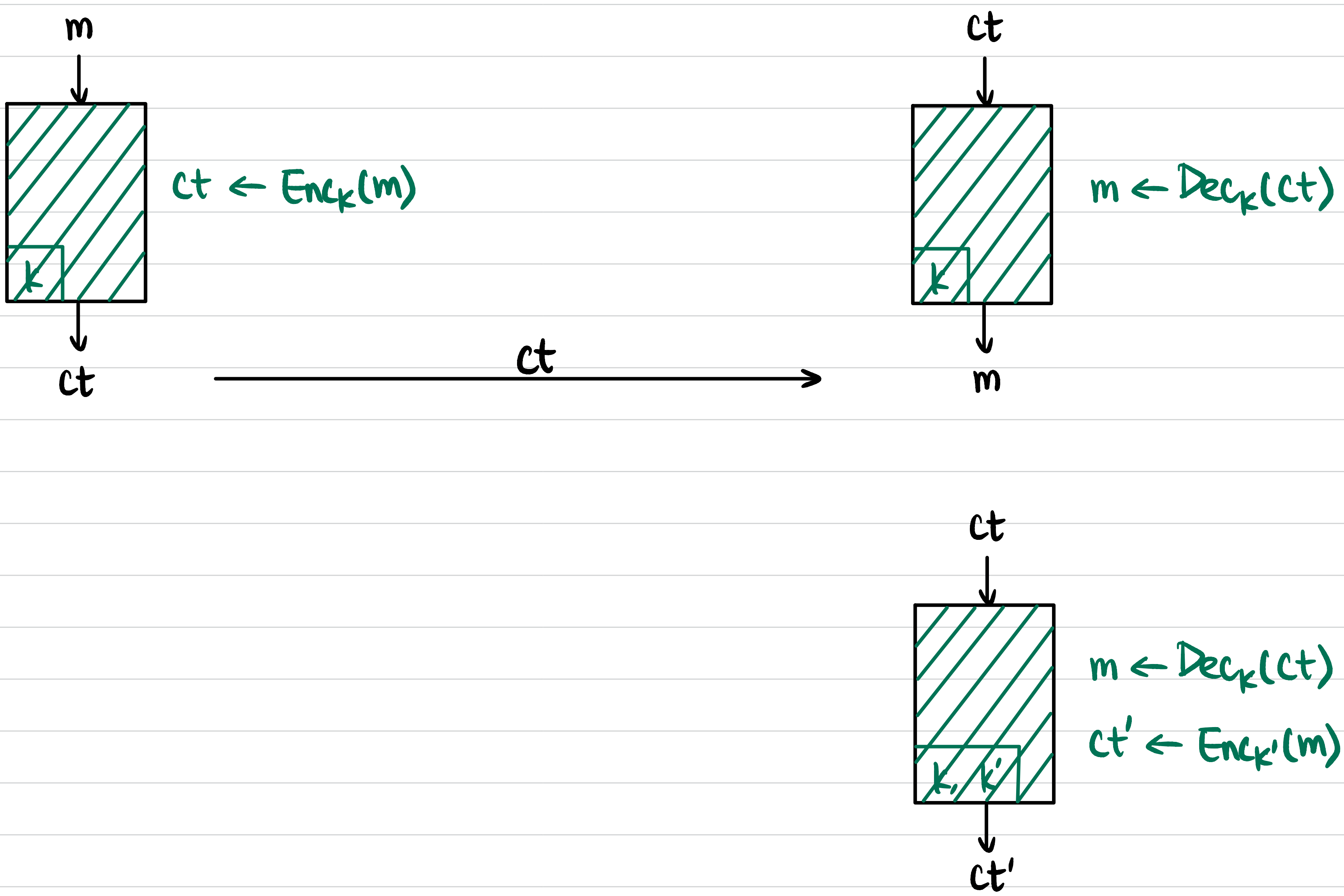
CSCI 1515 Applied Cryptography

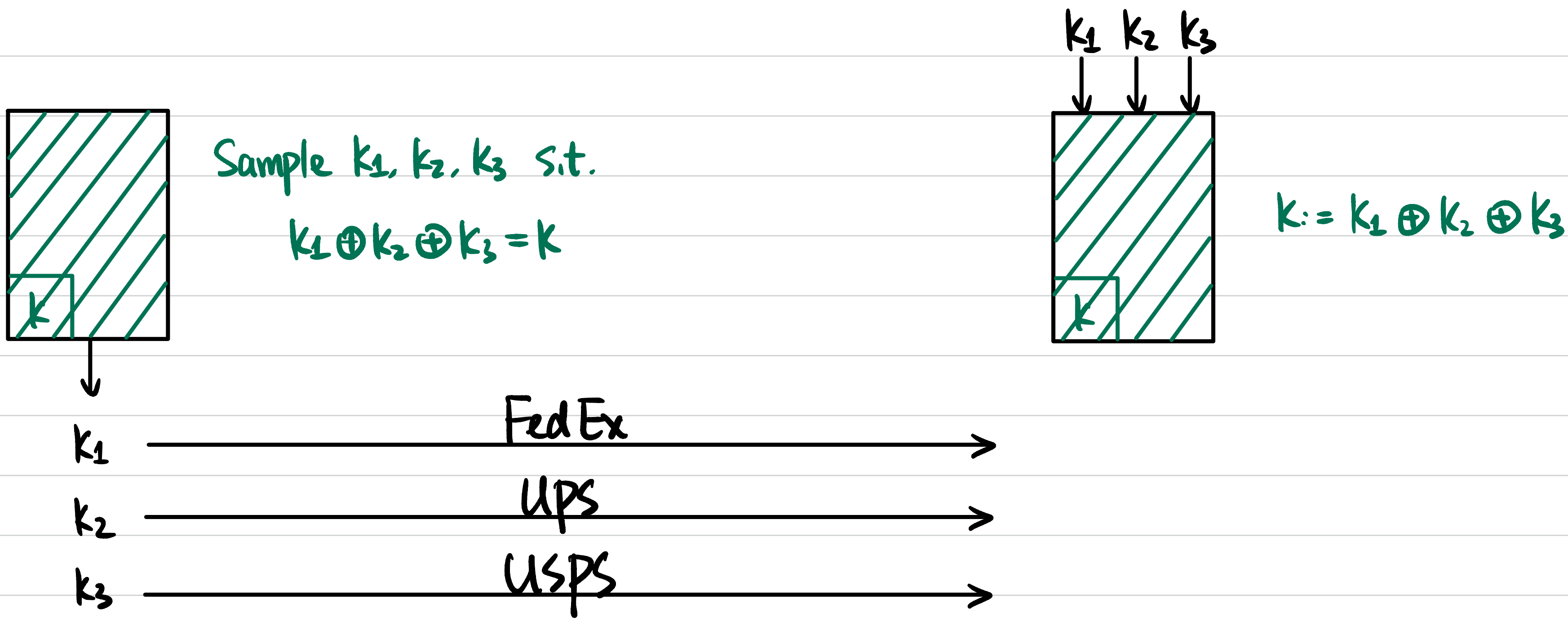
This Lecture:

- Secure Hardware: HSM
- Introduction to Secure Multi-Party Computation
- Feasibility Results of MPC

Hardware Secure Module (HSM)



Key Agreement

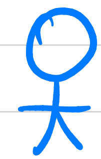


Secure Multi-Party Computation

Alice

x

Bob



y

Second date?

$$f(x, y) = x \wedge y$$

Who is richer?

$$f(x, y) = \begin{cases} 0 & \text{if } x > y \\ 1 & \text{otherwise} \end{cases}$$

Mutual friends?

