Advanced Tools from Modern Cryptography

Lecture 8

MPC: Simulation-Based Security

Security for MPC

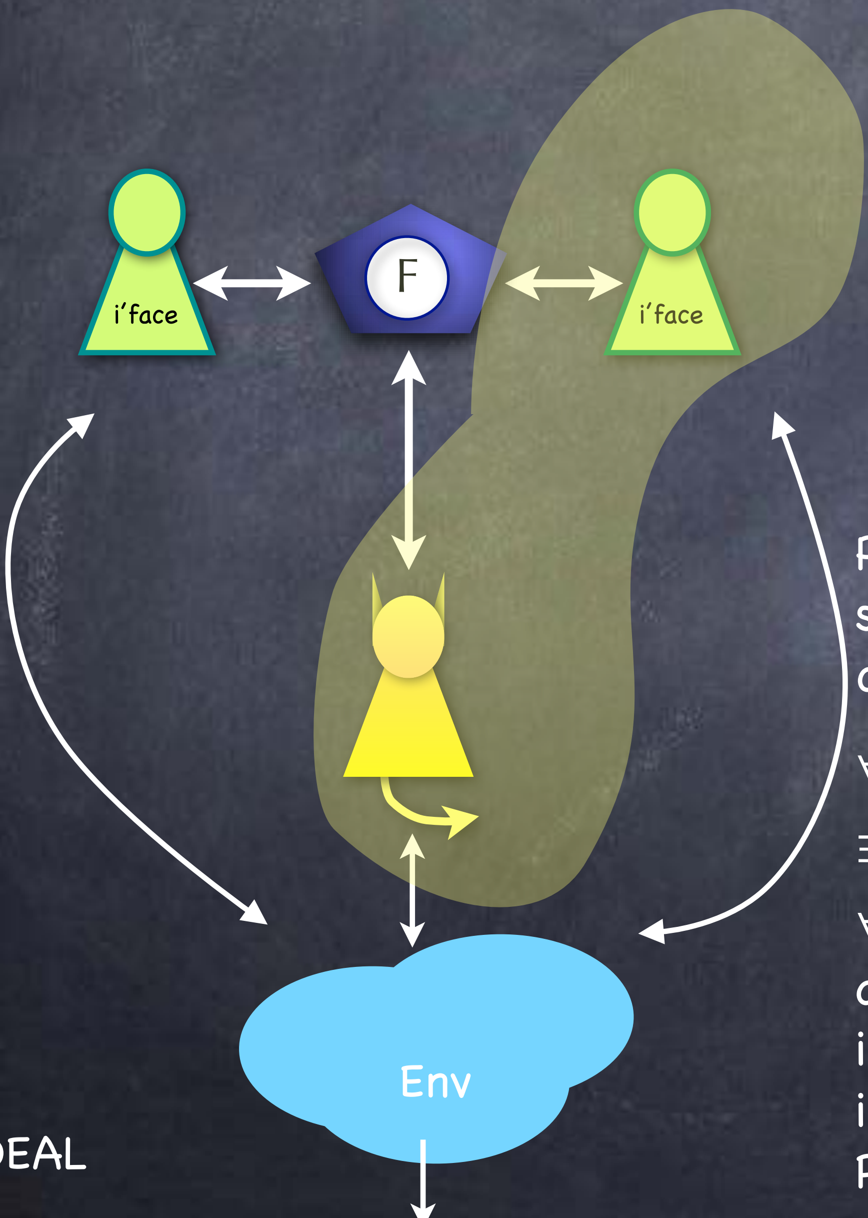
- Recall: For passive security, secrecy is all the matters
- For a 2-party functionality f, with only Bob getting the output, perfect secrecy against corrupt Bob:
  i.e., $\forall$ x, x′, y s.t., $f(x,y) = f(x',y')$, $\text{view}_{\text{Bob}}(x,y) = \text{view}_{\text{Bob}}(x',y)$
  - In particular, if (y, f(x,y)) uniquely determines x (i.e., if $f(x',y)=f(x,y) \Rightarrow x'=x$), then OK for view to reveal x
- In the computational setting, just replace = with ≈ ?
  - We should ask for more!
  - E.g., f is a decryption algorithm, with key x and ciphertext y
  - Often, a (long enough) ciphertext and message uniquely determines the key
    - But not OK to reveal the key to Bob!

Because, uniquely determines ≠ reveals!

