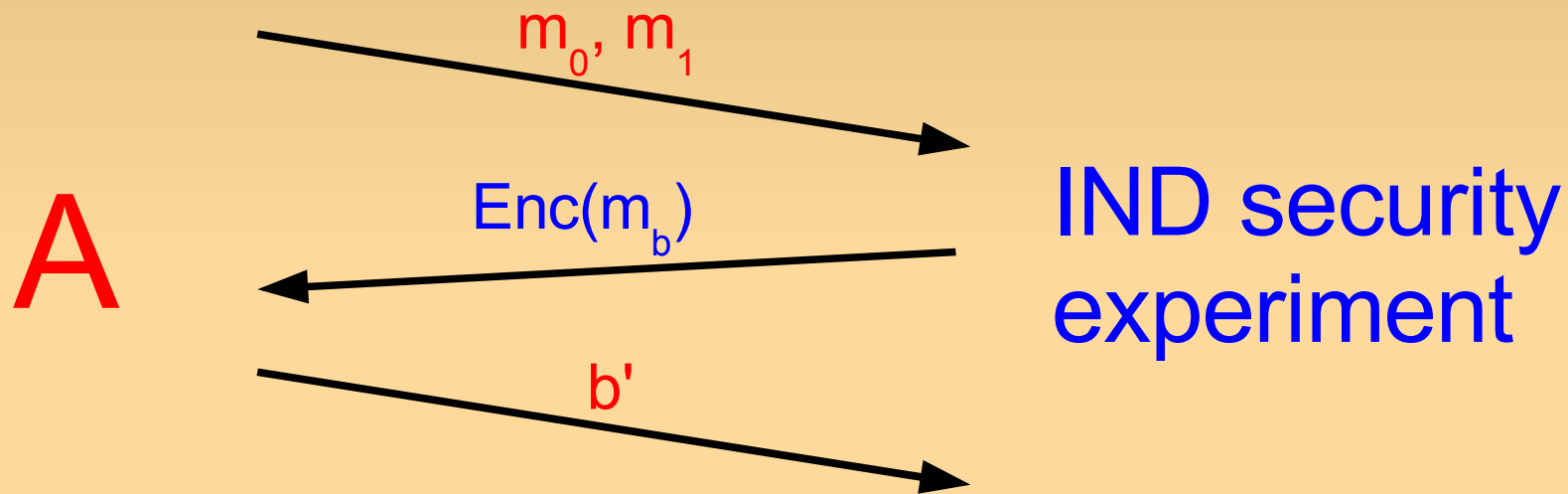


Towards Key-Dependent Message Security in the Standard Model

Dennis Hofheinz (CWI),
Dominique Unruh (Saarland University)

Encryption scheme security

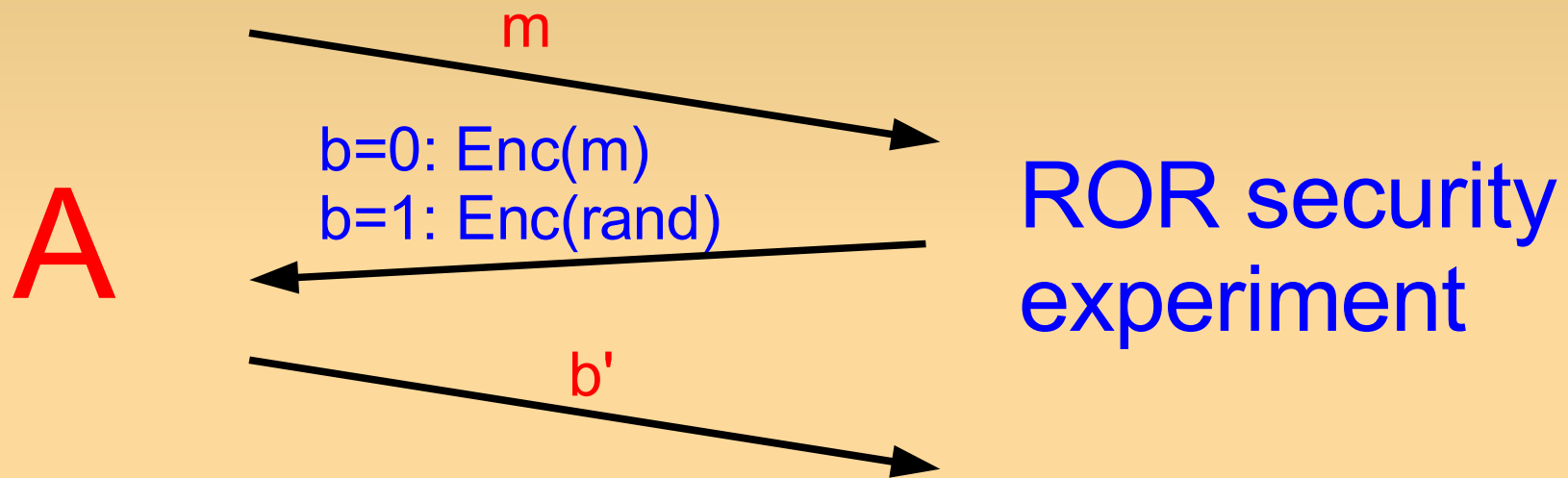
- Idea: two encryptions indistinguishable



