Security Notions for Bidirectional Channels

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FSE 2017
Tokyo, Japan

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Outline

Secure channels and how they are modeled

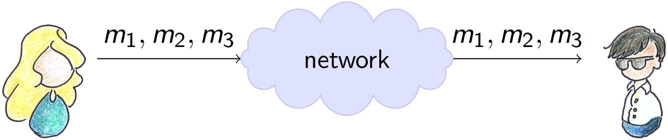
Security notions for bidirectional channels

Analysis of bidirectional channel design

Communication channels

- setting: two-party communication over the Internet
- goal: deliver messages and preserve sending order
- how to achieve this: TCP/IP

Good, if there are only Alice and Bob (idealized world)



m_1, m_2, m_3

network

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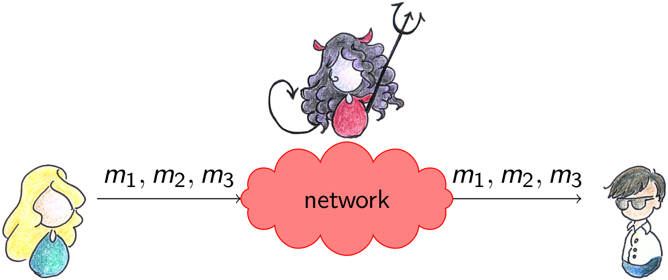
Cryptographic channels (a.k.a. secure channels)

- setting: two-party communication over the Internet
- goal: **protect** communication from adversaries



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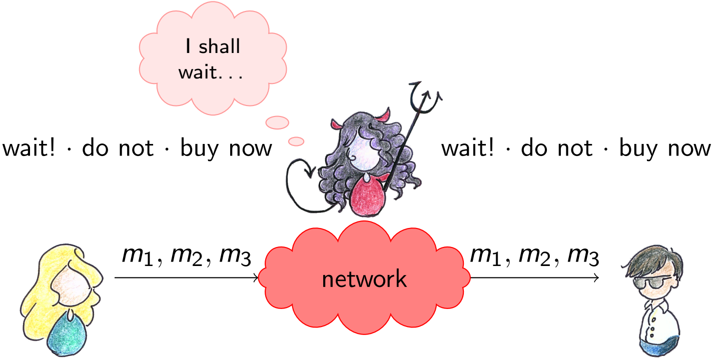
- security (informally): prevent eavesdropping



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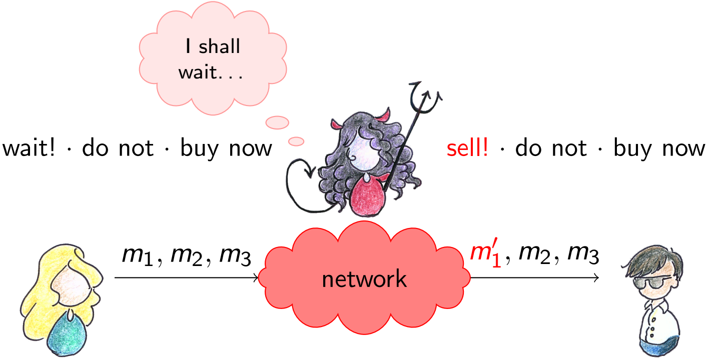

I shall wait. . .

wait! · do not · buy now

sell! · do not · buy now

m_1, m_2, m_3

network

m'_1, m_2, m_3

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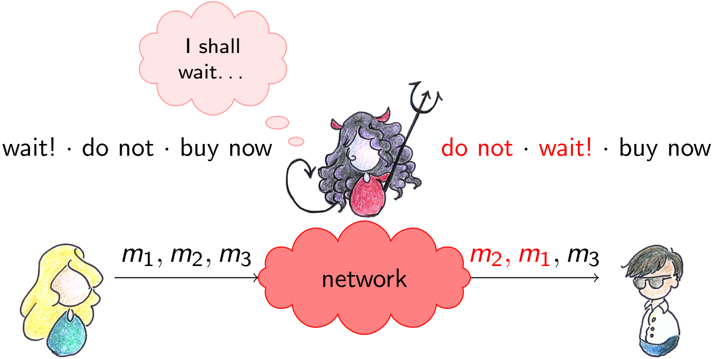