Security for MPC

- Compare the protocol execution with an "ideal" execution involving an incorruptible trusted party
  - Trusted party collects all inputs, carries out all computation and delivers the outputs (over private channels)
  - Ideal is the best we can hope for
- If anything that could "go wrong" with the protocol execution could happen with the ideal execution too, then it is not the protocol's fault

Simulation-Based Security



IDEAL

Protocol is secure (and correct) if:

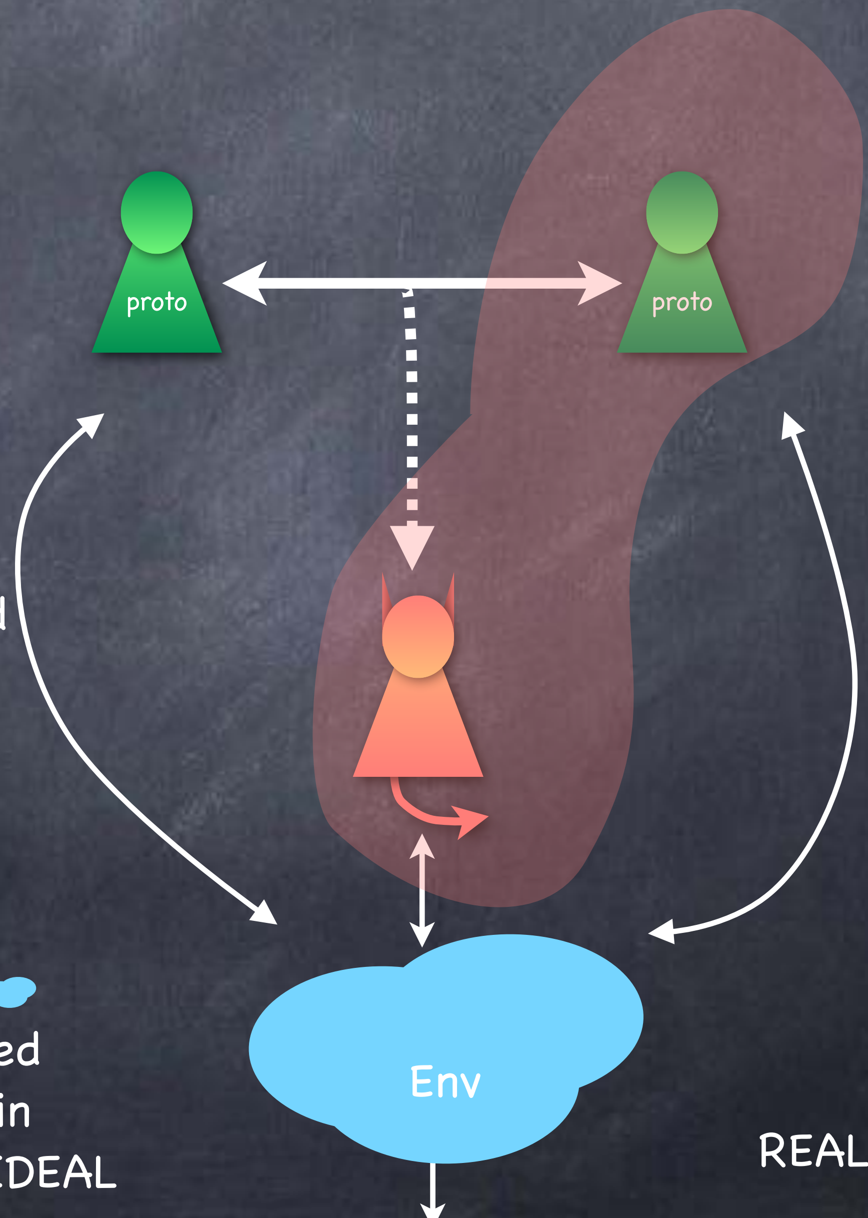
∀

∃ s.t.

