Poly Onions: Achieving Anonymity in the Presence of Churn

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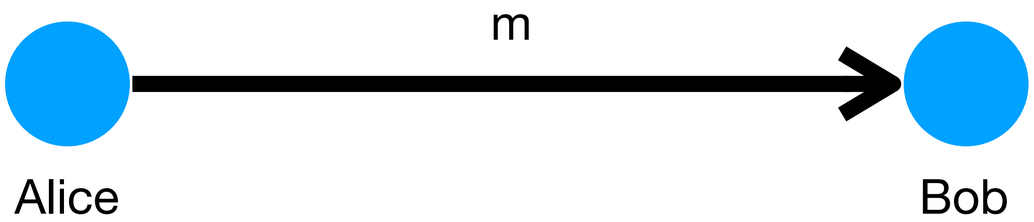
Our Problem

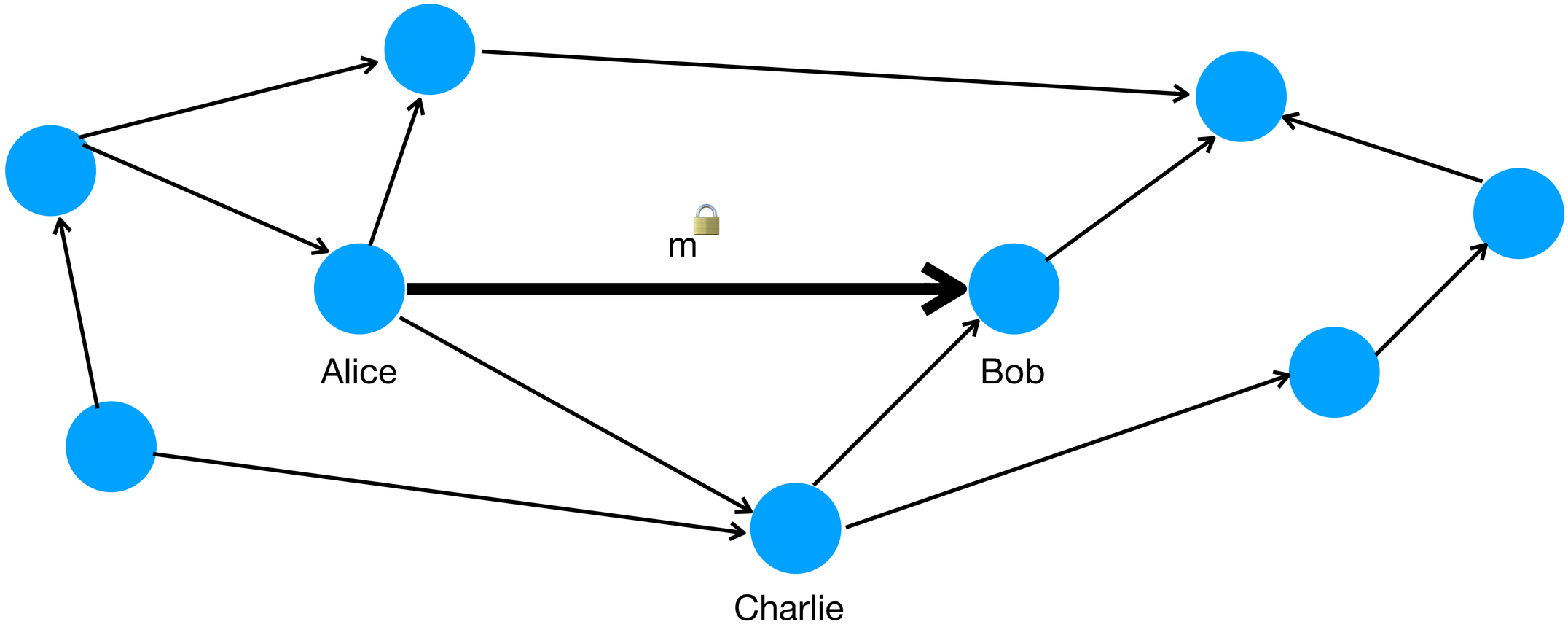
Alice wants to **anonymously** send a message to Bob



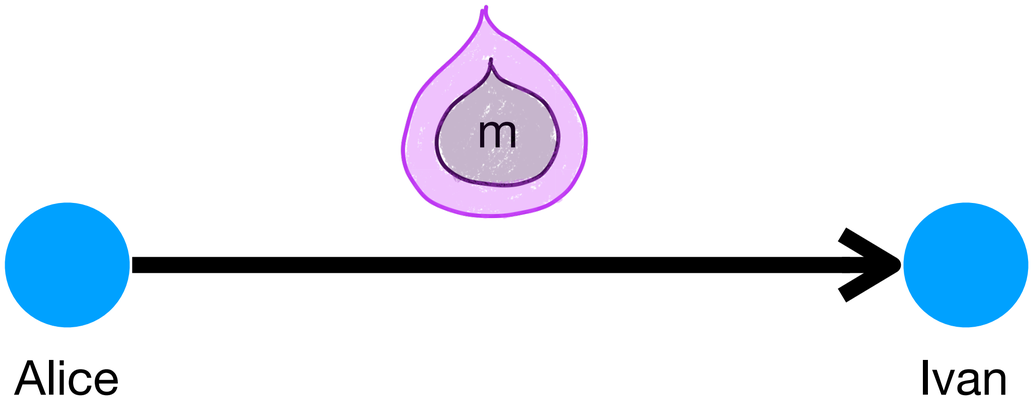
What do we mean by anonymous?

Adversary can’t tell who Alice is talking to

Even if it can **observe all network traffic** & **corrupt** constant fraction of nodes



Solution: Onion Routing



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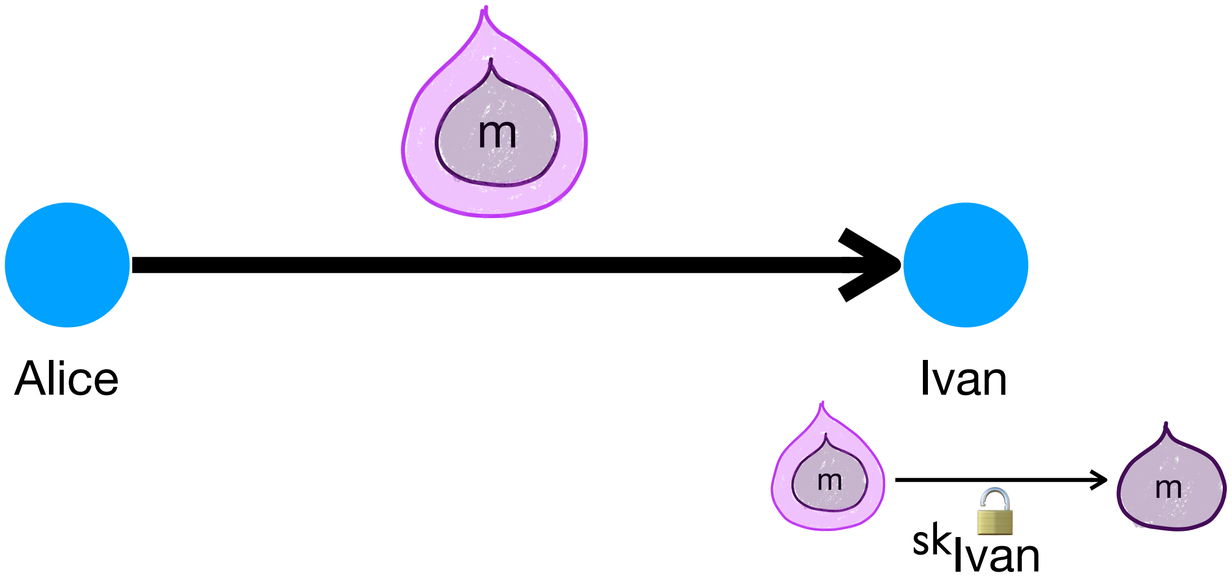

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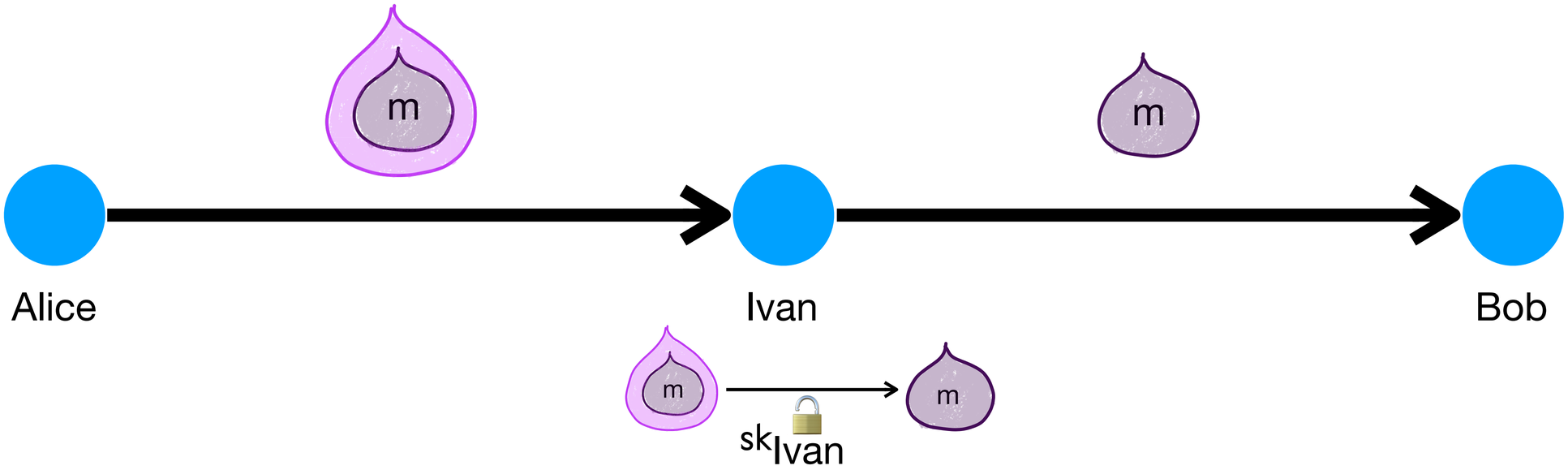

