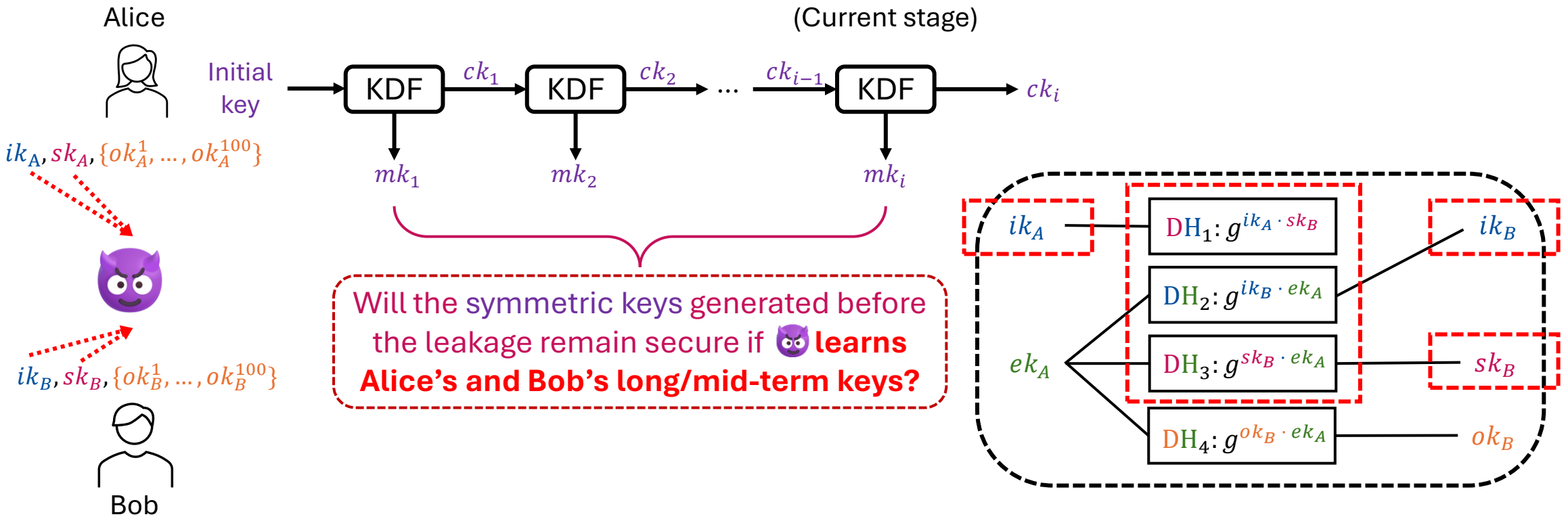

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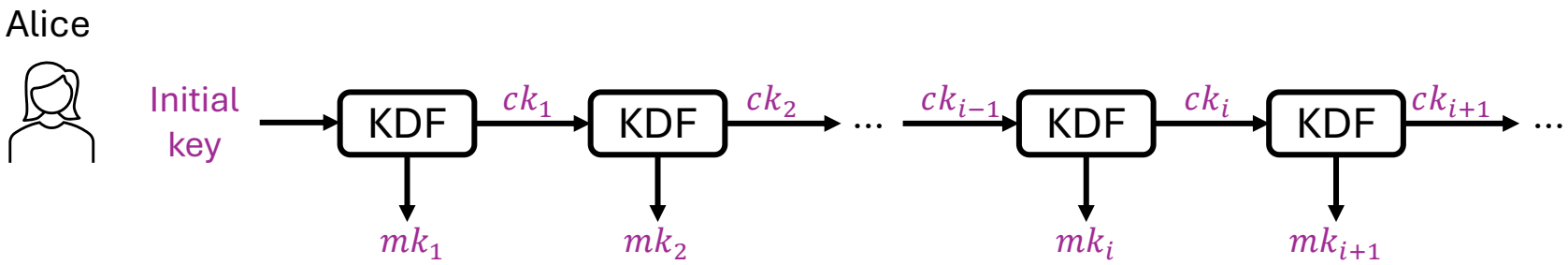

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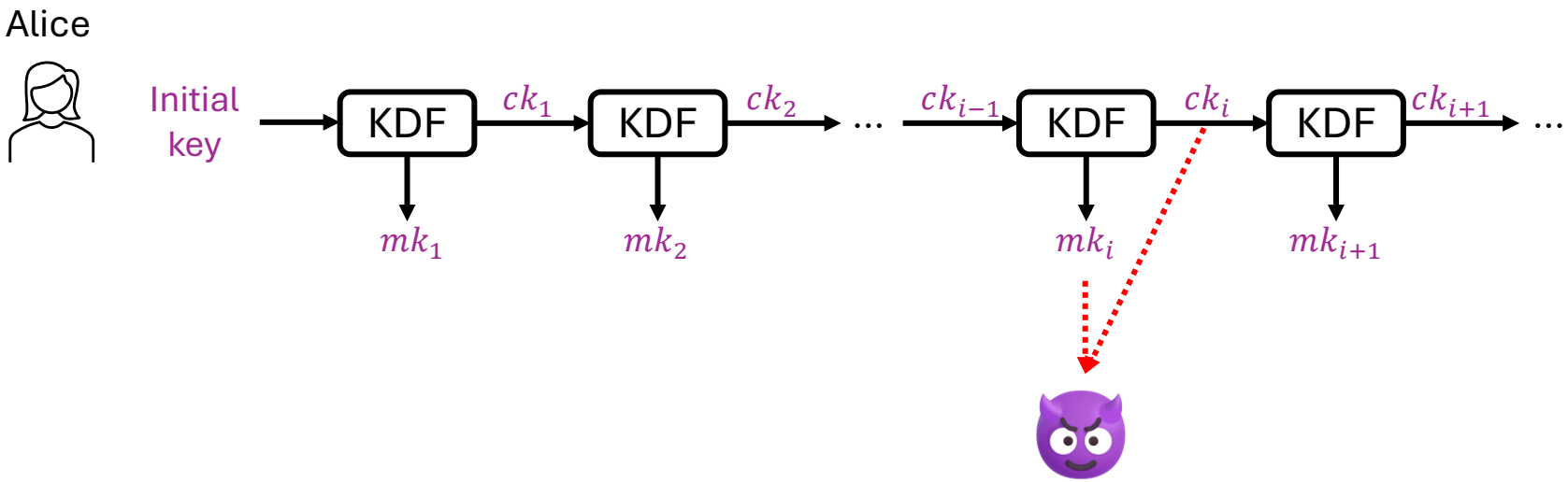

