Integrating Causality in Messaging Channels

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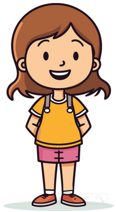
SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Marc Fischlin

TECHNISCHE
UNIVERSITÄT
DARMSTADT

Motivation

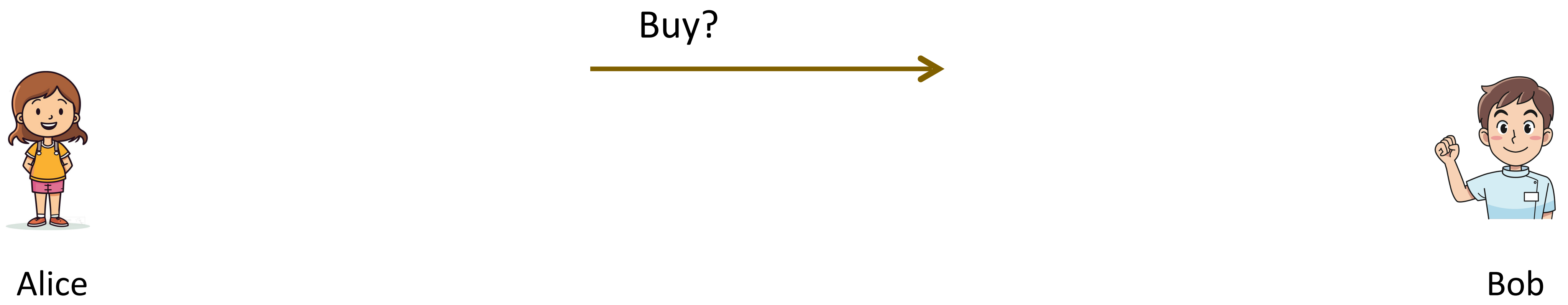
Secure (End-to-End) Messaging: Causality



Alice

Bob

Secure (End-to-End) Messaging: Causality



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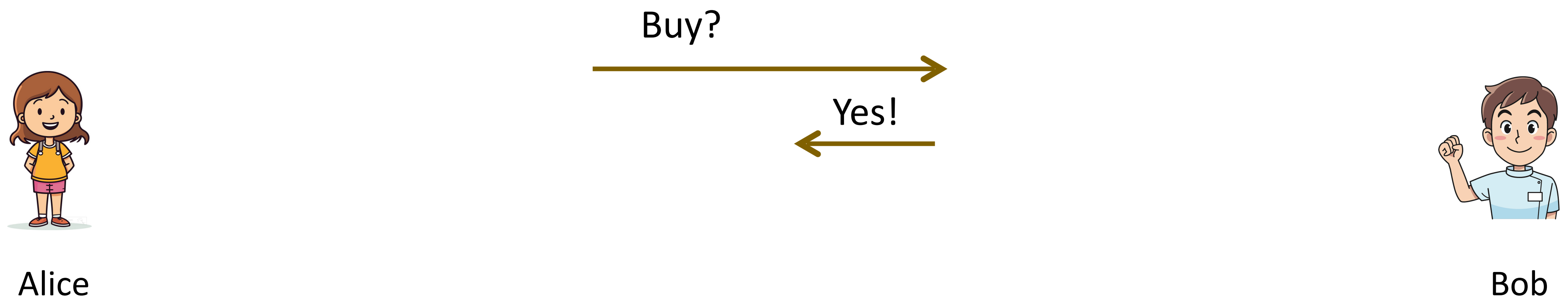

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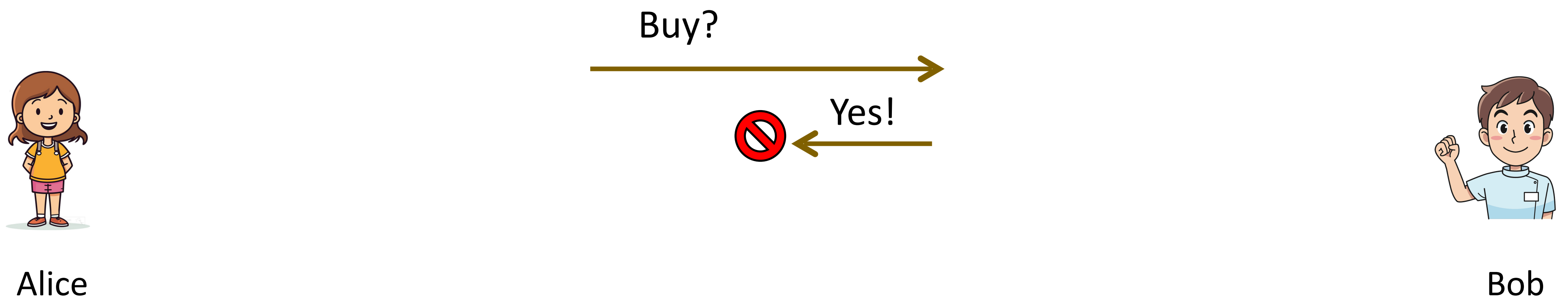

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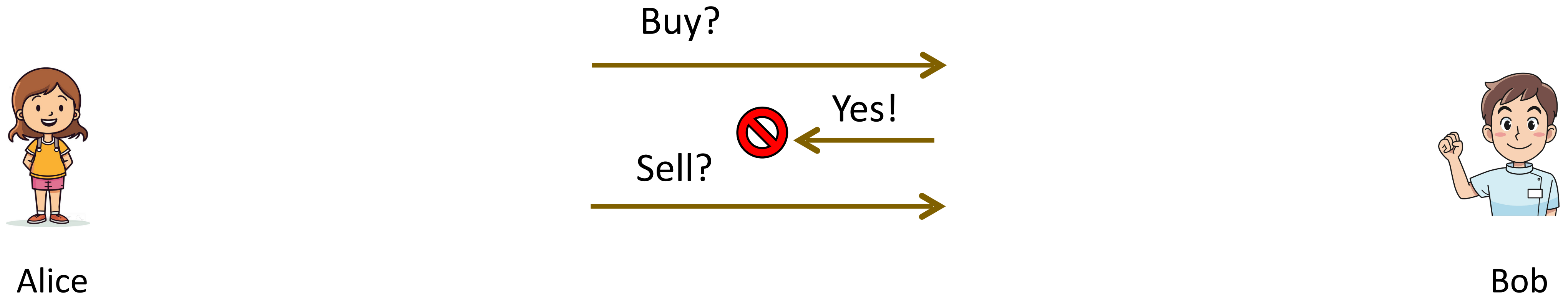

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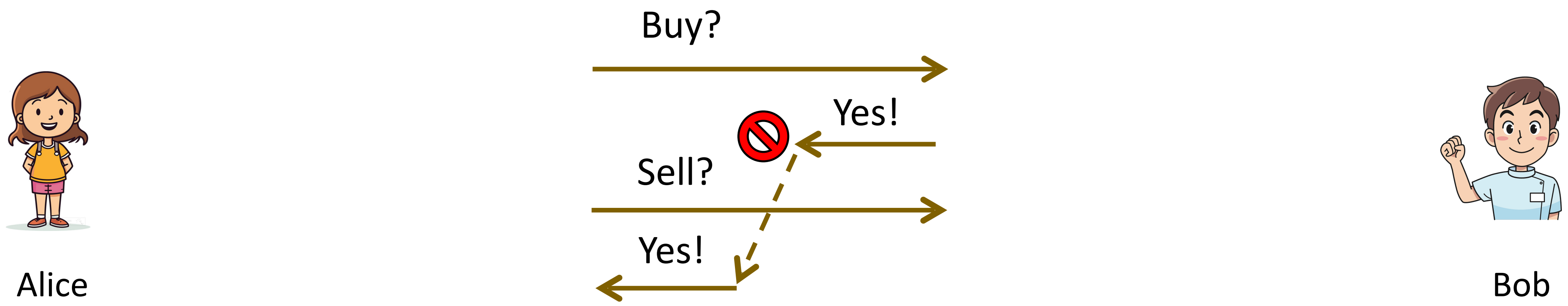

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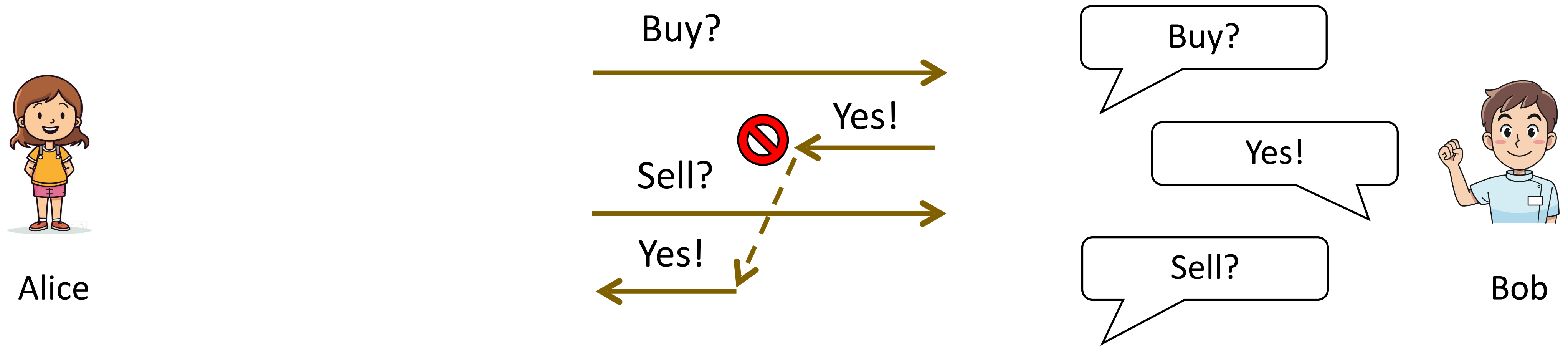