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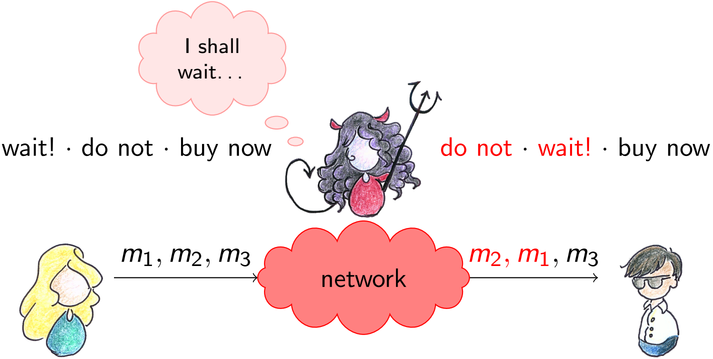
make real world close to idealized world



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m_1, m_2, m_3

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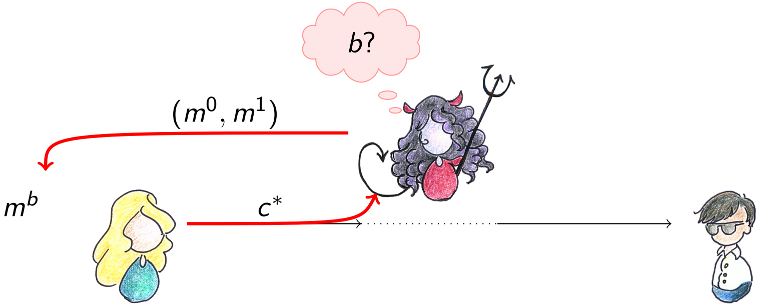
m_2, m_1, m_3

Modeling channel security [BKN'02]

Confidentiality

- intuitively: ciphertext hides plaintext
- formally: **IND-CPA** (a.k.a. 'passive')



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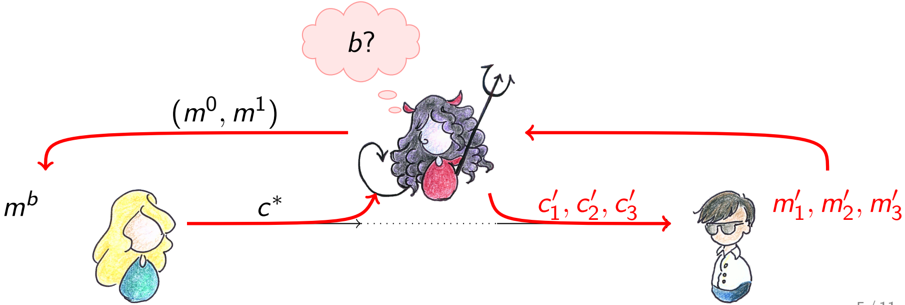

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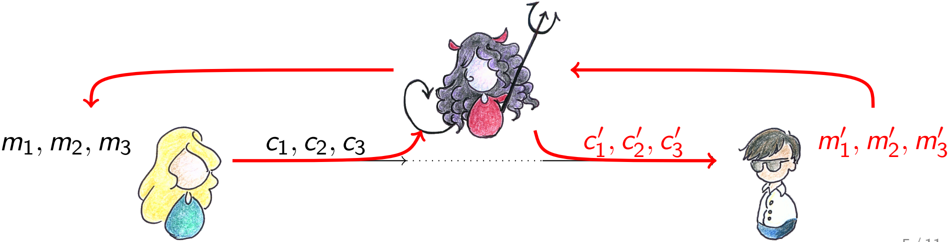
- formally: **INT-PTXT**



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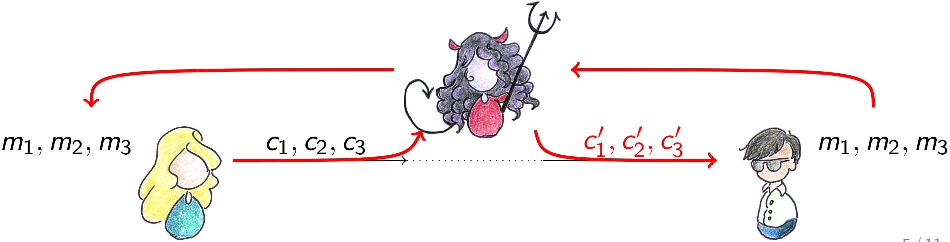