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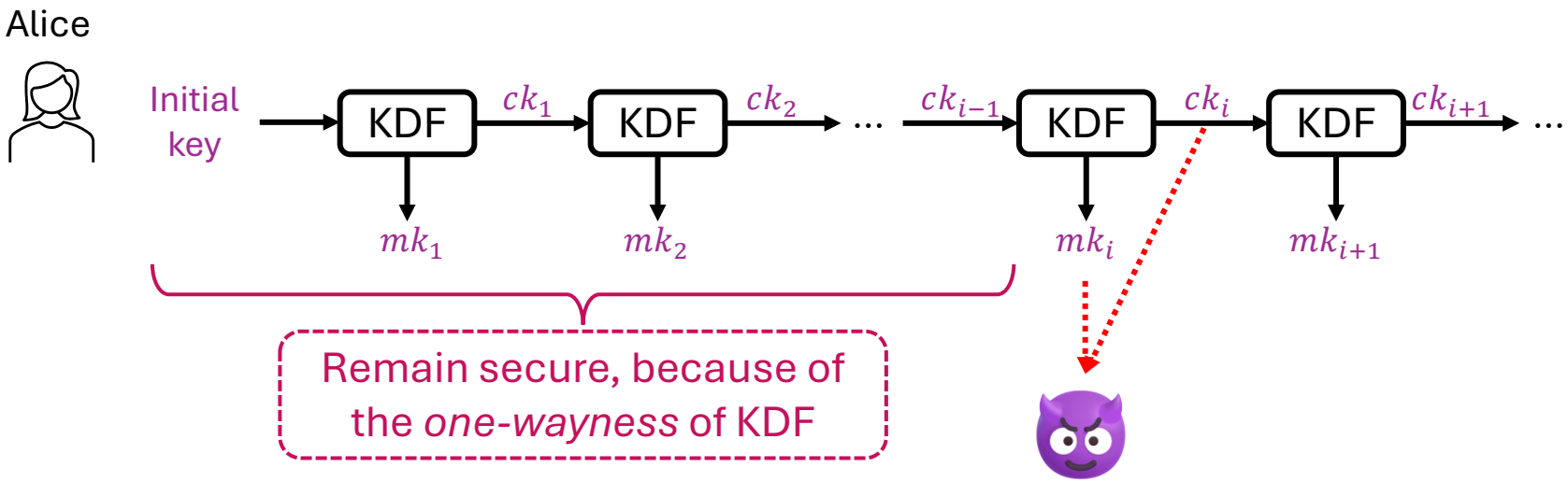