- Scheme IND secure (IND-CPA/IND-CCA)
 \Leftrightarrow no **A** achieves $\Pr[b'=b] > 1/2$
- **A** also gets encryption oracle/public key

Encryption scheme security

- Equivalent to IND: ROR (real-or-random)



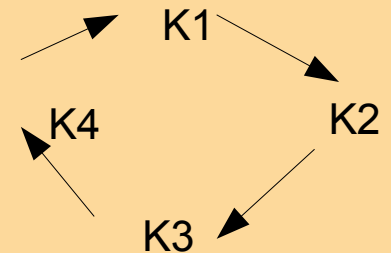
- Scheme ROR secure (ROR-CPA/ROR-CCA)
 \Leftrightarrow no **A** achieves $\Pr[b'=b] > 1/2$
- Multiple ROR queries allowed

Applications of IND/ROR

- IND/ROR-style definitions are elegant
 - Strict, reasonable, achievable, useful
- But: ...if you want to encrypt your hard drive?

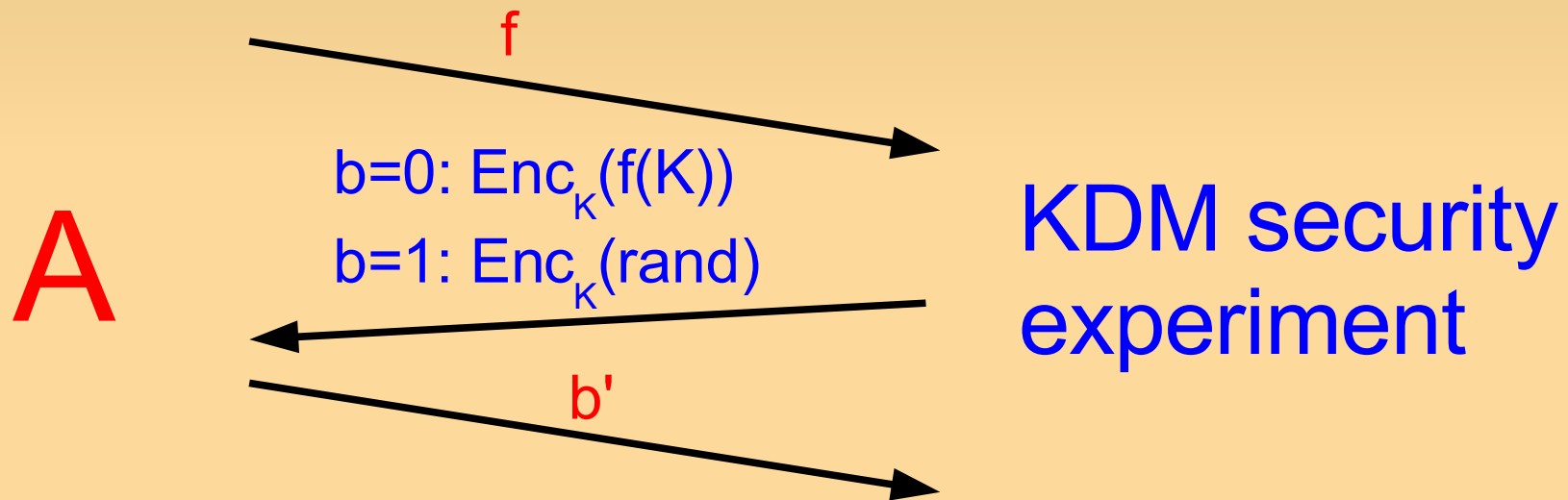
Enc_K ()