$$f(X, Y) = X \cap Y$$

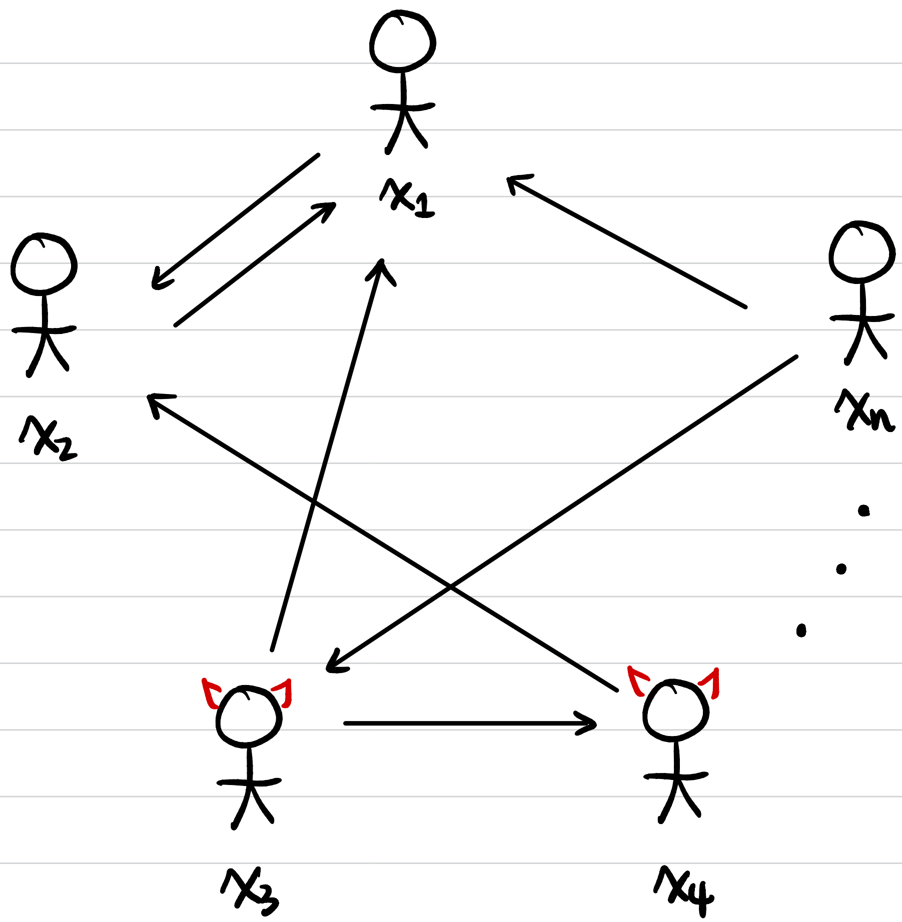
Secure Two-Party Computation (2PC)

$$z = f(x, y)$$

Applications:

- Password Breach Alert (Chrome / Firefox / Azure / iOS Keychain)
- Privacy-Preserving Contact Tracing for COVID-19 (Apple & Google)
- Ads Conversion Measurements / Personalized Advertising (Google / Meta)

Secure Multi-Party Computation (MPC)



$$z = f(x_1, \cdots, x_n)$$

Secure Multi-Party Computation (MPC)

Applications:

- Privacy-Preserving Inventory Matching (J.P. Morgan)
- Setup Ceremony to securely generate CRS (Zcash)
- Distributed Key Management (Unbound / Coinbase)
- Federated Learning (Google Keyboard Search Suggestion)
- Auctions (Danish sugar beet auction)
- Boston gender wage gap (Boston Women's Workforce Council)

- Study / Analysis on Medical Data
- Fraud / Money Laundering Detection (banks)

Setting

- n parties $P_1, P_2, \cdots, P_n$
  with private inputs $x_1, x_2, \cdots, x_n$

- Jointly compute $f(x_1, x_2, \cdots, x_n)$

- Communication:
  Authenticated secure point-to-point channels between each pair (P_i, P_j)
  (Sometimes also assume broadcast channel)

- The adversary can "corrupt" a subset of the parties
  (e.g. at most t parties)

What properties do we want?

General Security Properties

- Correctness: The function is computed correctly.
- Privacy: Only the output is revealed.
- Independence of Inputs: Parties cannot choose inputs depending on others' inputs.

- Security with Abort: Adversary may "abort" the protocol. (preventing honest parties from receiving the output)
- Fairness: If one party receives output, then all receive output.
- Guaranteed Output Delivery (GOD): Honest parties always receive output.

Adversary's Power

Allowed adversarial behavior:

- **Semi-honest** / passive / honest-but-curious:
  Follow the protocol description honestly,
  but try to extract more information by inspecting transcript.

- **Malicious** /active:
  Can deviate arbitrarily from the protocol description.