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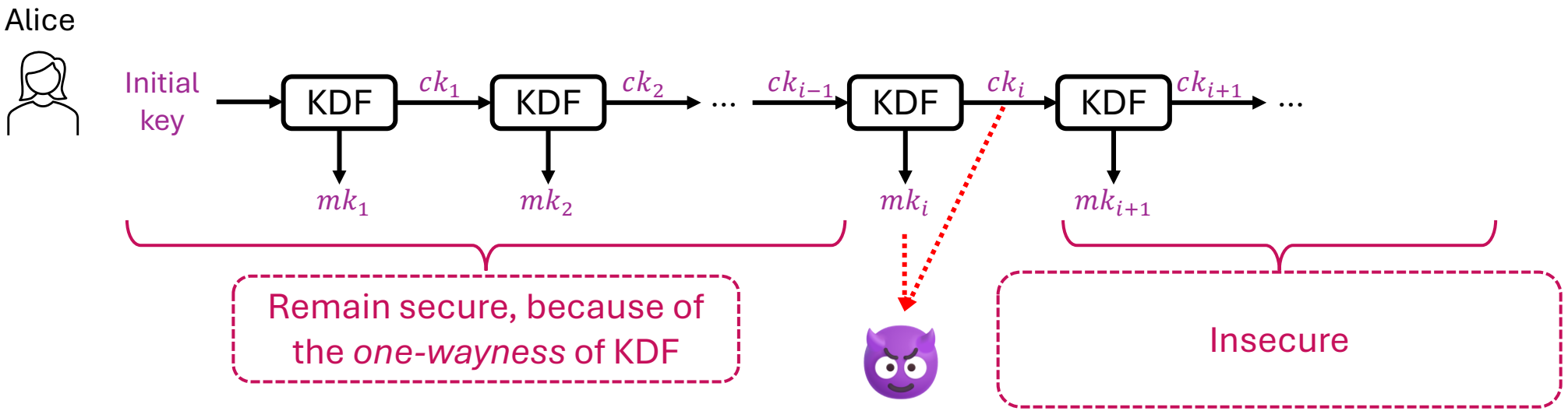
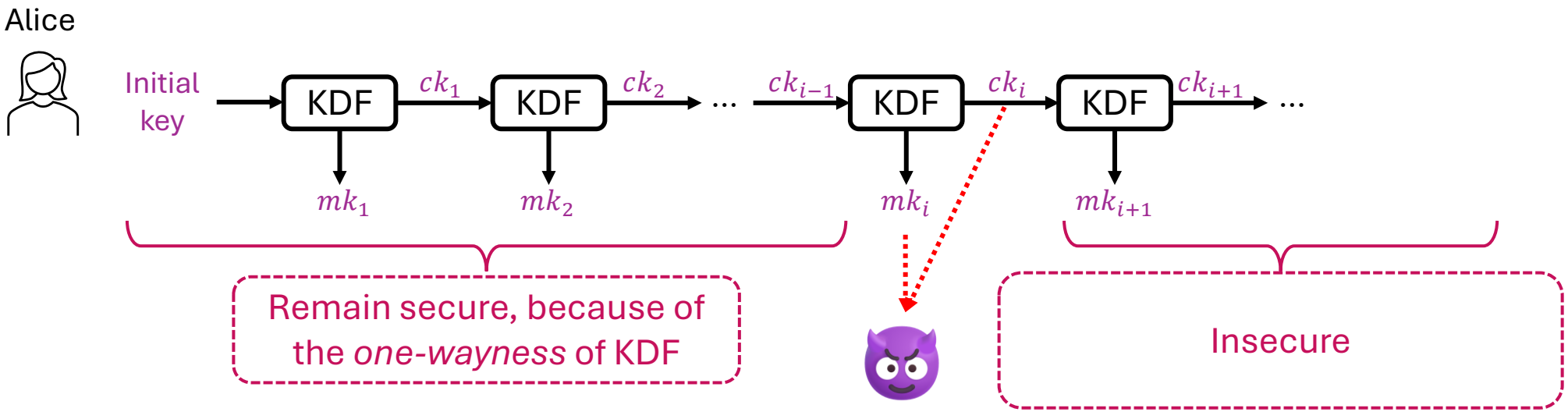


Backward Secrecy

- Future communication remains secure even if a current session key is compromised



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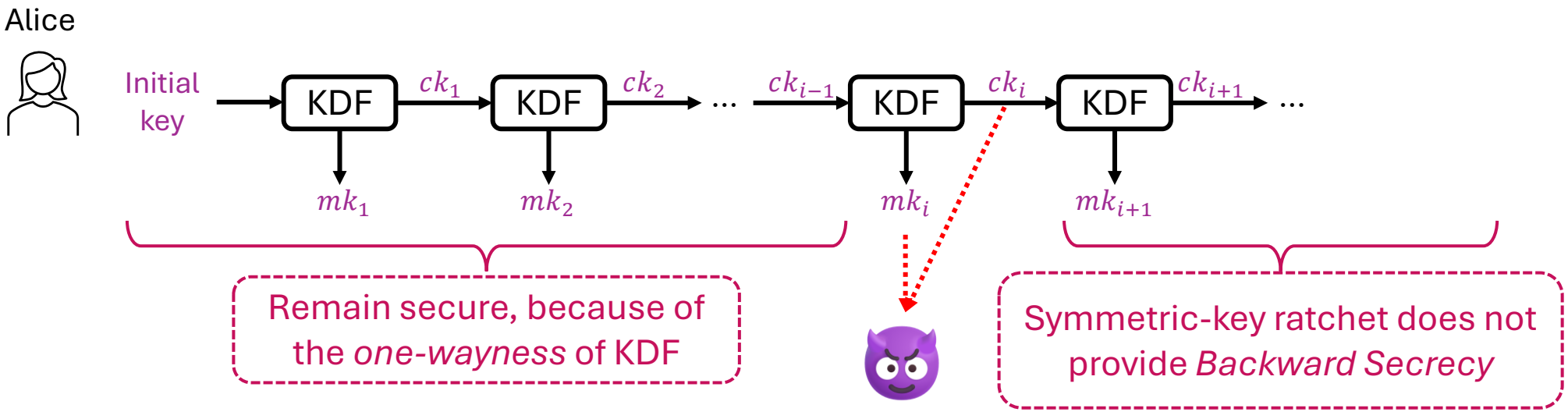

