Round-optimal Honest-majority MPC in Minicrypt and with Everlasting Security

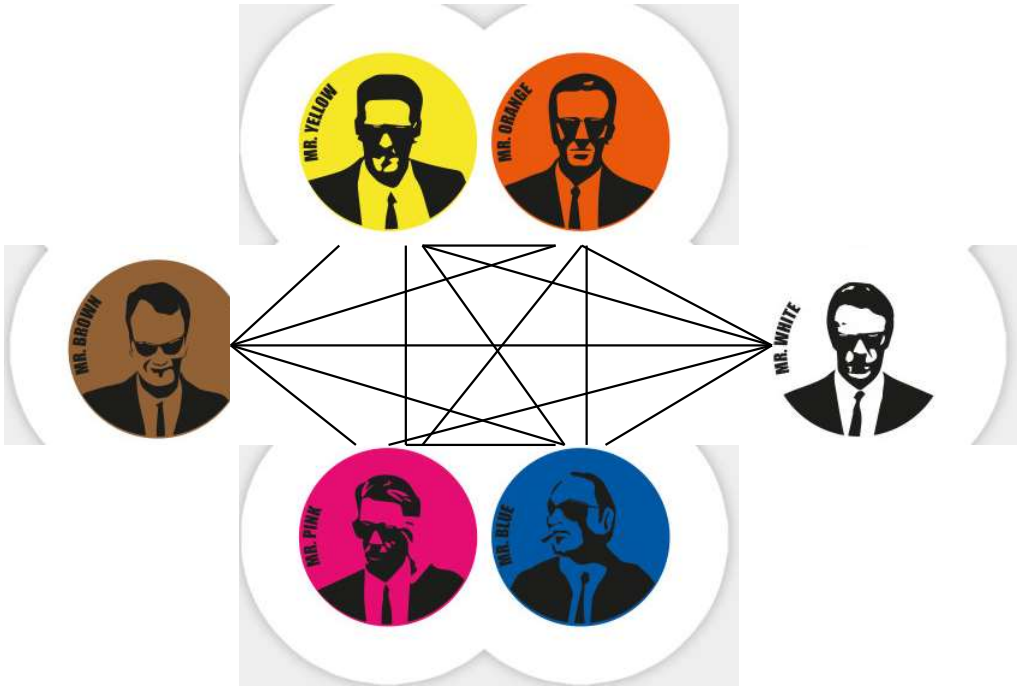
Benny Applebaum

Eliran Kachlon

Arpita Patra

Multiparty Computation

The model:



Multiparty Computation

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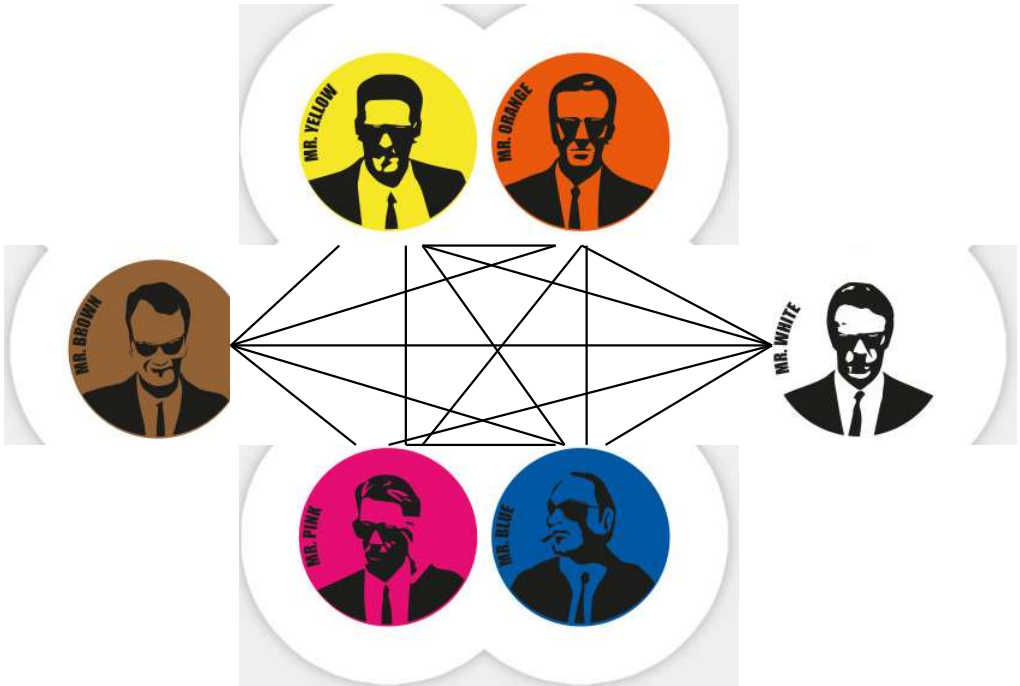

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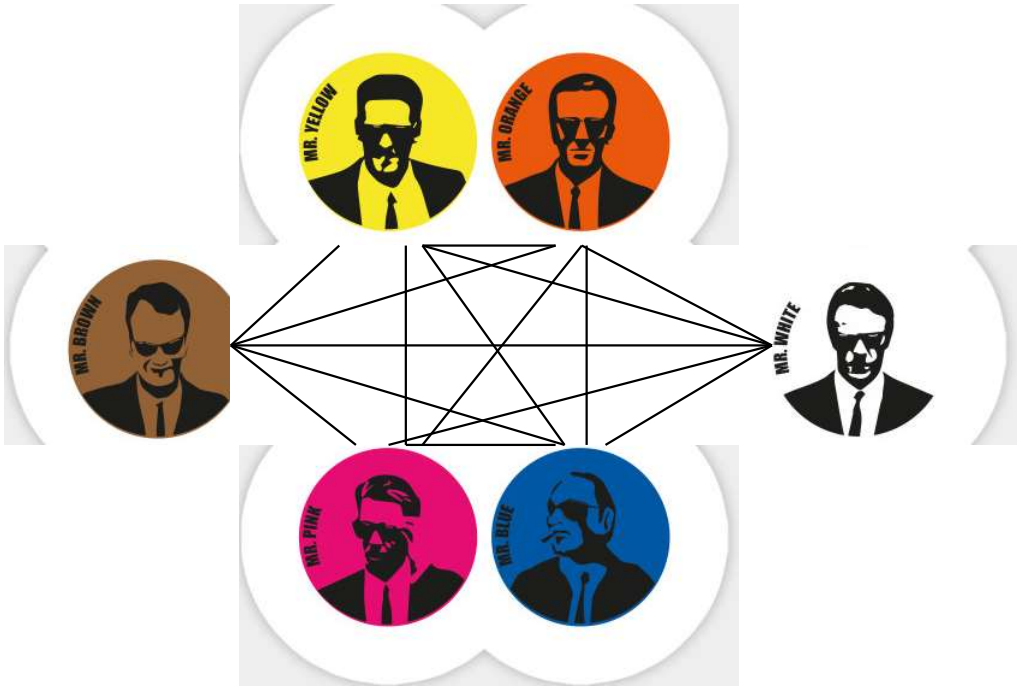

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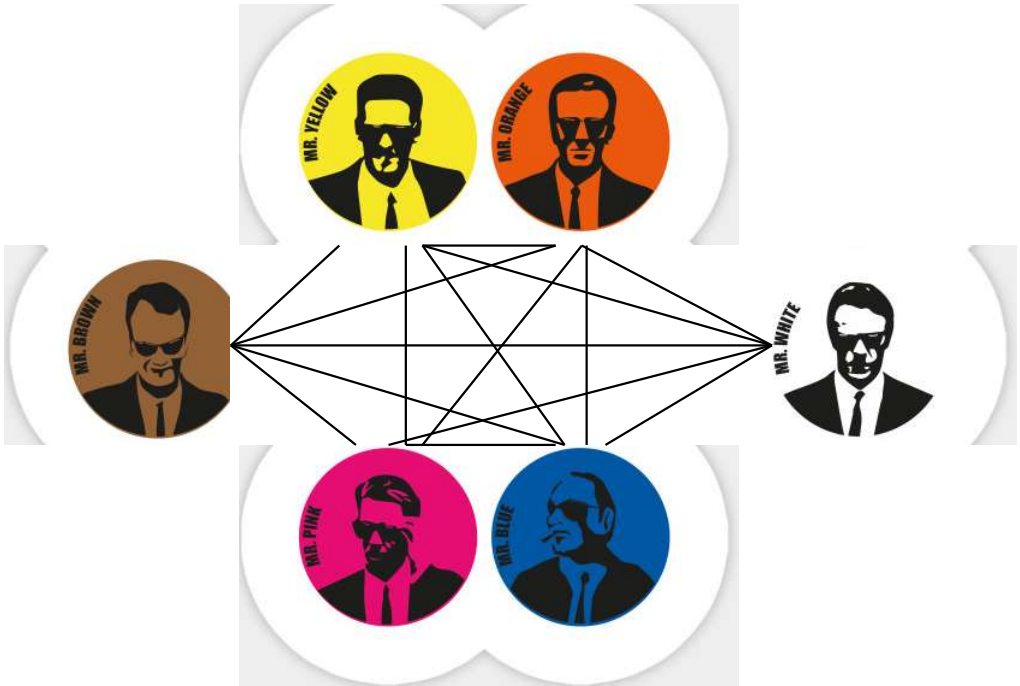
- Broadcast



Multiparty Computation

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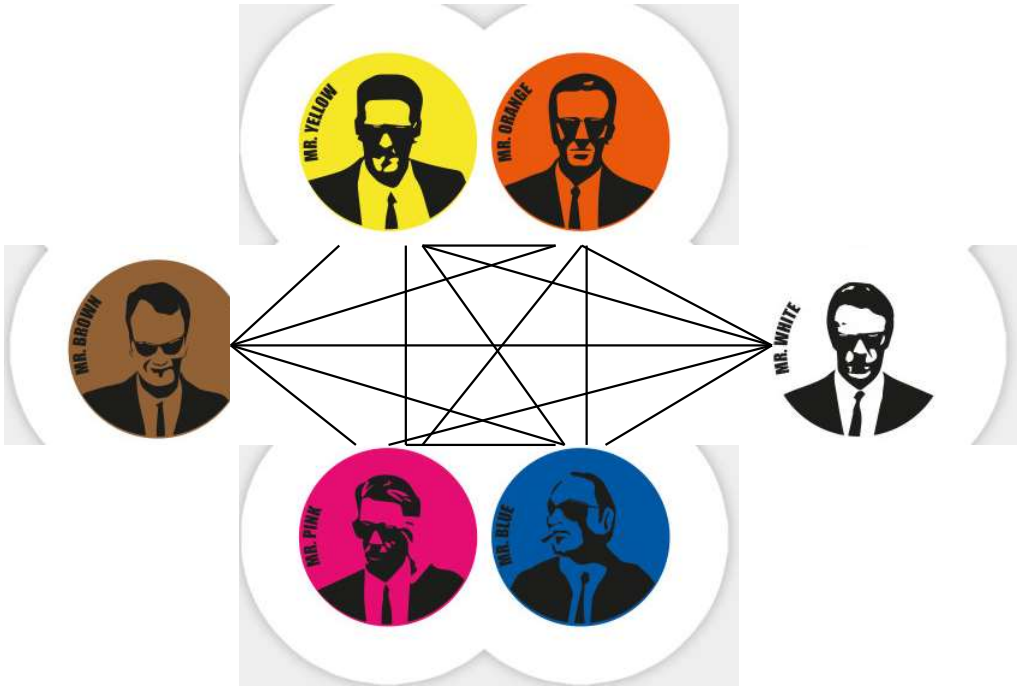
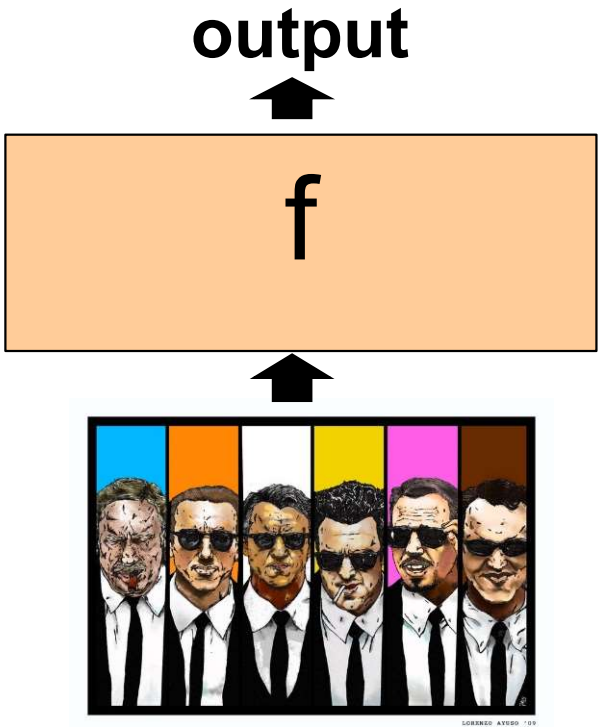
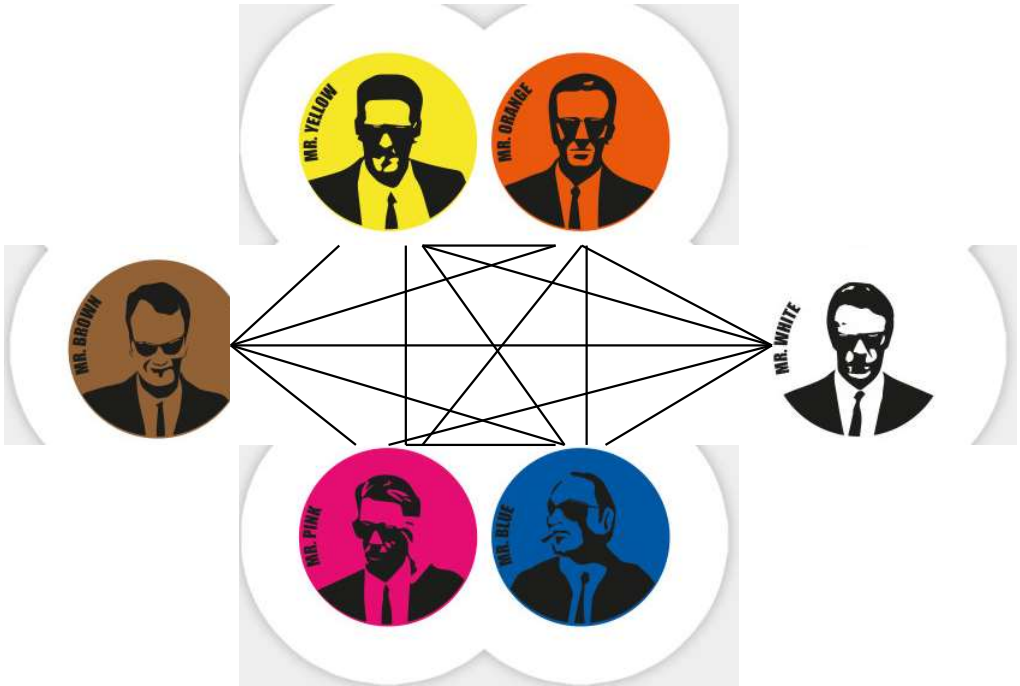