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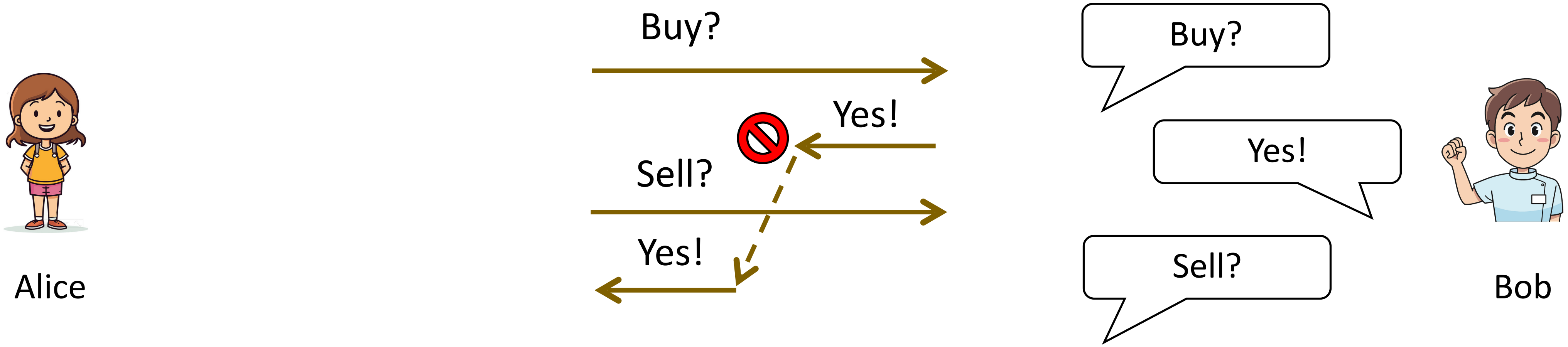

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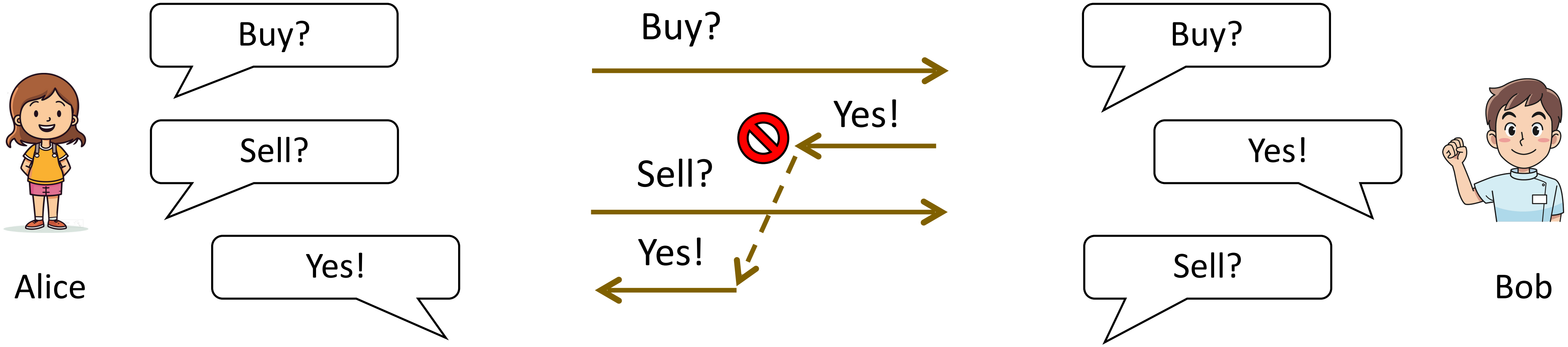

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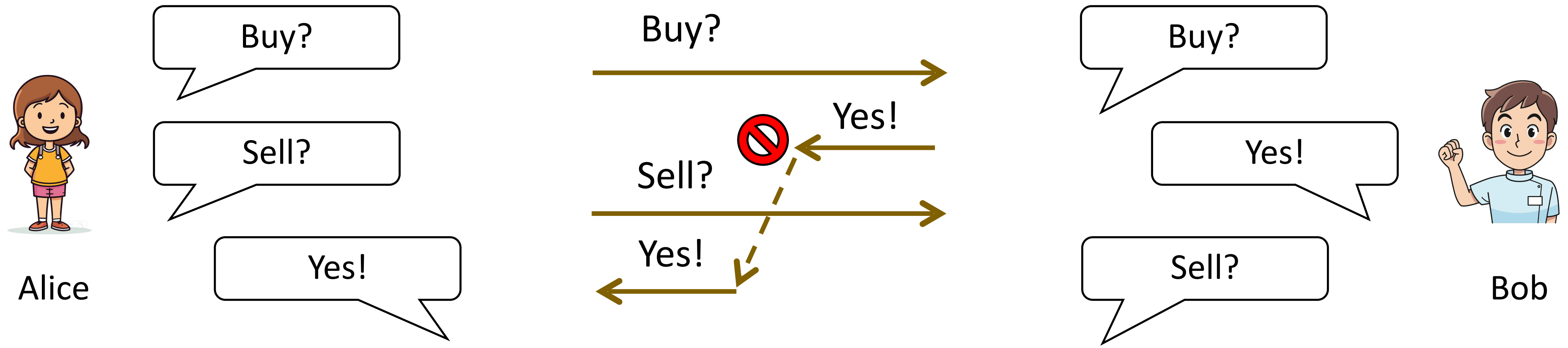

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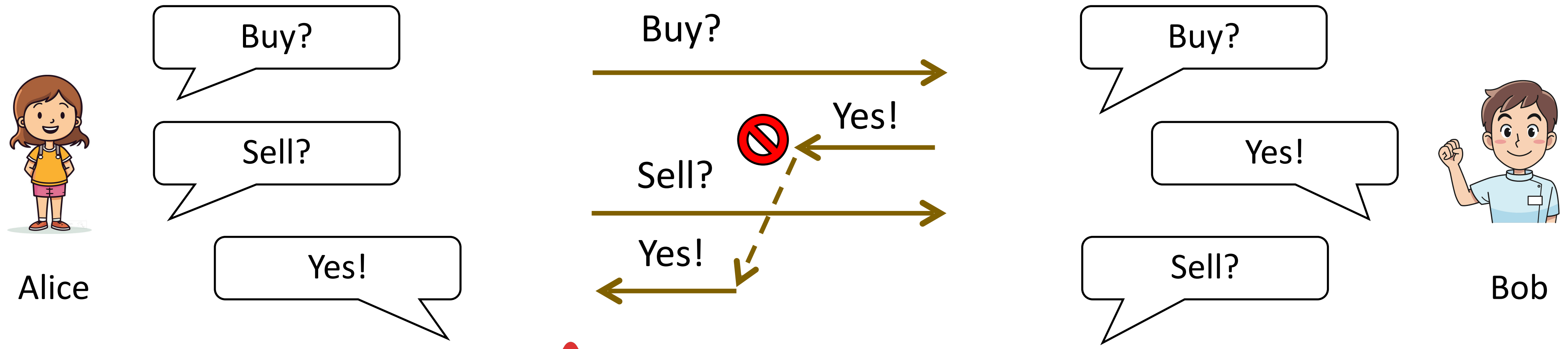

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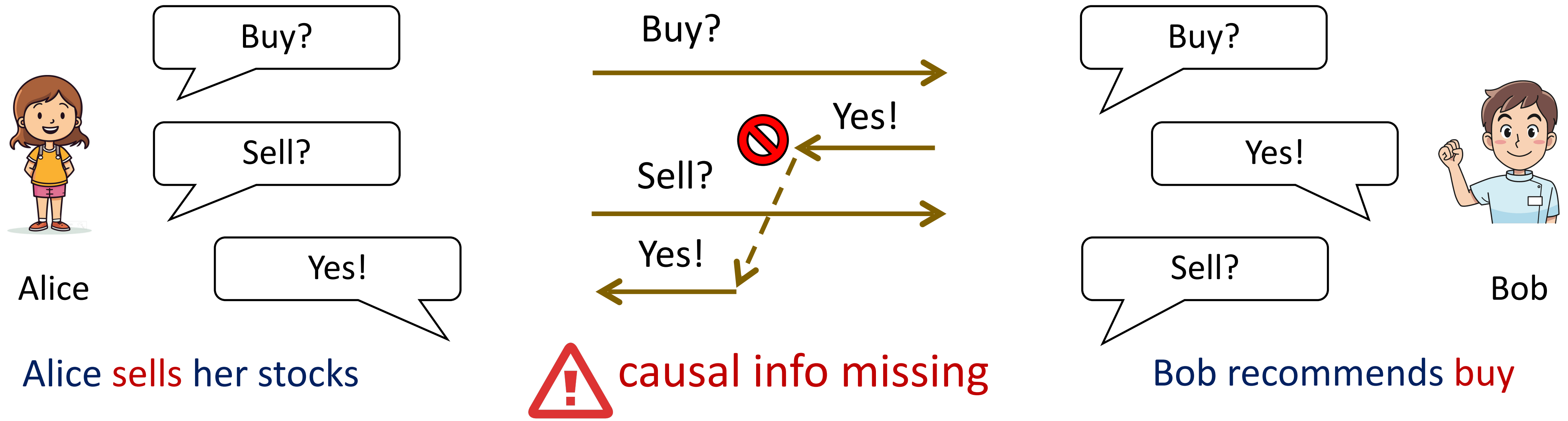