Diffie-Hellman Ratchet

- X3DH + Symmetric-key Ratchet
  - X3DH provides *Forward Secrecy*
  - Current session key compromises does not lead to the compromise of previous session keys
    - (by the one-wayness of KDF in Symmetric-key Ratchet)
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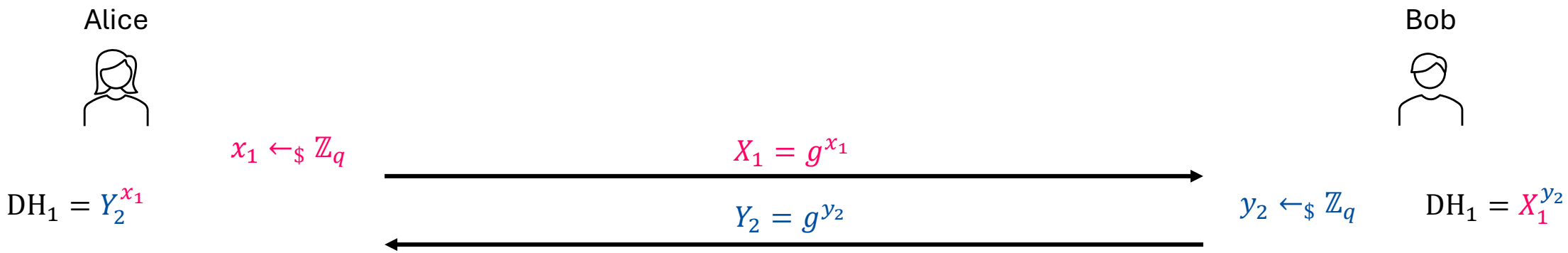
- Solution: Diffie-Hellman Ratchet

Diffie-Hellman Ratchet

- A toy example: Running DHKE continuously with *rotating ephemeral keys*…



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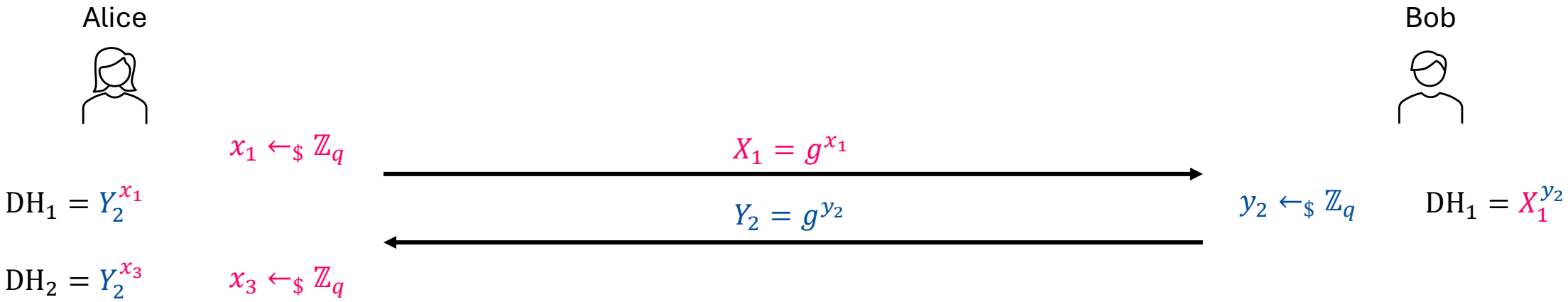

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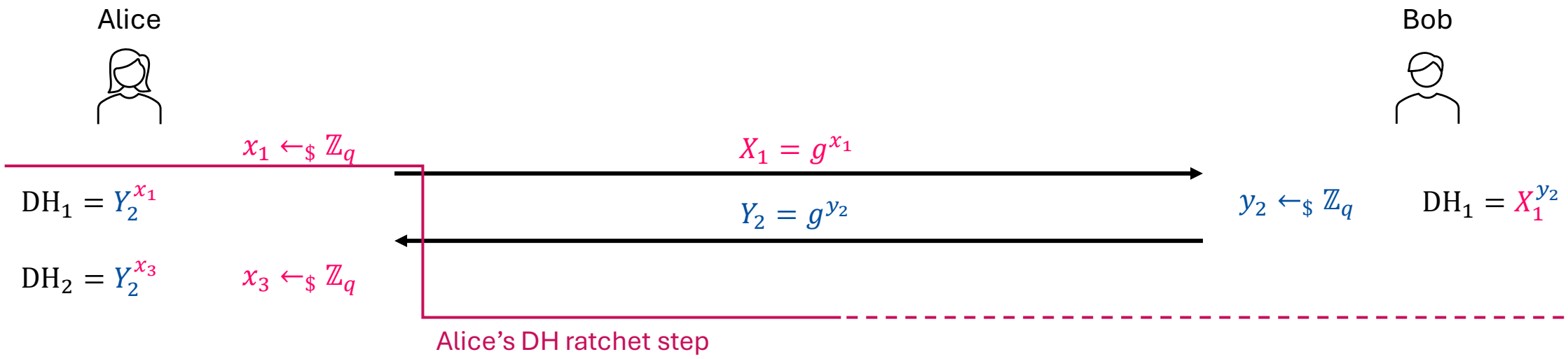