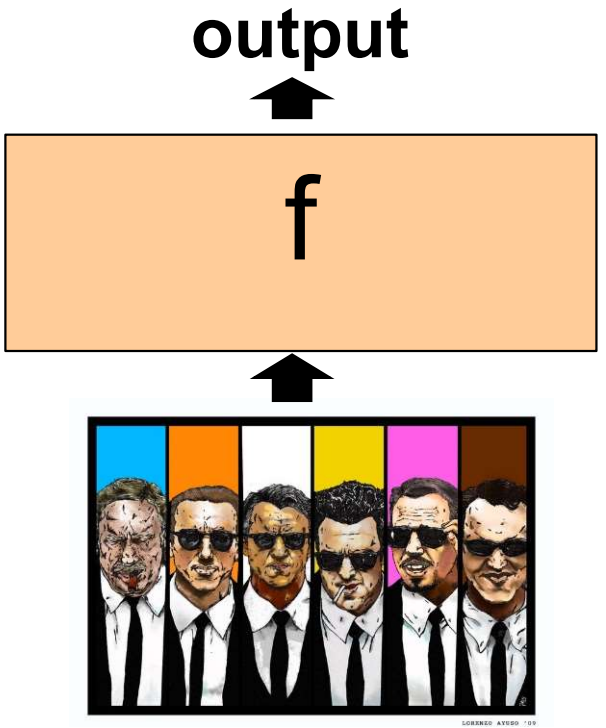


Multiparty Computation

Computational security:

- computationally-bounded adversary





Multiparty Computation

Computational security:

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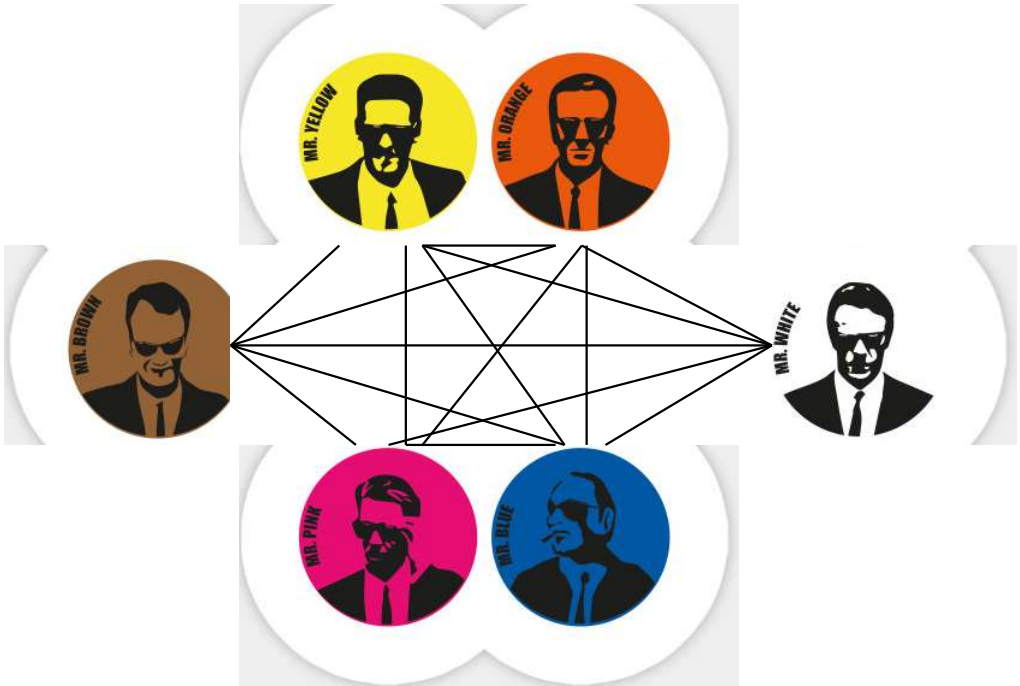

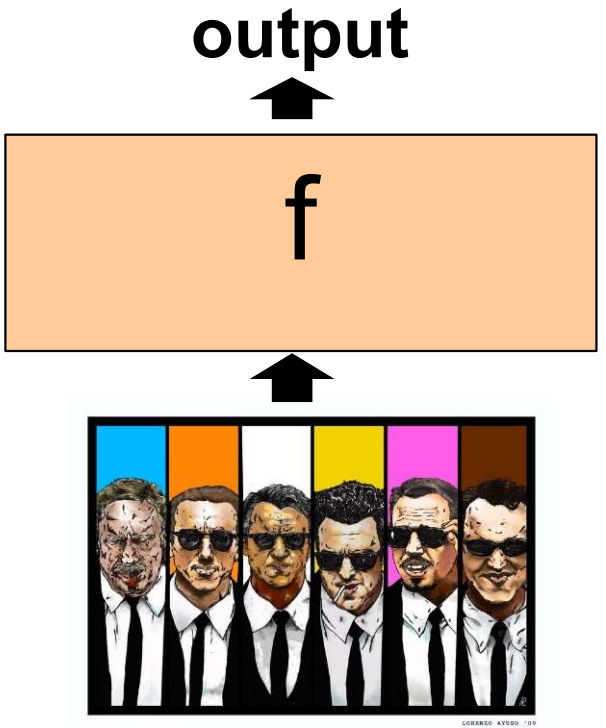

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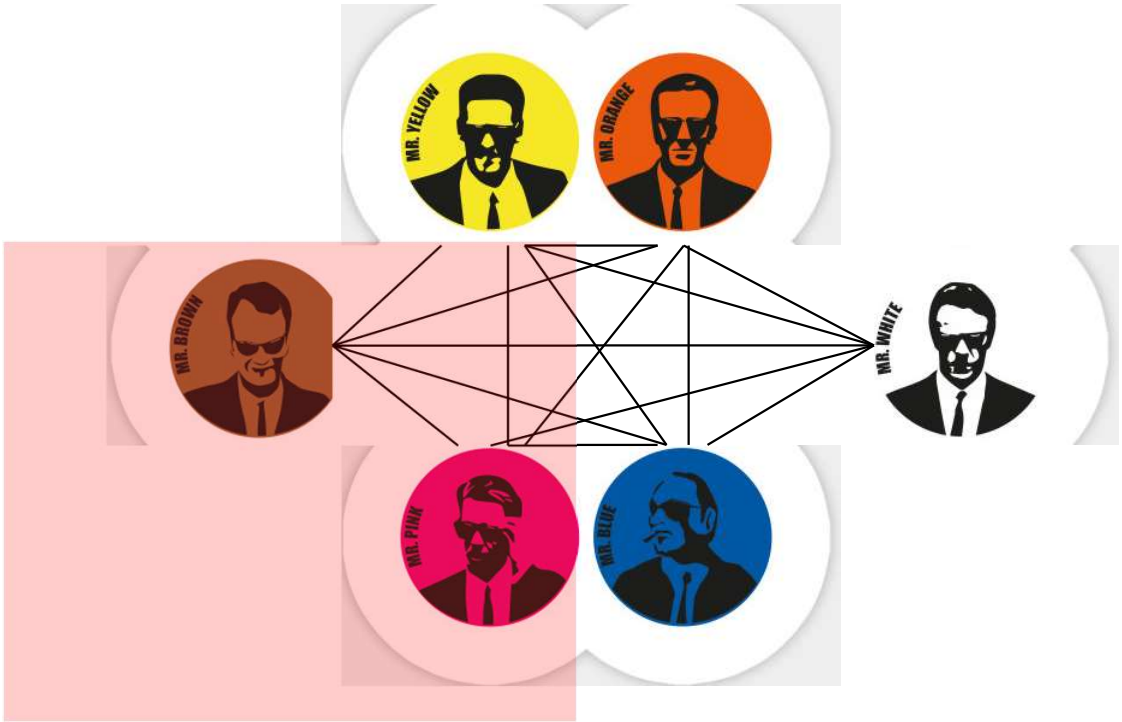

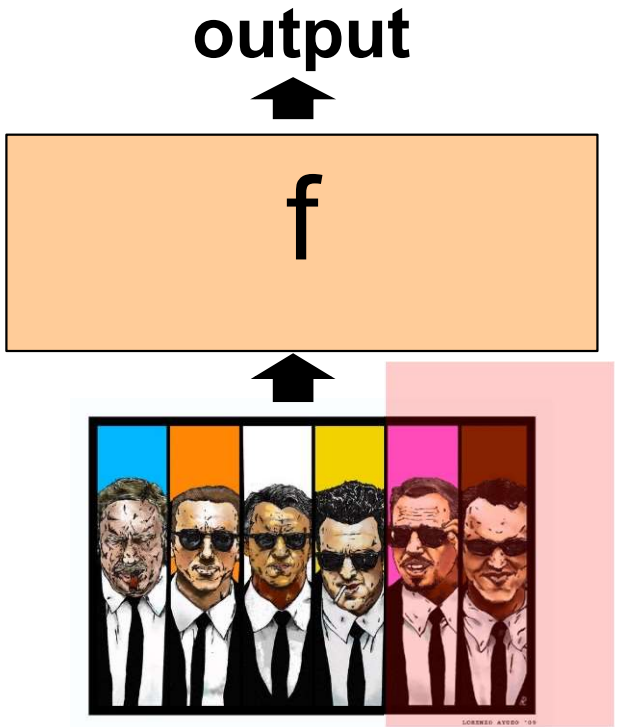

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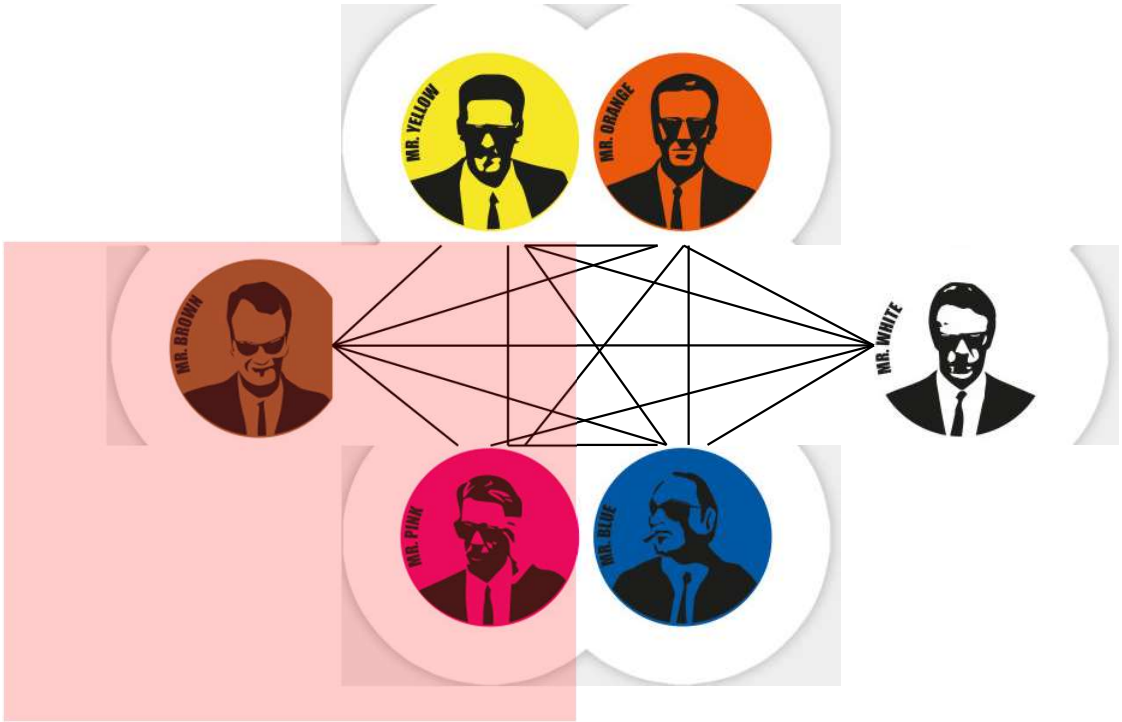