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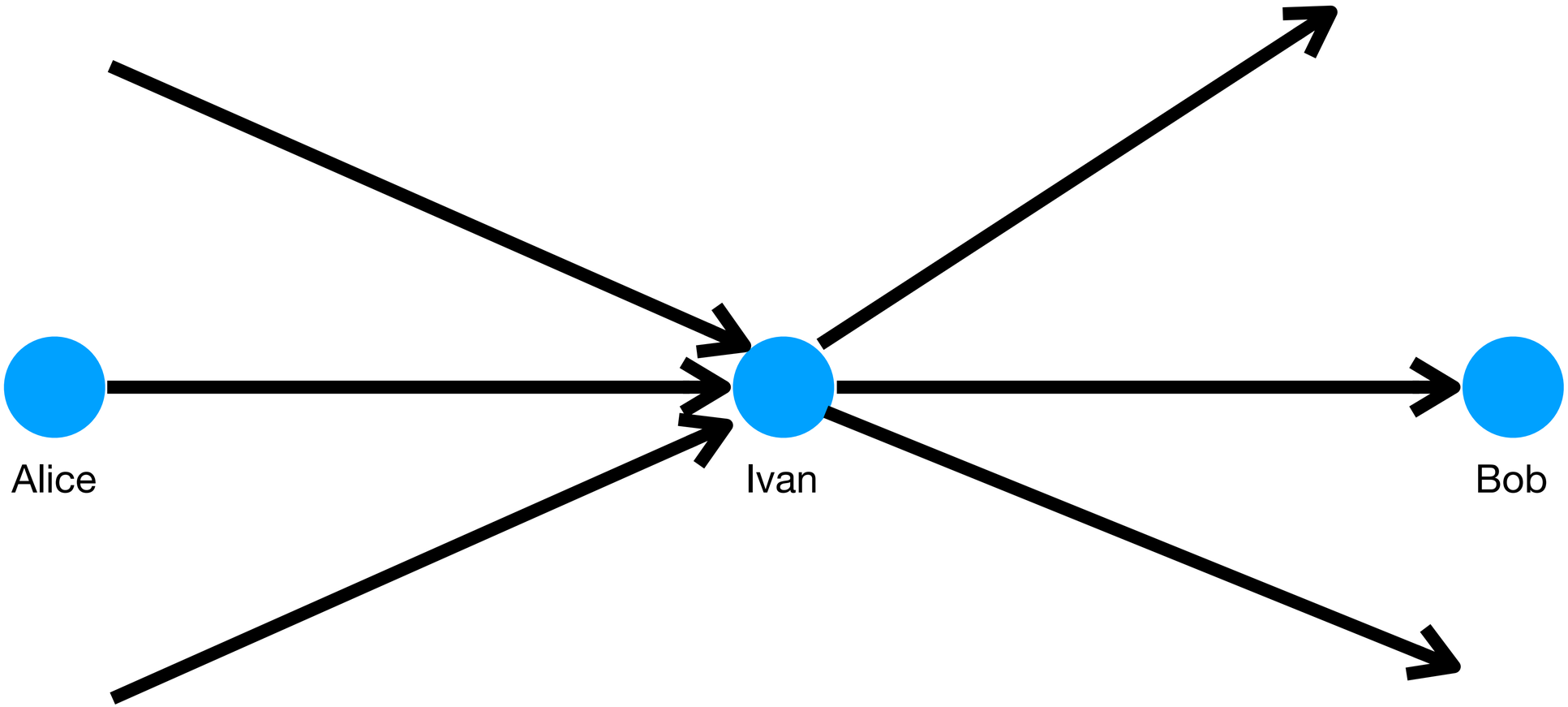
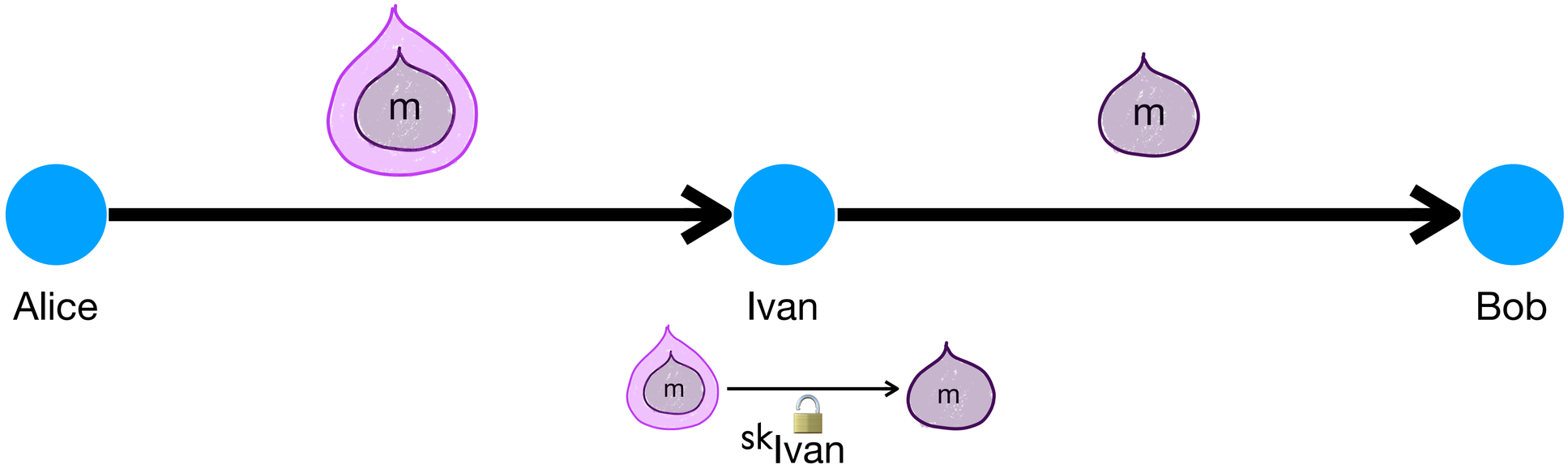


Onions **mix** at honest intermediaries

Solution: Onion Routing

There exists an onion routing protocol that is anonymous with $\text{polylog}(\lambda)$ rounds [Ando, Lysyanskaya, Upfal ‘18]



