Collusion-Preserving Computation

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Overview

- Motivation & Goals
- Definition
- Fall-back Security
- Synchronization Pollution
- Implications for Game Theory
- Future Directions

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  - "R realizes F" = R can be used in place of F
  - "capabilities of deviating coalitions" = such that even collaborating "dishonest" players can do no more with R then they could with F
  - "arbitrary composition" = regardless of any concurrent activities in which they may be involved.

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    - Extreme case of deviating coalitions.
- Collusion-Free (CF) MPC robust in the presence of side-channels.
    - CF (provably) not concurrently composable
- Other (intuitive) examples requiring bounds on collaborating dishonest players.
    - Incoercability: Coercer/Informant & Coercee.
    - Auctions: Bid fixing by corrupt bidders.
    - Bounded Isolation: Useful for say, poker or bridge

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- Concrete communication resource R & construction for many F.
- Explore implications for composable Game

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- Arbitrary composition [Can, PW, CLOS, CDPW,...]
  - Exa: UC, GUC, JUC, etc.
    - But monolithic adversary
- Collusion-Free (CF) computation [LMPS, ILM, ASV, AKLPSV]
  - Bounds deviating coalitions (via split adversaries)

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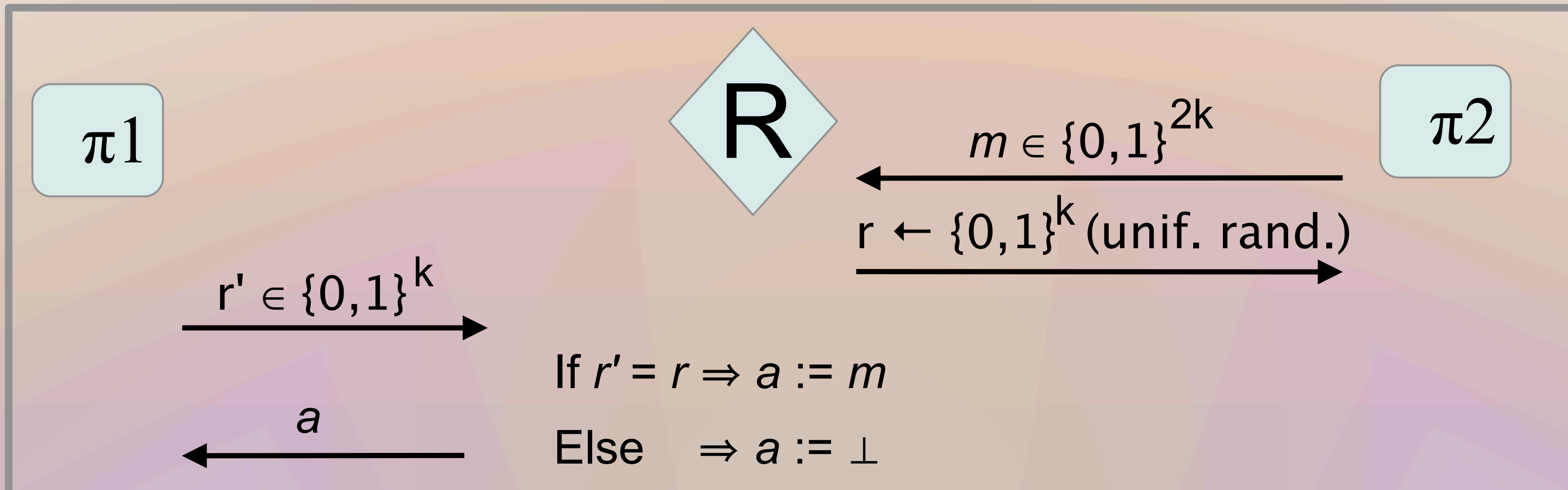