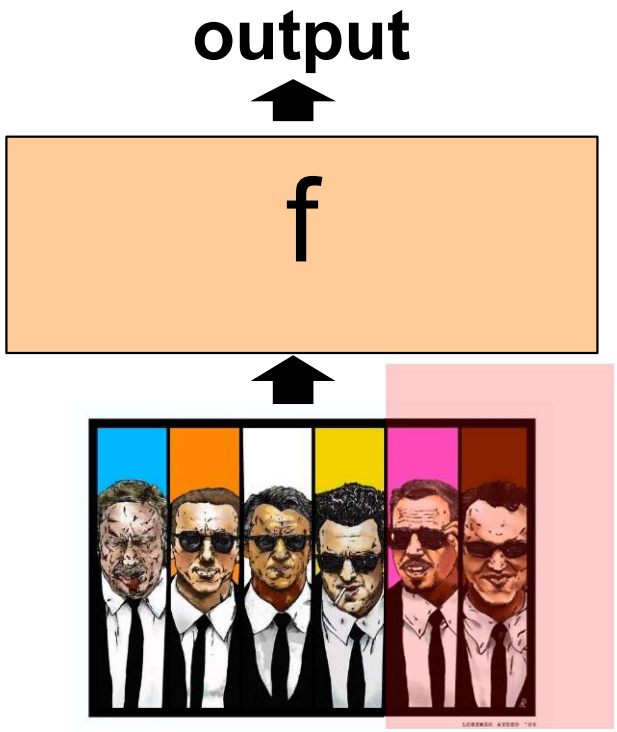

Multiparty Computation

Computational security:

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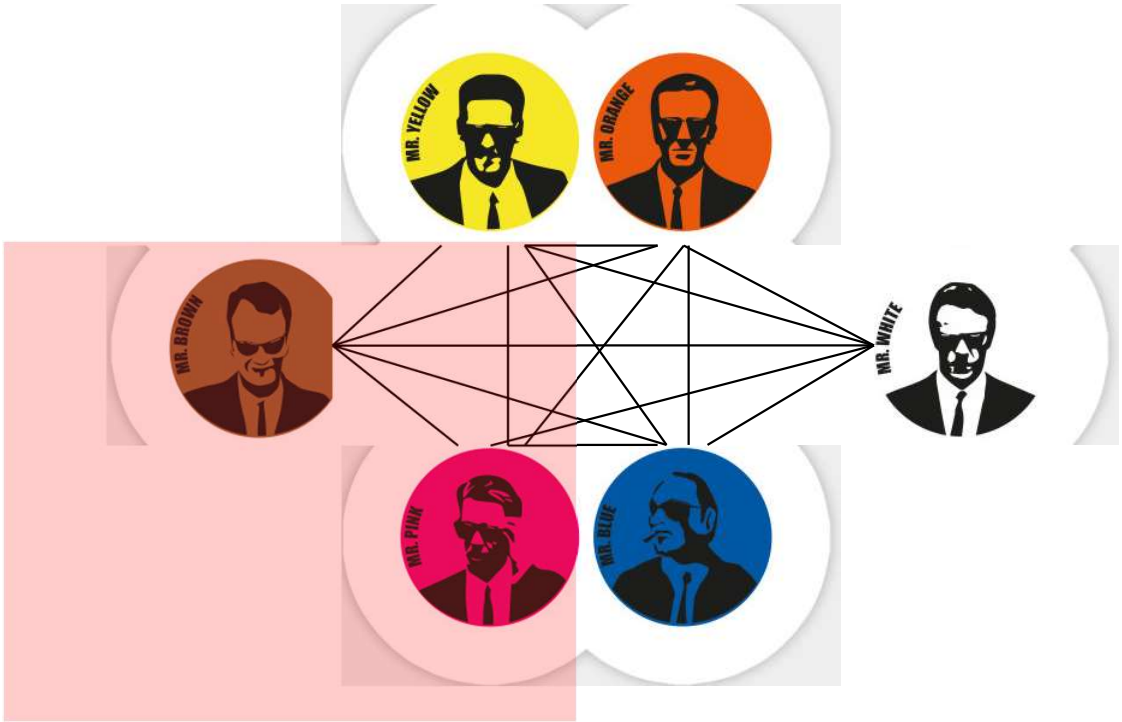
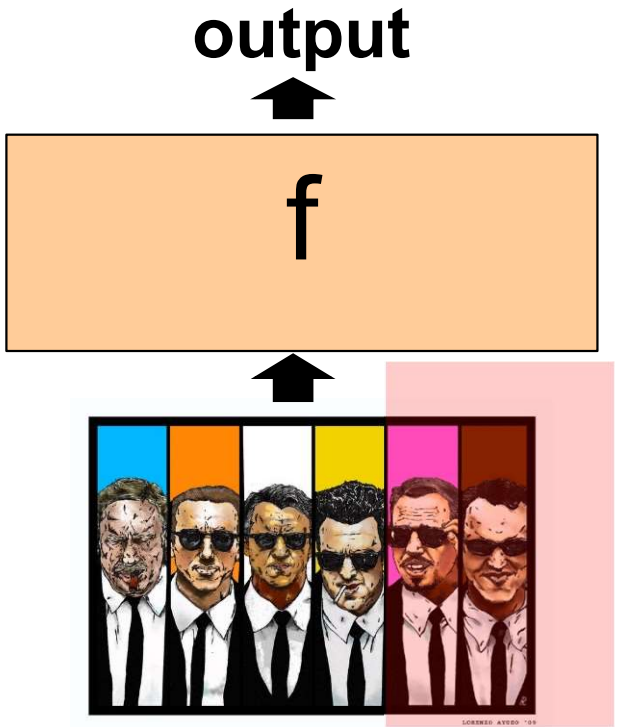
- controls up to T<N/2 parties
- active (Byzantine)
- Full security (including GOD)





Round Complexity

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No 2-round protocol for general MPC.

[Gennaro, Ishai, Kushilevitz, Rabin]

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3 rounds	CRS	Threshold FHE (LWE)	[GLS15]

[Gordon, Liu, Shi]

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[Badrinarayanan, Jain, Manohar, Sahai]

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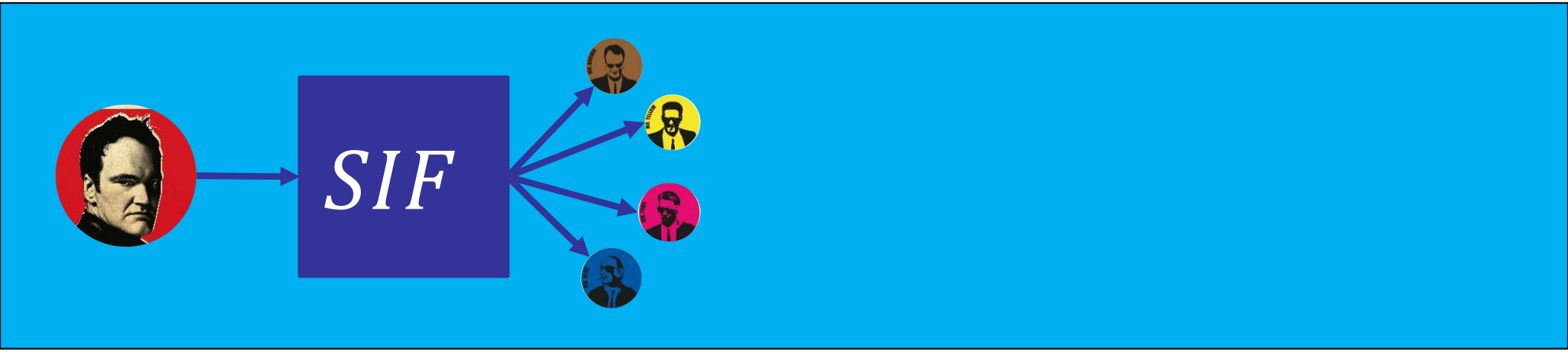
3 rounds	plain	PKE+NIZK	[ACGJ18]

[Ananth, Choudhuri, Goel, Jain]

Round Complexity

Round-optimal MPC from **Minicrypt**-type assumptions?

Main Result: Compiler



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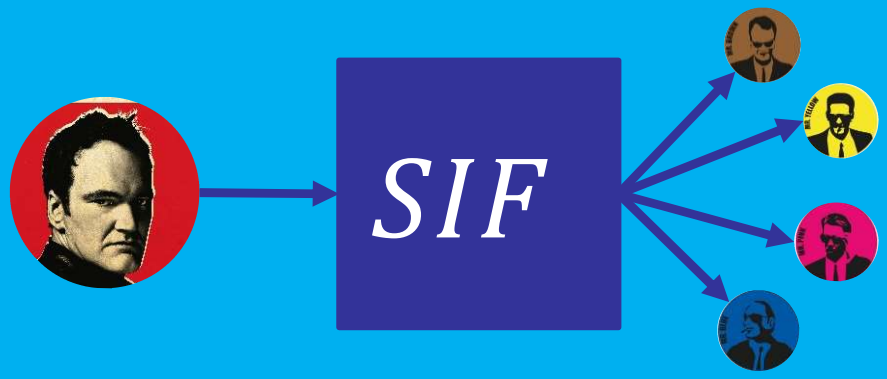

2-round protocol:

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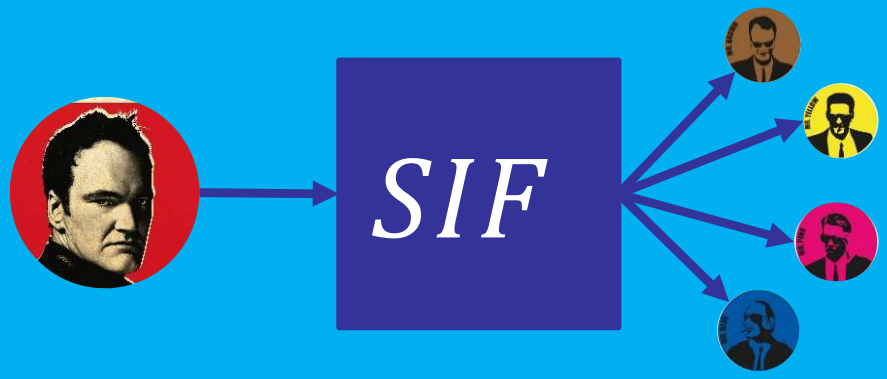

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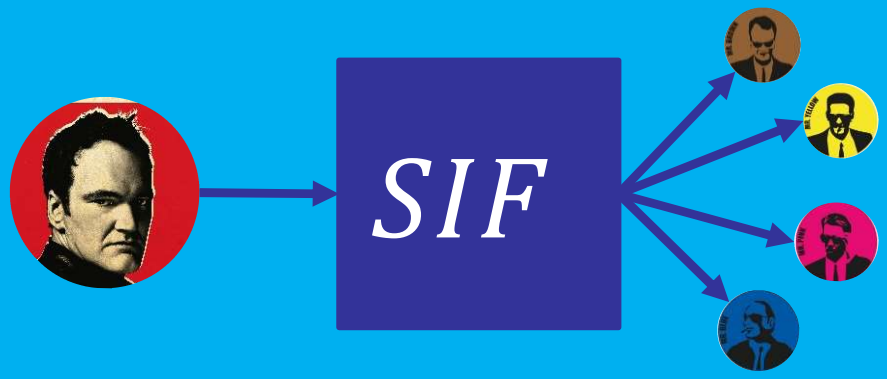

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Non-interactive commitments

3 round general MPC protocol

Compilation

Assuming **non-interactive commitments*** [AKP22]

2-round SIF (online/offline)

- Constant #parties – honest majority $t < \frac{1}{2}n$.
- Polynomial #parties – almost honest majority $t < 0.499n$.

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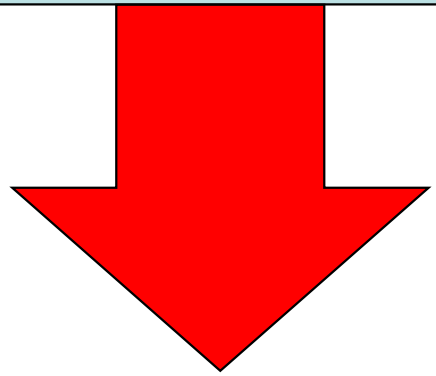

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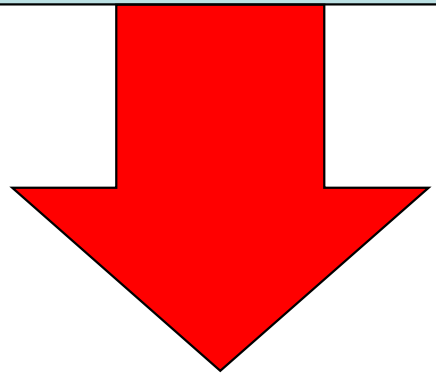

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Can be based on Minicrypt-type assumptions:

- 1-1 OWFs with sub-exp hardness [Blum81, Yao82, GL89]
- OWFs with sub-exp hardness + CRS [Naor91]
- OWFs with sub-exp hardness + derand. assumptions [BOV03]

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Provide **everlasting security** for $NC1$ circuits**:**

Adversary is bounded during the execution

but computationally *unbounded* after the execution

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How to select the hash function?

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- Additional offline round
- Fixed function for uniform adversary

The Construction

Outline

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- 2-round semi-malicious for general MPC.

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  - Play honestly, can choose input and rand.