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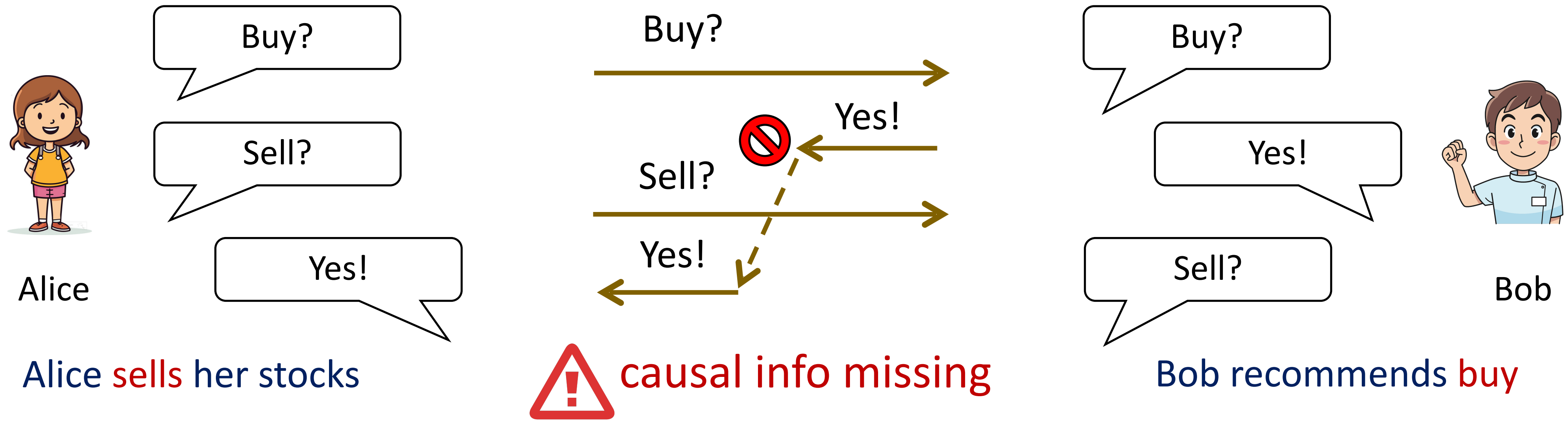

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- What leads to confusion? Exact causal relations of real communication is missing.
  - E.g., Alice does not know “Yes!” is a response to “Buy?”.

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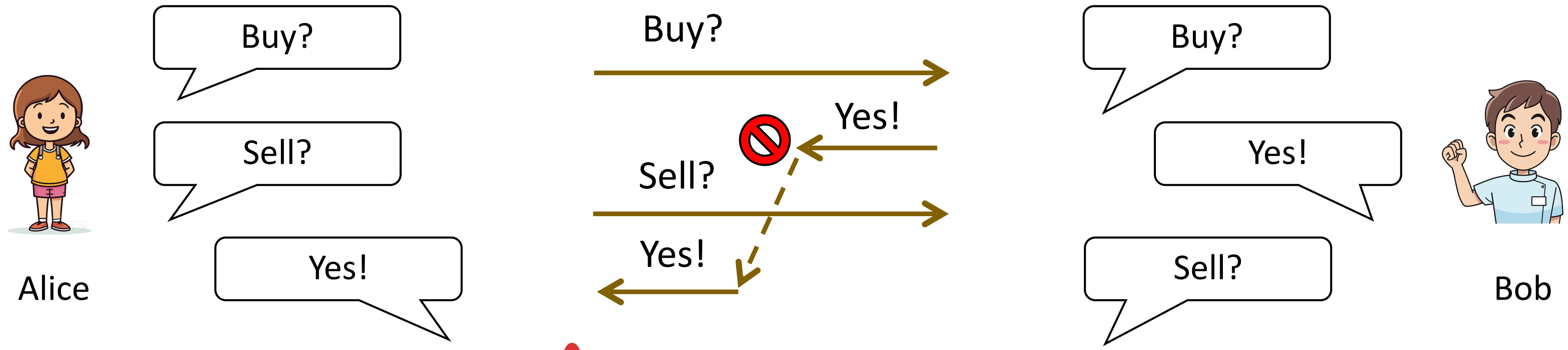

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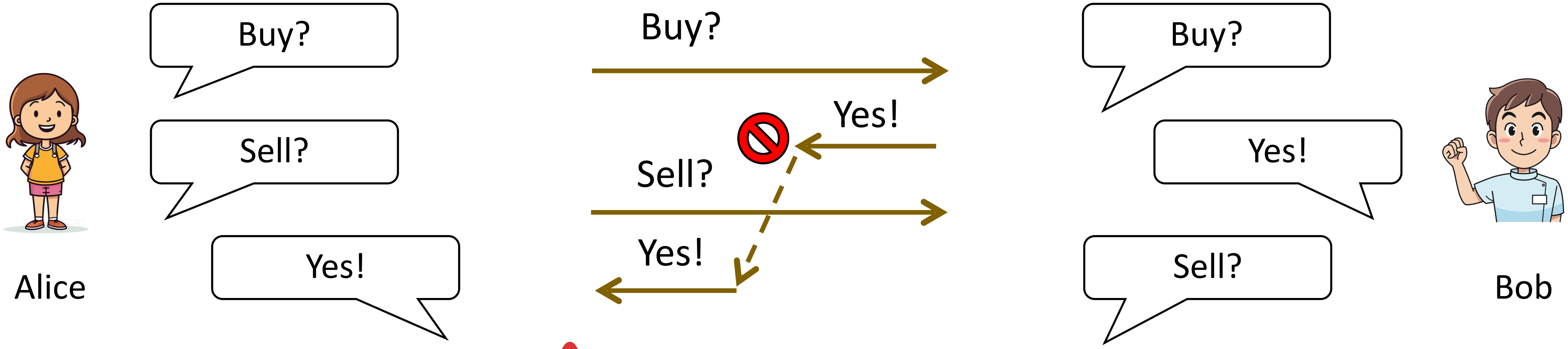

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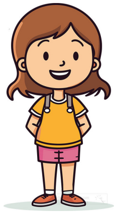
Secure Abuse Reporting: Causality



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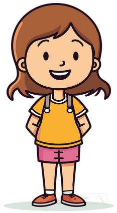
What was the worst insult you have ever heard?



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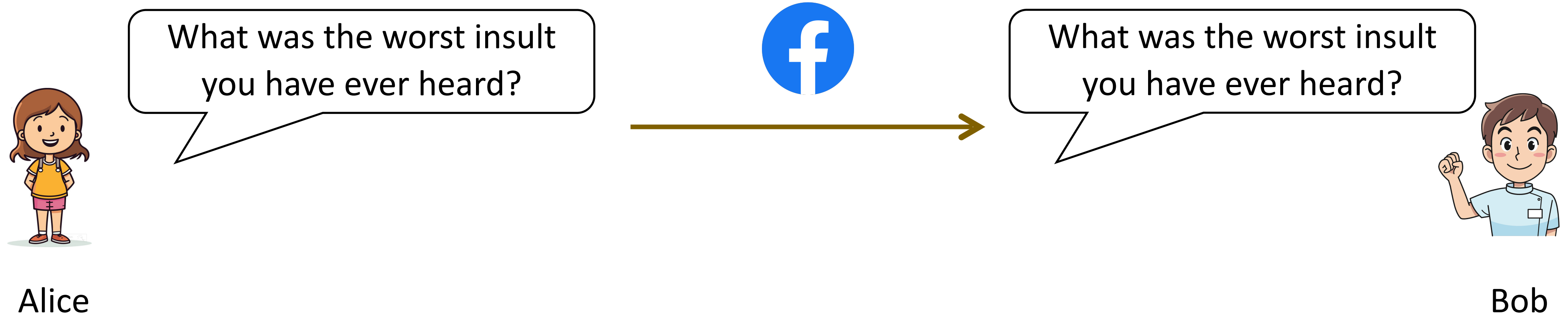

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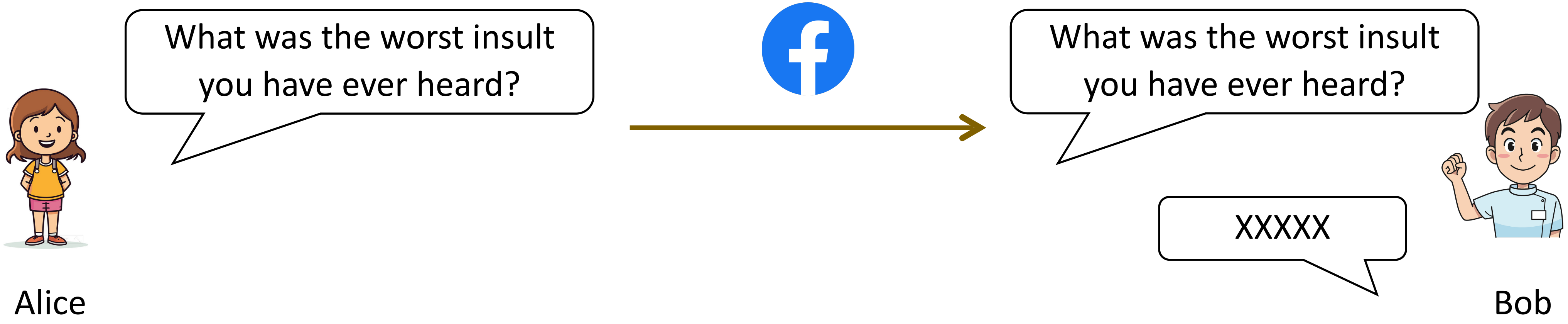

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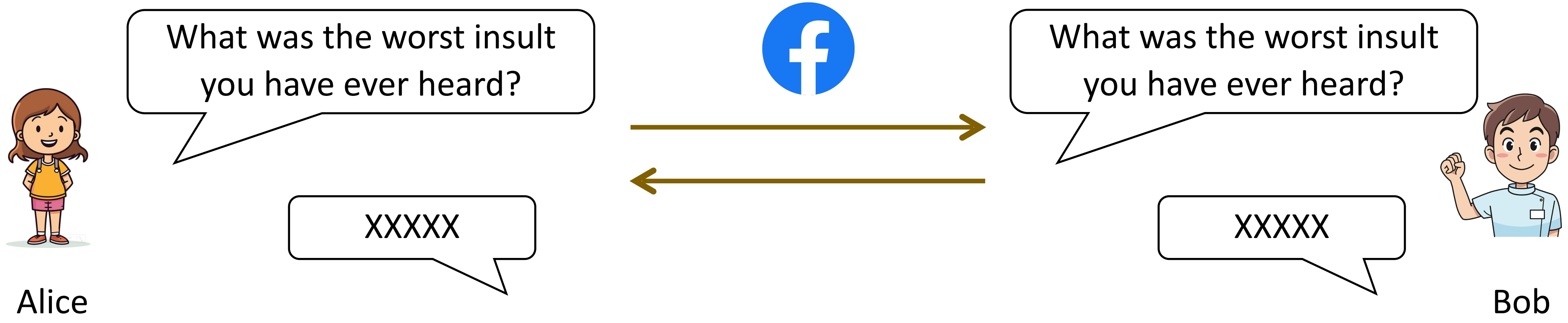

