Adaptive and Composable Non-committing Encryptions

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Motivation

- Security against more powerful adversary is more preferable.
- However, constructing protocols that withstand a wider class of adversaries is usually harder to achieve…
- We consider to construct a secure channel protocol against an adaptive (more powerful) adversary in the UC framework.

Adversarial Models in Cryptographic Protocol

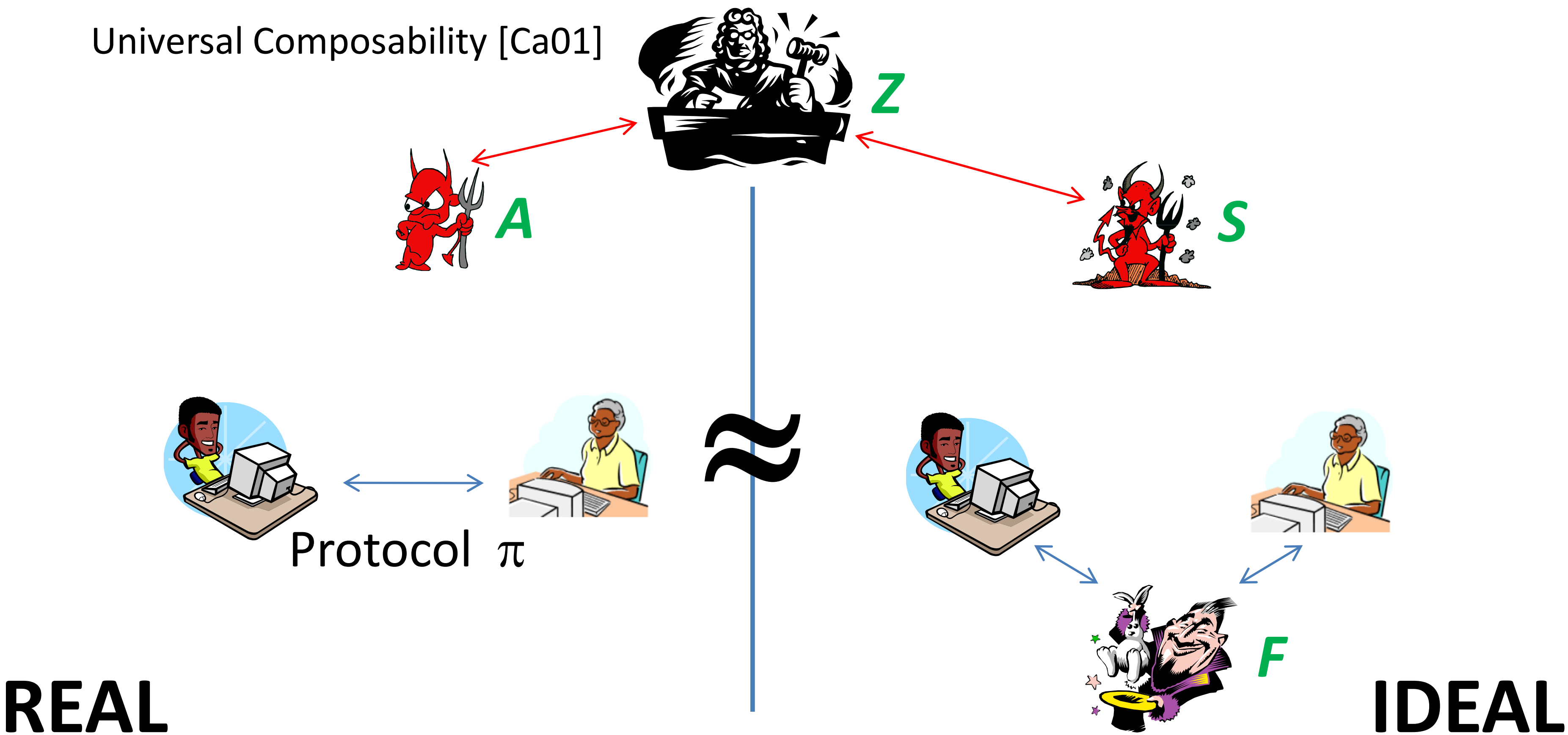
- Static vs Adaptive
  - Static adversary
    - needs to decide the set of players to corrupt prior to the execution of the protocol
  - Adaptive adversary
    - can corrupt players during the execution of the protocol arbitrarily
    - More flexible and realistic
- Erasure vs Non-Erasure
  - In the erasure model, players are assumed to be able to erase the past data when corrupted by an adversary
    - So the adversary cannot get the past computation history even if it corrupt a player
  - The erasure model is not realistic and may be impossible…
- Adversarial models have a large influence on security proof
- In particular, an adaptive adversary in the non-erasure model makes it hard to construct a secure channel