∀

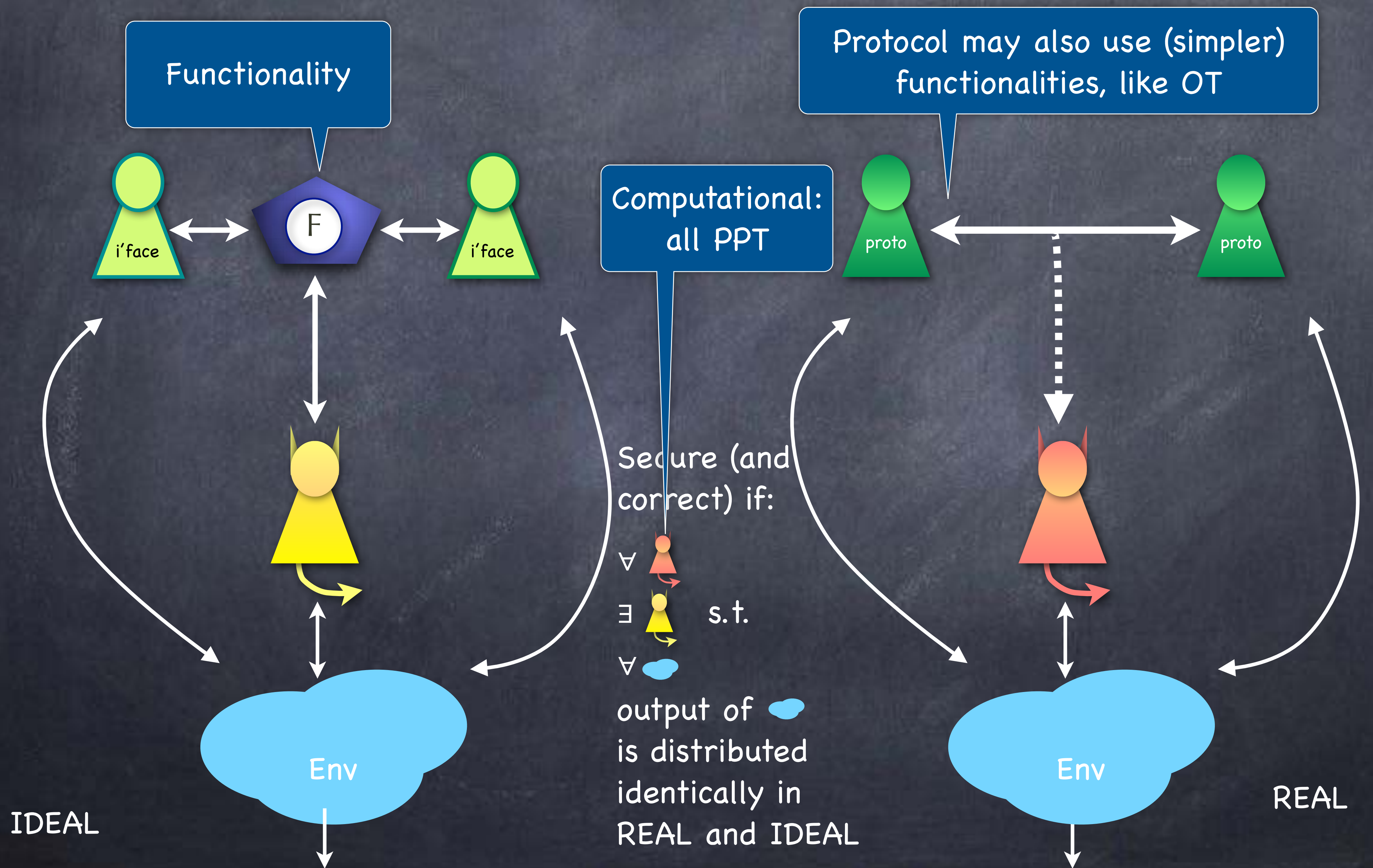
output of

is distributed identically in REAL and IDEAL



REAL

Simulation-Based Security



Variants of Security

- Same definitional framework can be used to define various levels of security!
  - Passive adversary: corrupt parties stick to the protocol
    - Will require corrupt parties in the ideal world also to use the correct inputs/outputs
  - Universally Composable security: Active adversary interacting with the environment arbitrarily
  - Standalone security: environment is not "live." Interacts with the adversary before and after (but not during) the protocol
  - Super-PPT simulation: meaningful when the "security" of ideal world is information-theoretic
- Non-simulation-based security definitions for MPC: Useful for intermediate tools (but often too subtle for final applications)

Trust Issues Considered

- Protocol may leak a party's secrets
  - Clearly an issue -- even for passive corruption
- Protocol may give adversary illegitimate influence on the outcome
  - Say in poker, if adversary can influence hands dealt
  - An issue even when no secrecy requirements
    - e.g., Exchanging inputs
- Simulation-based security covers these concerns
  - Because the ideal trusted party would allow neither

