

Advanced Tools from Modern Cryptography

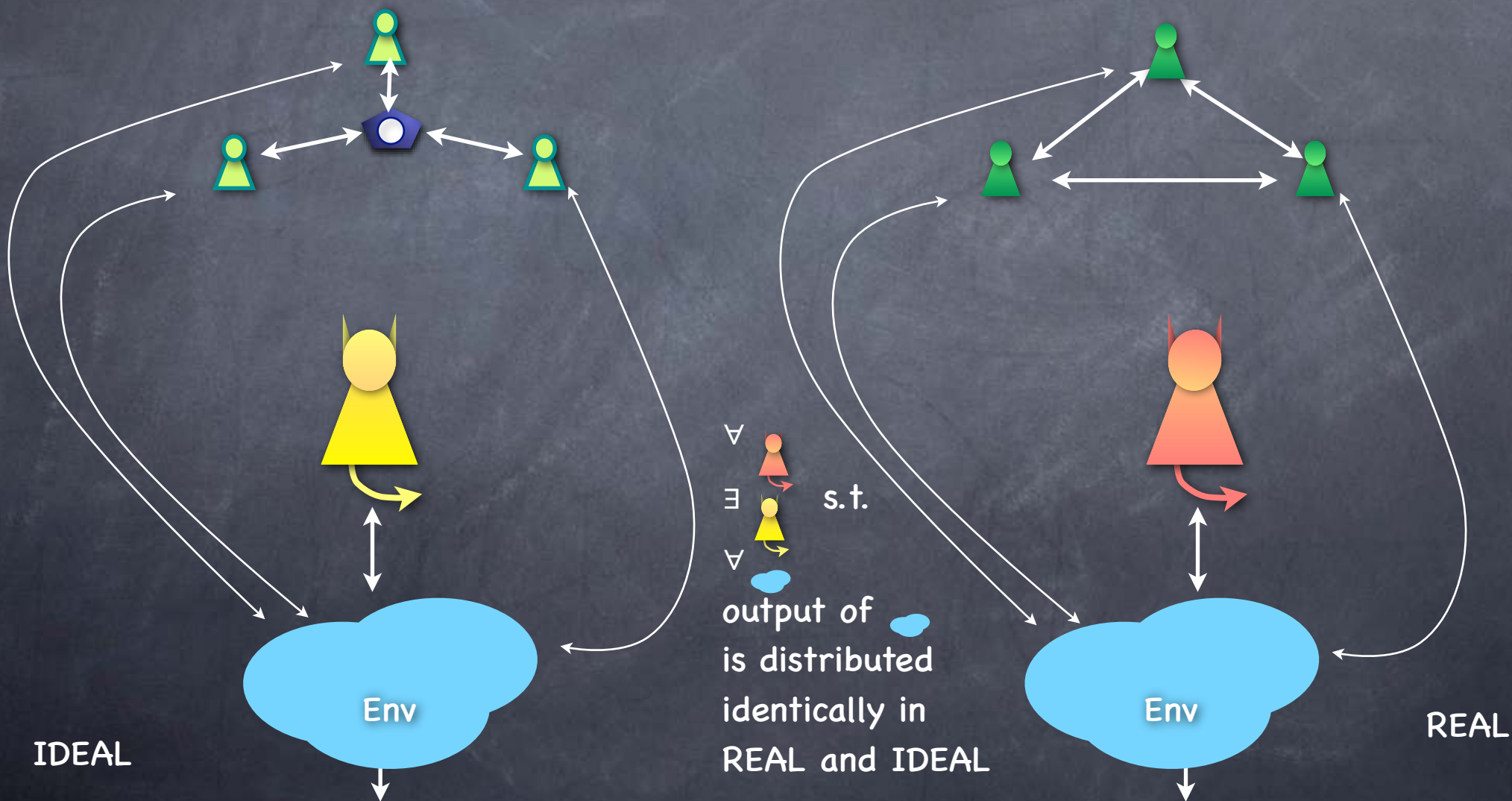
Lecture 11

MPC: UC Theorem. UC Limitations.