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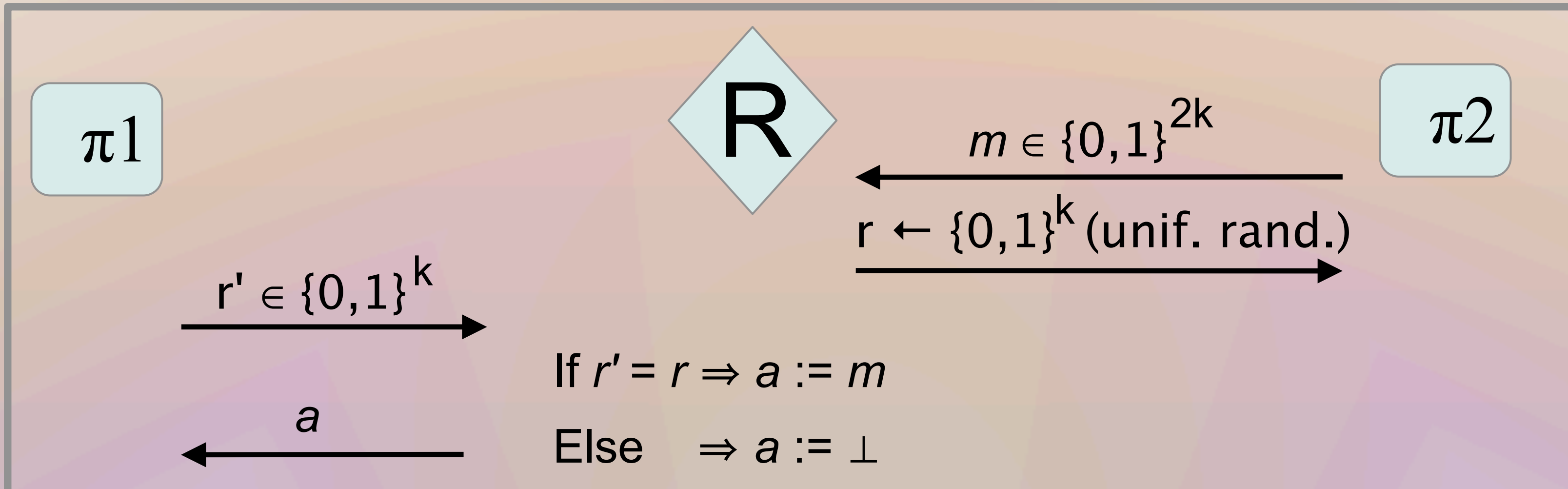

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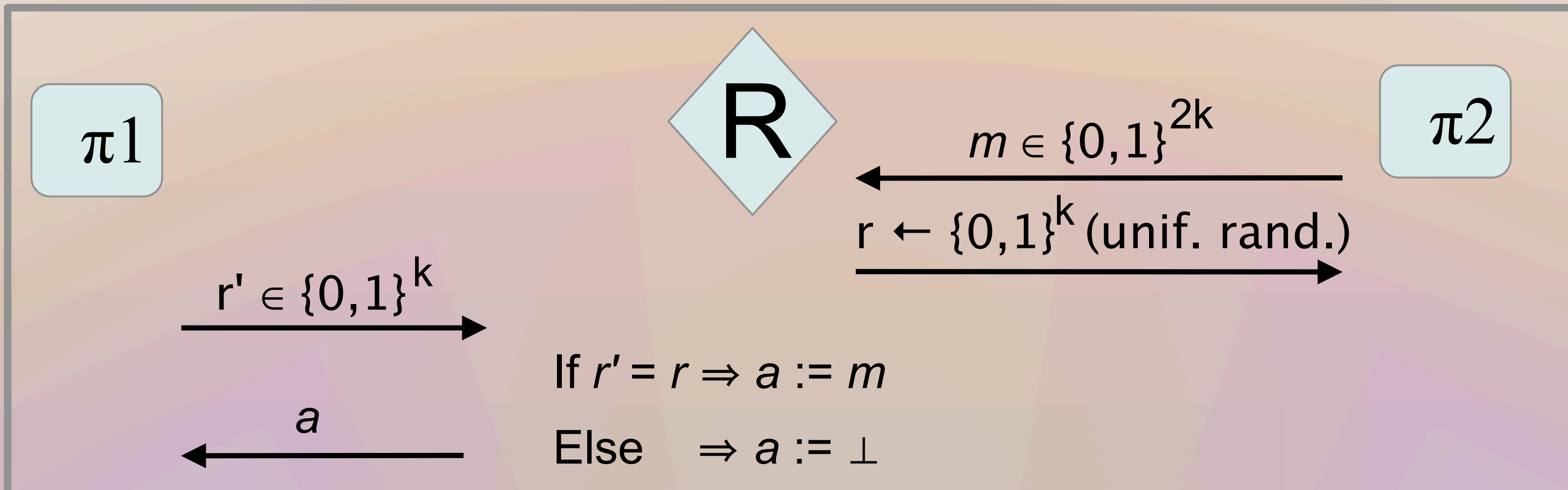