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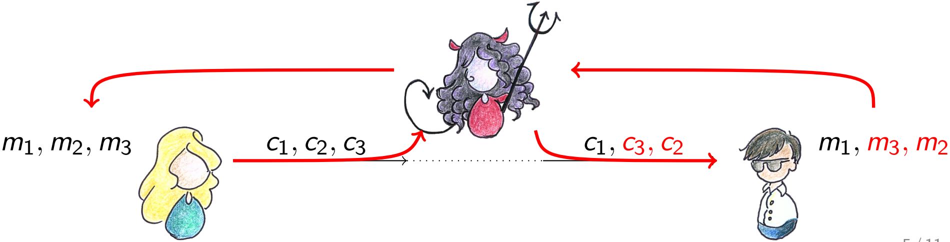
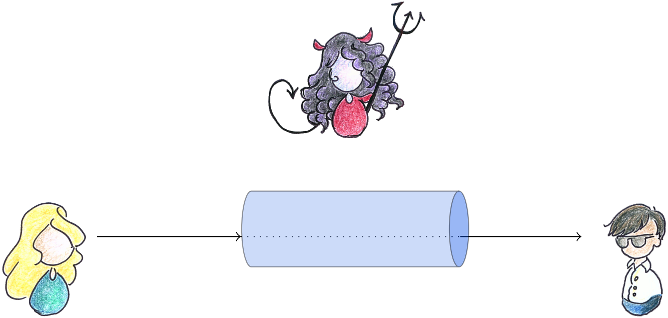
both incorporate replay and reordering protection



Cryptographic channels in theory: state of the art

- channel security: IND-CPA + **INT-CTXT** ($\Longrightarrow$ **IND-CCA**)
- also called 'stateful authenticated encryption' (stateful AE)
- introduced to analyze (and prove) SSH channel security [BKN02]
- reference model to analyse TLS [JKSS12,KPW13,. . .]



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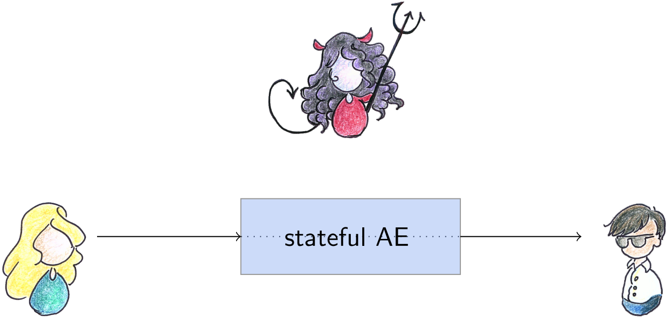
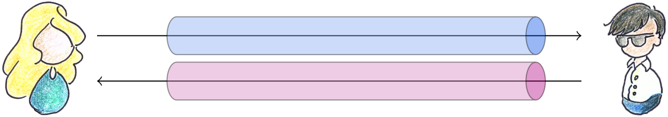
stateful AE considered good abstraction of a secure channel



Channels are used for bidirectional communication

- prior work: 'Sender → Receiver' communication
- practice: channels protect bidirectional communication
- standard approach employs two independent unidirectional channels

canonic composition of unidirectional channels



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- folklore: unidirectional security ⟹ bidirectional security

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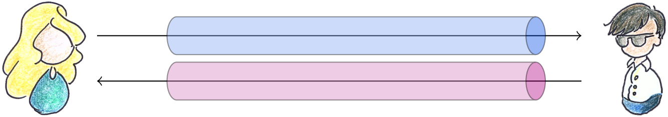

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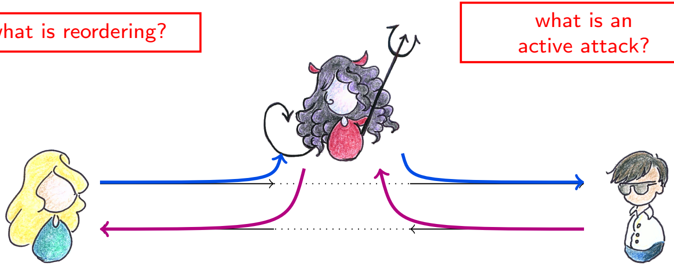
what does it mean
‘bidirectional security’?

what is reordering?

what is an
active attack?