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- IT variant of [ACGJ18]

2-round Semi malicious

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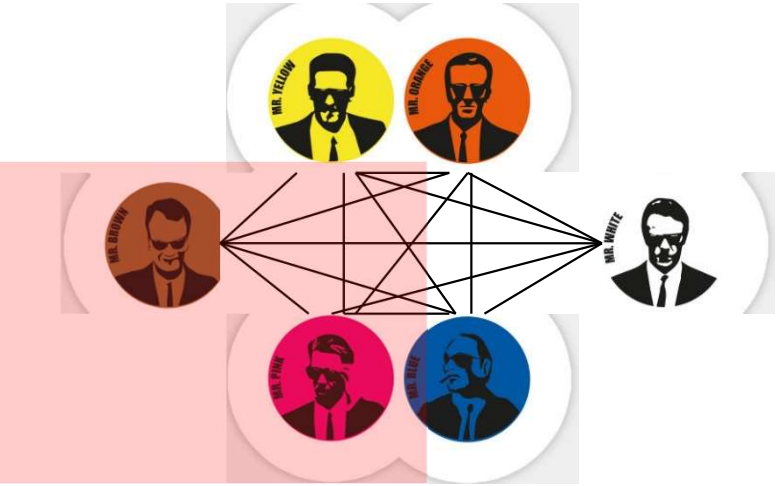
private channels



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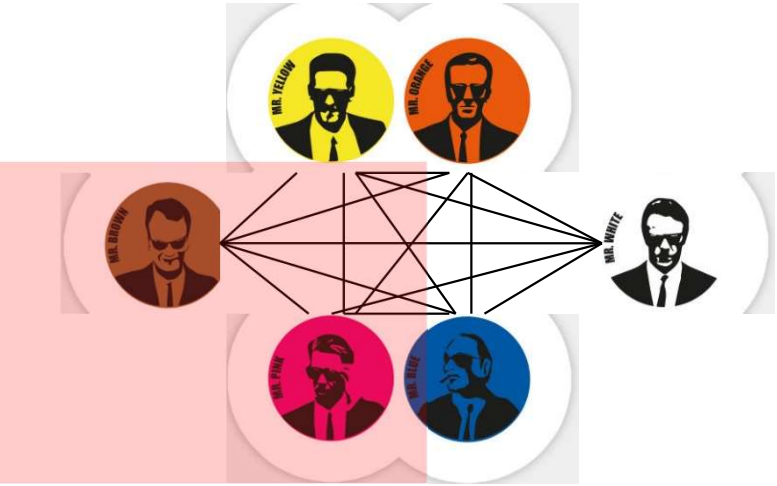
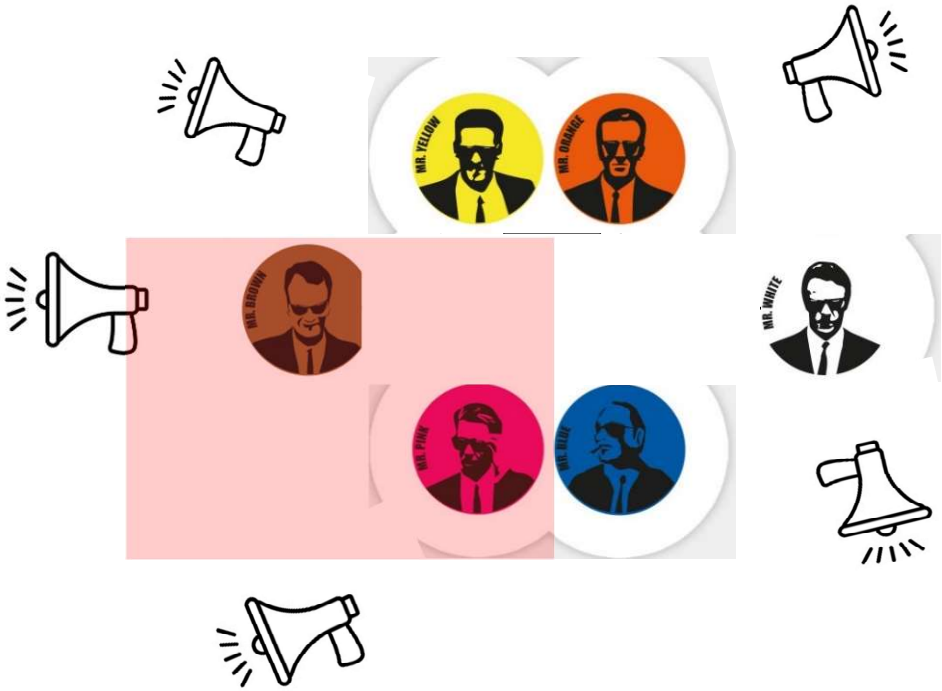


Round 2:
Broadcast channel



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Fail-stop Adversary

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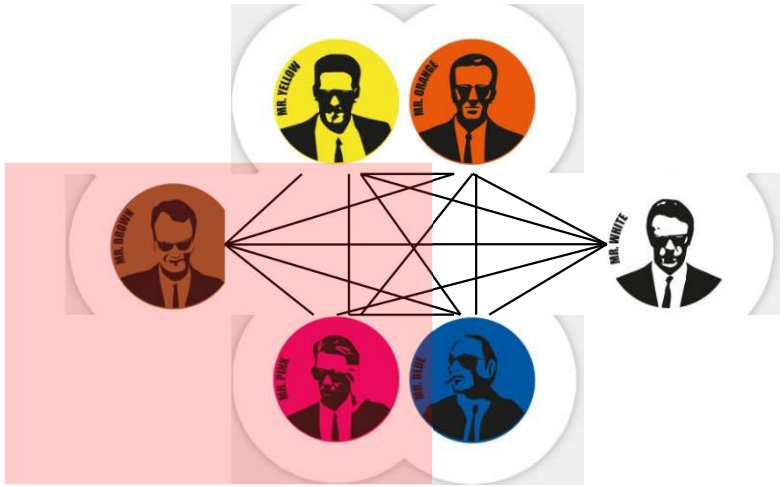

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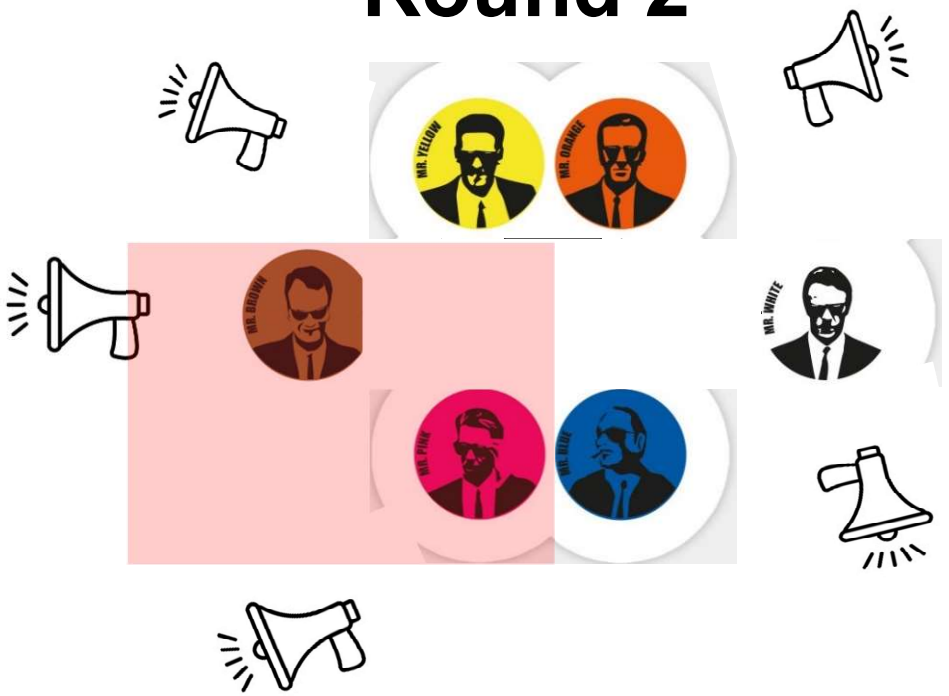

Fail-stop Adversary

- First-round aborts

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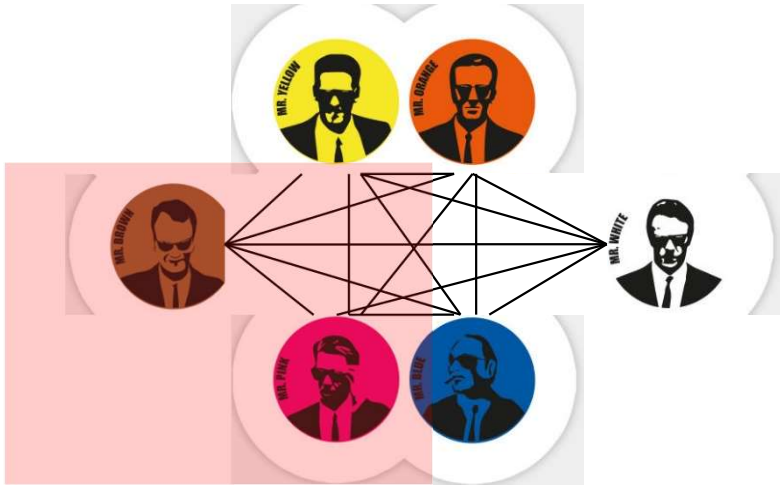

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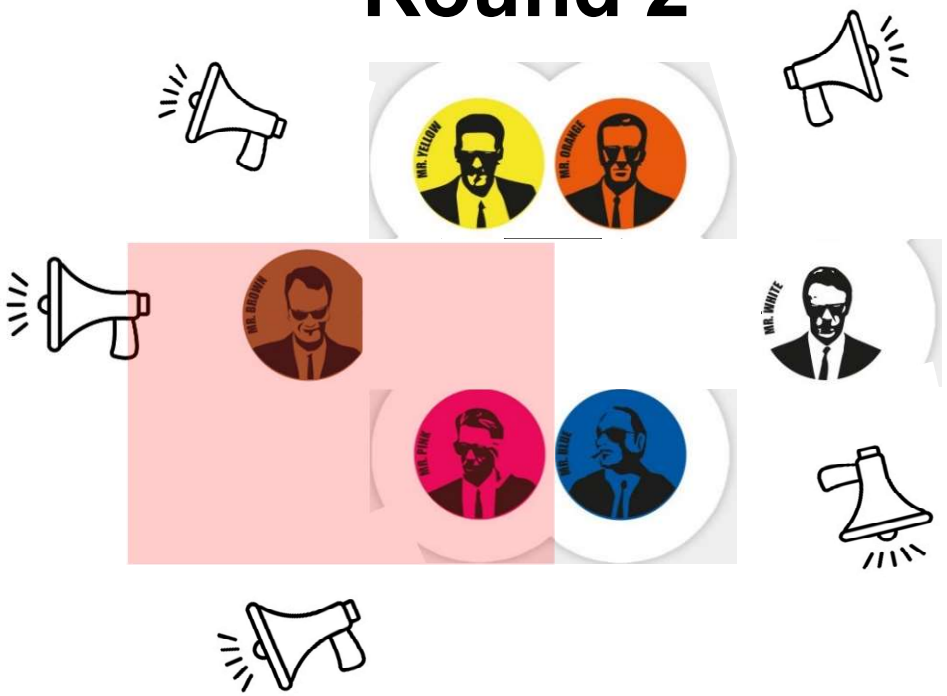
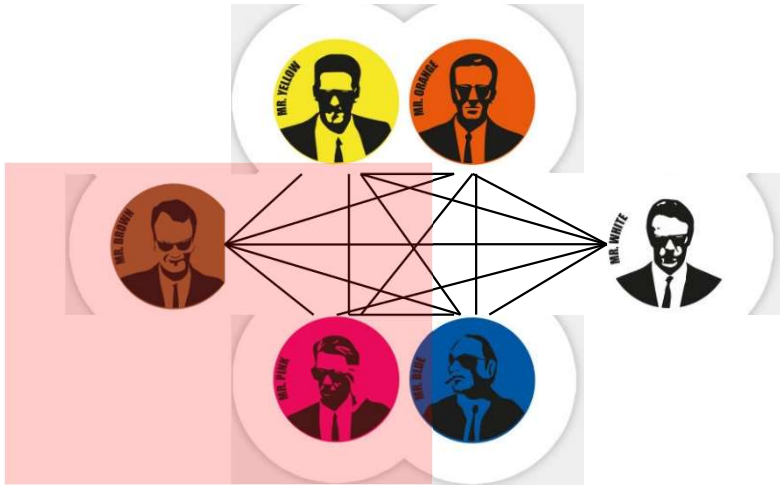


Fail-stop Adversary

- First-round aborts
- Second-round aborts

Round 1



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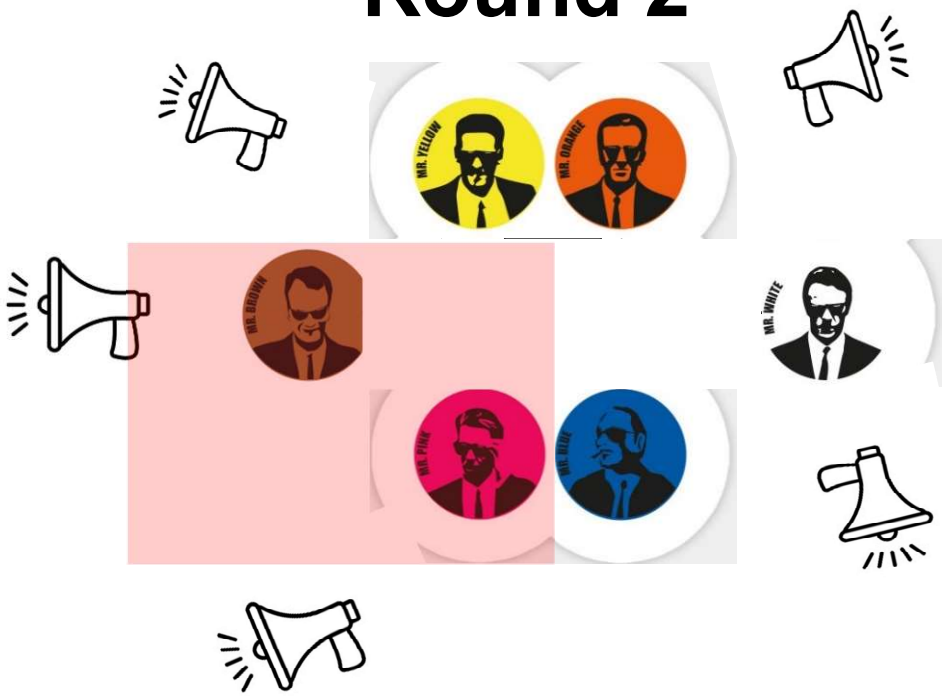