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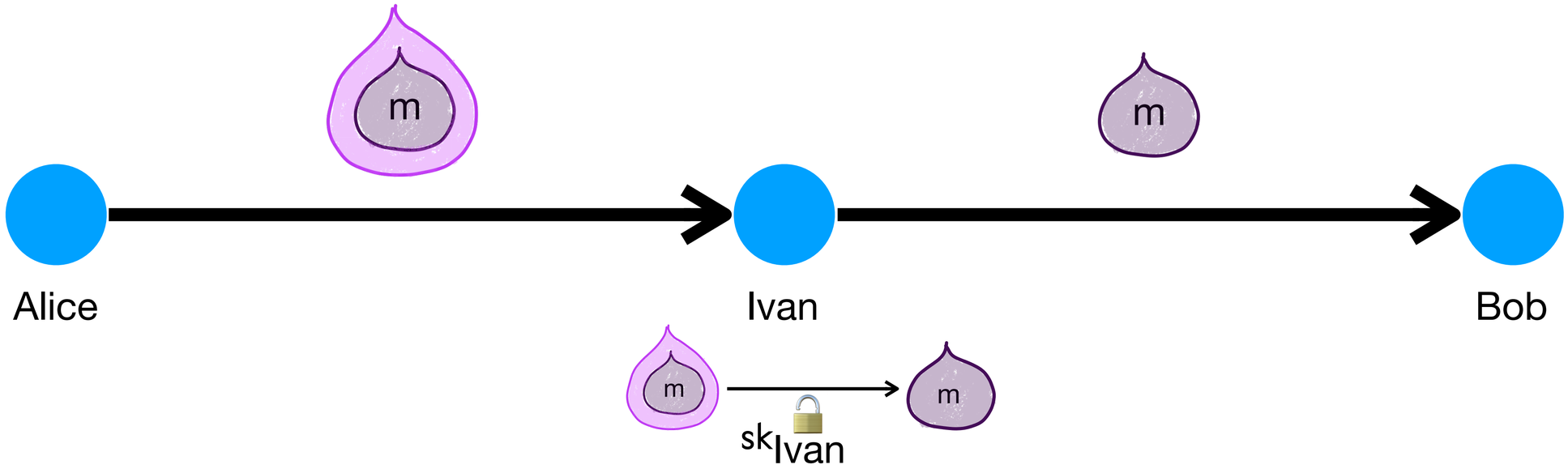
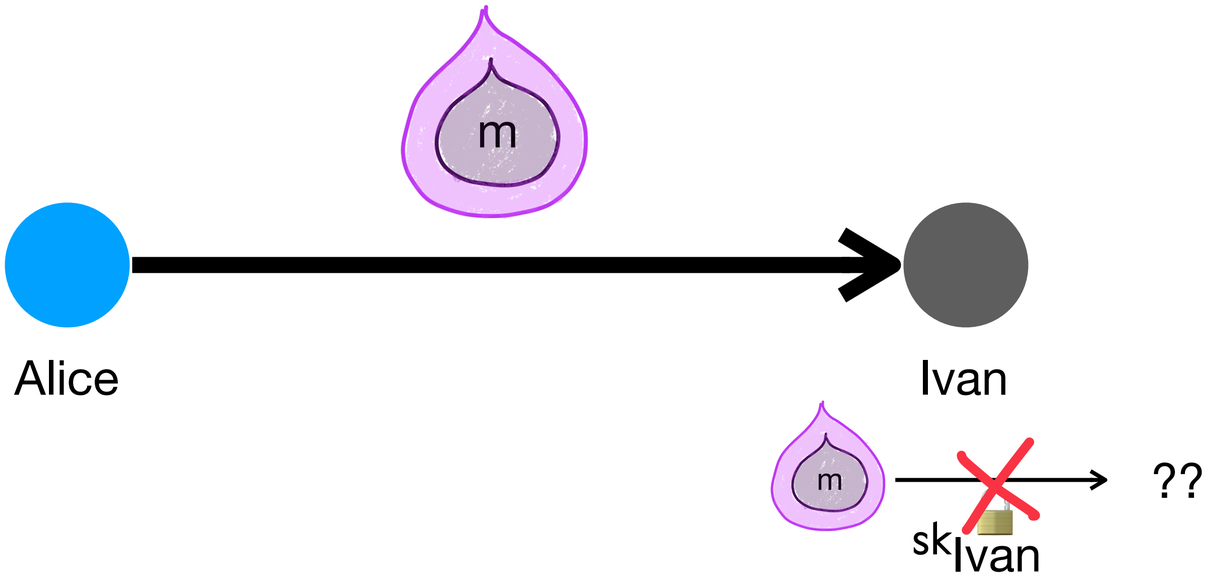
There exists an onion routing protocol that is anonymous with $\text{polylog}(\lambda)$ rounds [Ando, Lysyanskaya, Upfal ‘18] **in the single-run setting without churn**



What if Ivan is offline?



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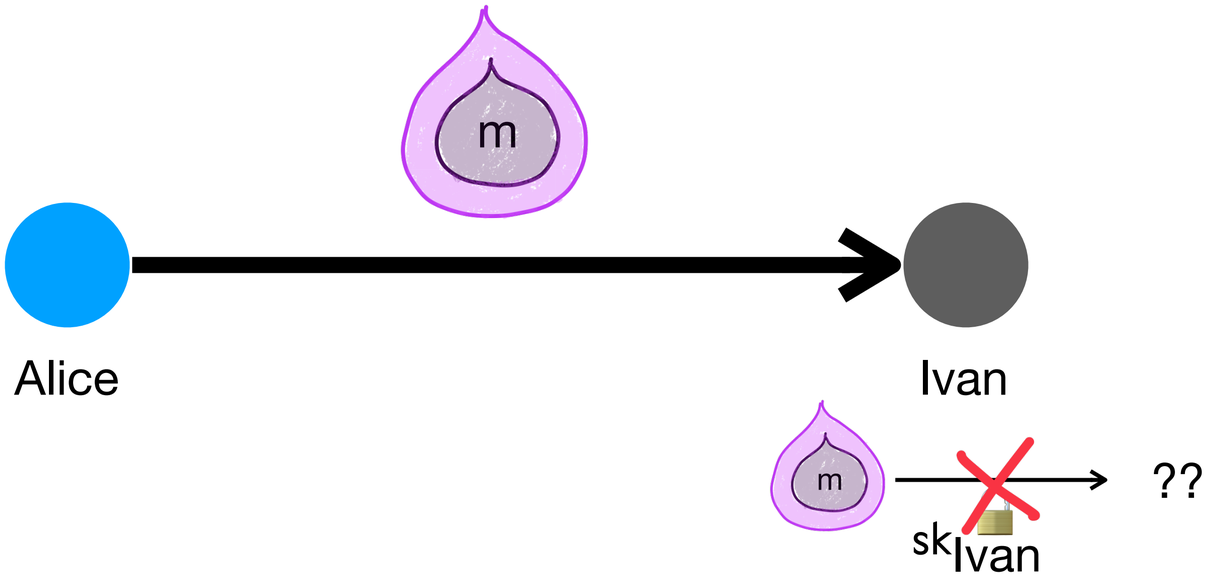

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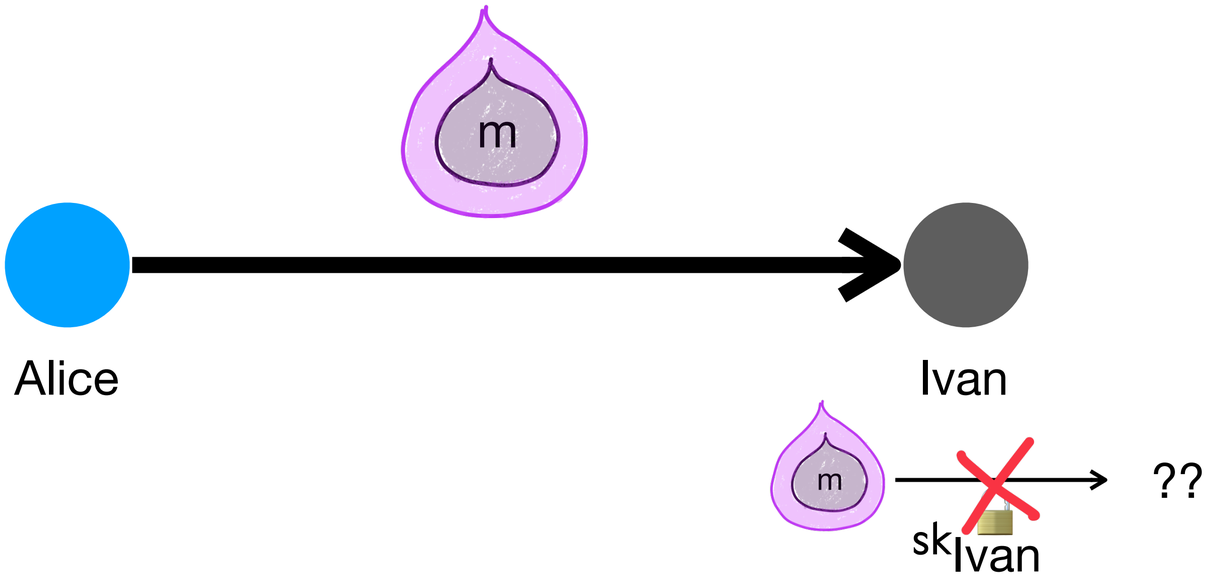
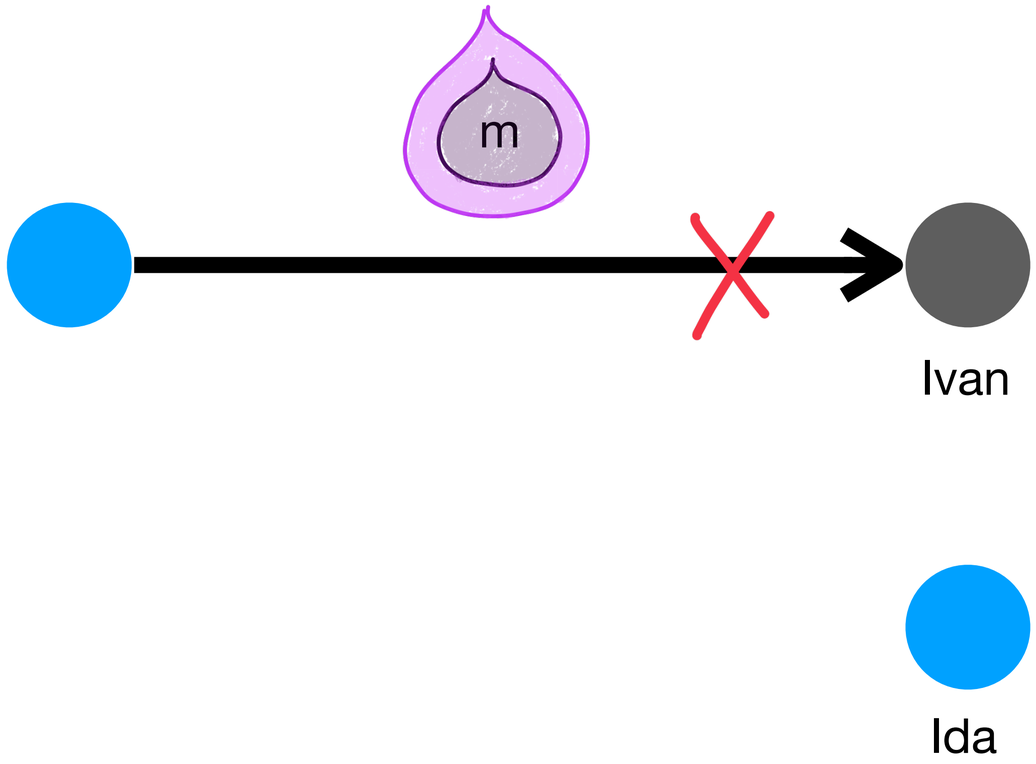