RECALL

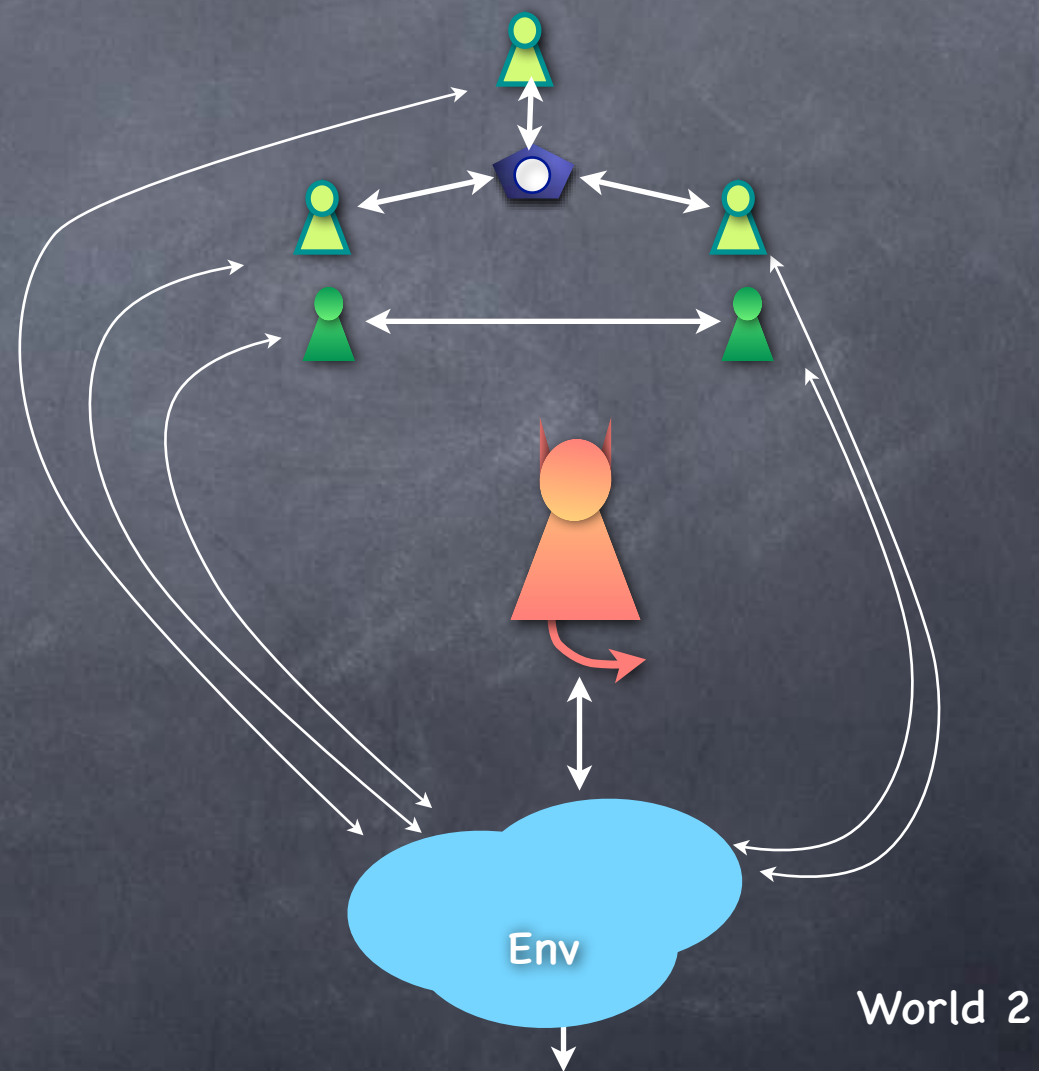
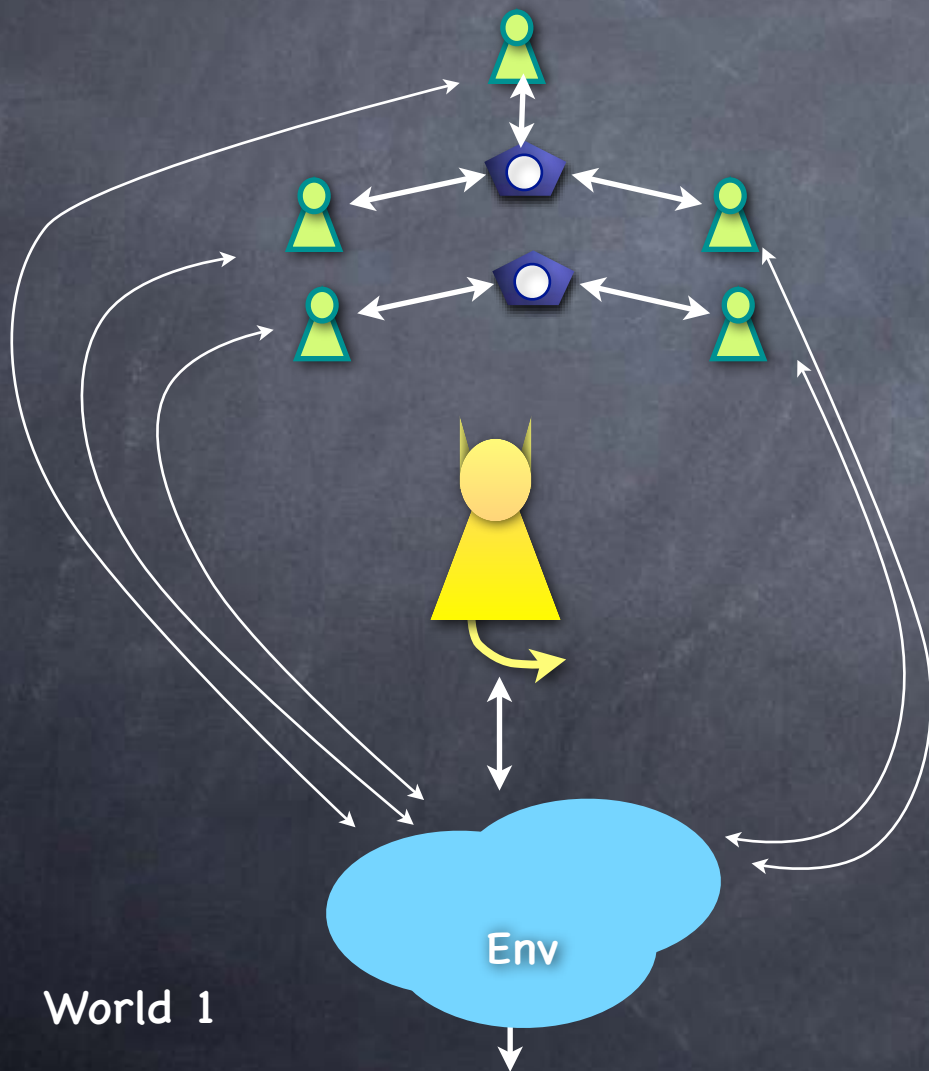
UC Security