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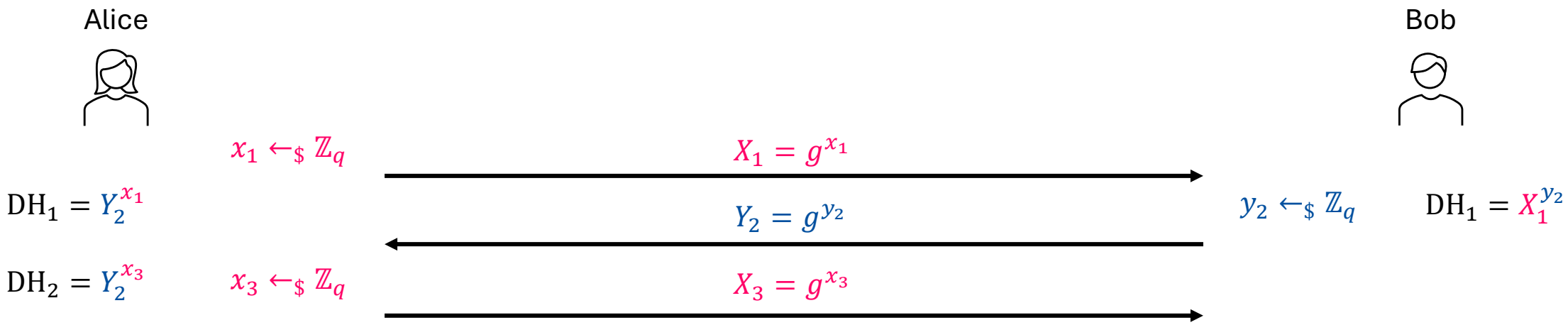

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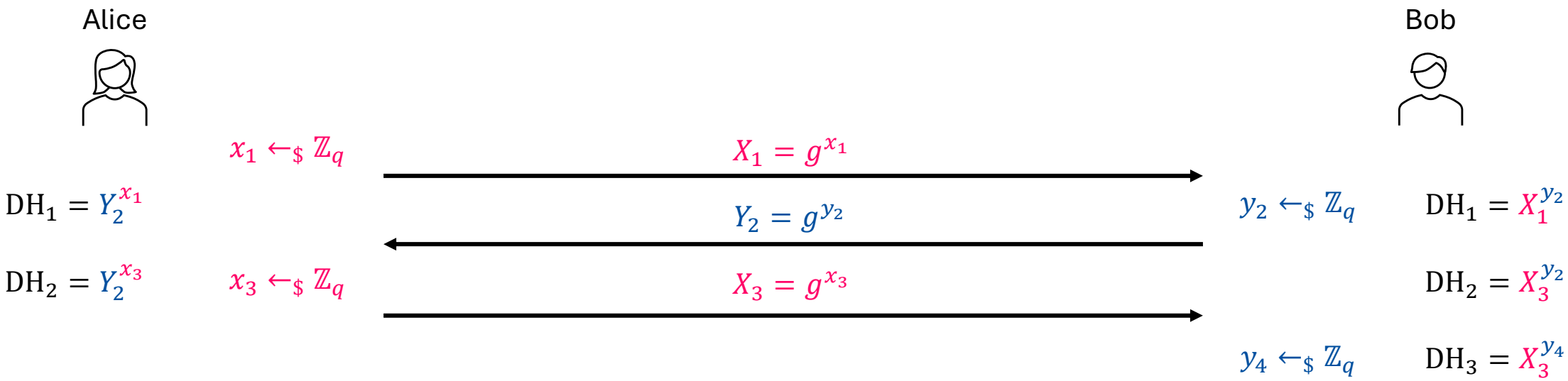

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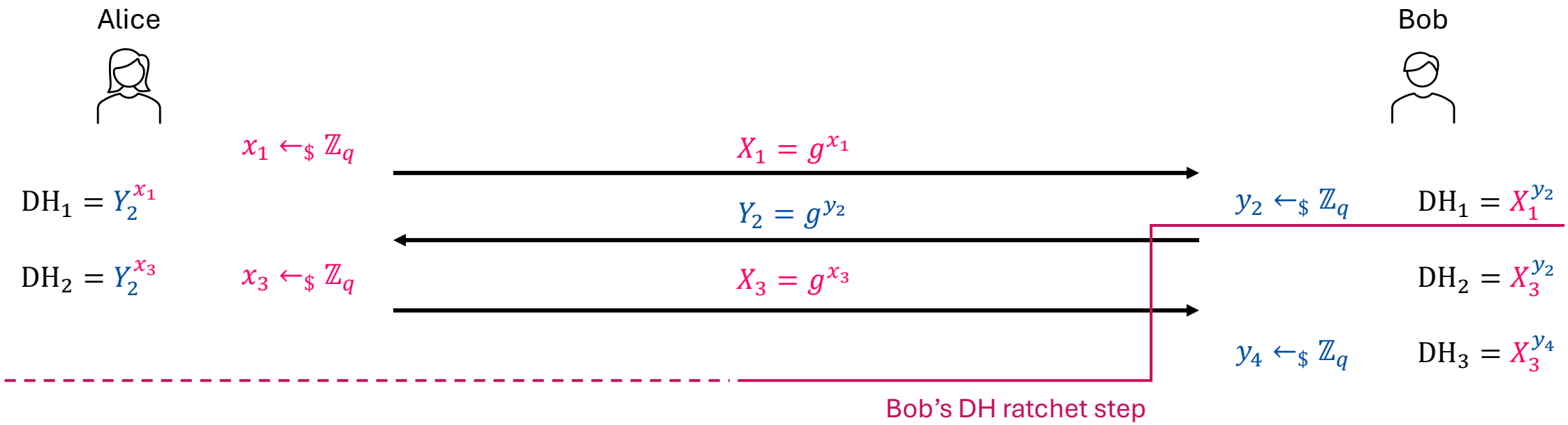