Onion is *dropped*

First attempt: duo onions

[Iwanik, Klonowski, Kutyłowski ‘05]

Idea: onion is peelable by Ivan *and* Ida



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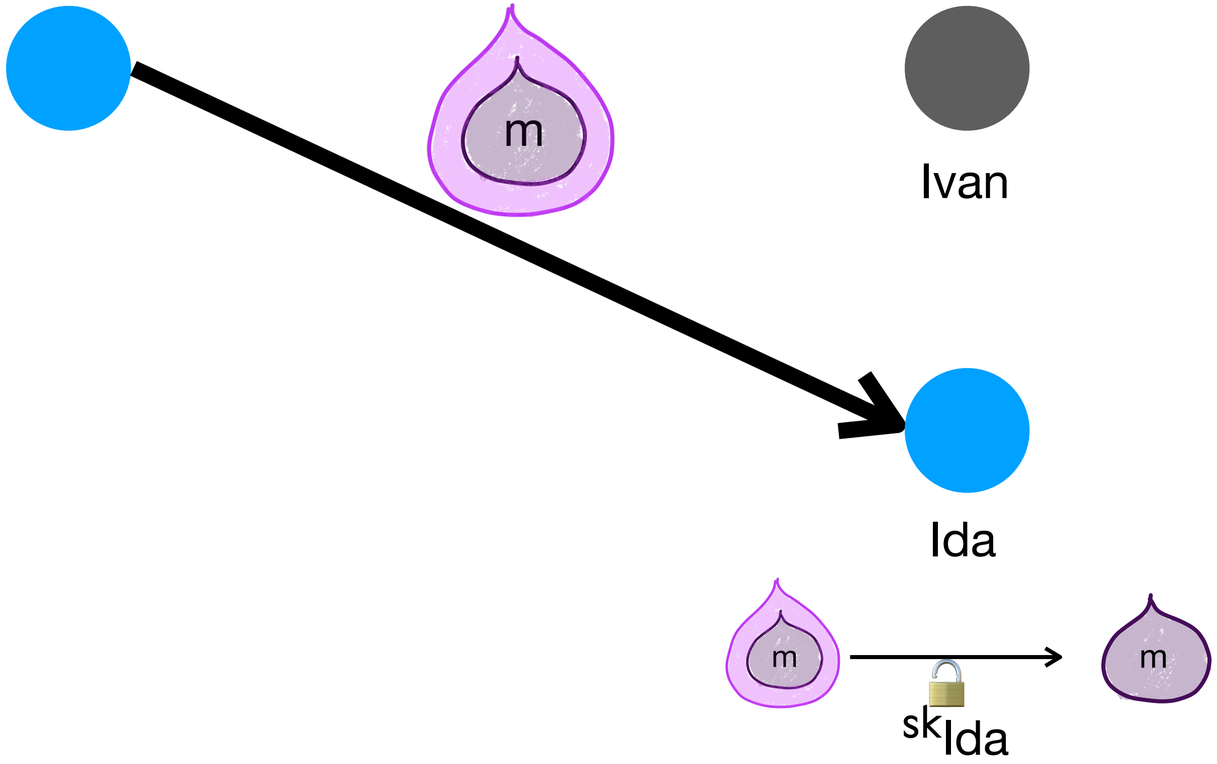
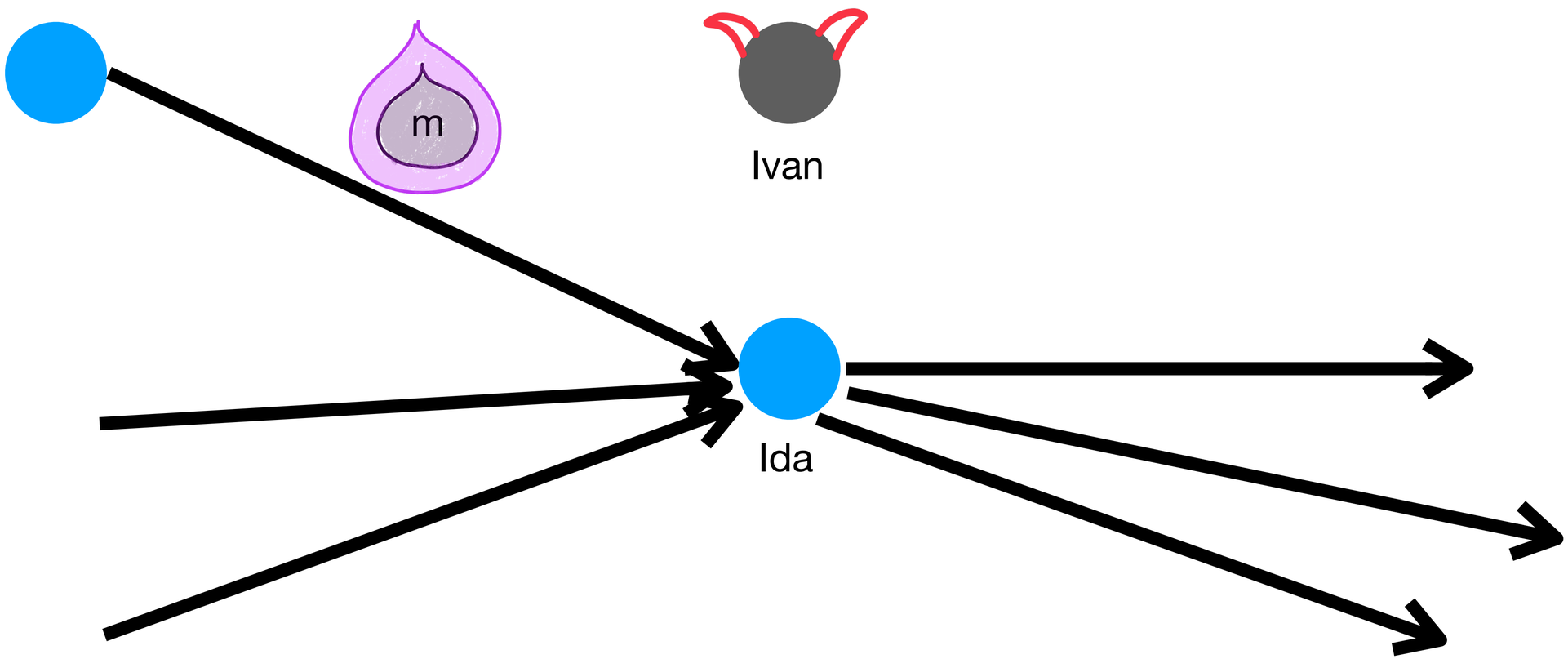