REAL is as secure as IDEAL if:



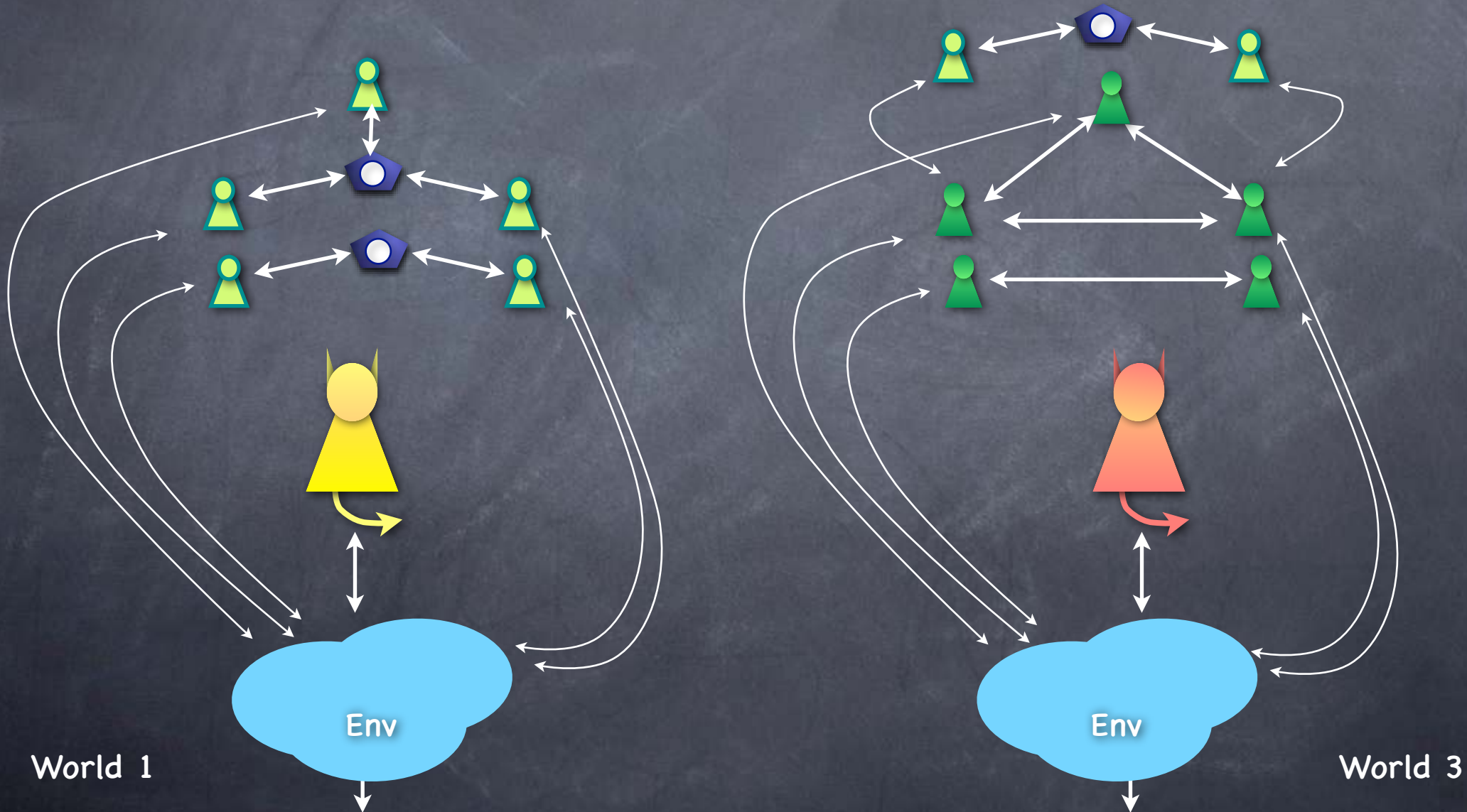
Universal Composition

Replace protocol  with  which is as secure, etc.