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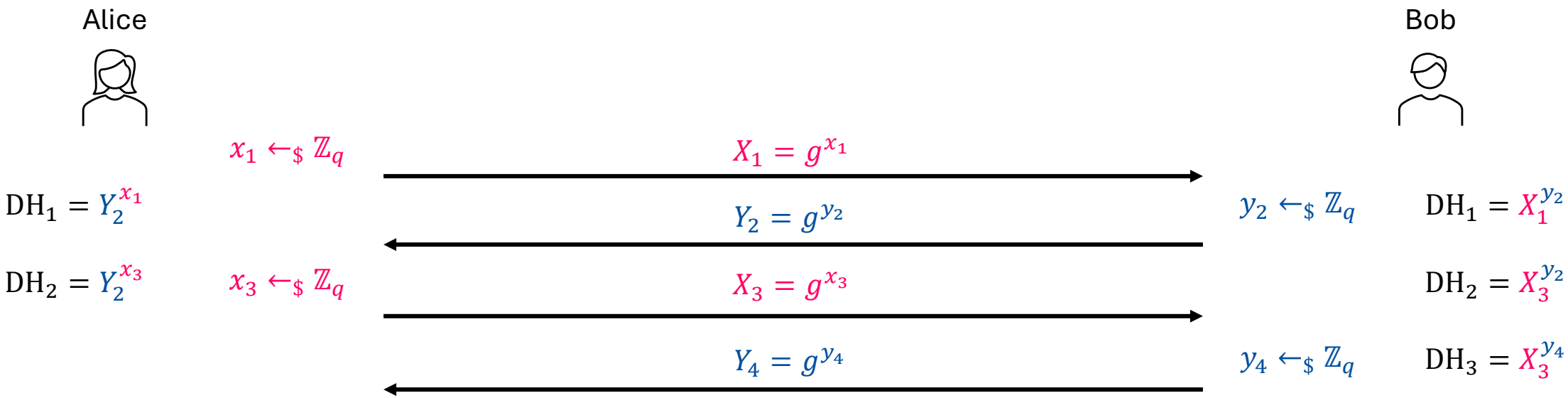

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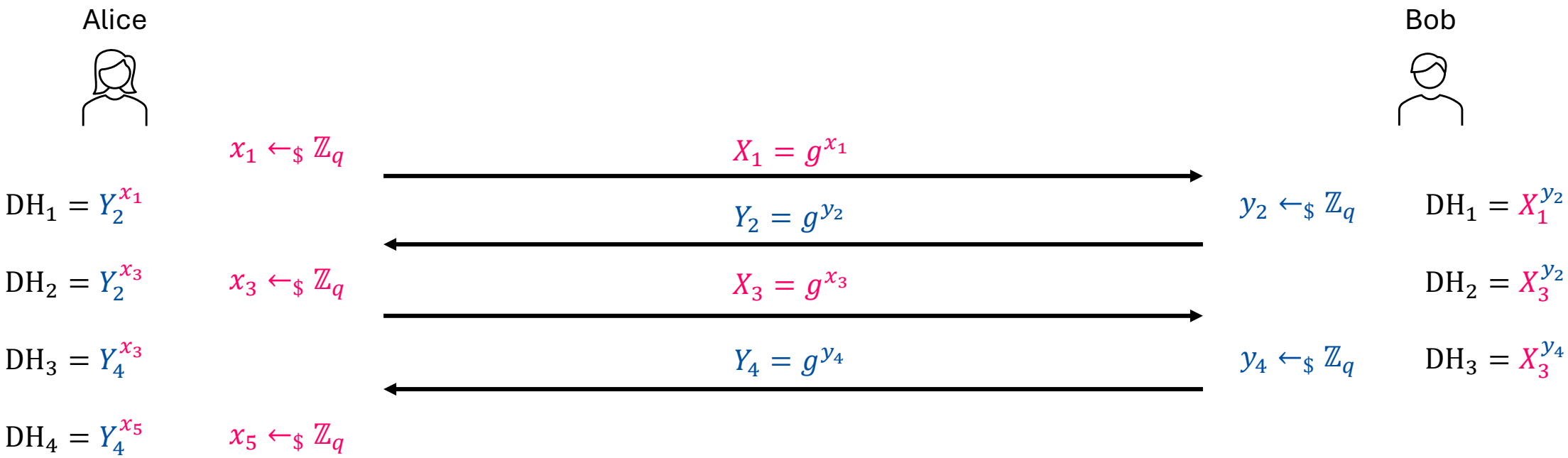