Example: Coin-Tossing

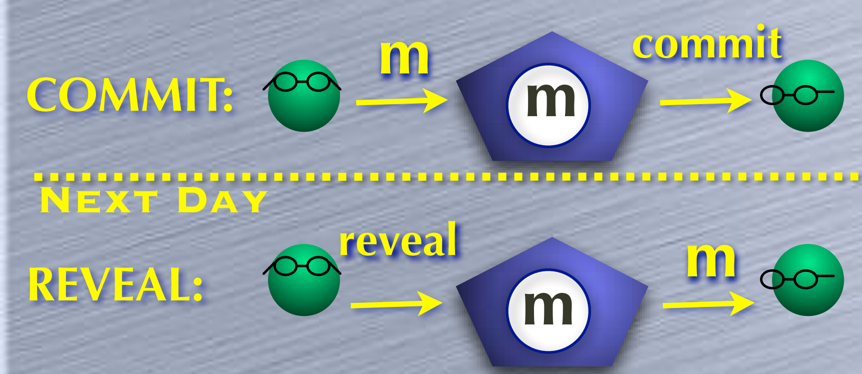
- Functionality F_{coin} samples a uniform random bit and sends it to all parties
- Security against passive corruption is trivial (Why?)
- Fact: Impossible to (even stand-alone) securely realise against computationally unbounded active adversaries
- Protocol for stand-alone security against PPT adversaries using commitment
  - If given ideal commitment functionality, information-theoretic security

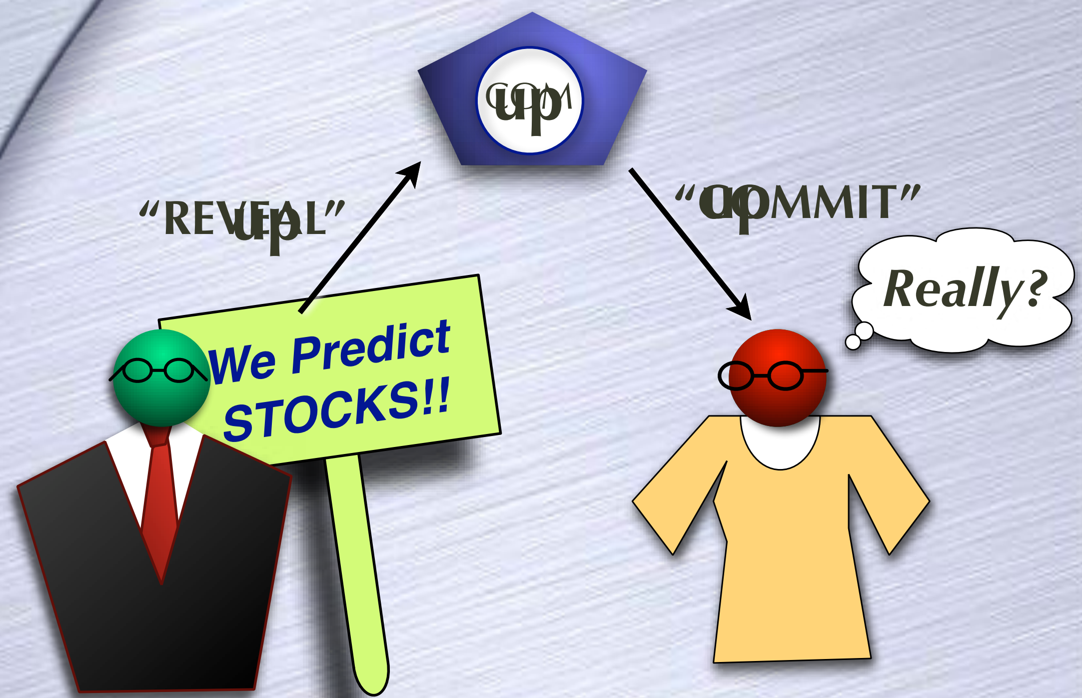
Commitment

- Commit now, reveal later
  - Intuitive properties: hiding and binding

IDEAL World

30 Day Free Trial





Example: Coin-Tossing

- A (fully) secure 2-party protocol for coin-tossing, given an ideal commitment functionality F_{com}
- Alice sends a bit a to F_{com}. (Bob gets "committed" from F_{com})
- Bob sends a bit b to Alice
- Alice sends "open" to F_{com}. (Bob gets a from F_{com})
- Both output $c=a\oplus b$
- Simulator:
  - Will get a bit c from F_{coin}. Needs to simulate the corrupt party's view in the protocol, including the interaction with F_{com}
  - If Alice corrupt: Get a from Alice. Send $b = a\oplus c$.
  - If Bob corrupt: Send "committed". Get b. Send $a = b\oplus c$.
- Perfect simulation (why?)