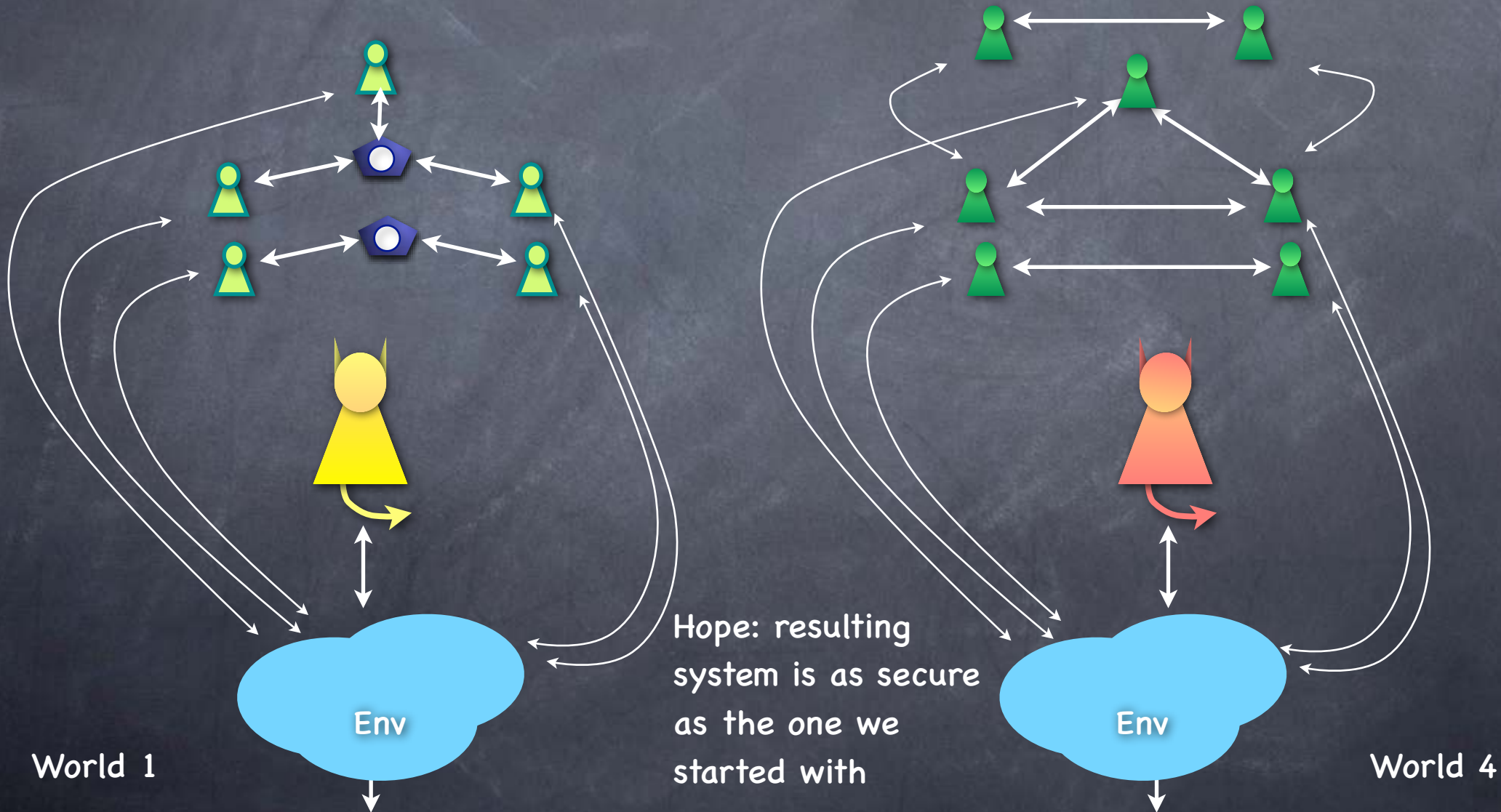
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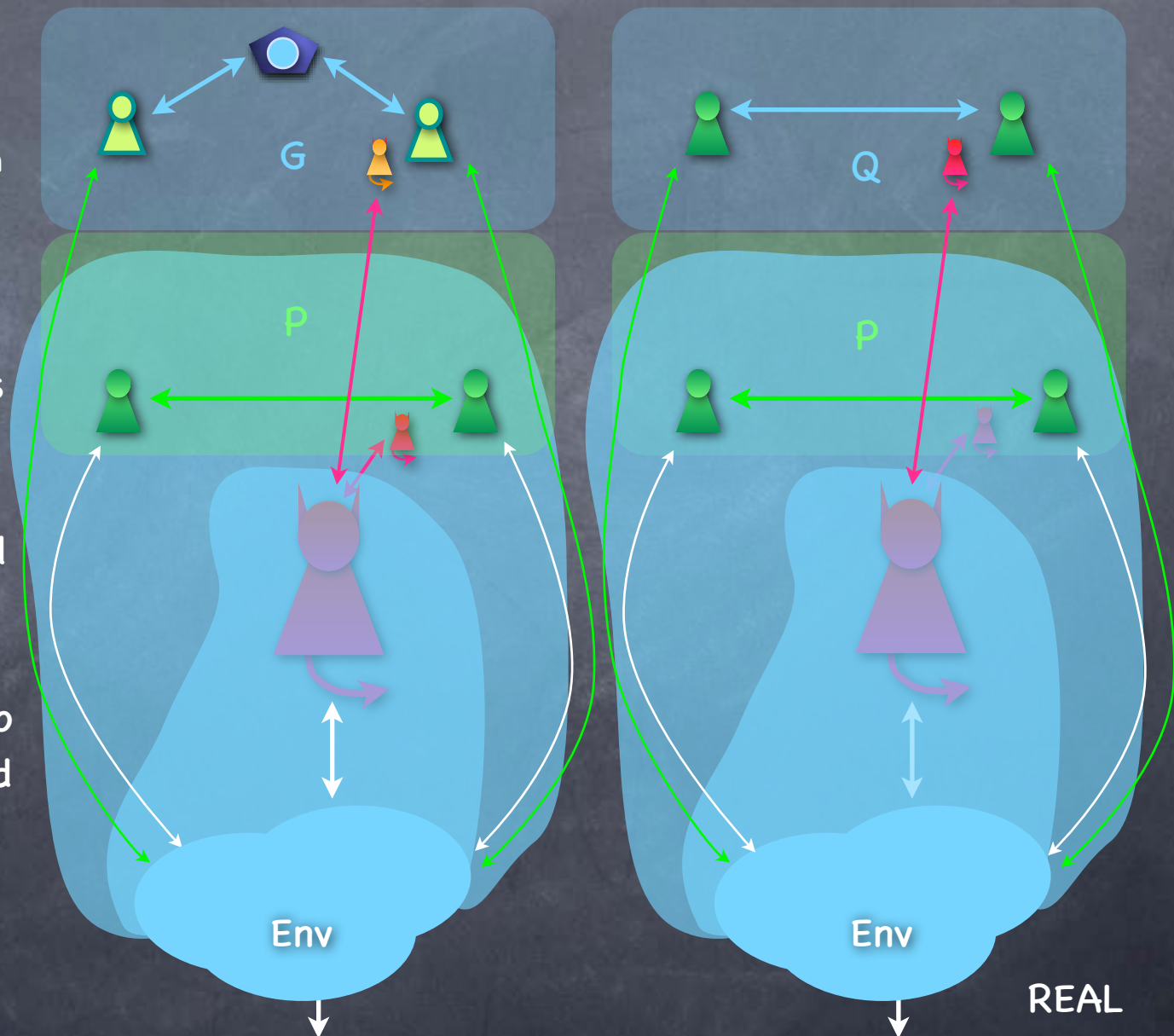