Problem: no mixing

If *either* Ivan or Ian is corrupted, the adversary can trace the onion



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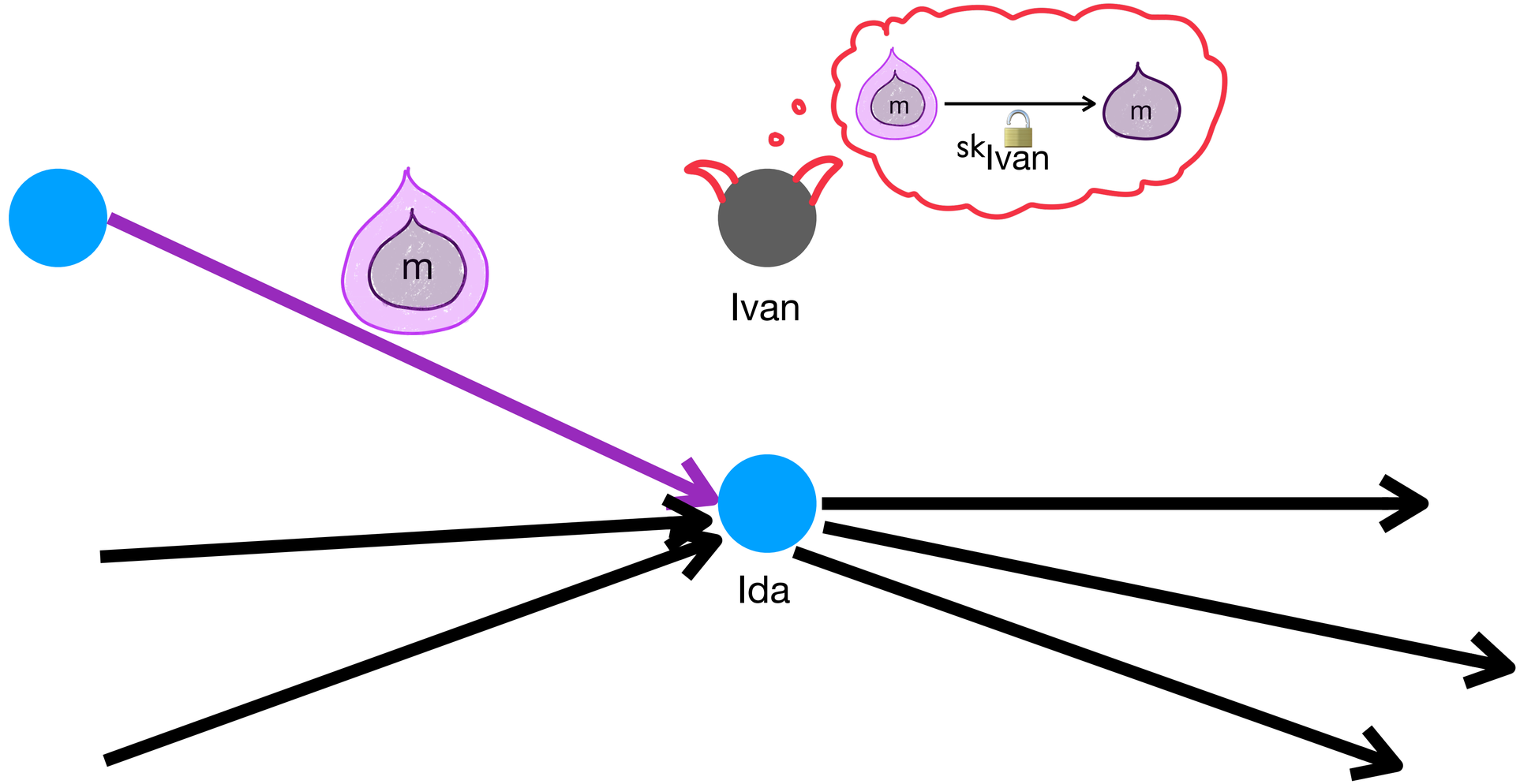
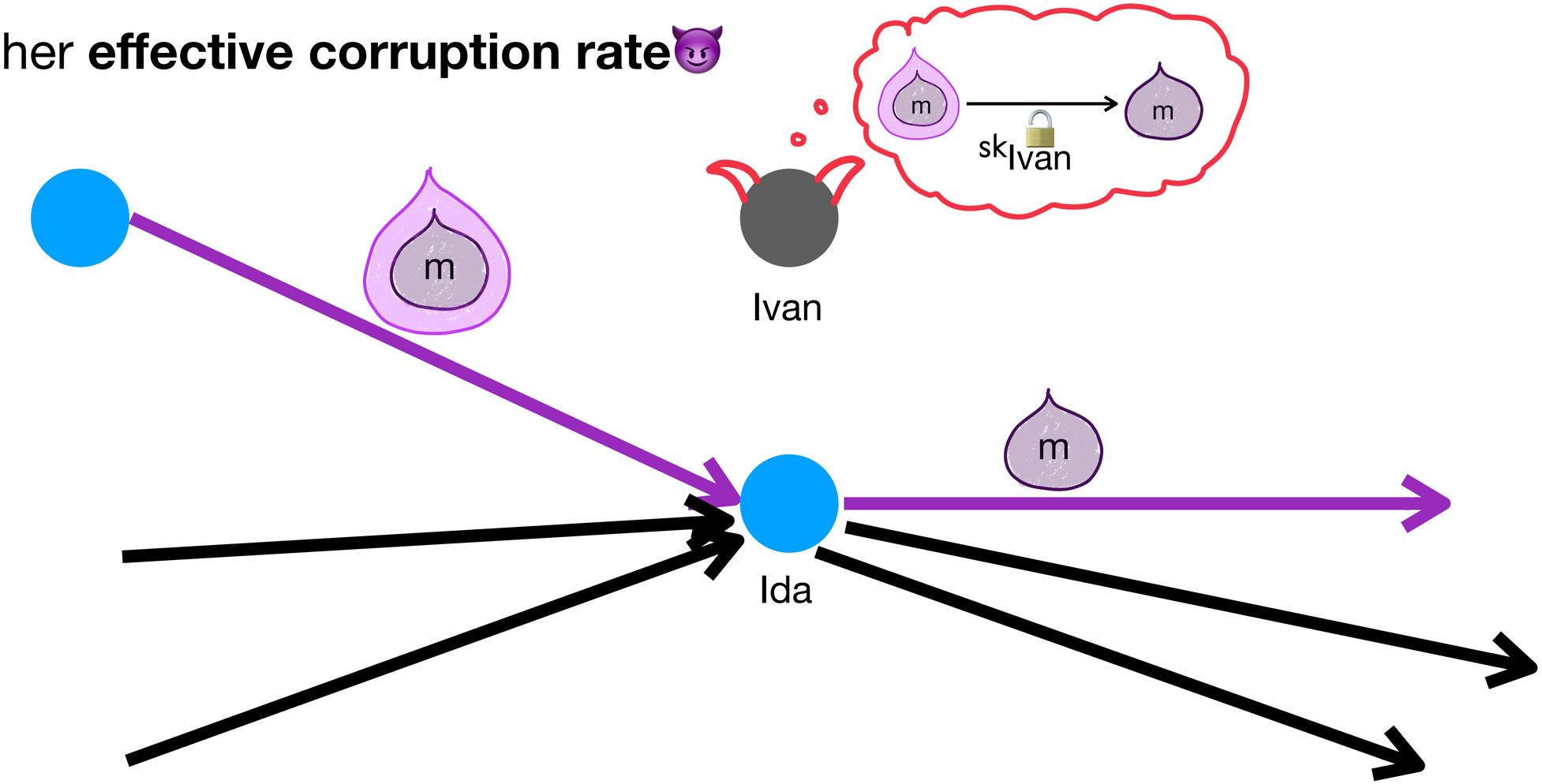


Problem: no mixing

If *either* Ivan or Ida is corrupted, the adversary can trace the onion

➡️ higher **effective corruption rate**😈



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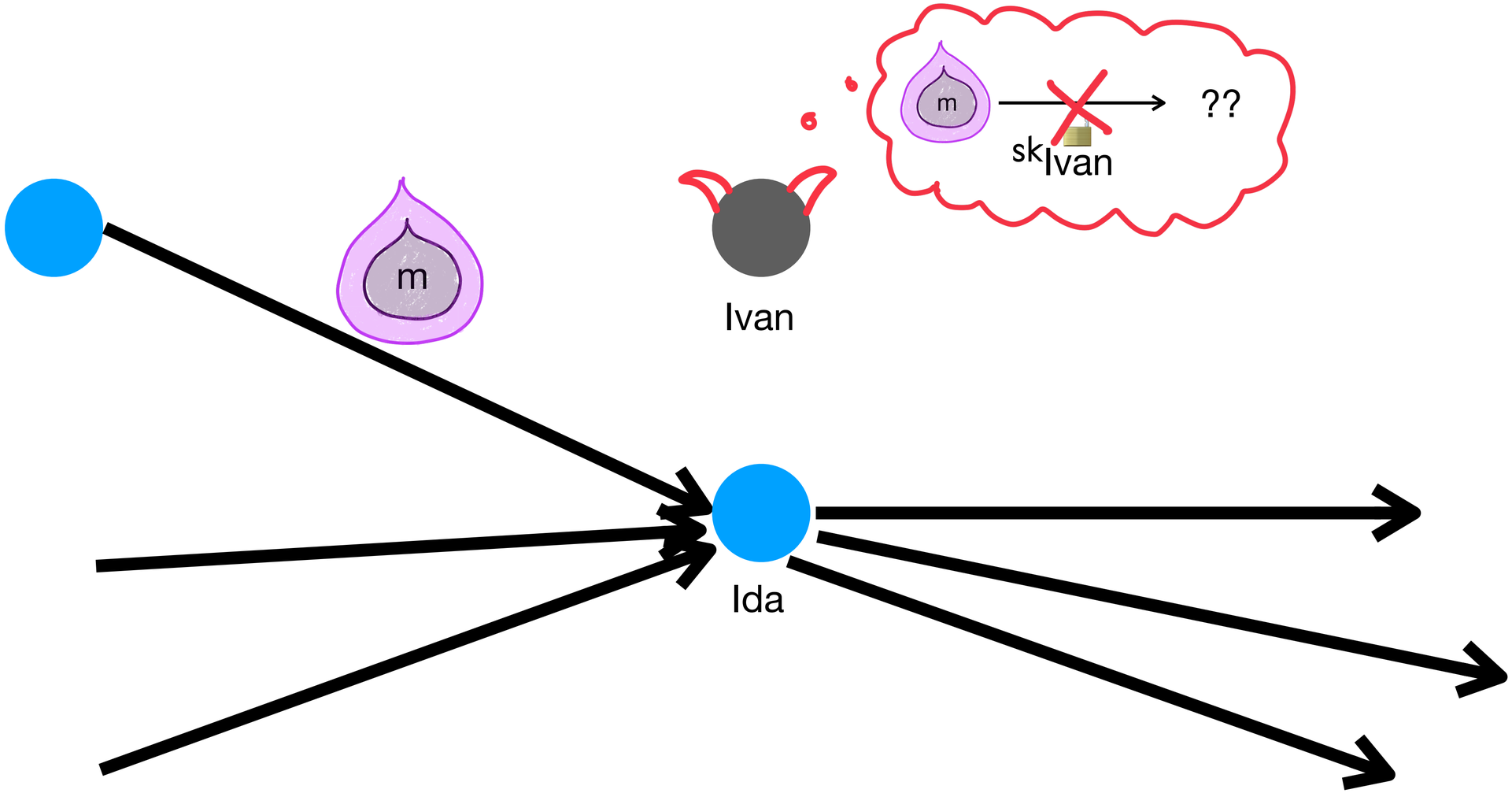