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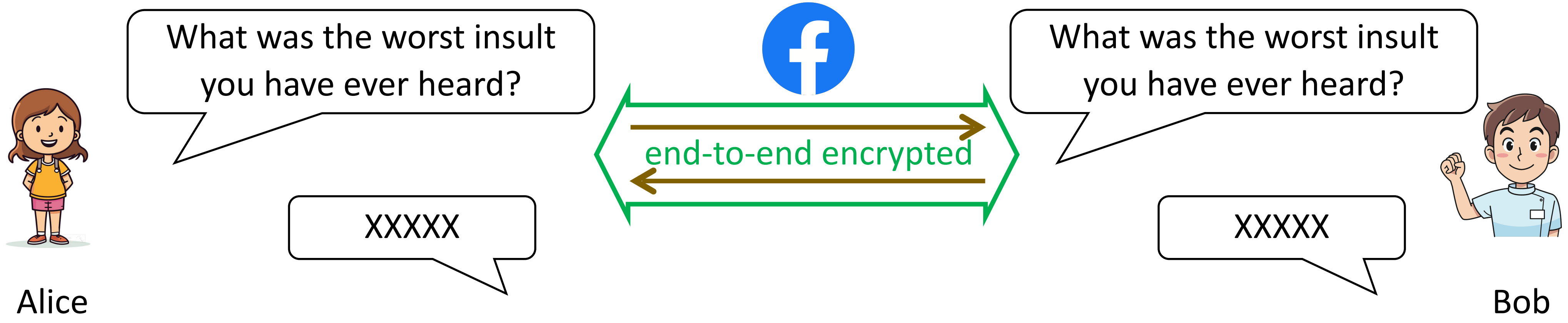

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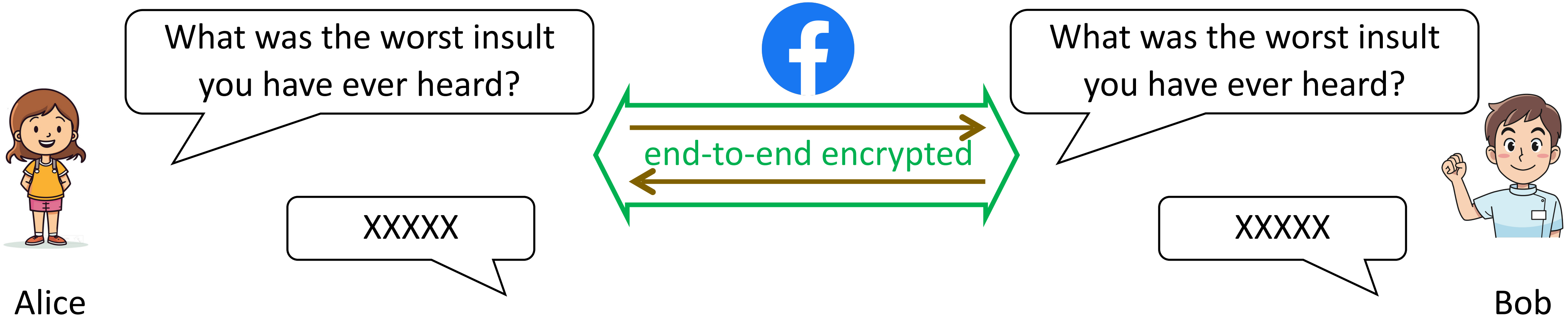

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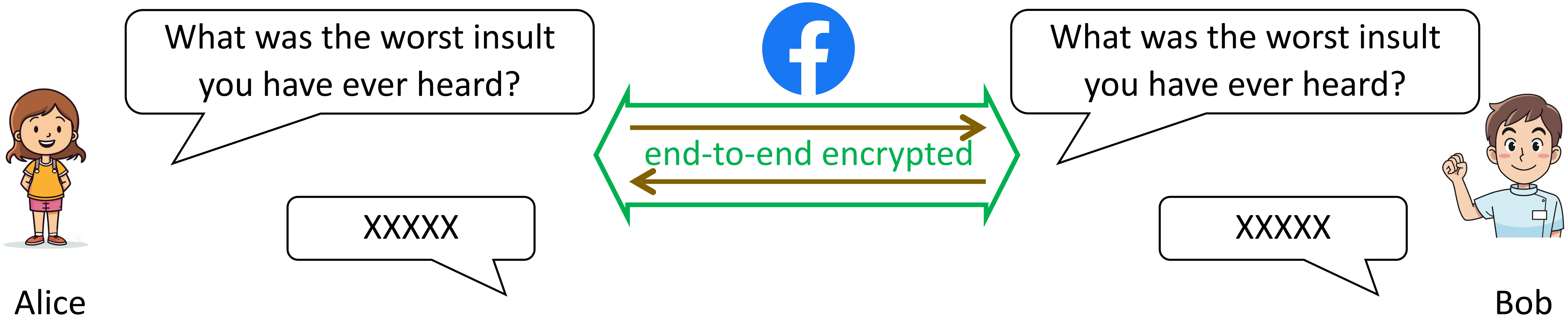

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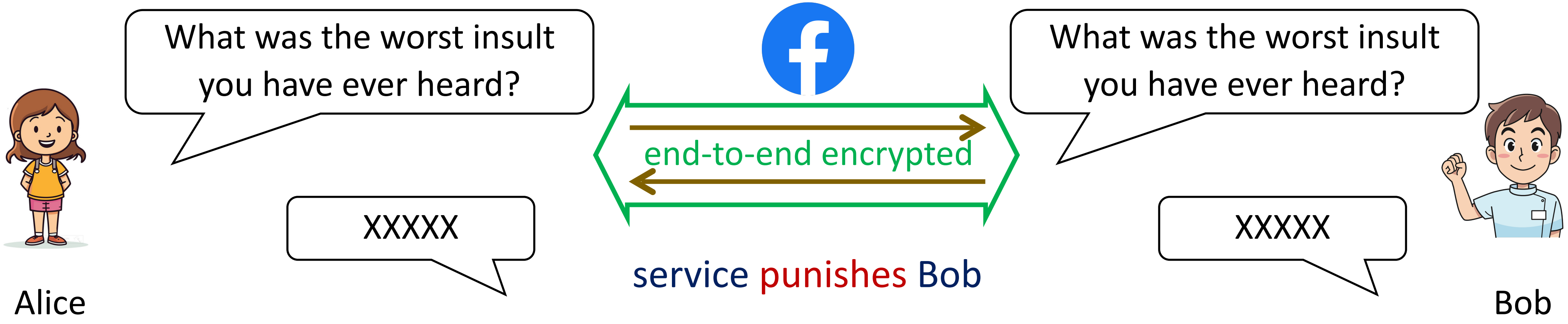

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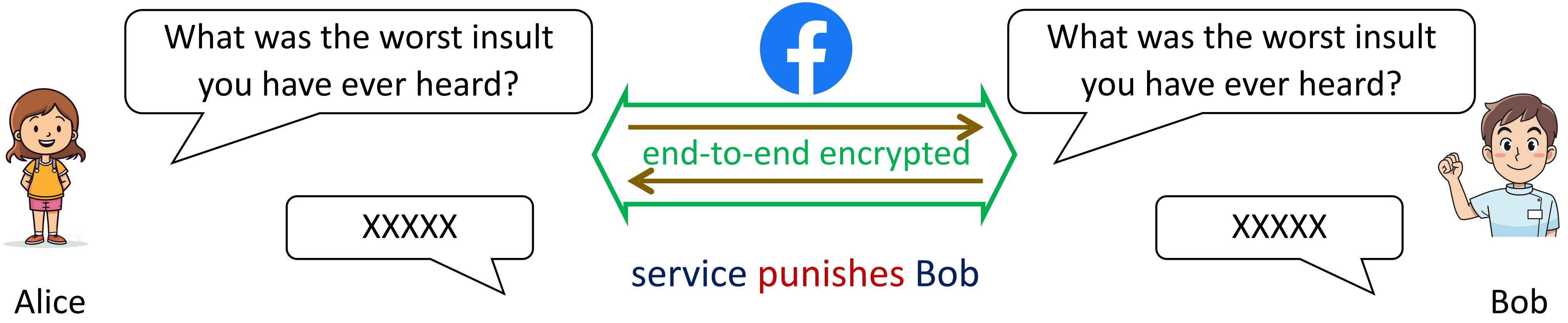

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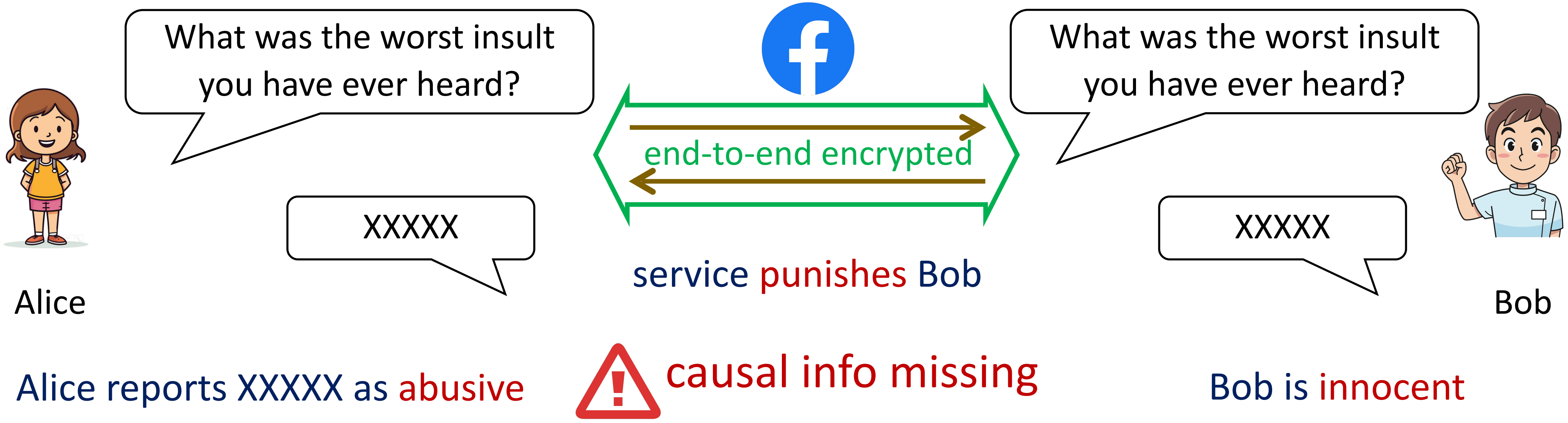