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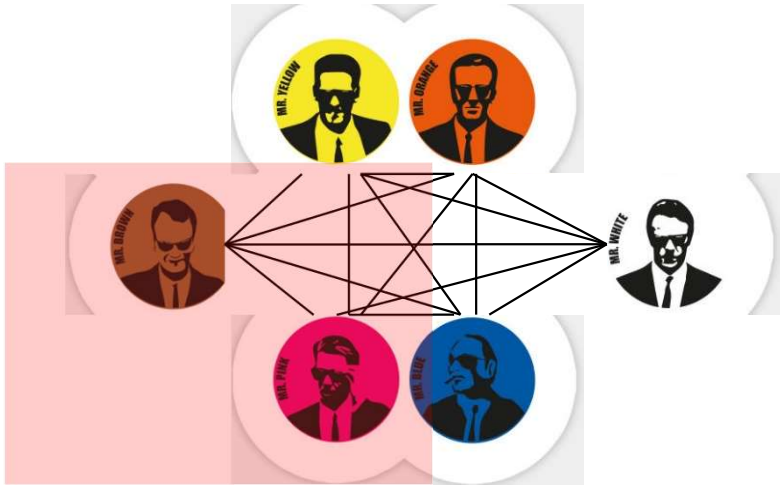

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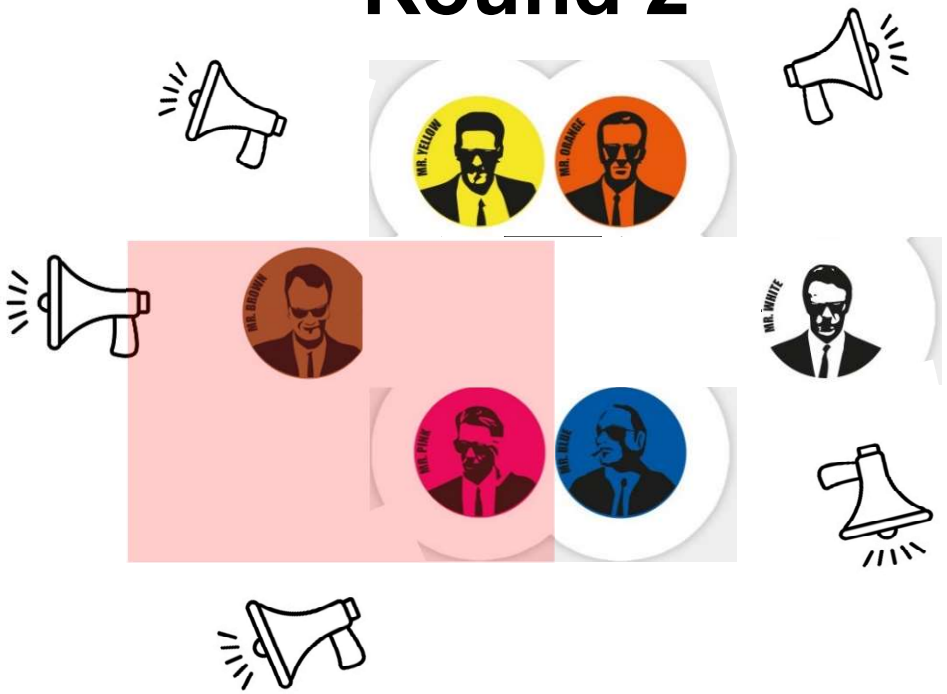

Second-round Fail-stop

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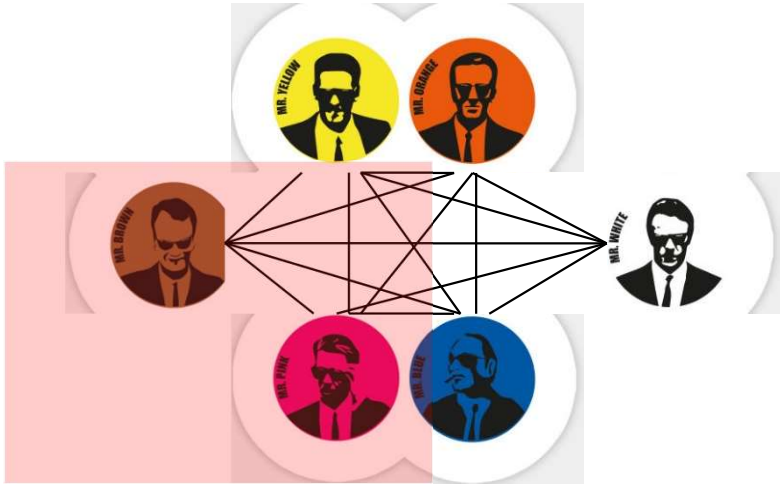

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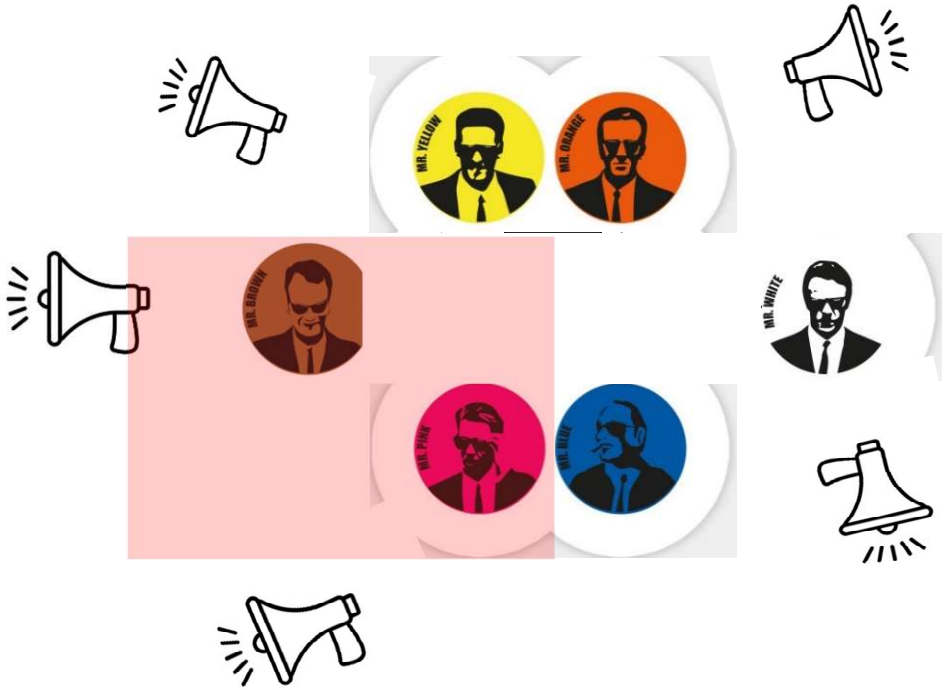

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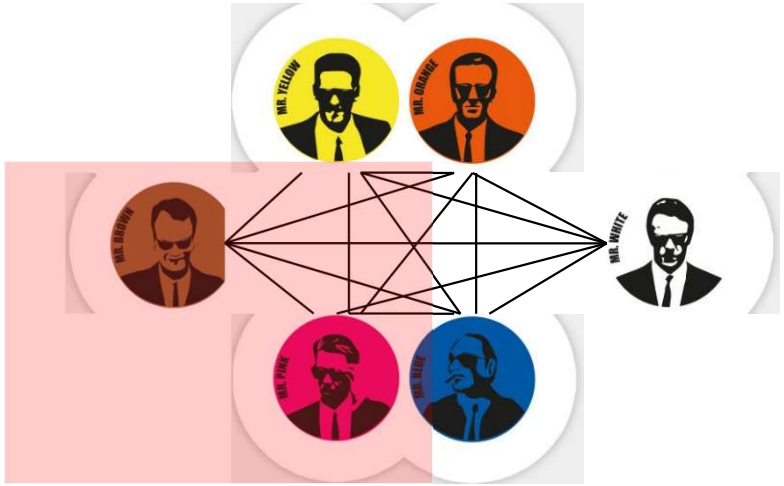

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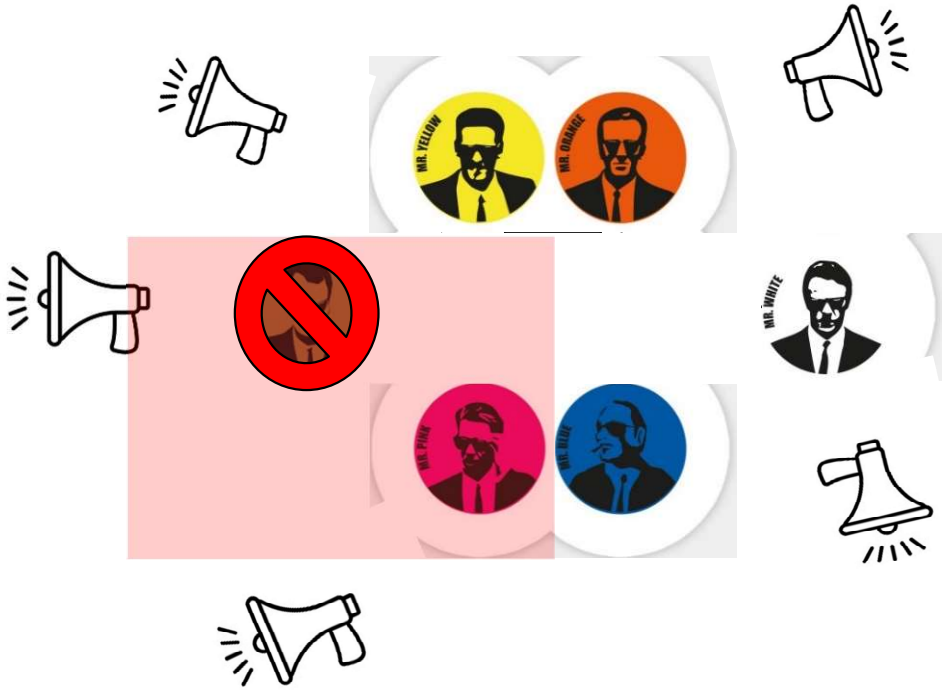
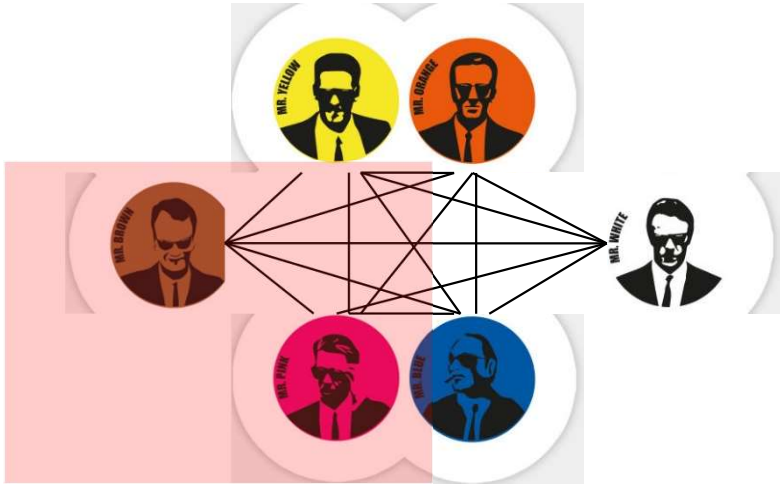


Second-round Fail-stop

Step I: public communication.

Round 1



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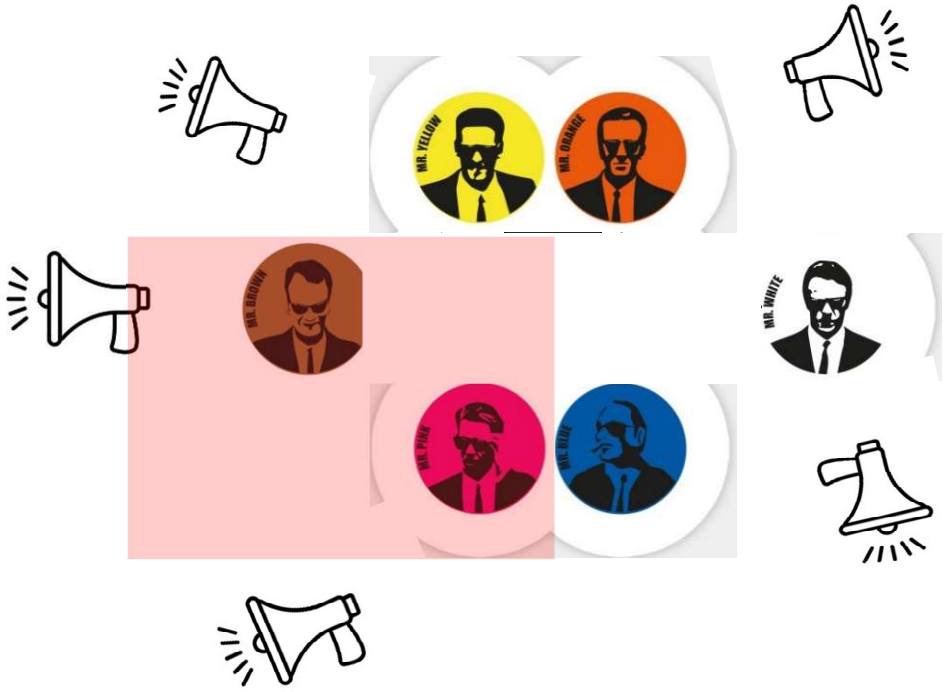
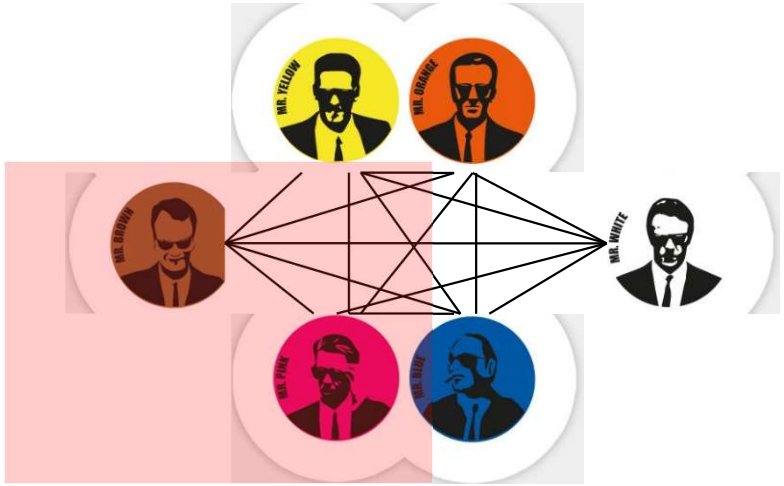


Second-round Fail-stop

Step I: public communication.
Step II: Forcing broadcast.