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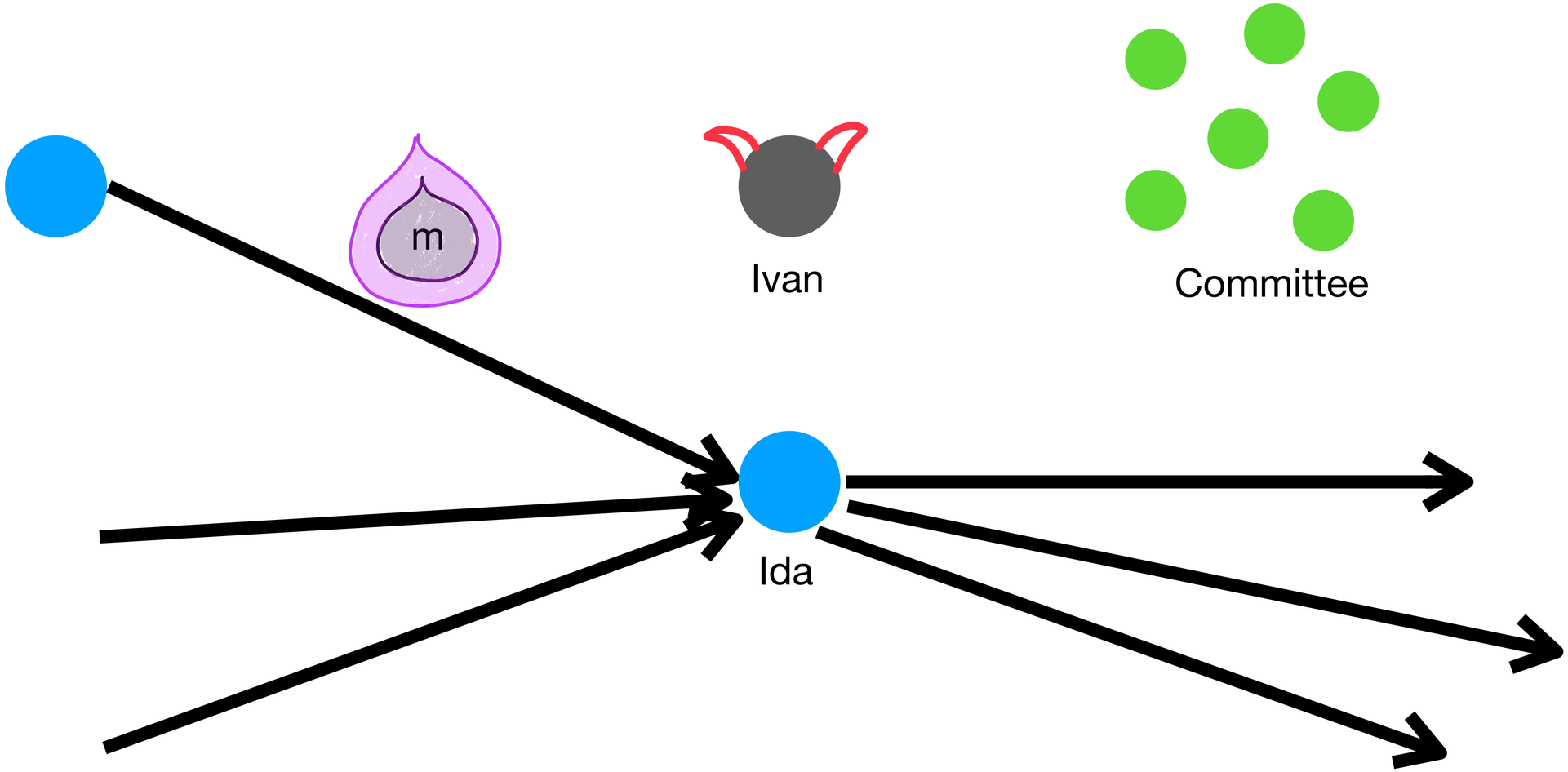

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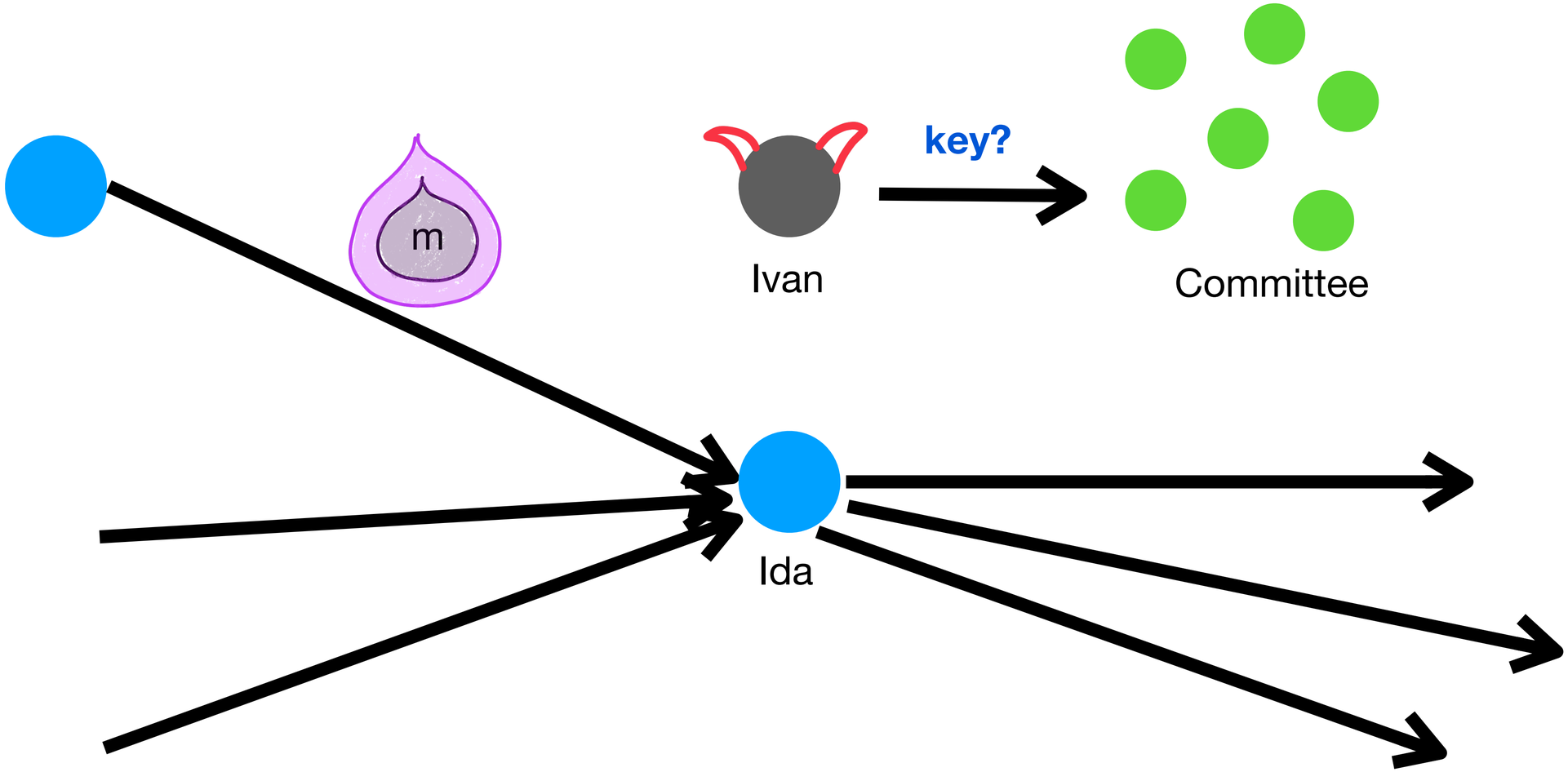