- ...or your protocols have key cycles?
- IND-CCA does not help here!



Stronger: KDM security

- [Black, Rogaway, Shrimpton 2002]:
 - Reasonable to look at stronger notion:



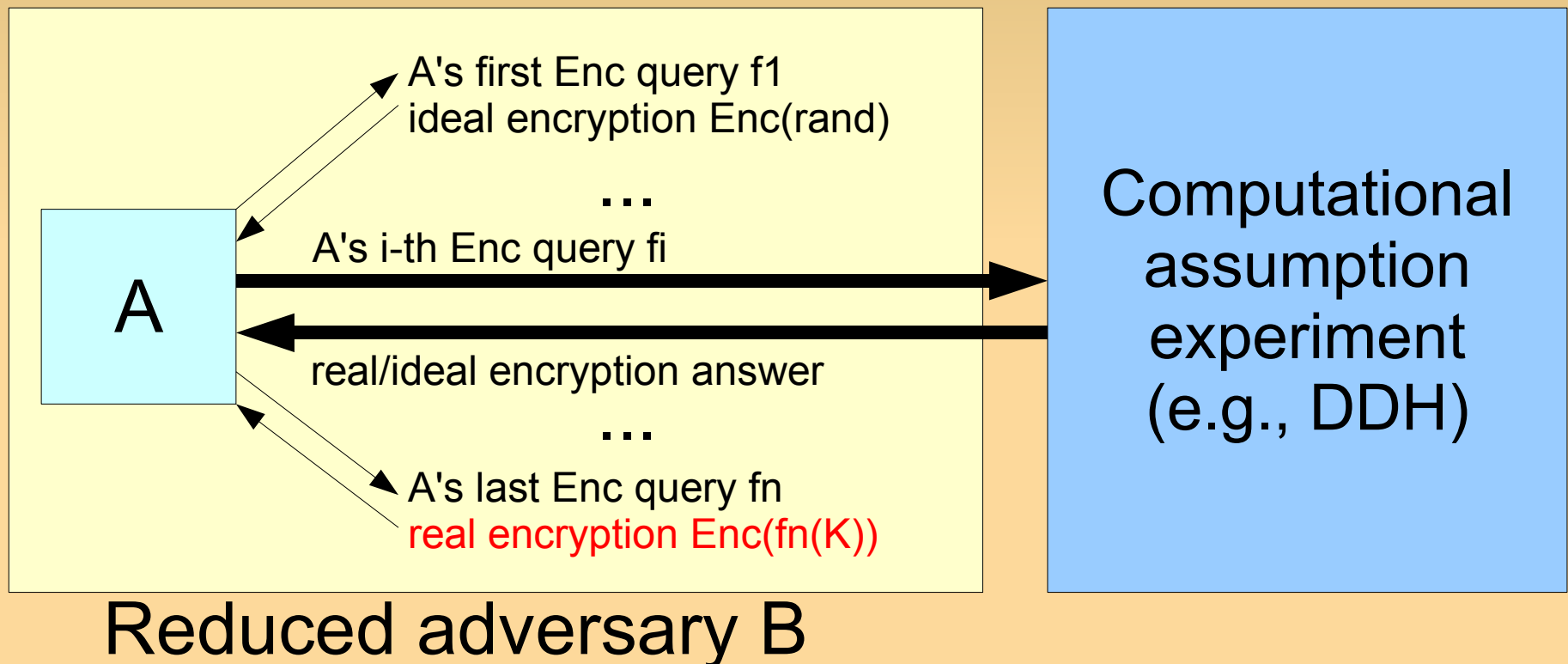
- A gets multiple queries
- Implies IND/ROR, good for use cases