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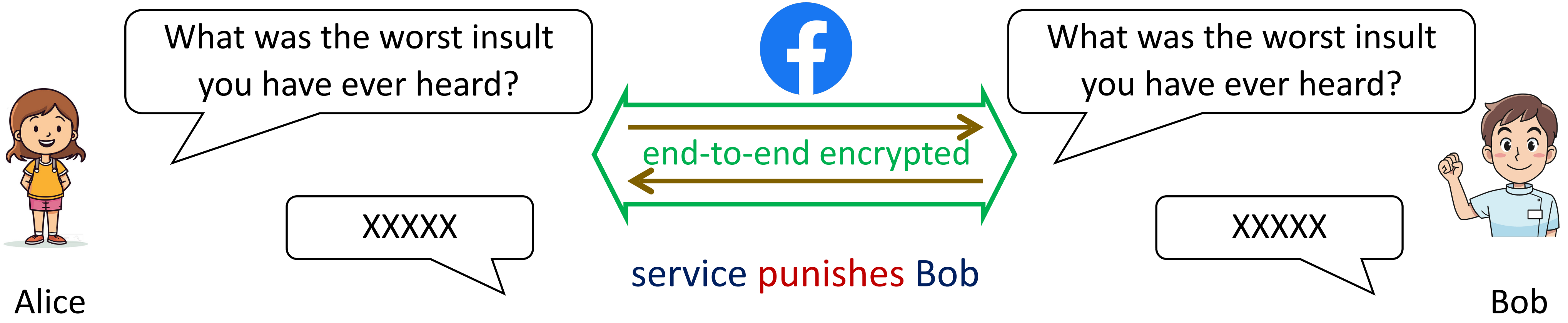

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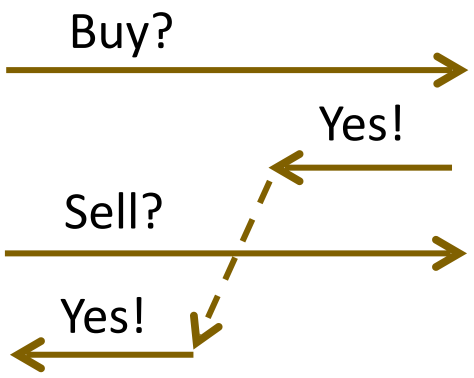
This talk will focus on causality in **secure messaging** due to time limit…

Causality Model

Causality Model: Causality Graphs

- We define **causality graphs** to model global causal info of real communication:

real communication



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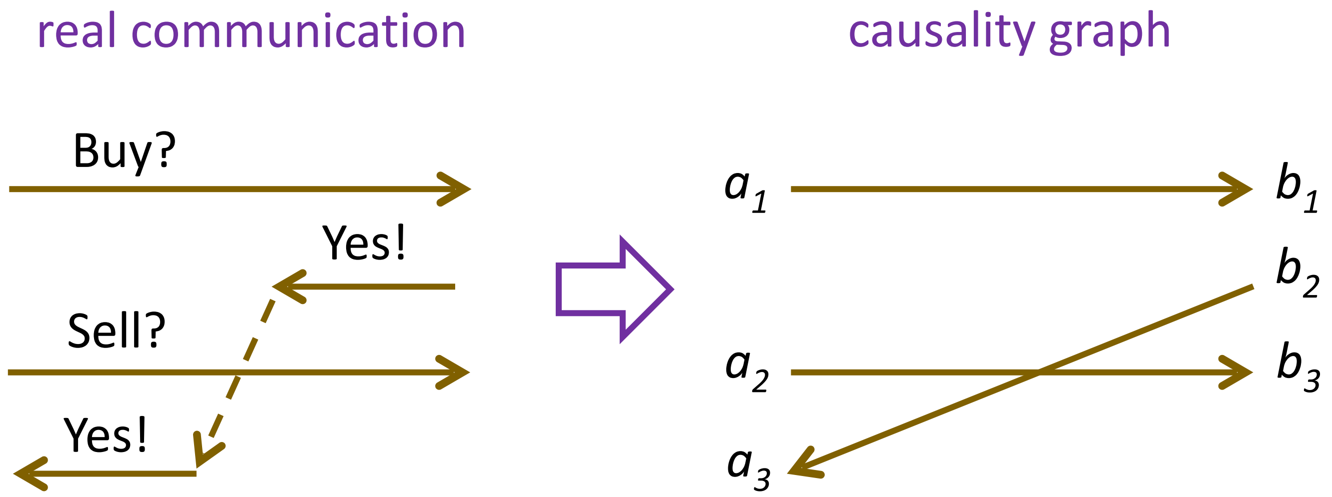

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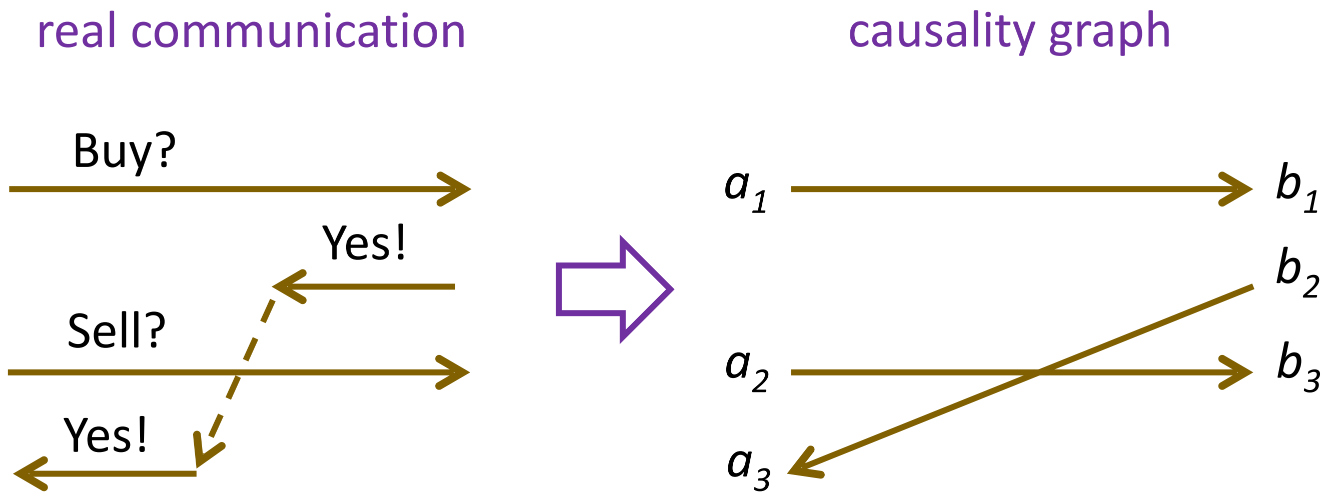

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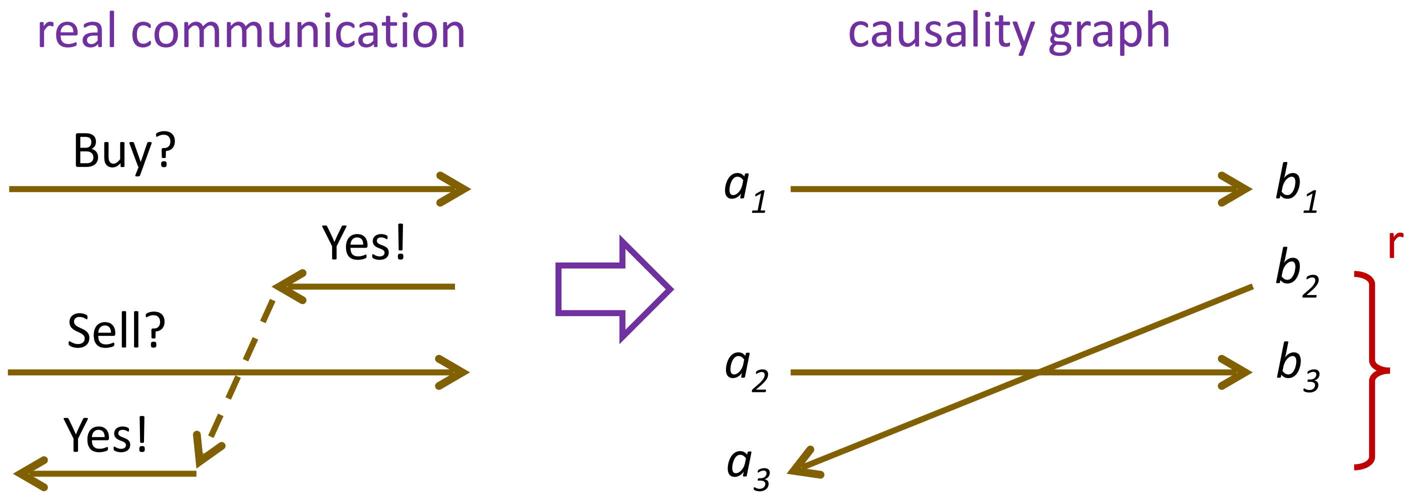