Universal Composition

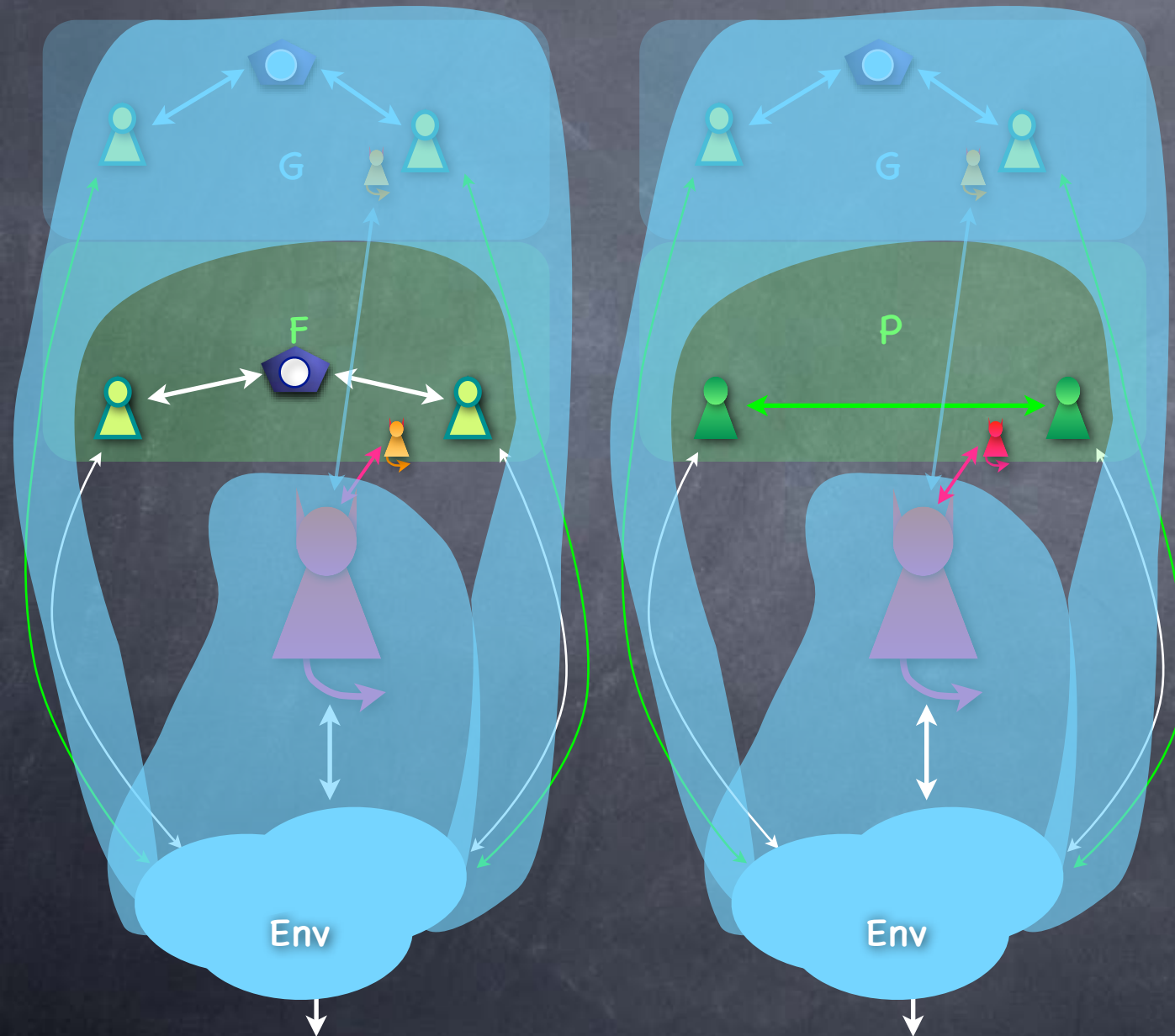
- Start from world A (think “IDEAL”)
 - Repeat (for any poly number of times):
 - For some 2 “protocols” (that possibly make use of ideal functionalities) I and R such that R is as secure as I, substitute an I-session by an R-session
 - Say we obtain world B (think “REAL”)
 - **UC Theorem:** Then world B is as secure as world A
- Gives a modular implementation of the IDEAL world

Proving the UC theorem

- Consider environment which runs the adversary internally, and depends on “dummy adversaries” to interface with the protocols
- Now consider new environment s.t. only Q (and its adversary) is outside it
- Use “ Q is as secure as G ” to get a new world with G and a new adversary