KDM: previous work

- Soundness results (related assumptions)
 - Acyclicity assumptions (e.g. [Abadi, Rogaway 1998])
 - ...or security under key cycles (e.g. [Adao et al 2005])
- Key cycle security [Camenisch, Lysyanskaya 2001]
- KDM def/RO scheme [Black, Rogaway, Shrimpton 2002]
- Adaptive KDM [Backes, Pfitzmann, Scedrov 2006]
- Concurrent work: [Halevi, Krawczyk 2007]
 - Positive & negative results in **standard** model

KDM: hard to achieve

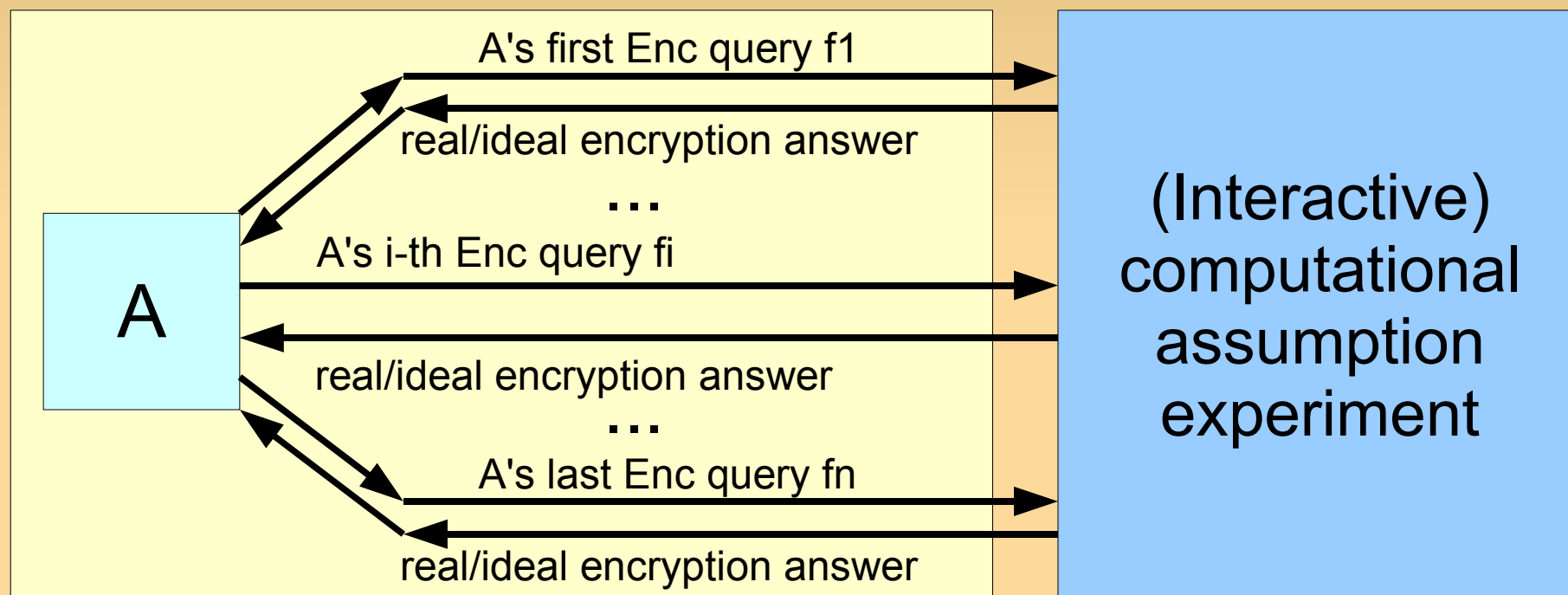
- Usual way hybrid arguments are done:



- But: no way to simulate $\text{Enc}_K(f(K))$ in B

KDM in the standard model

- Possible but not interesting:



Reduced adversary B

- Security essentially **is** the assumption 😞

Weakening KDM

- KDM hard to achieve in standard model
- [BRS01] uses statistical RO properties
 - Analysis breaks down without independence of oracle queries
- Several weakenings of KDM imaginable
 - Smaller class of allowed dependencies (i.e., functions f) [Halevi, Krawczyk 2007]
 - Bound number of encryptions (this talk)
 - Or: consider stateful schemes (this talk)

Idea: bounded KDM security

- Setting: KDM with bounded # encryptions
 - Idea: if key is sufficiently bigger than **all** encryptions then key always contains enough entropy such that entropy smoothing works

- Example scheme:

$$\text{Enc}_K(m) = (\overset{\text{UHF}}{h}, h(K) + m)$$

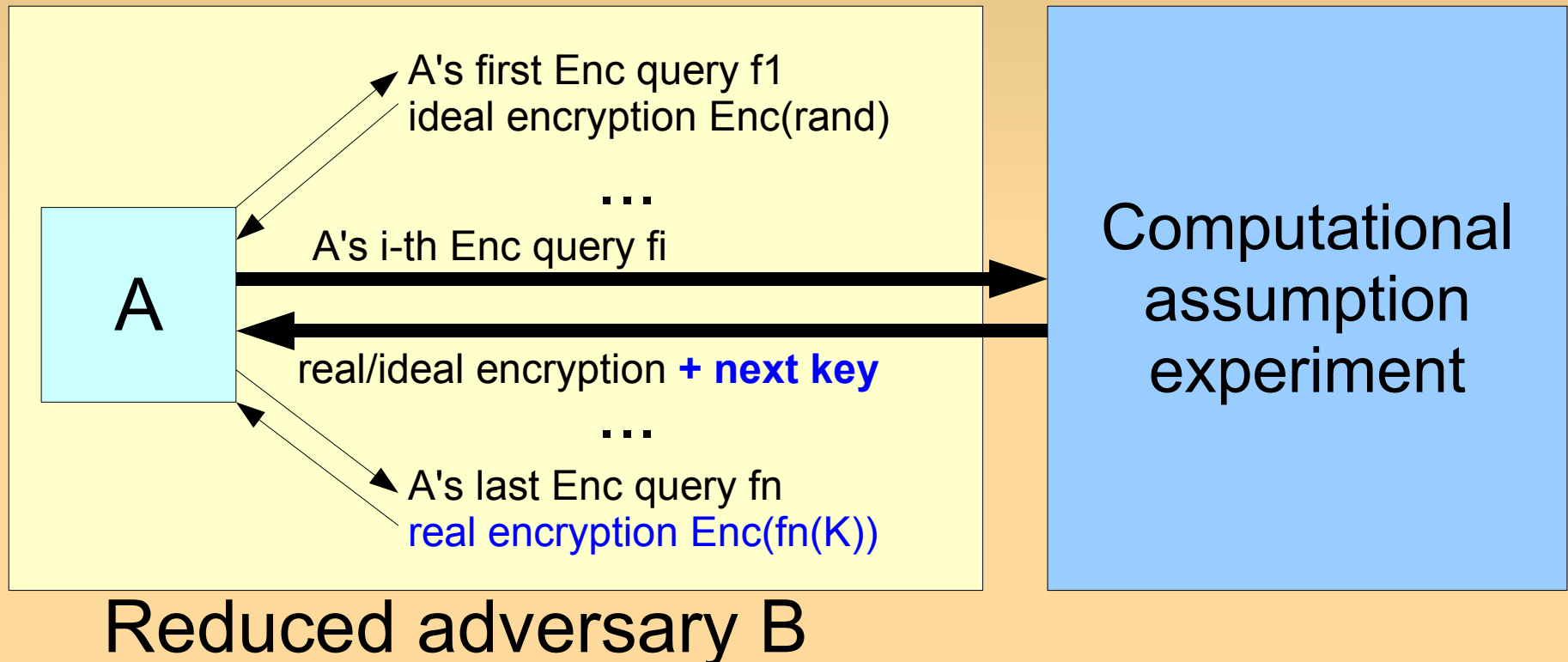
- If $|K| > |m| (2n+3)$ (where $n = \#$ encryptions) then this scheme is KDM secure (statistically)