Round 1



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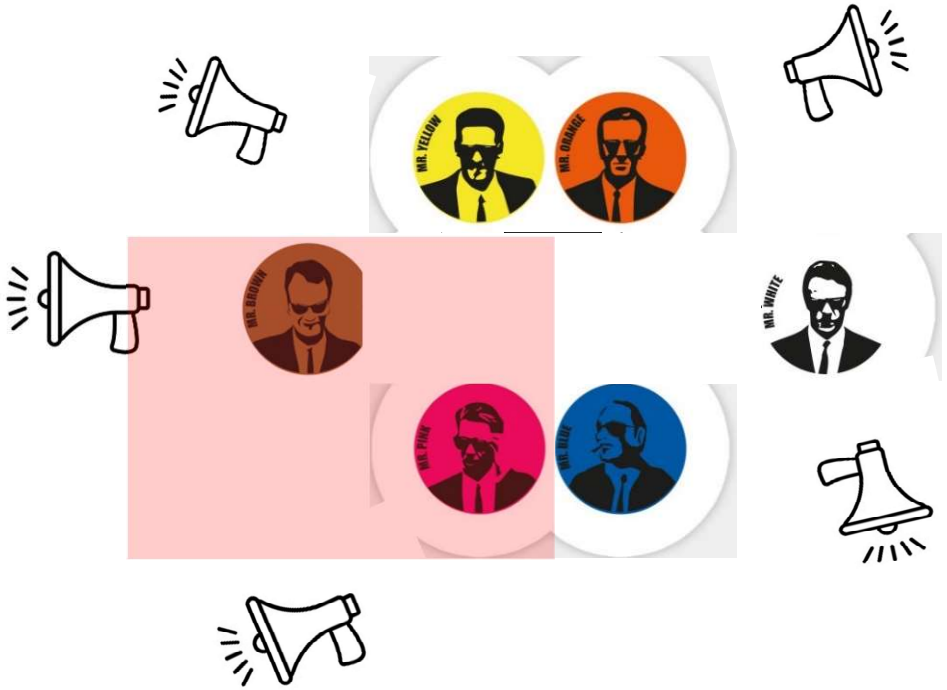

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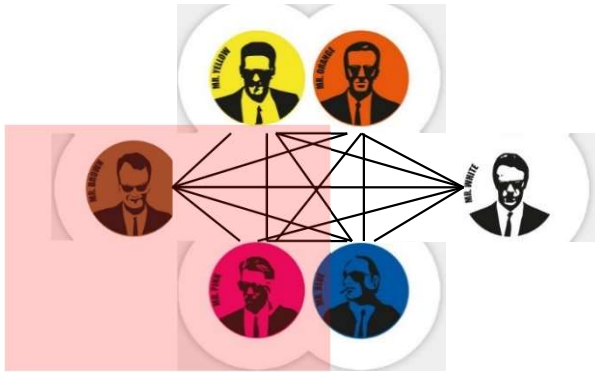

Exchange one-time pads

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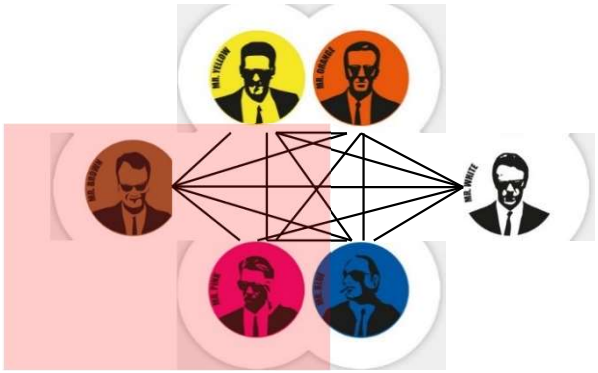
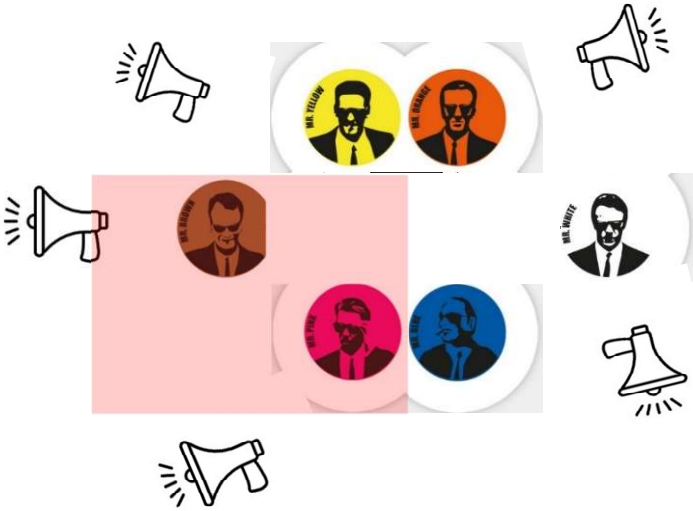


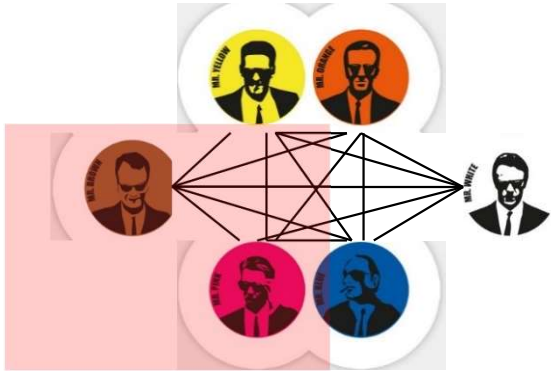
Round 2



Second-round Fail-stop

Step I: public communication.

Round 0



Exchange one-time pads

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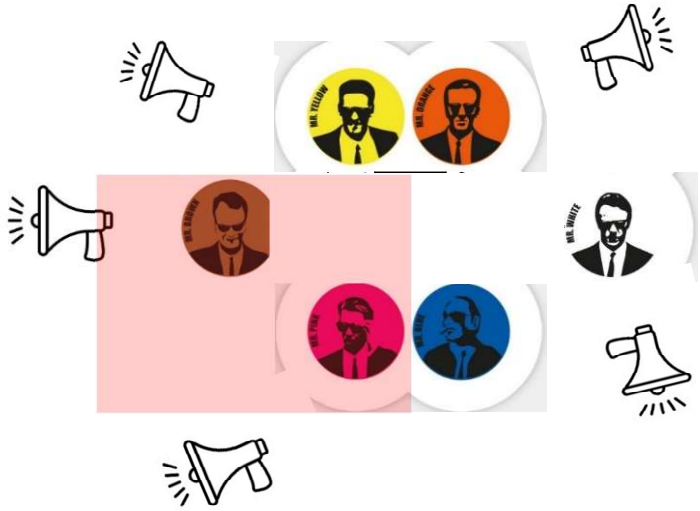
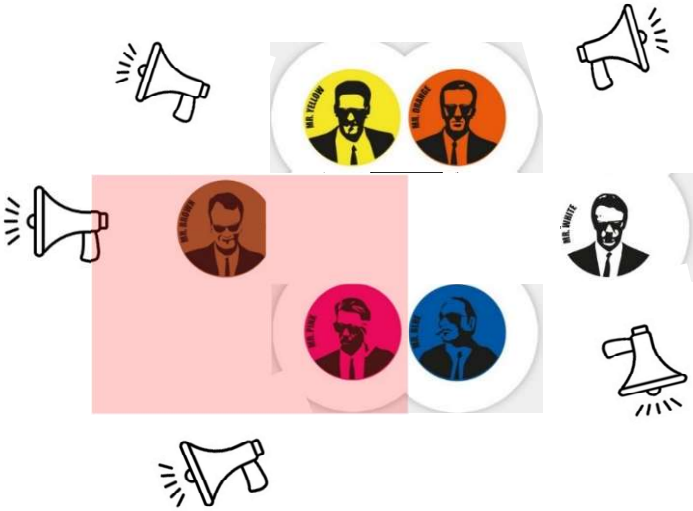


Round 2



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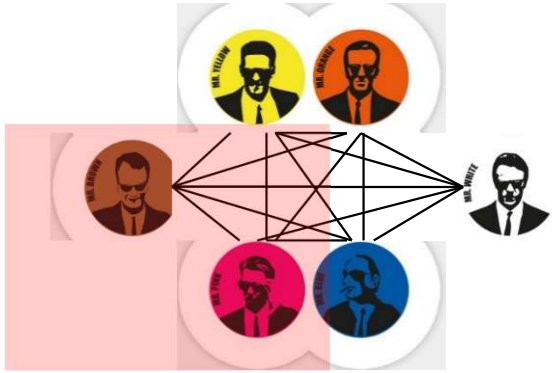

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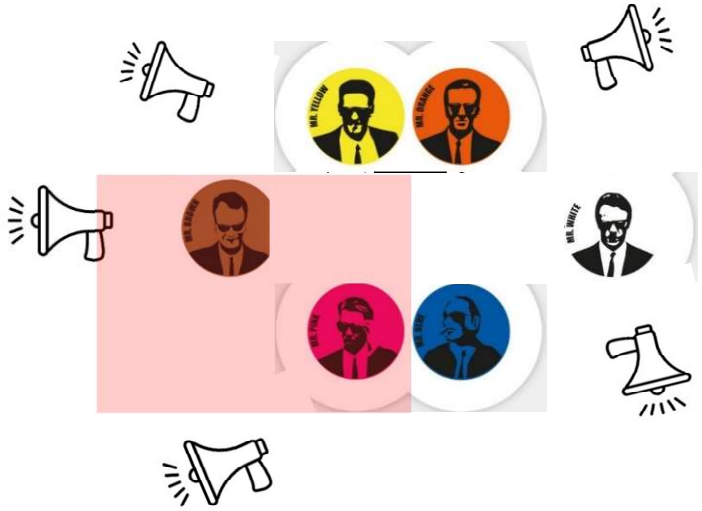
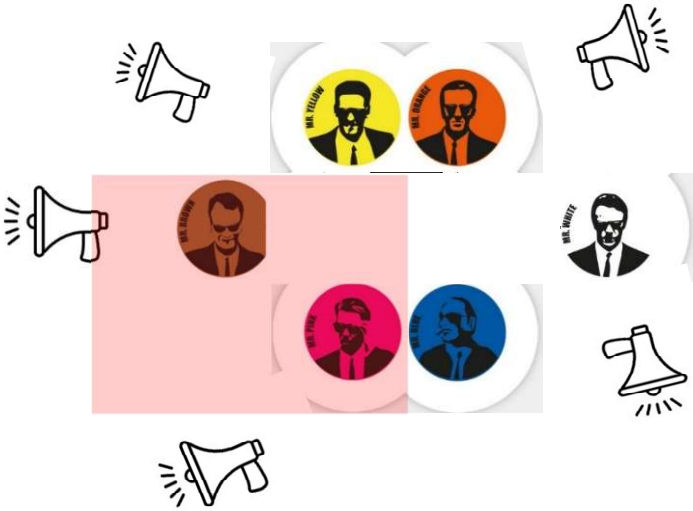


Round 2



Previous works: public-key encryption.

Second-round Fail-stop

Step II: Forcing broadcast

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- BC of Mr Brown is a function G_i of $\left(x_i, r_i, (\rho_{i,j})_j, (A_{j,i})_j\right)$

Second-round Fail-stop

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Second-round Fail-stop

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  - Labels of $(x_i, r_i, (\rho_{i,j})_j)$ are known in Round 1
  - Mr. Brown shares the labels of $(A_{j,i})_j$.
  - Correct labels of $(A_{j,i})_j$ recovered in Round 2.

Outline

- ~~2-round semi-malicious.~~
- ~~3-round fail-stop.~~
- 3-round active.