Adaptive Security for Secure Channel

- Secure channel is a basic cryptographic primitive.
- However, to construct a secure channel against an adaptive adversary, **traditional public key encryption** is not sufficient…
- [Nie02] proved that no non-interactive communication protocol can achieve adaptive security without the random oracle(RO) model.
- So we need an interactive protocol to realize a secure channel against an adaptive adversary w/o the RO model.

Security Definition in UC Framework

Universal Composability [Ca01]



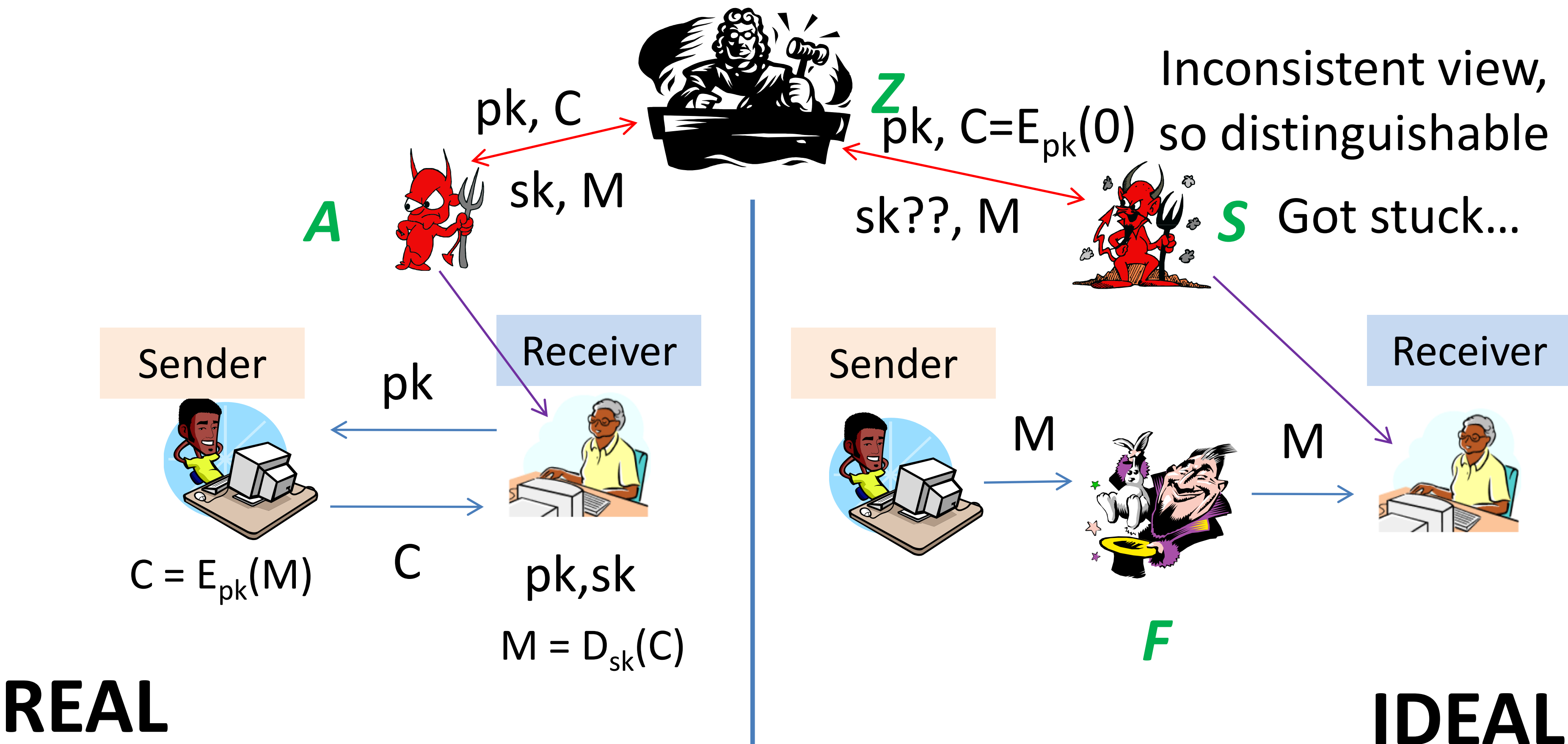
Protocol π is a secure realization of an ideal functionality **F** if