- r is uniform random and F allows no communication between simulators. $\Rightarrow$ Can always simulate for $\pi 1$ with $a = \perp$.
  $\Rightarrow$ R CF-realizes F via π.
- Now compose with C ; a k-bit channel from $P2 \rightarrow P1$. Use it transmit r. So P2 can learn m from R . But using F & C the simulators can communicate at most k. I.e. π is no longer simulatable!

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- Immediate results:
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  - CP strictly generalizes (G)UC realization notions.

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- Issues:
  - R depends on F
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    - However at least R must only be “programmable” but not fully “non-uniform”.
  - If R mis-behaves all bets are off.
    - Usually we don't care about this case. But trust is a rare commodity.

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    - If π is run with any R* then F is GUC-realized.
- Now trivial construction no longer works because it achieves no fallback security.

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- Recall CF construction of Mediated Model of [ASV, AKLPSV]. Idea: “assisted SFE in the mediator's head”
    - For functionality F, let protocol π = GMW(F).
    - “Mediator” resource M runs π on behalf of players “in her head”.
    - Player Pi's internal state in π shared between Pi and M.
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- CP Construction Idea:
    - Use π = GUC(F) with setup S.
        - GUC allows us to reuse S across protocols.

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- Recall Intuitive Goal: Ensure corrupt colluding parties get no more from R then from F.
  - Technically: Can simulate with split simulators
- Solutions:
  1. Remove subliminal communication channels (“steganography freeness”) [Sim84]
  2. Remove “randomness pollution” for CF [LMS05, ILM05,...]

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Synchronization Pollution (2)

- This work: Identify and mitigate new security concern.
- Def. “Synchronization Pollution” = Adversaries obtain more synchronization of events using R then using F.
    - Intuitive problem: more observable events from R than from F ⇒ Adversaries more coordinated.
    - Technical Problem: F doesn't provide simulators enough synchronization for them to coordinate the events in their on-line simulations.
        - Not an issue for CF because distinguisher (unlike environment) is off-line.

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- Problem: ρ is multi-round $\Rightarrow$ Has many public ordered events.
- Q: What is minimal synchronization obtained from 2-party SFEs used to “assist” R in running ρ?
- A: Surprisingly, only output-delivery synchronization.
    - Ideal World: F delivers output only after players activated enough to “fuel” an execution of ρ.
    - Technically: 2-party SFEs now hide all events in ρ.
    - e.g. Round number? Message received? From who? Message sent? To who? State changed? (!!!)
    - [AKLPSV]: hides only internal state of Pj and message contents for ρ.

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- **Theorem**: For a large class of F we give a resource and protocol that CP-realize F with GUC-fallback.

Applications to GT

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    Goal: Bring GT models closer to reality (Crypto :)).

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2) Show how to replace ideal mechanism with cryptographic protocol games on a network s.t.

   - Game theorists can design and analyze ideal and fully trusted mechanisms
   - but games can be played by computers over (special) networks s.t.
   - less trust placed in network than mechanism achieving essentially the same game.

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- New security notions leveraging split-simulators.
    - Example: Capturing enforced properties like incoercability.
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- Wanted: Local stability notion for Concurrent GT.
- Relations to Abstract Cryptography framework [MR11].

Thank You!