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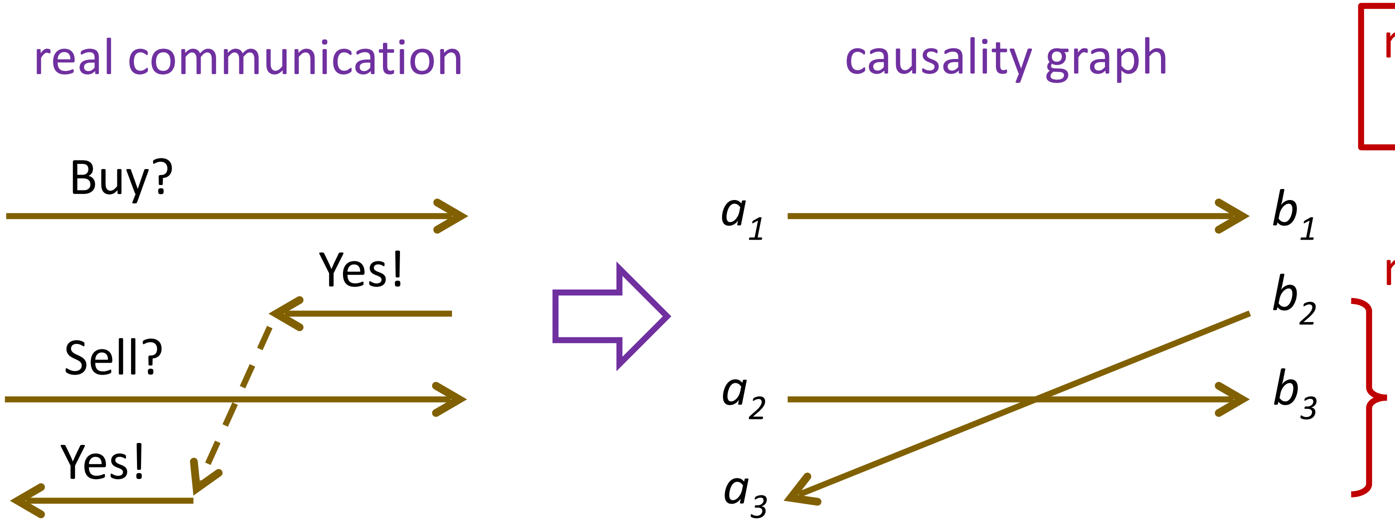

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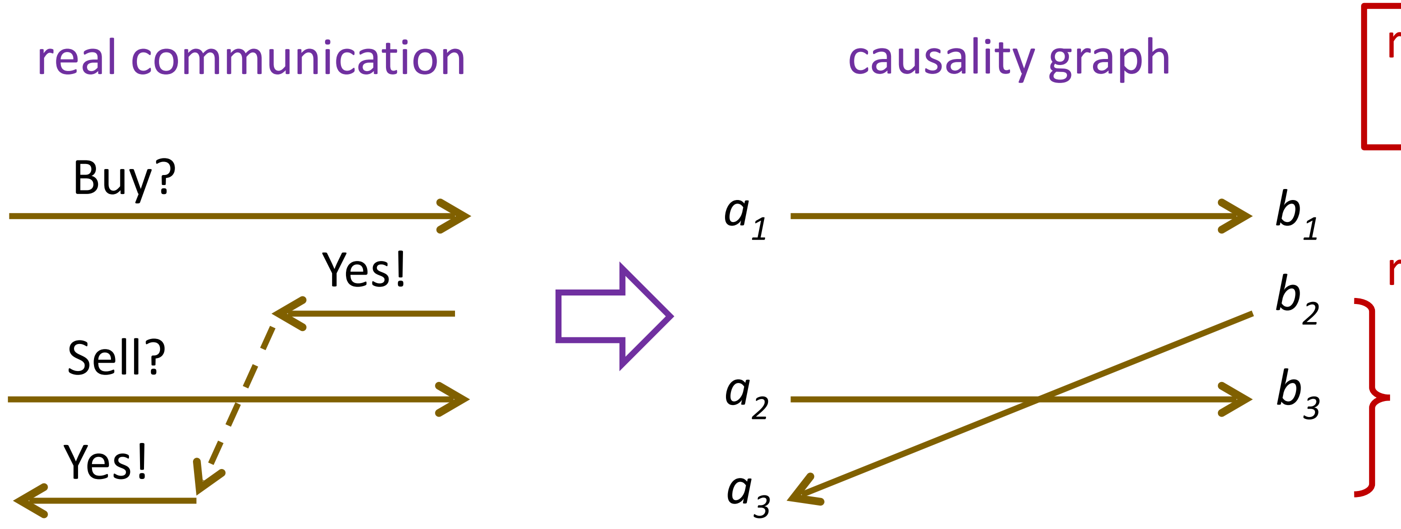

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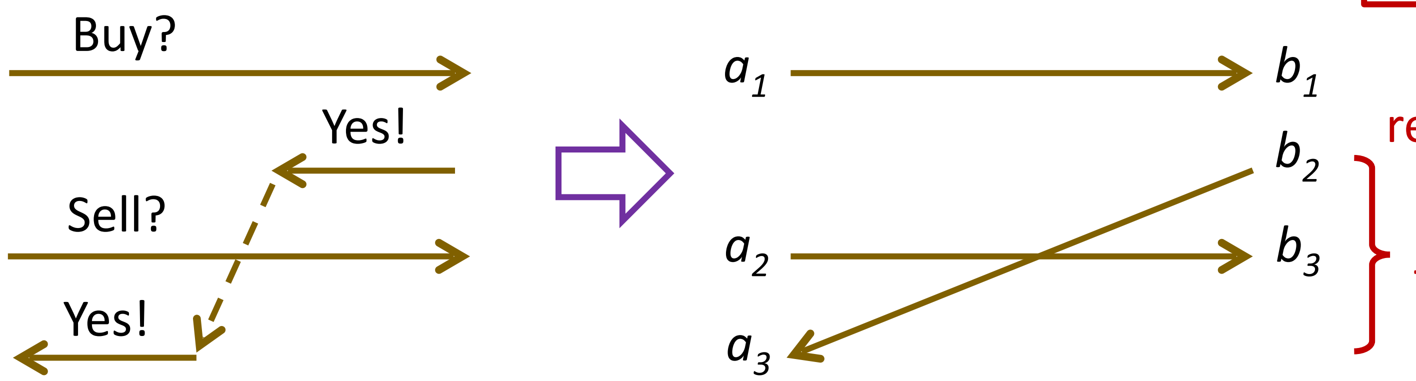

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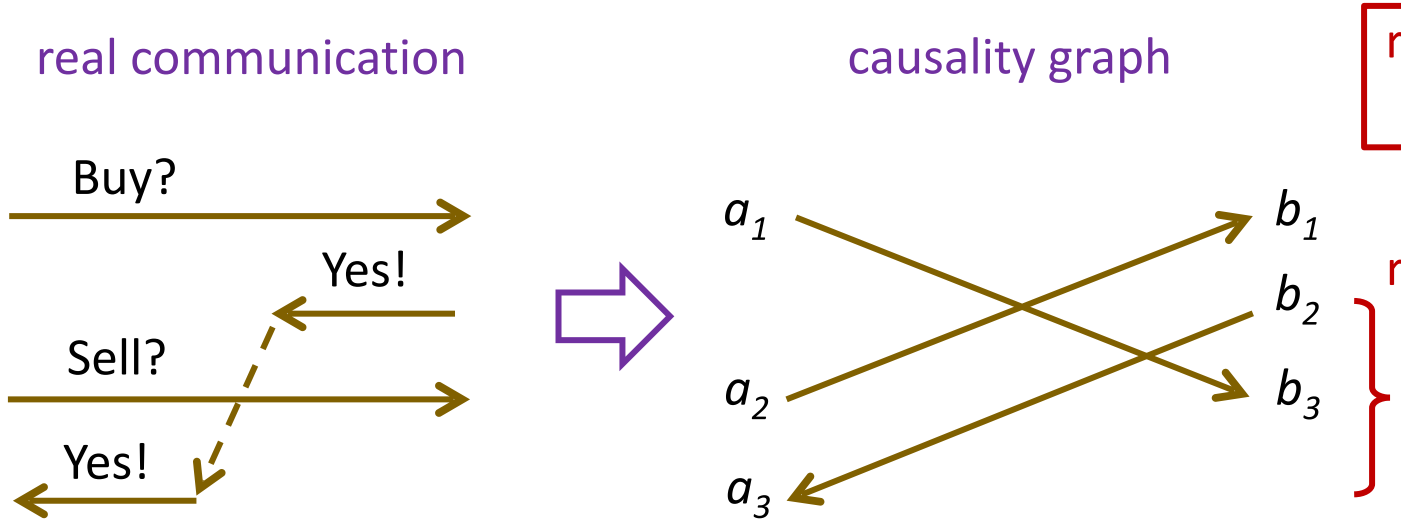