Active Adversary

Main idea: Prove honest behaviour via zero-knowledge proofs

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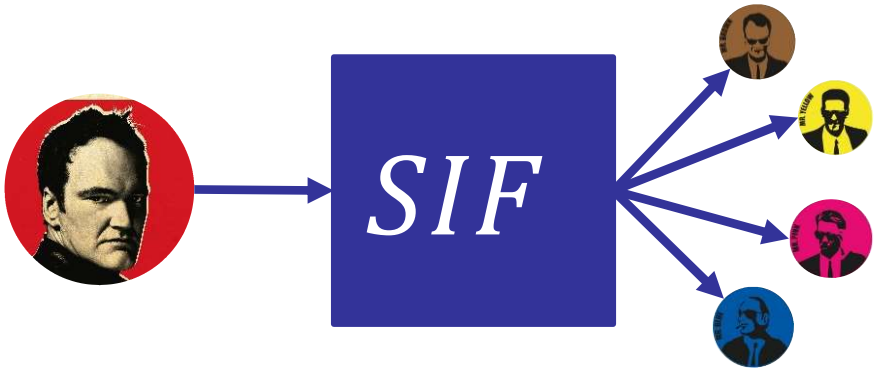

(x, w) $\quad if\ R(x, w) = 1 \quad Return\ (x, \text{true})$

$\quad\quad\quad\quad if\ R(x, w) = 0 \quad Return\ (x, \text{false})$

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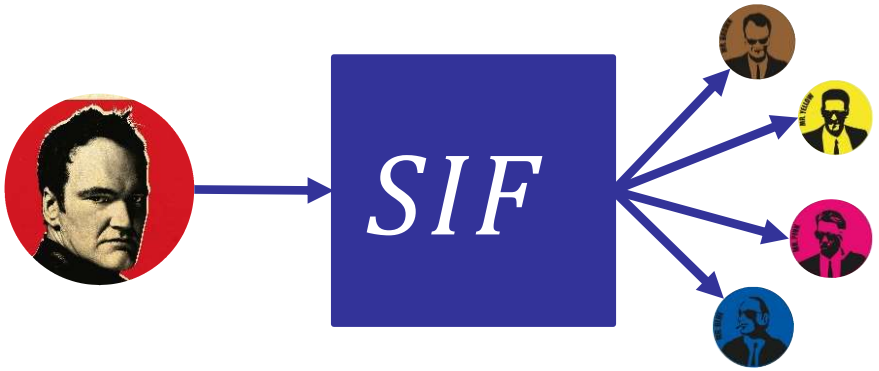

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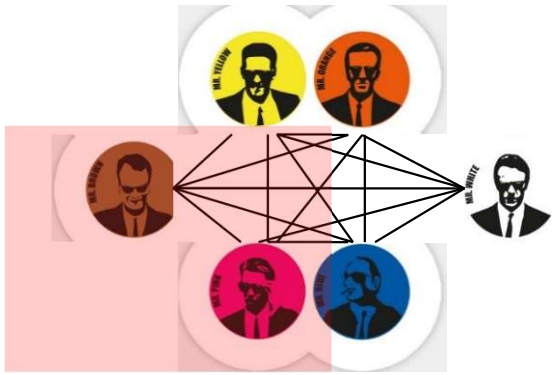
2-round protocol:

- 1 offline round
- 1 online round

Active Adversary

Round 0



Exchange one-time pads

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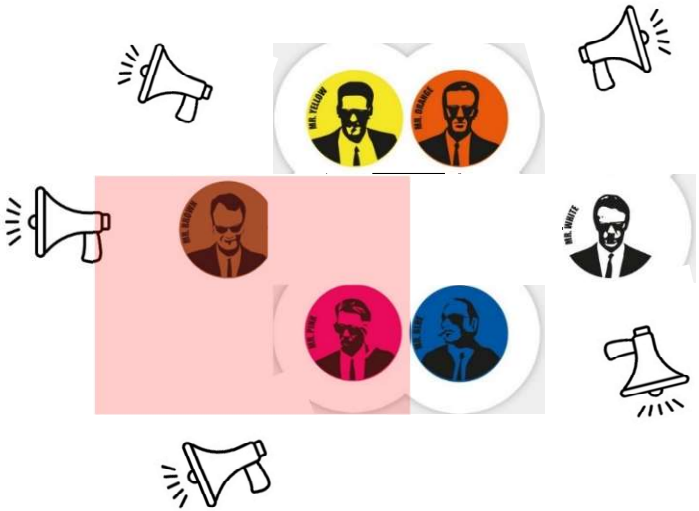
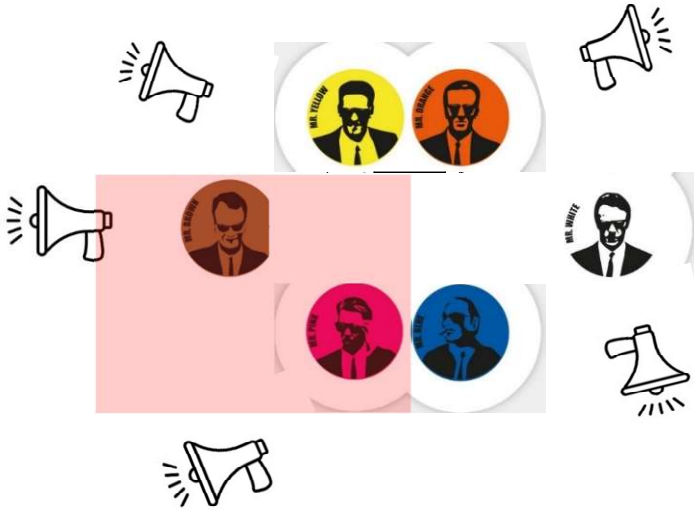
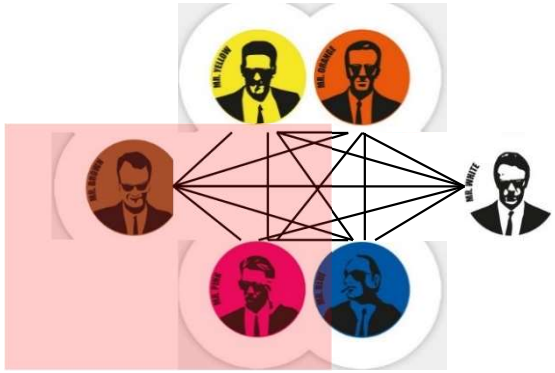


Round 2



Active Adversary

Round 0



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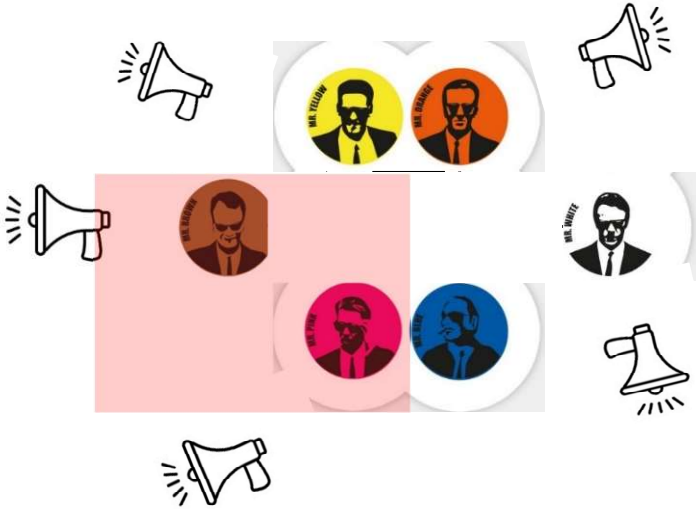
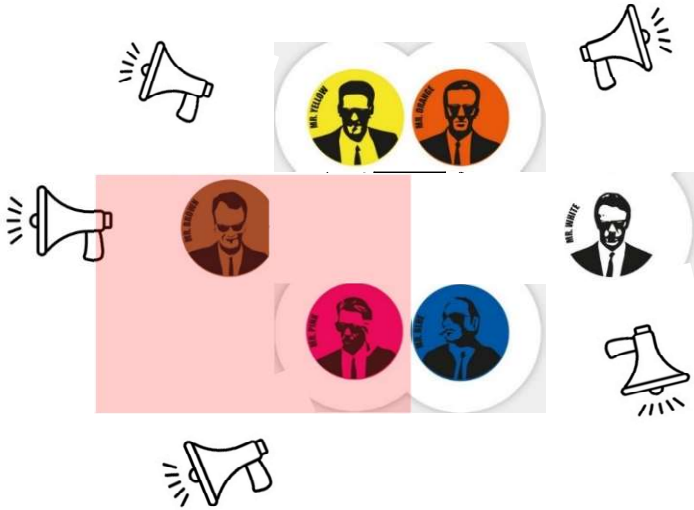


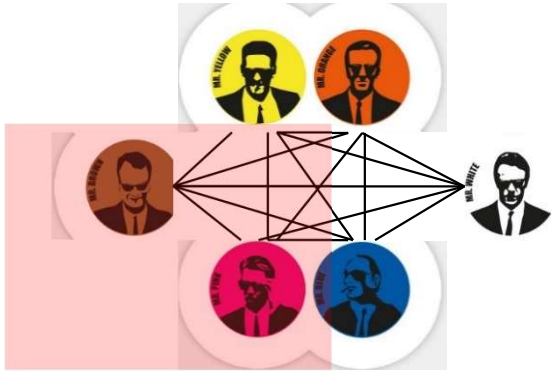
Offline round of SIF

Round 2



Active Adversary

Round 0



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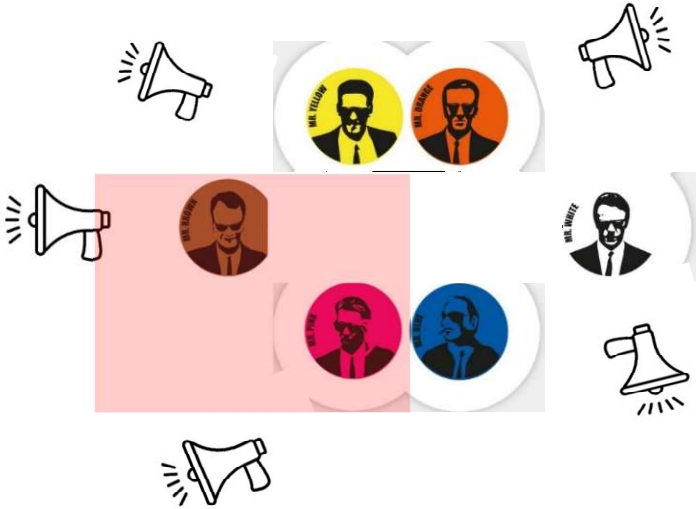
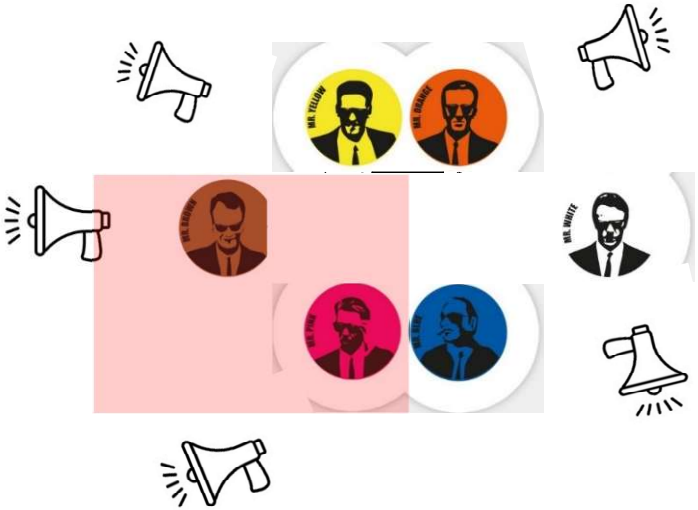


Prove honest behaviour in Rounds 0 and 1.

Round 2



Active Adversary

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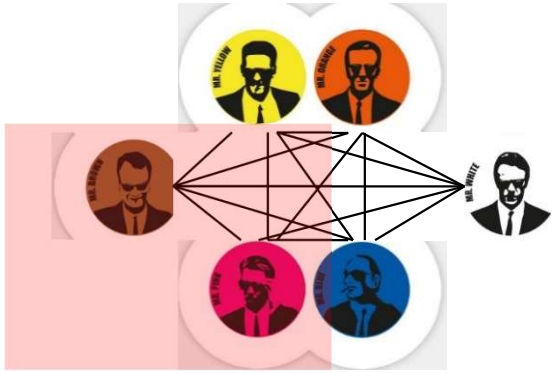

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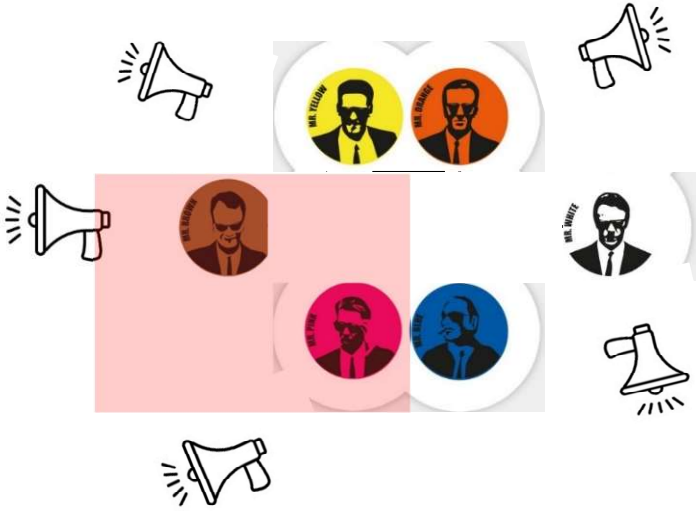

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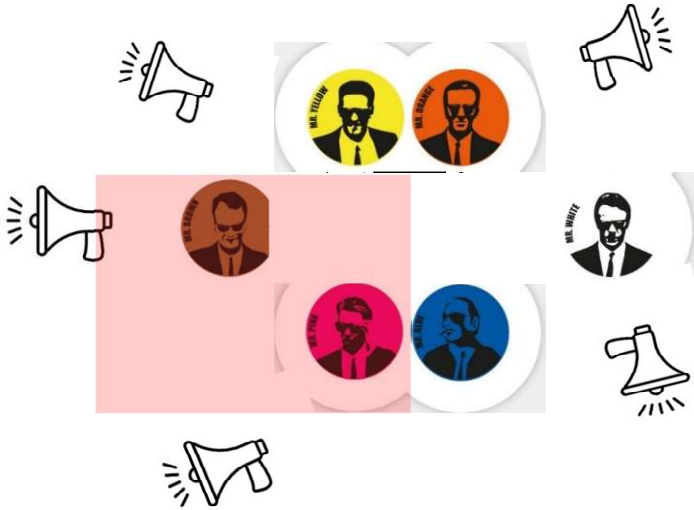
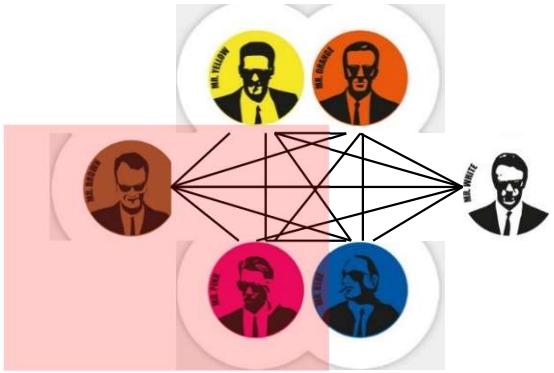
Round 2



Prove honest behaviour in Round 2.