Our contribution in a nutshell

Defining bidirectional security

- confidentiality: IND-2-CPA, IND-2-CCA
- integrity: INT-2-PTXT, INT-2-CTXT
- notions reflect that → and ← are not independent of each other

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Relations among notions

- INT-2-CTXT $\Longrightarrow$ INT-2-PTXT
- IND-2-CCA $\Longrightarrow$ IND-2-CPA
- INT-2-CTXT + IND-2-CPA $\Longrightarrow$ IND-2-CCA

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- INT-2-CTXT + IND-2-CPA $\Longrightarrow$ IND-2-CCA

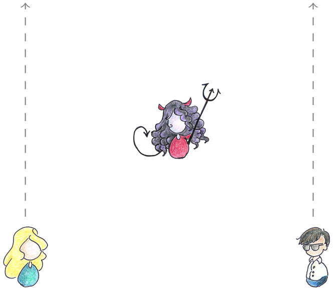
Analysis of the canonic composition

- question: can security be lifted from unidirectional components?
- our results question common belief…

Active attacks in a bidirectional setting

active ≈ deviation from honest behavior

manipulation of ciphertexts or of their order (akin to unidirectional setting)



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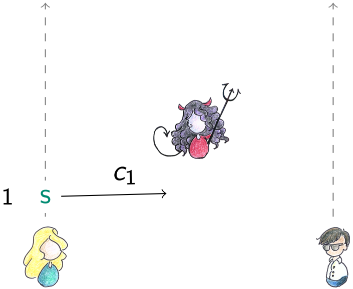

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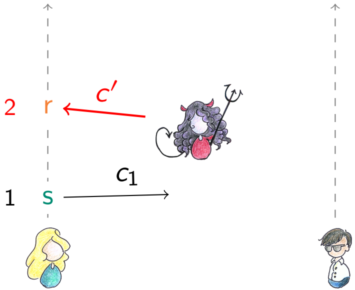

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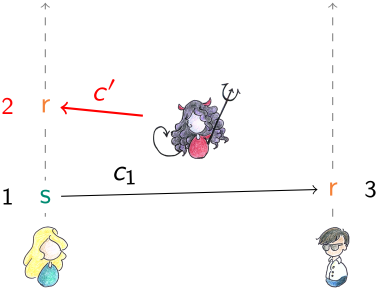
Our model additionally allows to express that:

- 'passive' query may chronologically follow 'active' query (concurrency)



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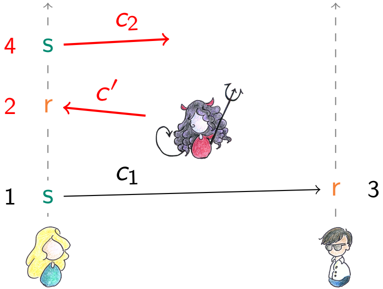

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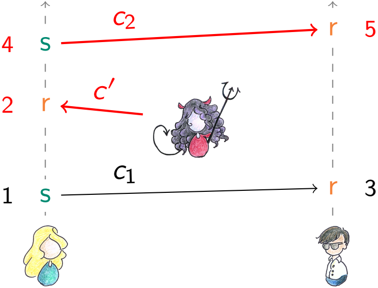
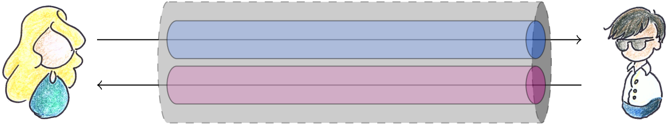
- active attack on ← may influence security of →



Bidirectional security of the canonic composition

Generic analysis: can security be lifted from unidirectional components?

- INT-PTXT + INT-PTXT $\Longrightarrow$ INT-2-PTXT
- INT-CTXT + INT-CTXT $\Longrightarrow$ INT-2-CTXT
- IND-CPA + IND-CPA $\Longrightarrow$ INT-2-CPA



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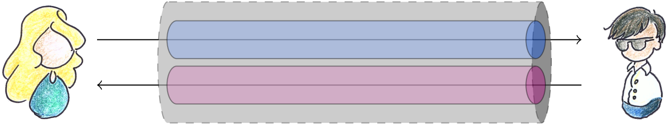
- IND-CCA + IND-CCA $\not\Longrightarrow$ INT-2-CCA



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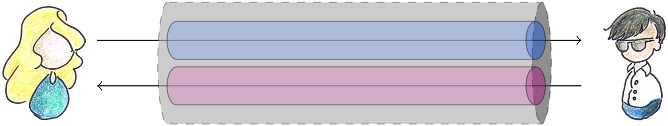
Bidirectional security of TLS and SSH (the good news)

- TLS and SSH channel offer stateful AE security [K01,BKN02,PRS11]
  Encode-then-E&M for SSH, CBC-based M-then-E for TLS
- our result: they also offer **IND-2-CCA** and **INT-2-CTXT** security



Summary

This work

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- analyze ‘canonic composition’
- confirm security of (crypto core of) TLS and SSH channels

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Thank you!