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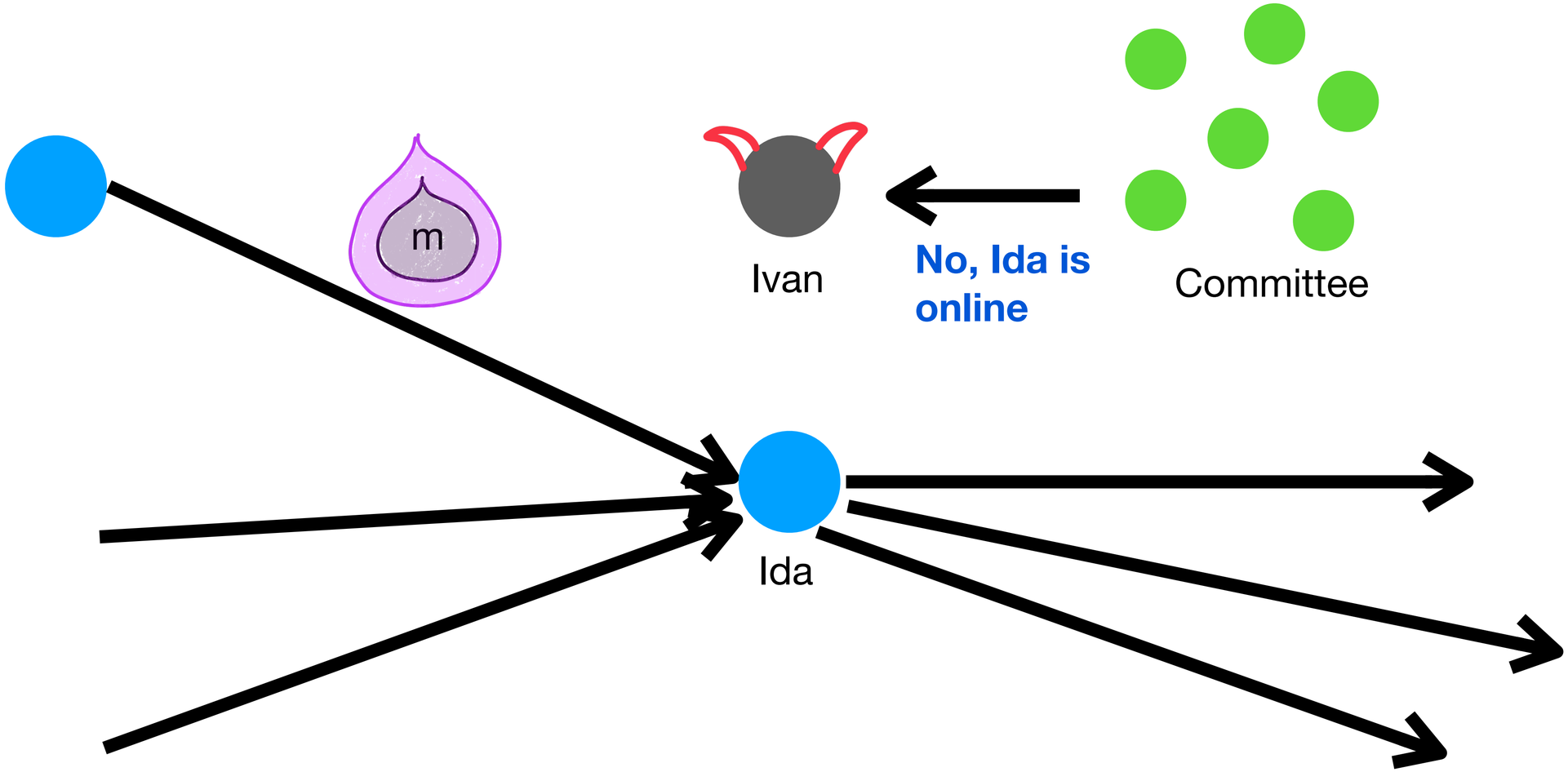

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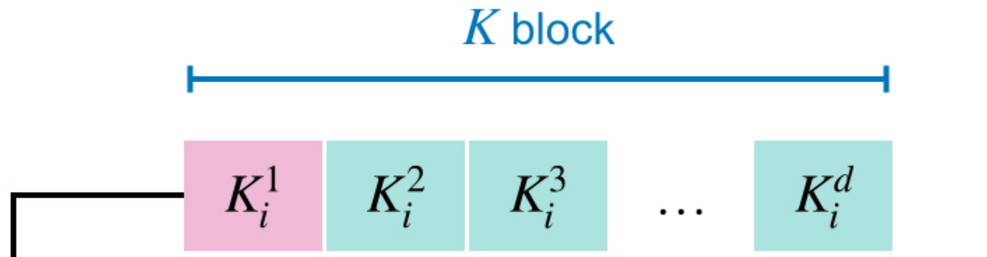
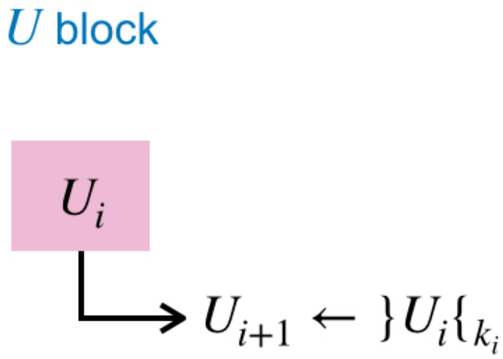
- An alternate candidate needs a key from a **committee** to peel the onion
- Have mixing if primary candidate is **honest and online**
  - **Probability of this is independent of # candidates**
- Can extend to any number of candidates
  - **Boosts probability that onion is not dropped**

Ida: first candidate
Ivan: second candidate



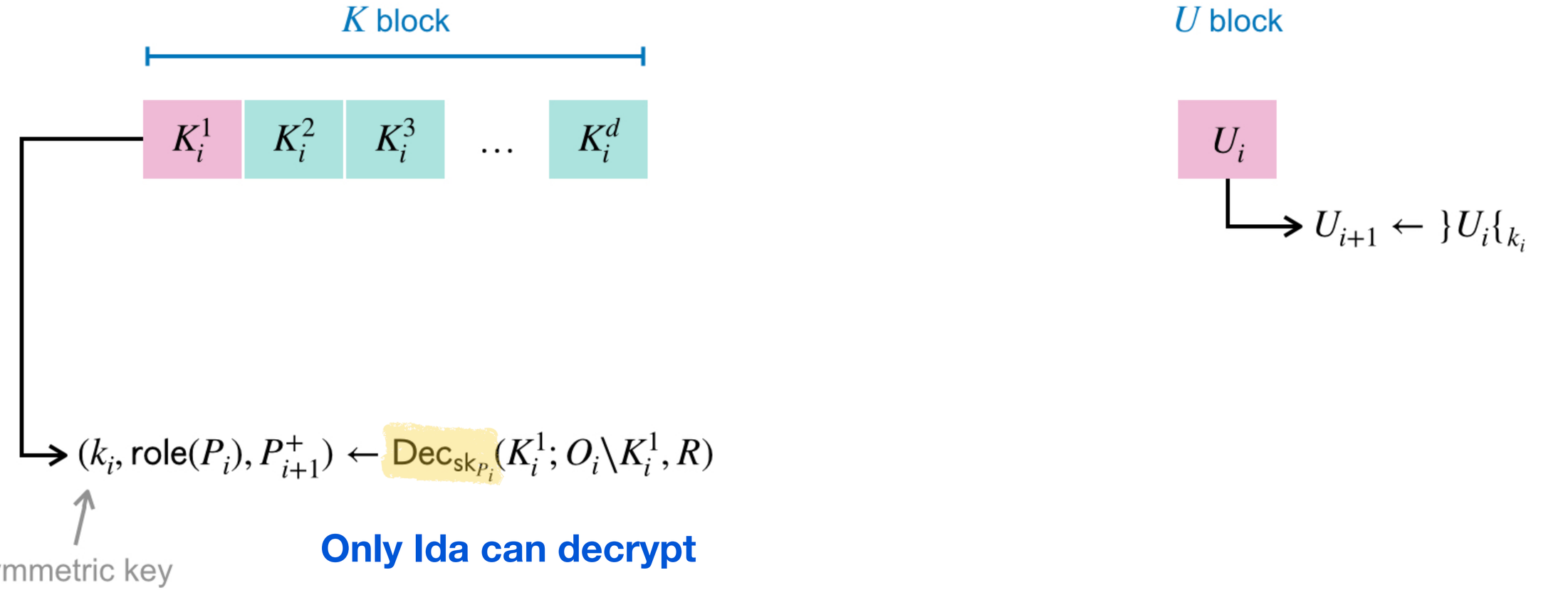


$(k_i, \text{role}(P_i), P_{i+1}^+) \leftarrow \text{Dec}_{\text{sk}_{P_i}}(K_i^1; O_i \backslash K_i^1, R)$