Adversary's Computing Power:

- **Unbounded computing power** ⇒ Information-Theoretic (IT) Security
- **PPT bounded** ⇒ Computational Security

Feasibility Results

Computational Security:

Semi-honest Oblivious Transfer (OT)

$\Downarrow$

semi-honest MPC for any function with $t < n$ (# corrupted parties)

$\Downarrow$

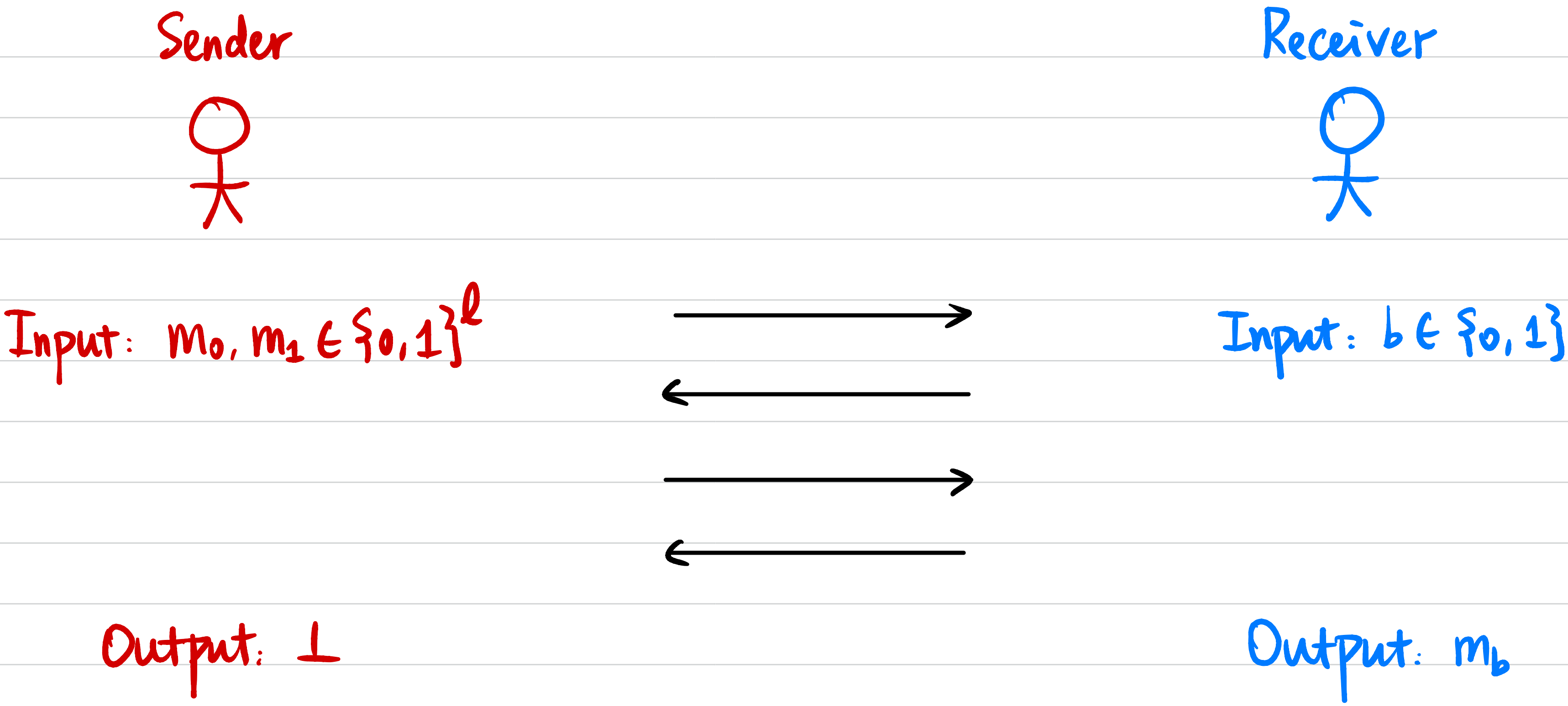
malicious MPC for any function with $t < n$