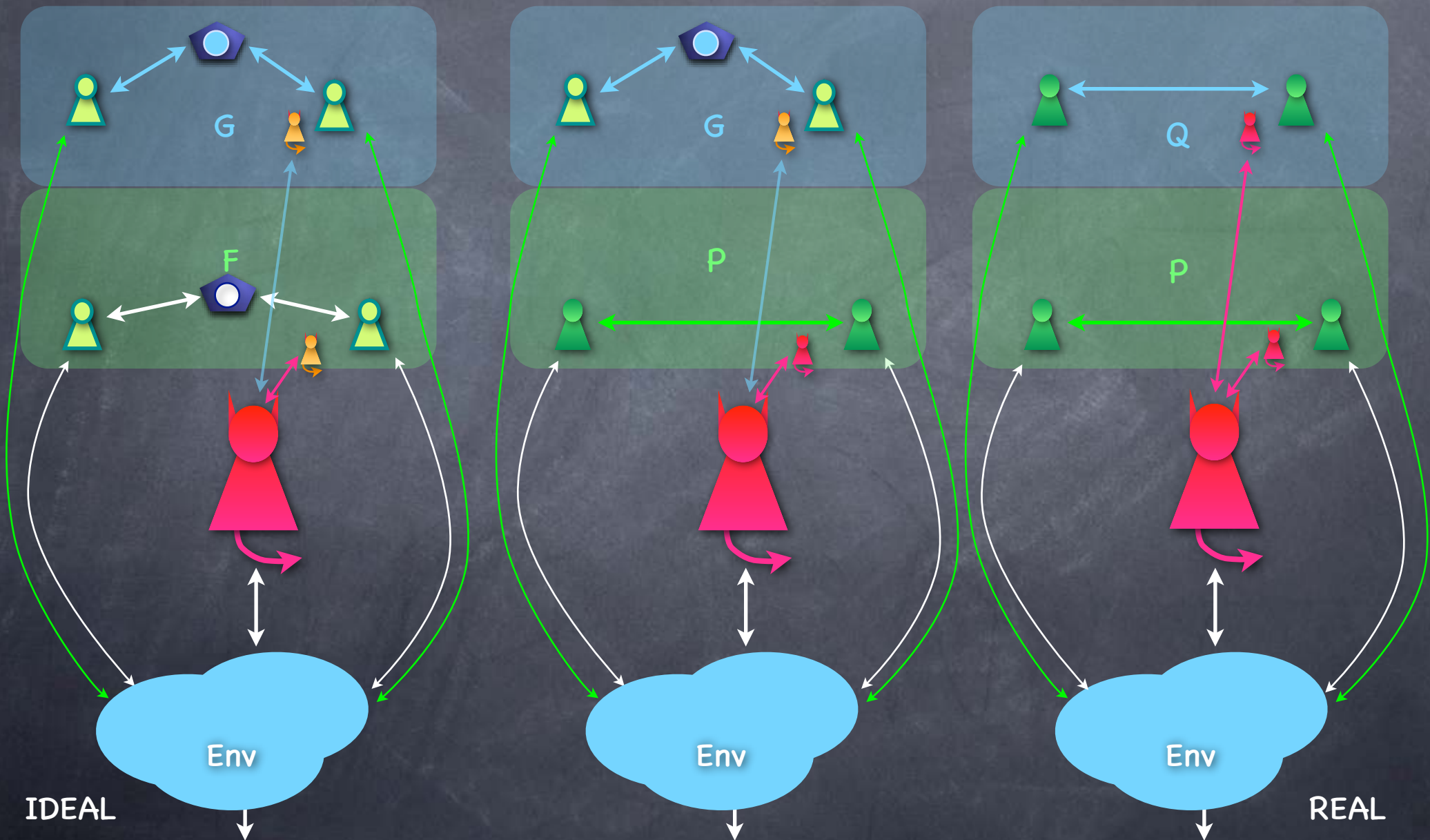


Proving the UC theorem

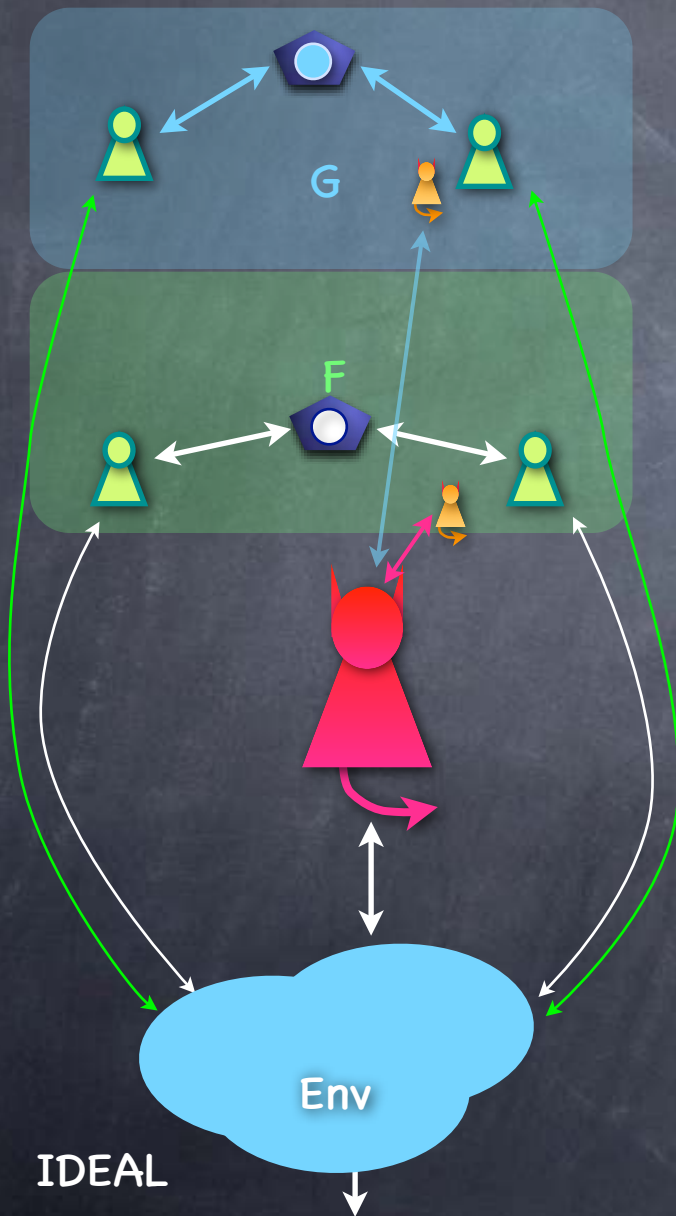


- Now consider new environment s.t. only P (and adversary) is outside it
- Note: G and simulator for Q/G are inside the new environment
- Use " P is as secure as F " to get a new world with F and a new adversary

Proving the UC theorem

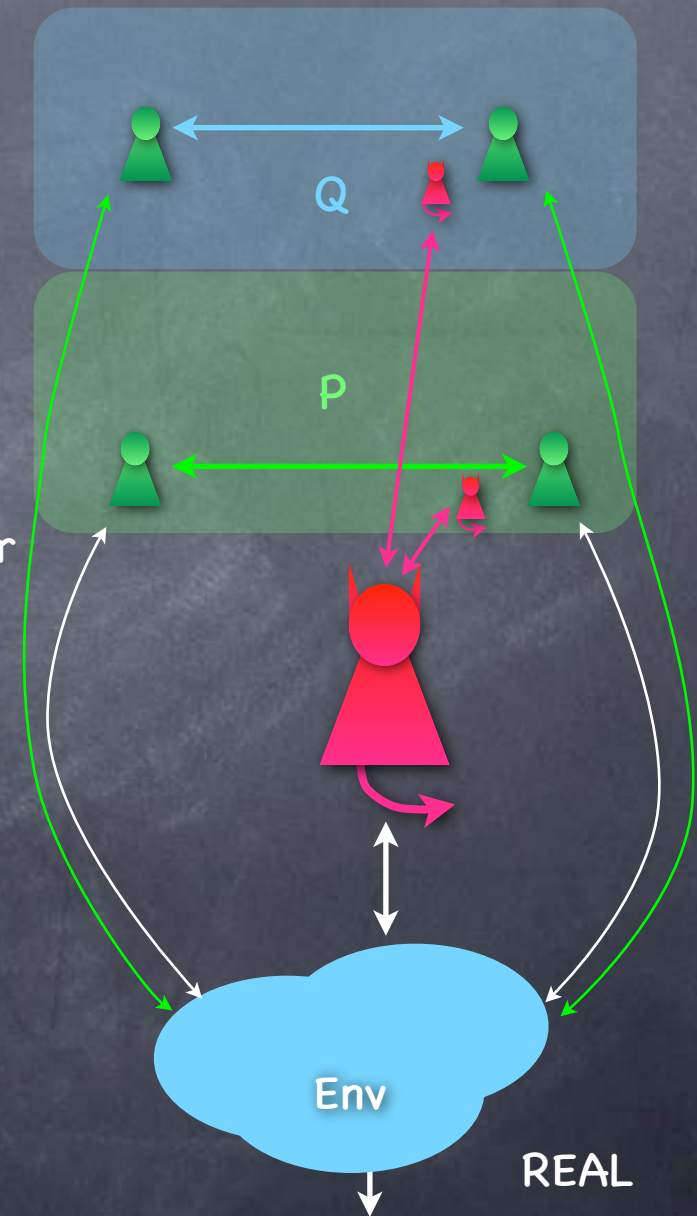


Proving the UC theorem



☛ Hence $REAL \approx IDEAL$

☛ Main idea: Environment can model other sessions (real or ideal)



UC Secure MPC?

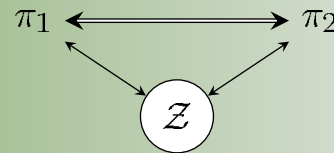
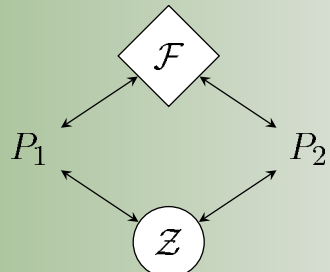
- UC-security is a strong security definition, and also enjoys the UC property
- But impossible to have “non-trivial” UC-secure MPC (for 2 parties)!
- Universal Composition possible when:
 - Passive corruption, or
 - Honest majority, or
 - Given trusted setups (e.g., OT), or
 - Using alternate security definitions (e.g., “Angel-aided simulation”: still meaningful and UC)