Idea: stateful schemes

- Intuition: update state after encryption
 - State/key before i -th encryption: K_i
- Two options:
 - Weak stateful KDM: trusted erasures ($f_i = f_i(K_i)$)
 - Strong stateful KDM: no erasures ($f_i = f_i(K_1, \dots, K_i)$)
 - No bound on # encryptions!
- We can achieve weak (but not strong)

Idea: stateful schemes

- Idea: weak stateful KDM allows hybrids:



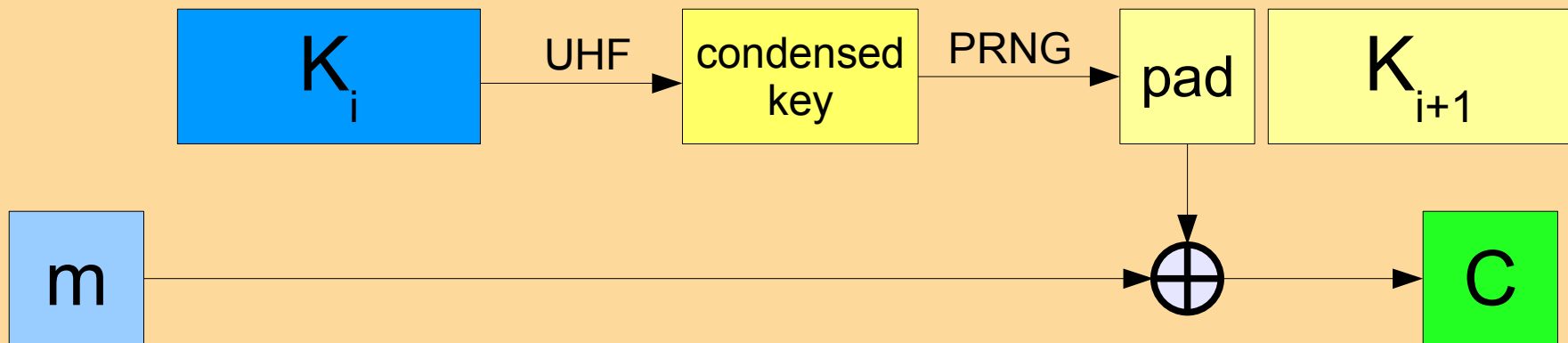
- "Direction" of hybrid argument matters!

Idea: stateful schemes

- Scheme (entropy smoothing + PRNG):

$ENC_{K_i}(K_i, m)$:

1. randomly pick UHF h
2. $condensed_key = h(K_i)$
3. $(pad, K_{i+1}) = PRNG(condensed_key)$
4. $C = (h, pad + m)$



Strong stateful KDM security?

- Setting: message depends on all previous keys:

$$f_i = f_i(K_1, \dots, K_i)$$

- Hybrid argument trick as before doesn't work
 - Reason: to produce any encryption, need K_1
- Still: very attractive goal (\rightarrow use cases)
 - Strong stateful KDM is weaker than full KDM...
 - ... but but for use cases, just as good

Conclusion

- KDM in standard model hard (but intriguing)
 - One-to-many encryptions/keys w/o hybrids
- Our approach: weaken security notion
 - Bounded # encryptions
 - Stateful schemes with trusted erasures
- Open: how to achieve full KDM security w/o RO
 - ...or strong stateful KDM security
 - ...or at least security in presence of key cycles
 - Different assumption? Impossibilities?