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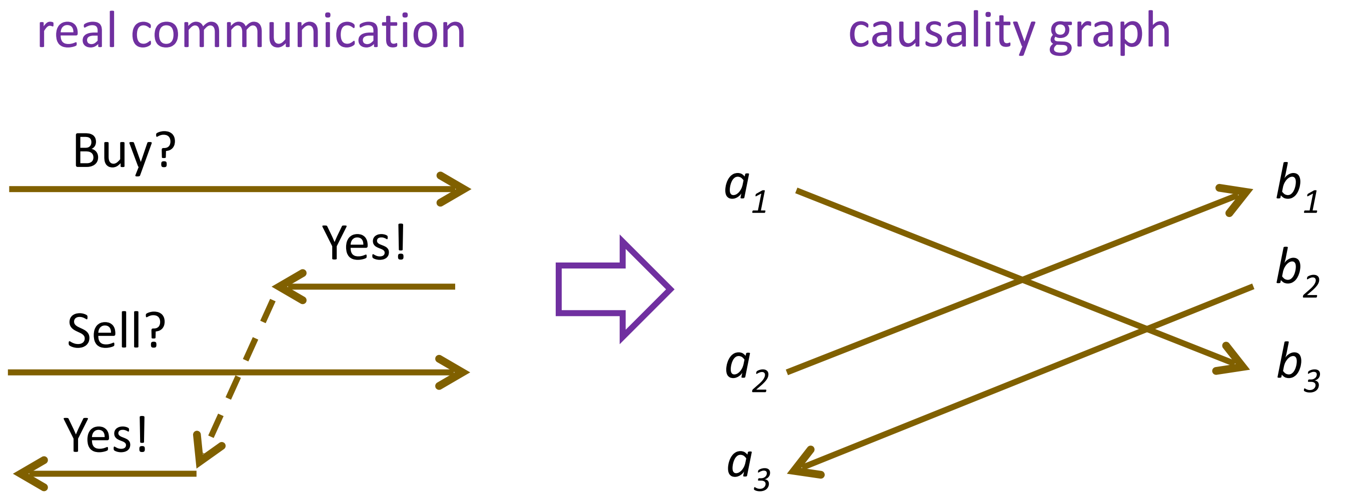

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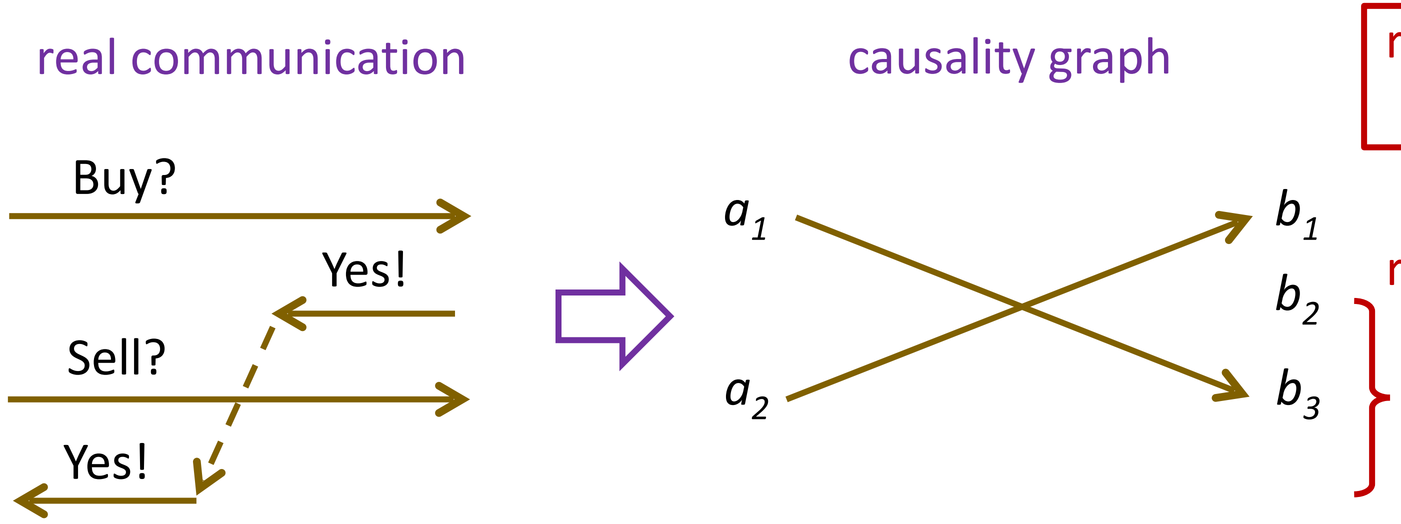

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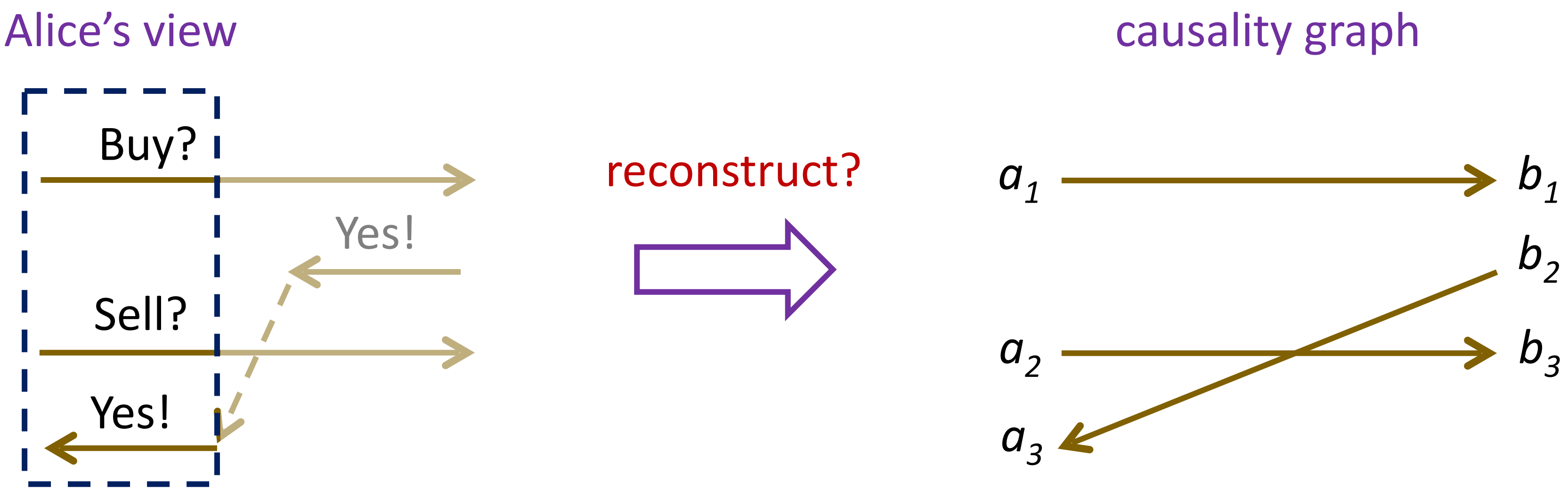

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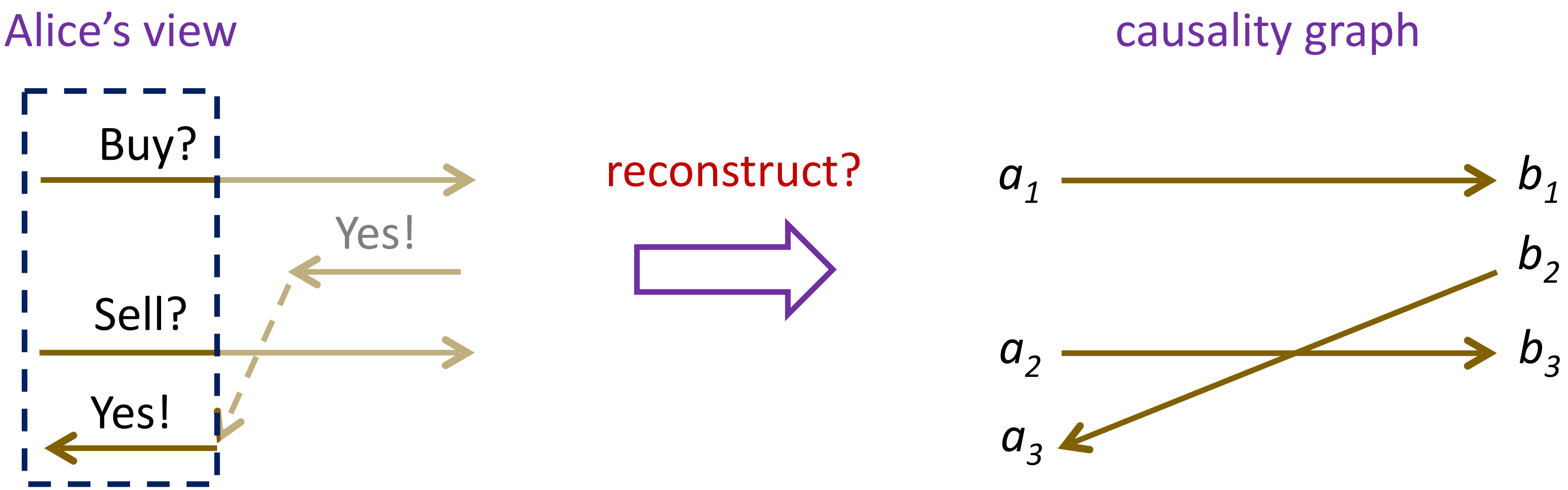

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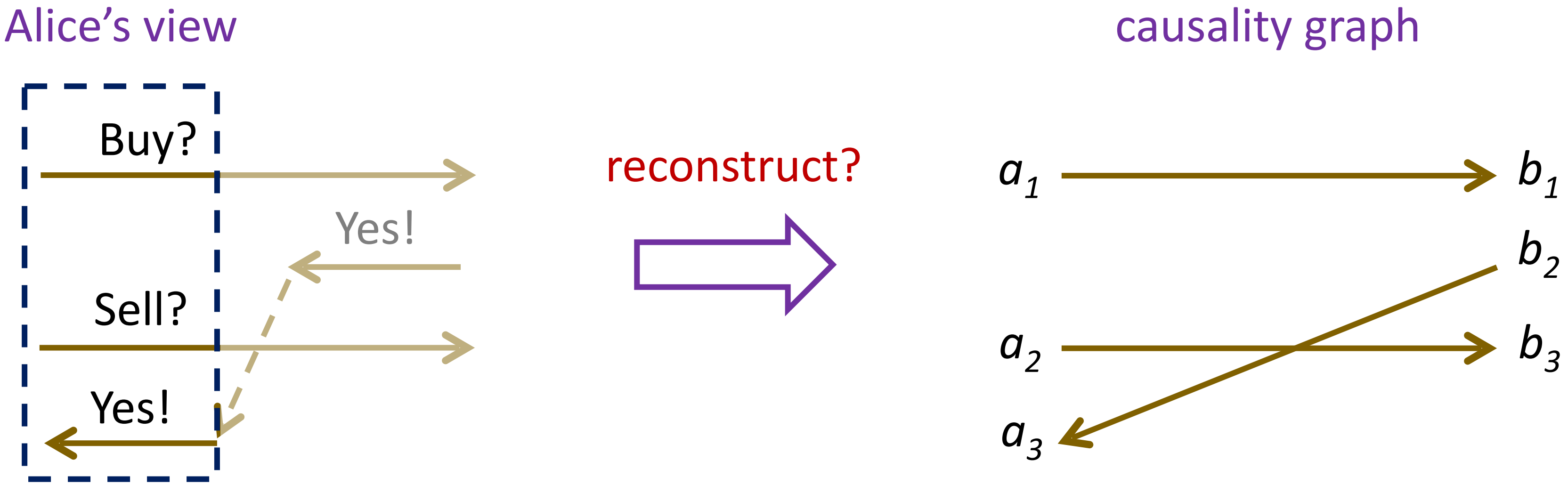
- **Strong Causality Preservation (SCP): CP + post-compromise security (PCS)**
  - **PCS** is important for secure messaging: can recover security after long-term key is corrupted



Alice's view

Buy?