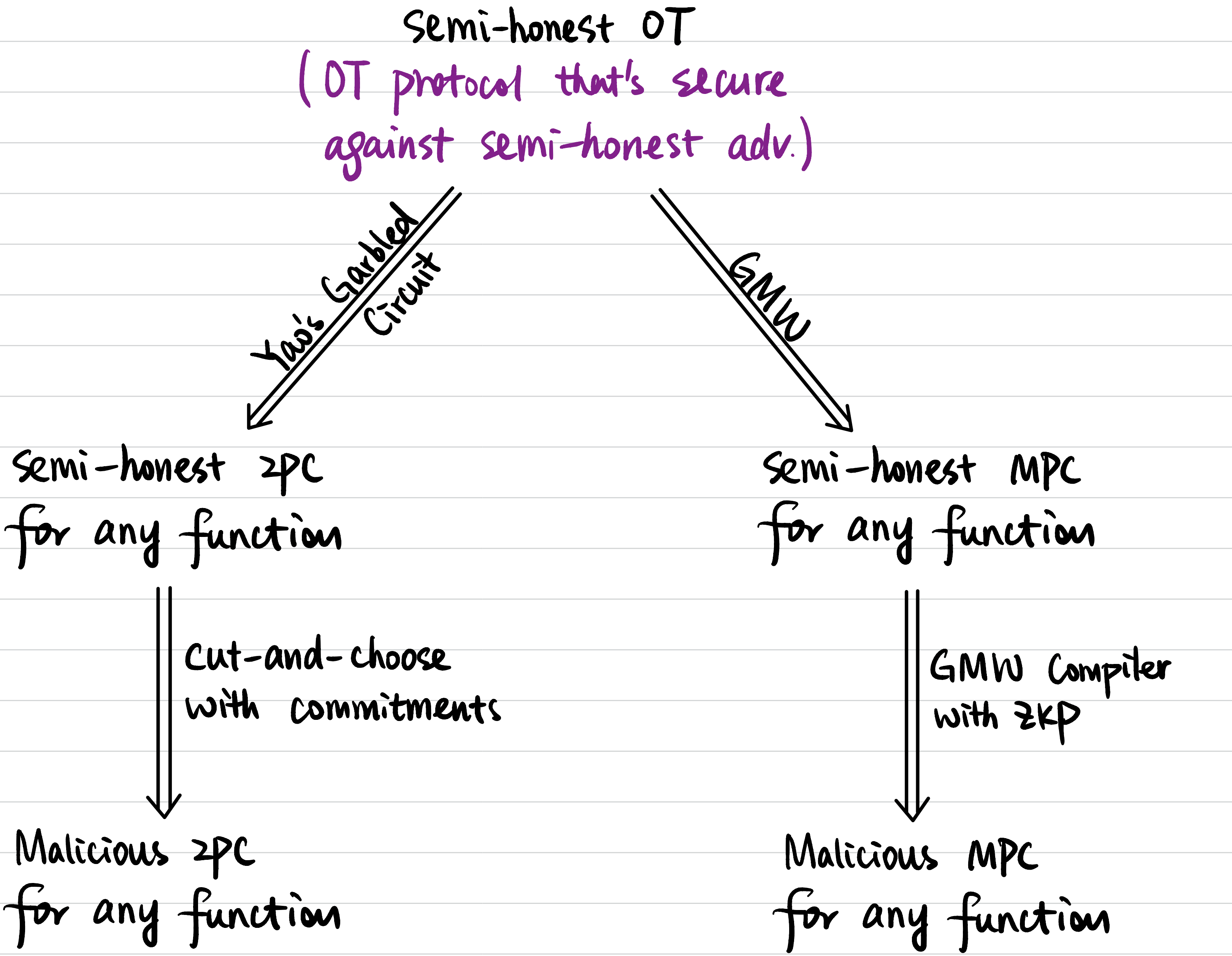
Information-Theoretic (IT) Security:

semi-honest/malicious MPC for any function with $t < n/2$ (honest majority)

↑ necessary

Oblivious Transfer (OT)




Semi-honest OT
(OT protocol that's secure against semi-honest adv.)
Yao's Garbled Circuit
GMW
Semi-honest 2PC for any function
Semi-honest MPC for any function
Cut-and-choose with commitments
GMW Compiler with ZKP
Malicious 2PC for any function
Malicious MPC for any function