for every real adversary **A**

there exists a simulator **S** s.t.

ideal & real worlds are indistinguishable to any environment **Z**

Secure Channel with Adaptive Adversary?



Non-committing Encryption needed instead of Public Key Encryption

Non-committing Encryption

- With non-committing encryption(NCE), we can construct a secure channel protocol against an adaptive adversary.
- Simulator can run an NCE protocol and create a fake ciphertext that can be opened to any chosen plaintext (0 or 1).
- Encryption is done for each bit of message M
  - inefficient, but same efficiency as other schemes in the non-erasure model
  - Price for adaptive security…

Building Block

- Naor-Pinkas randomizer (NPR) ϕ [NP01]
- Setup: $p = 2q+1$

  $G \subseteq Z_p^*$ is a subgroup of order q
- $\phi((g_1, g_2, h_1, h_2) \times (s,t))$ defined as

  $(u, v) = (g_1^s g_2^t \bmod p,\ h_1^s h_2^t \bmod p)$

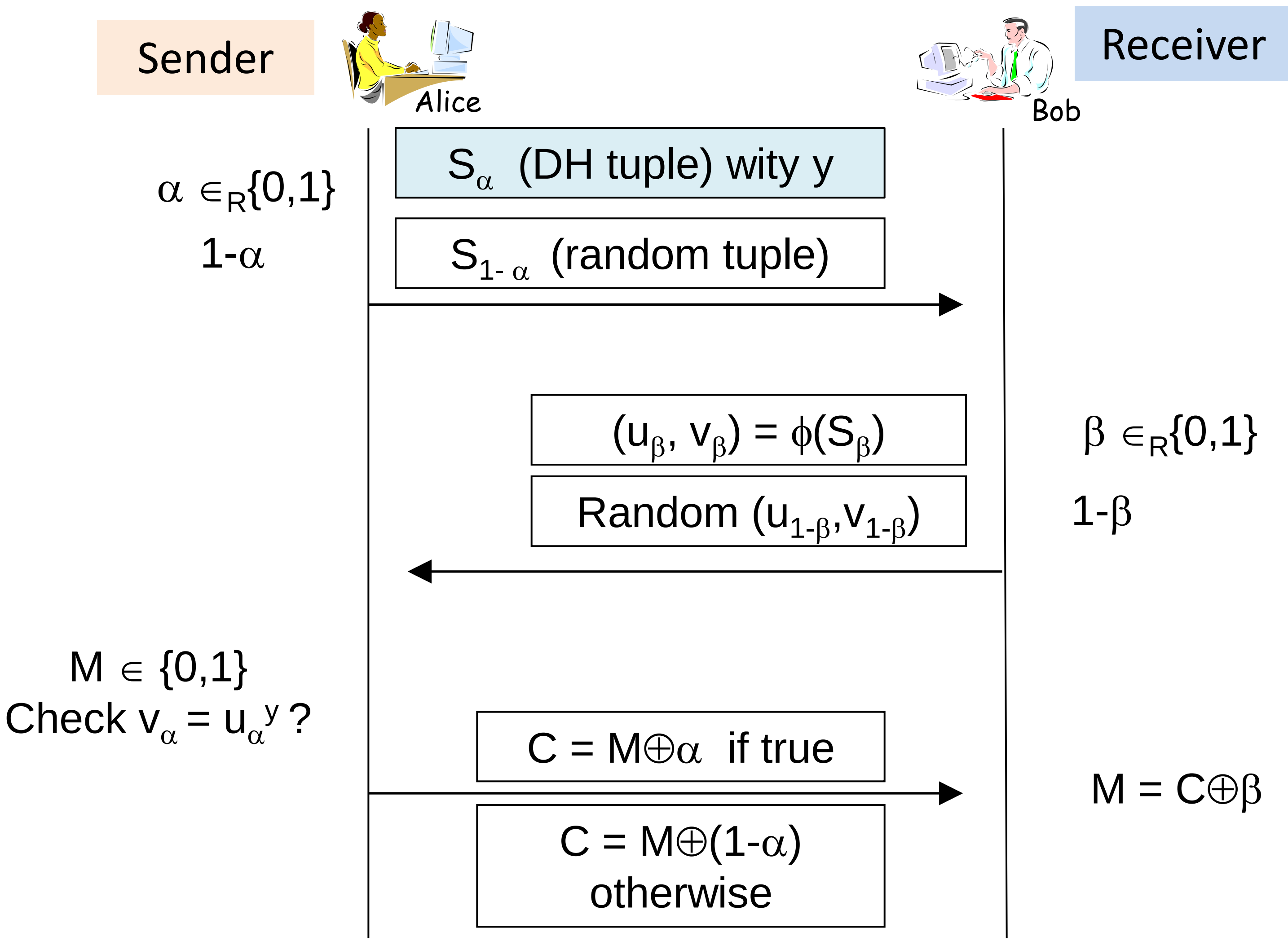
  where $s,t \in_R Z_q$,and $g_i, h_i \in G$
  - If $(g_1, g_2, h_1 = g_1^y, h_2 = g_2^y)$ is a random Diffie-Hellman tuple, we have $v = u^y \bmod p$
  - If (g_1, g_2, h_1, h_2) is a non-DH random tuple, (u,v) is a random tuple in G^2.