Symmetric key

Needed to peel rest of onion

Ida: first candidate
Ivan: second candidate



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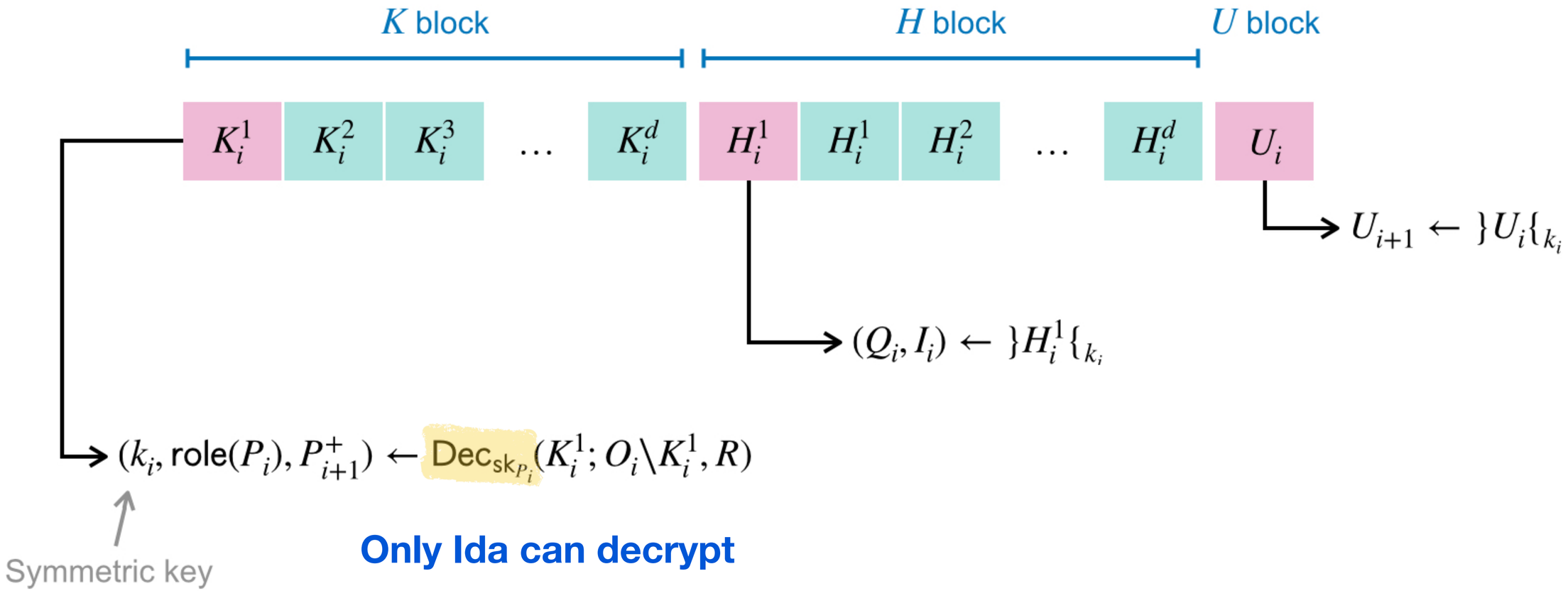

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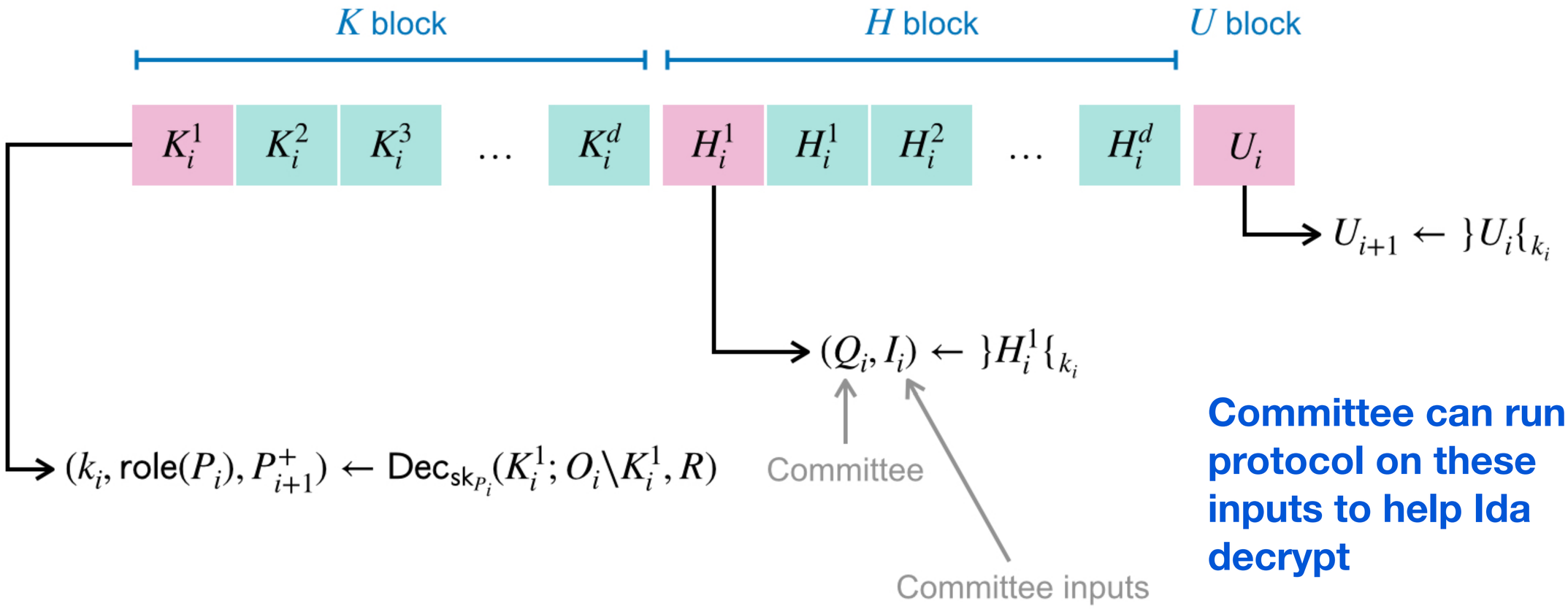

Committee can run protocol on these inputs to help Ida decrypt

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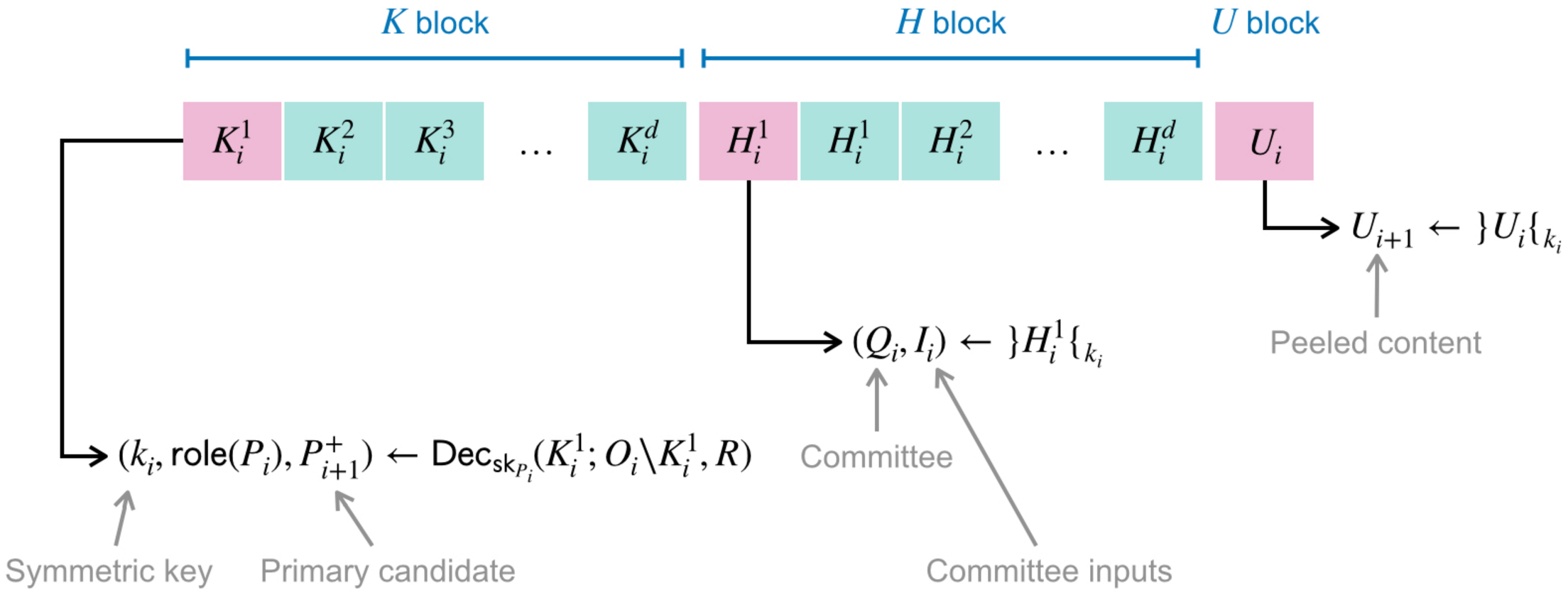

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Thank you!

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Luna, Megumi’s daughter and onion routing enthusiast