Defining bidirectional confidentiality (IND-2-CCA)

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**Send** $(u, m^0, m^1)$
    $c^* \leftarrow \mathrm{Send}(\mathrm{st}_u, m^b)$
    if $h_u = \mathrm{True}$
        $C_u[s_u] \leftarrow c^*$
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    Return $c^*$
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**Recv** $(u, c)$
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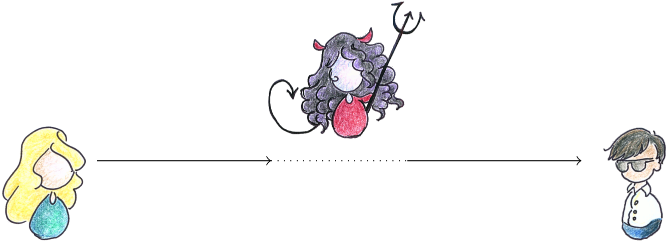

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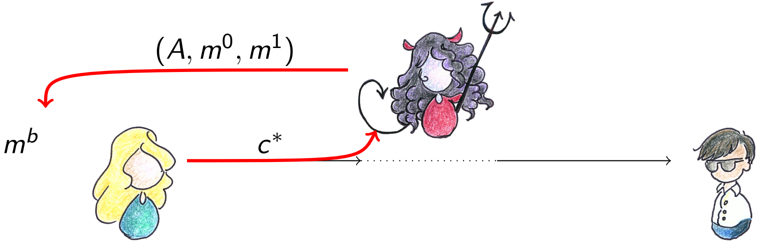

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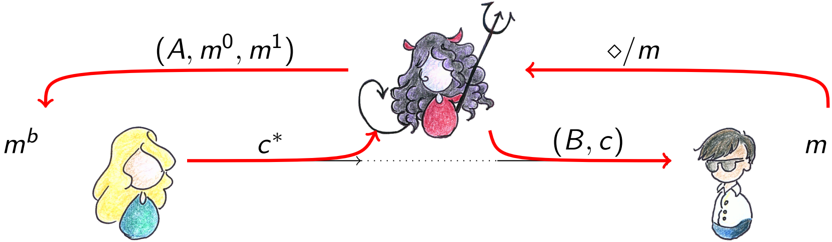

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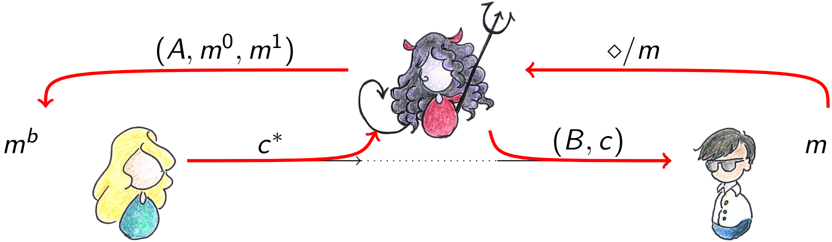

(A, m^0, m^1)

$\diamond / m$

m^b

c^*

(B, c)

m

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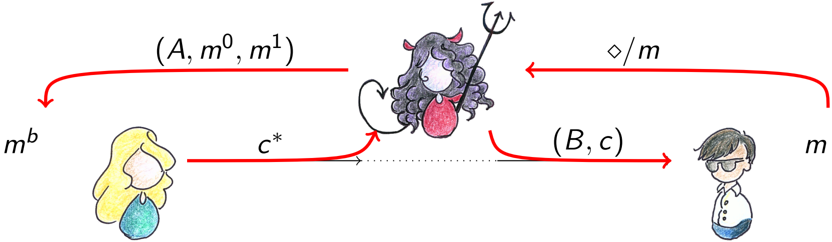

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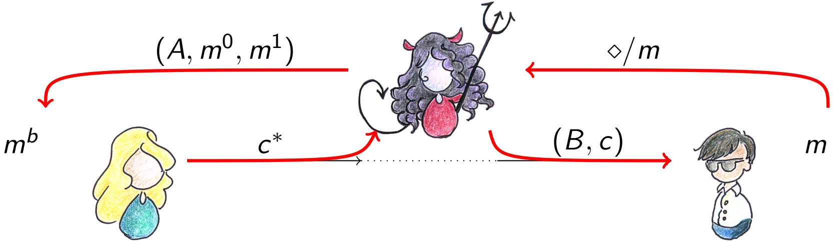
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