Building Block cont'd

- Canetti-Fischlin oblivious sampling & faking algorithms [CF01]

- By using the faking algorithm, the simulator can construct a fake transcript (computation history) to the environment ***Z***
  - in such a way that a Diffie-Hellman tuple looks completely random

Sketch of Construction



More Formal Construction

- Sender generates with secret $\alpha \in_R \{0,1\}$, y
  - $S_0 = (g_{1,0}, g_{2,0}, h_{1,0}, h_{2,0})$
  - $S_1 = (g_{1,1}, g_{2,1}, h_{1,1}, h_{2,1})$
  - where S_α is a DH tuple, $S_{1-\alpha}$ is a random tuple, and $h_{1,\alpha} = g_{1,\alpha}^y$, $h_{2,\alpha} = g_{2,\alpha}^y$
- Receiver generates with secret $\beta \in_R \{0,1\}$
  - $w_\beta = (u_\beta, v_\beta)$ from S_β with Naor-Pinkas randomizer
  - $w_{1-\beta} = (u_{1-\beta}, v_{1-\beta})$ at random
  - Sends w_β , $w_{1-\beta}$ to the sender
- Sender checks $v_\alpha = u_\alpha^y$ mod p?
  - If true, ciphertext $C = M \oplus \alpha$ where $\alpha = \beta$
  - Otherwise, ciphertext $C = M \oplus (1-\alpha)$ where $\alpha \neq \beta$

Proof in UC Framework

- Ideal functionality for non-committing encryption.
- Case analysis based on when the corruption occurs
- Simulator uses the Canetti-Fischling oblivious faking algorithm to show the randomness used in the corrupted player to the environment ***Z***.
- Indistinguishability based on DDH assumption

Functionality F_{NCE}[Ca01]

- Upon receiving an input (send, sid, m), do: If sid = (S, R, sid') for some R then send (send, sid, l(m)) to the adversary, generate a private delayed output (send, sid, m) to R and halt. Else, ignore the input.
- Upon receiving (corrupt, sid, P) from the adversary, where $P \in \{S,R\}$, disclose m to the adversary. Next, if the adversary provides a value m', and P=S, and no output has been yet written to R, then output (send, sid, m') to R and halt.

Summary

- Non-committing encryption protocol secure against an adaptive adversary with the DDH assumption
- Proof given in the UC framework and non-erasure model
- Can be used as a building block realizing secure channel in other protocols that need to be secure against an adaptive adversary

Thank you for you attention!