Impossibility of UC Security



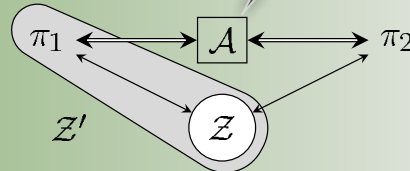
Indist. by security

Identical systems

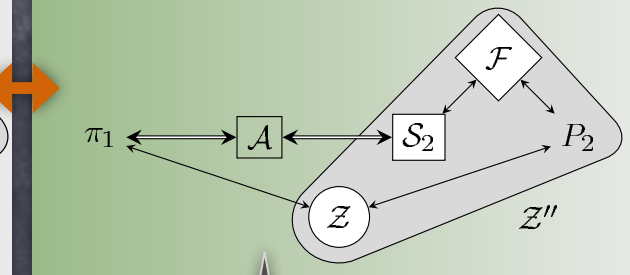
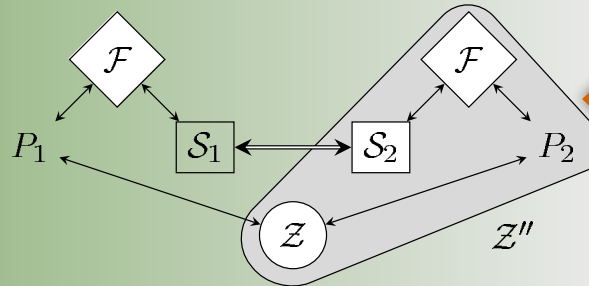
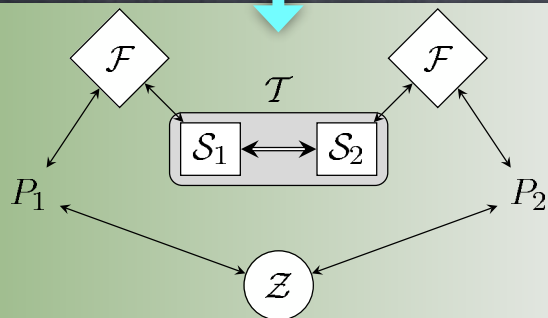
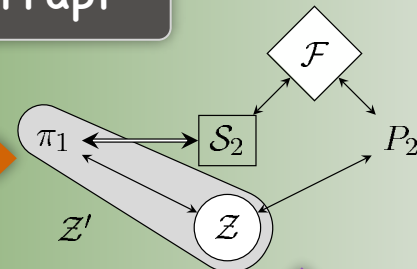


No corruption

F has a UC-secure protocol only if F is "splittable"
Very few are splittable!



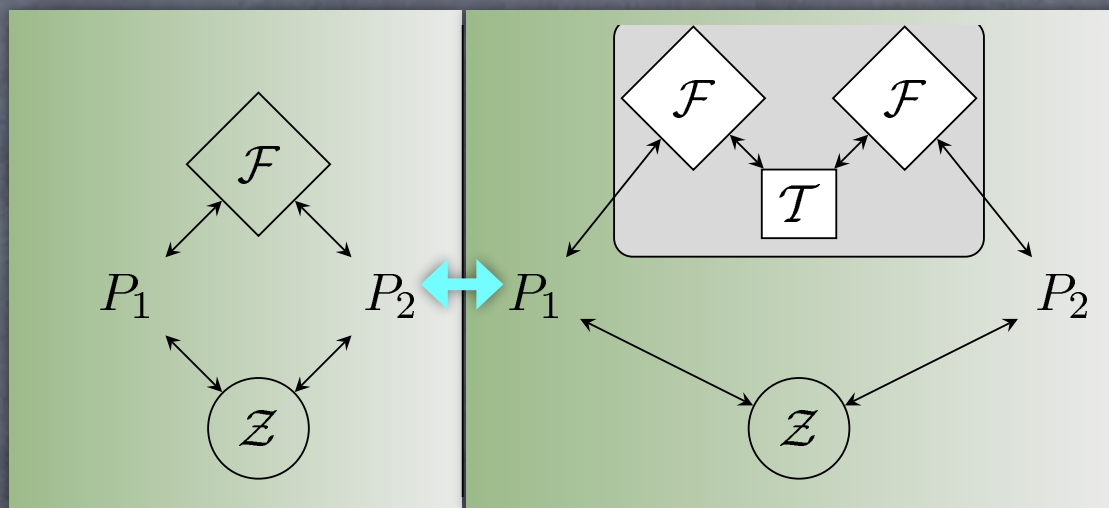
Party 1 corrupt



Party 2 corrupt

Splittable Functionalities

- F splittable if $\exists T \forall Z$ the outputs of Z in the following two experiments are negligibly far from each other:



- A splittable functionality essentially involves only communication and local computation. All splittable functionalities have UC-secure protocols.
- Most interesting functionalities are unsplittable. E.g., coin-tossing, commitment, XOR, OT, ...

UC Security Beyond 2 Parties Without Honest-Majority

- Any multi-party function F such that a 2-way partition of it is unsplittable is impossible to UC-securely realise
 - Consider F with an unsplittable partition f . Protocol Π_F gives a 2-party protocol Π_f . Π_F tolerates corruption of either part $\rightarrow \Pi_f$ tolerates corruption of either party
- So only “disseminating” and “aggregating” functionalities
- Disseminating: Only one party has input that influences the output of the others (e.g., broadcast, secret-sharing)
- Aggregating: Only one party has output that is influenced by the input of the others (e.g., group summation)
 - Not all aggregating functionalities have 2-way partitions that are splittable [Why?]

UC Security Beyond 2 Parties

- All disseminating functionalities are UC-securely realisable!

- e.g., Broadcast protocol

- Sender sends m to all Receivers

- Each Receiver sends m that it received to all others

- Each Receiver outputs m if it received the same m from all other Receivers. Else Aborts.

- Note: Here abort allowed. UC-Secure [Why?]

- Open: which aggregating functionalities are UC-securely realisable?

- e.g. additive-sharing based summation protocol (input parties play servers, only one output client) [Why UC-Secure?]