Active Adversary

Round 0



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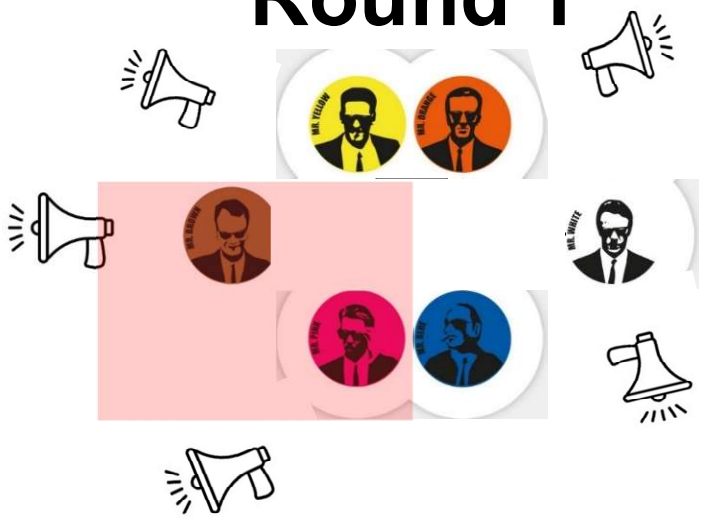
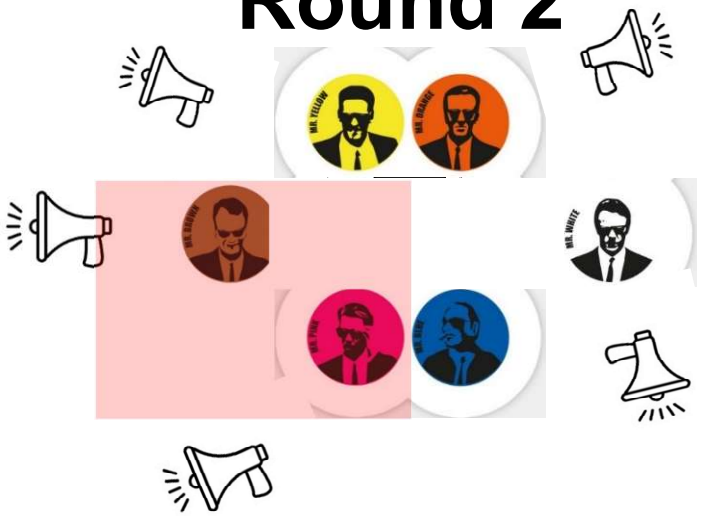


Round 2



Problem: Round 0 has private communication.

Active Adversary

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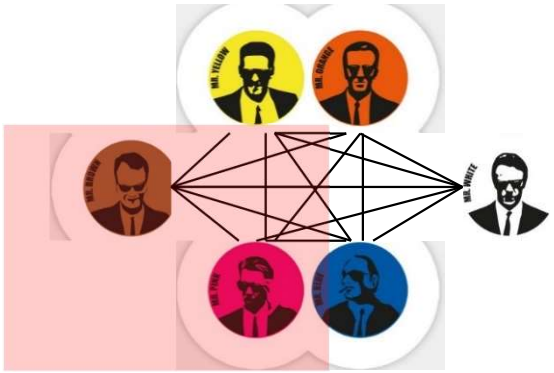

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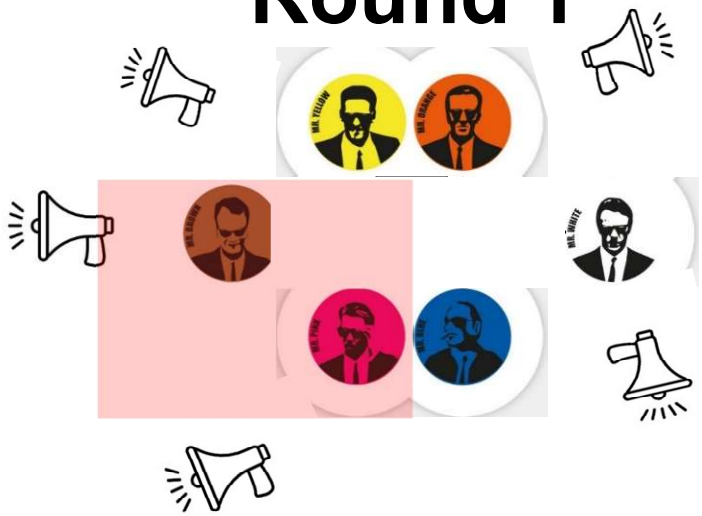
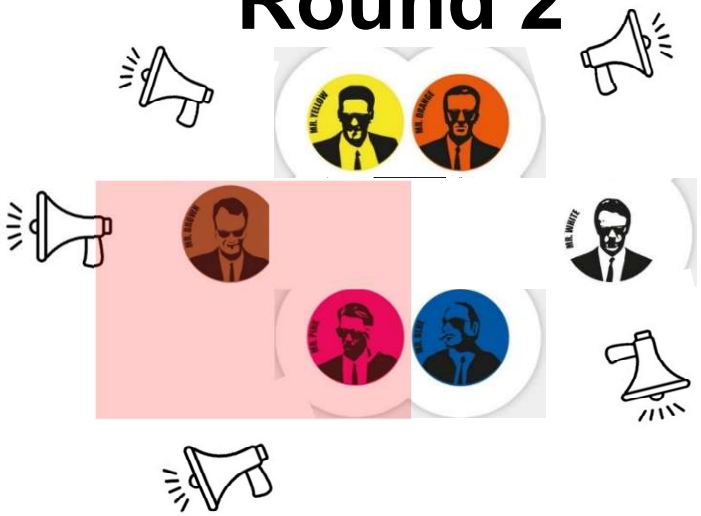


Round 2



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Active Adversary

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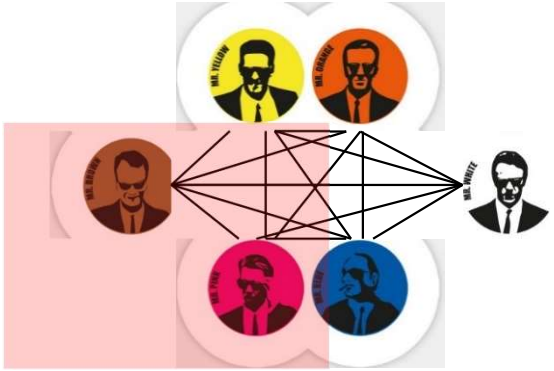

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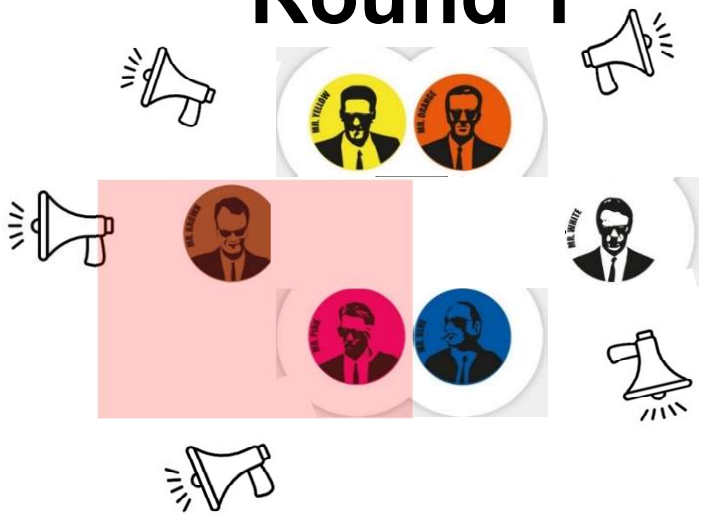
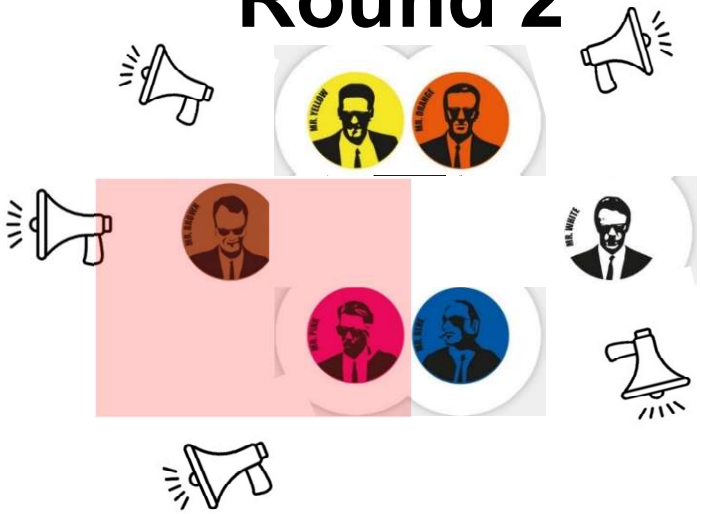


Round 2



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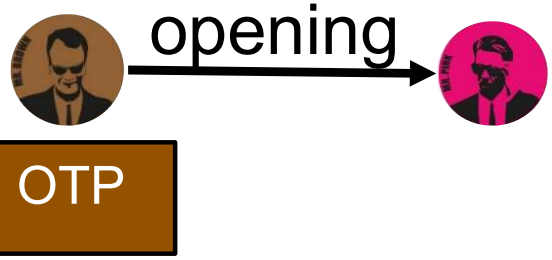

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Active Adversary

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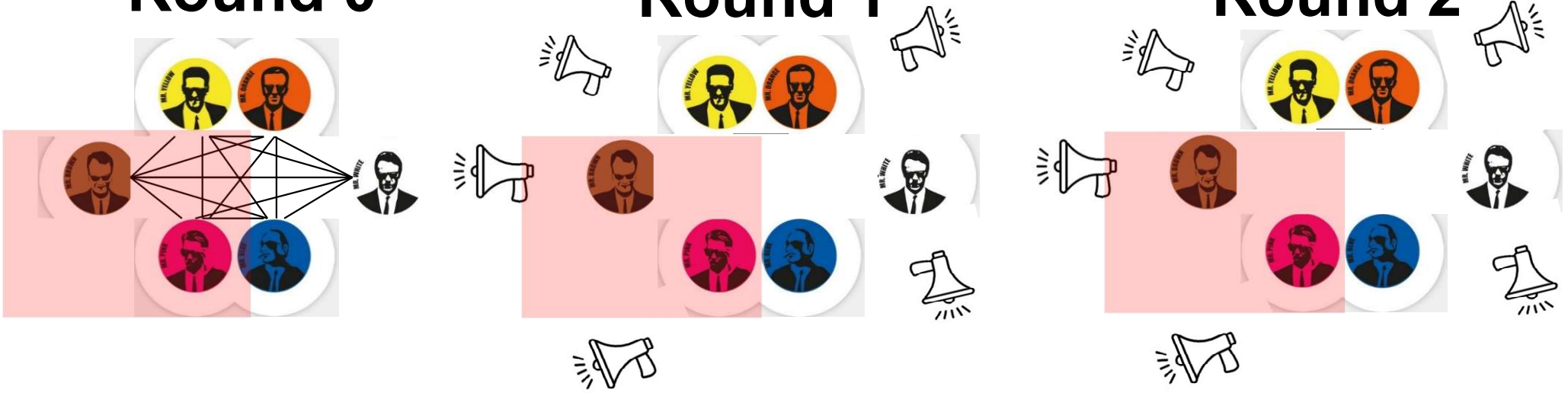

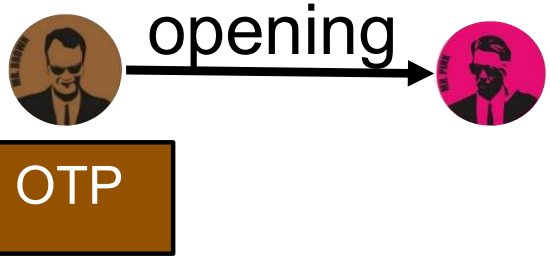

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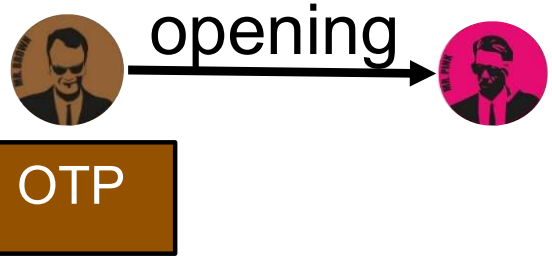

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  - **Valid opening:** Prove consistency with committed OTP.
  - **Invalid opening:** broadcast plaintext message.

Summary

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  - Full security

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Thank You!