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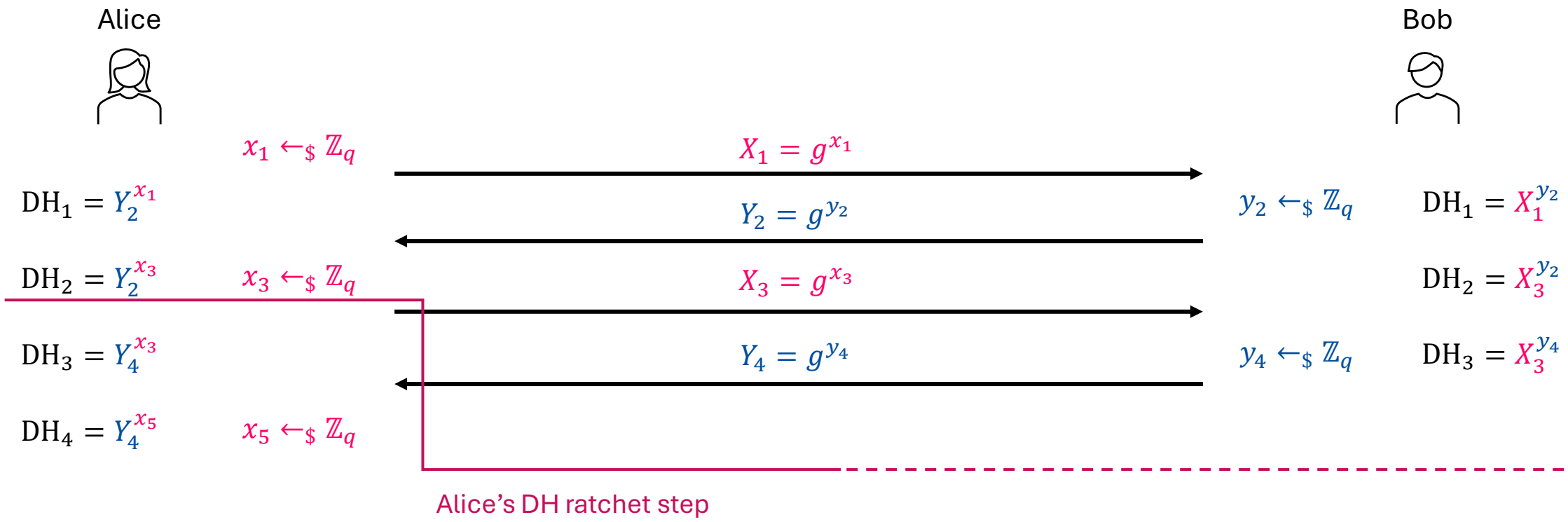

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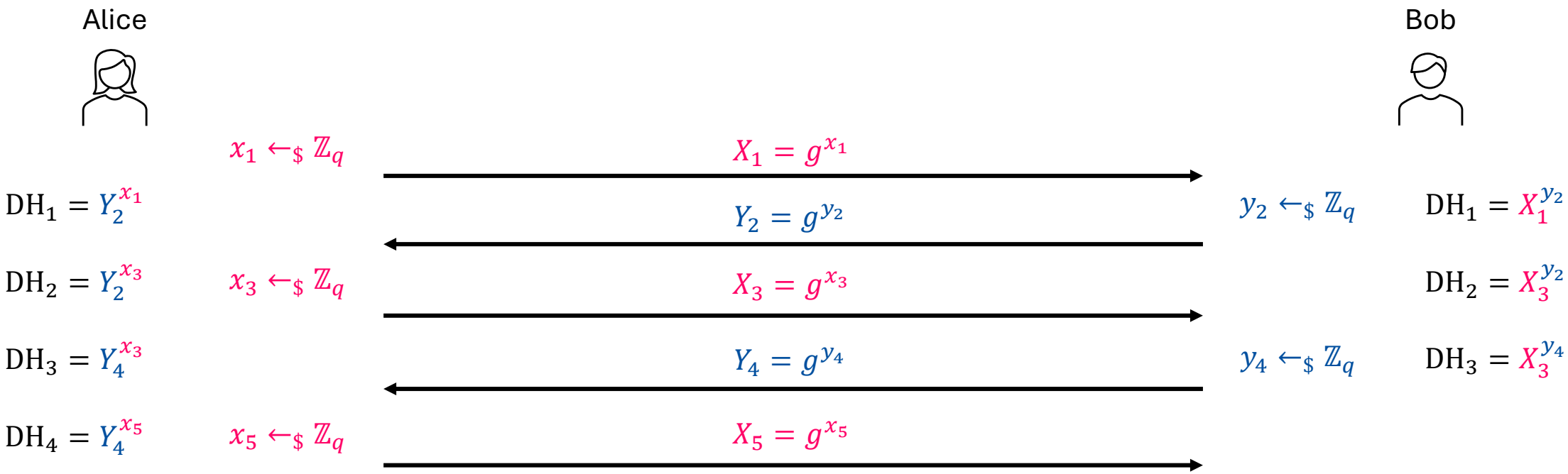

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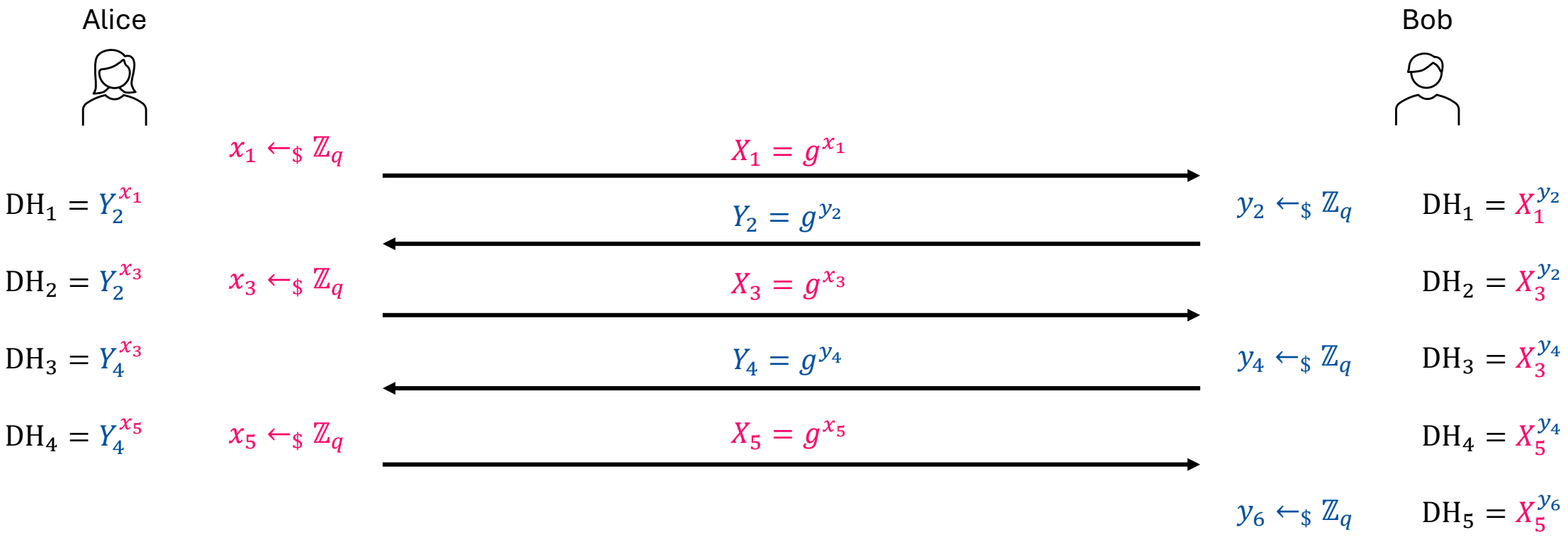

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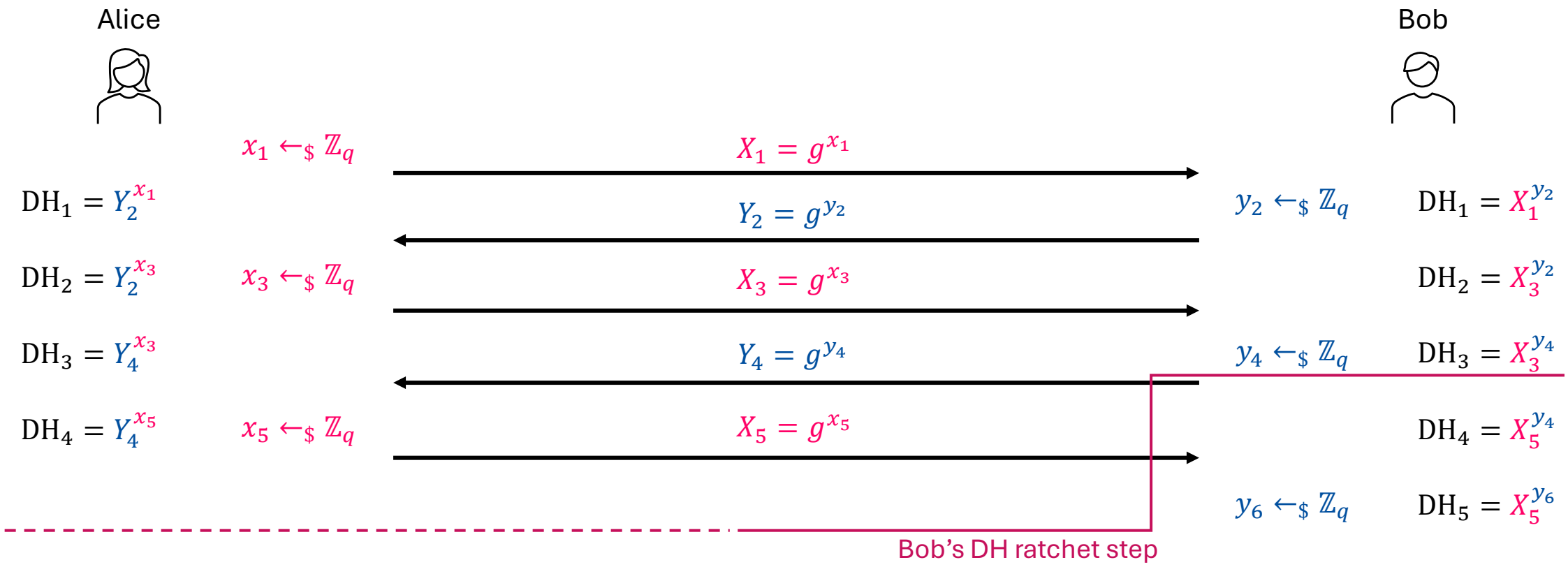

Diffie-Hellman Ratchet

- The main idea: Combine Symmetric-key Ratchet and Diffie-Hellman Ratchet
  - DH Ratchet generates fresh shared DH secrets continuously via rotating new ephemeral keys…
  - These fresh DH secrets feed into Symmetric-key Ratchet to add new secret information…

- More details will be explained in the next lecture

Coding Tasks

- Implement the Diffie-Hellman Ratchet algorithm (can be without sockets).

Homework

No Homework

...but the **deadline** for homework in Lectures 1 and 2 is

22.11.2024 at 23:59 (this Friday evening)

Further Reading

- Old news -- *WhatsApp's Signal Protocol integration is now complete:* *https://signal.org/blog/whatsapp-complete/*
- Technical Documentations of Signal: https://signal.org/docs/
- Cohn-Gordon et al's security analysis of Signal: https://eprint.iacr.org/2016/1013