Yes!

Sell?

Yes!

reconstruct?

causality graph

a_1

b_1

b_2

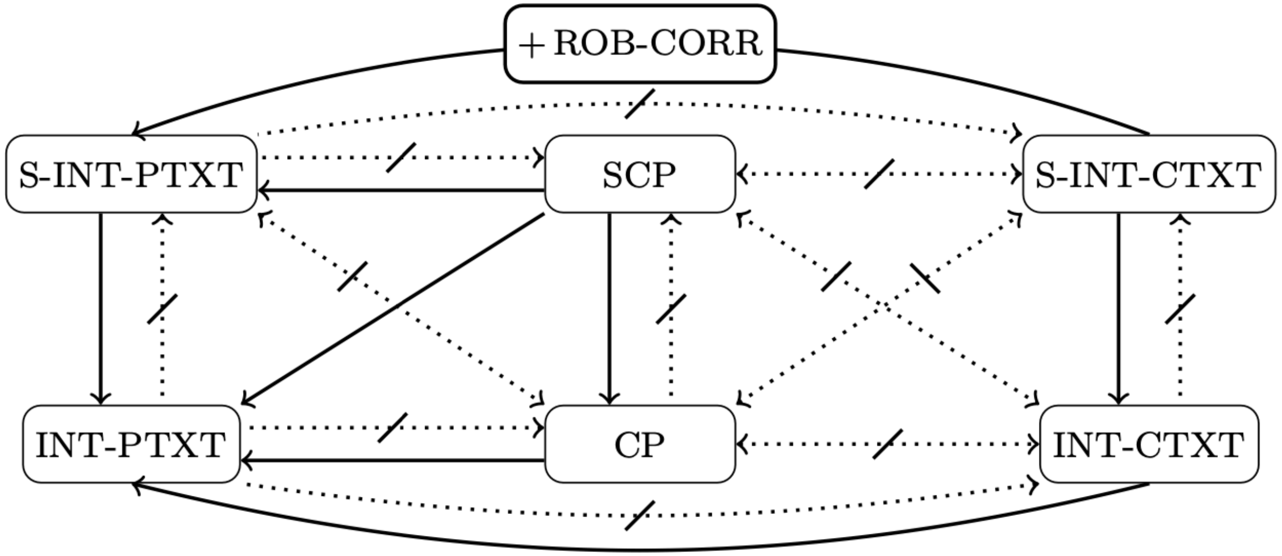
a_2

b_3

a_3

Causality Model: Security Definitions

- Relations to integrity notions (leading “S-” refers to post-compromise security):



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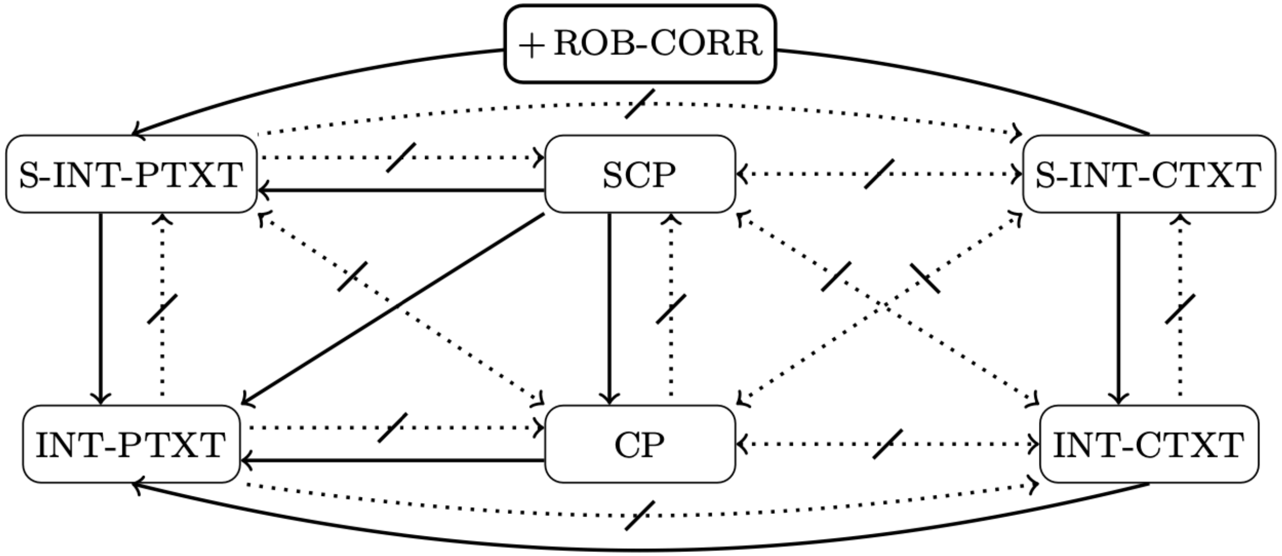
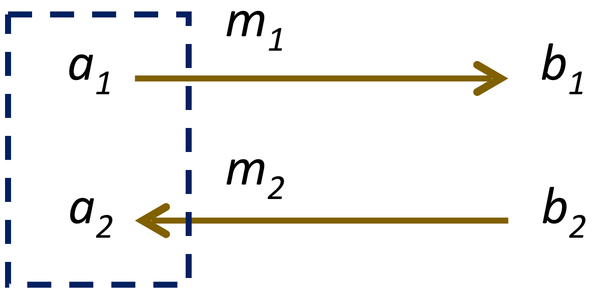


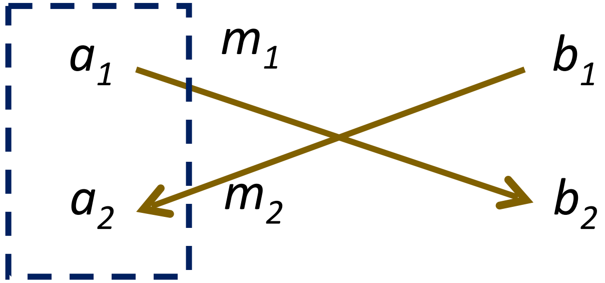
- We have complete separation results between causality notions **(S)CP** and ciphertext integrity notions **(S-)INT-CTXT** as expected.

Analysis of Real-World Protocols

Causality Preservation of TLS 1.3

- TLS 1.3 does not preserve causality:
  - E.g., left user's view is identical in both cases, so cannot reconstruct the correct causal info





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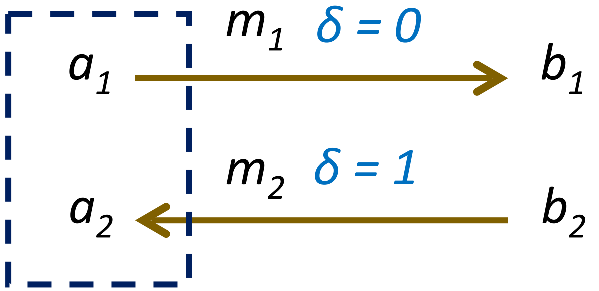

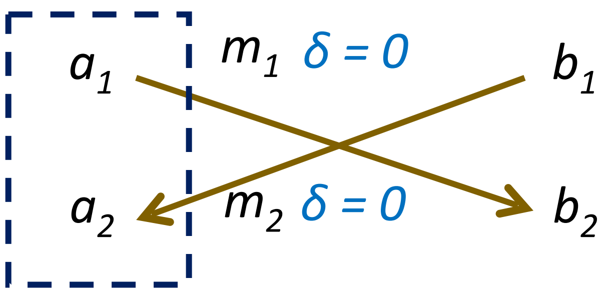

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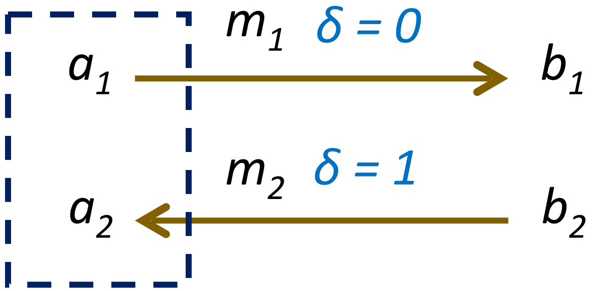

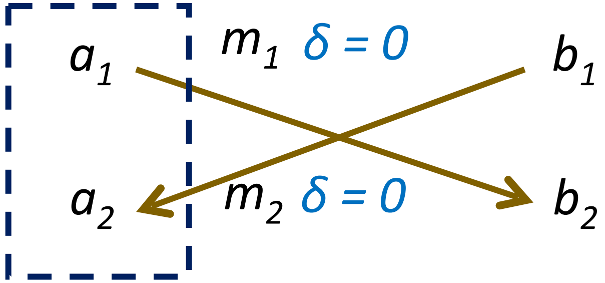

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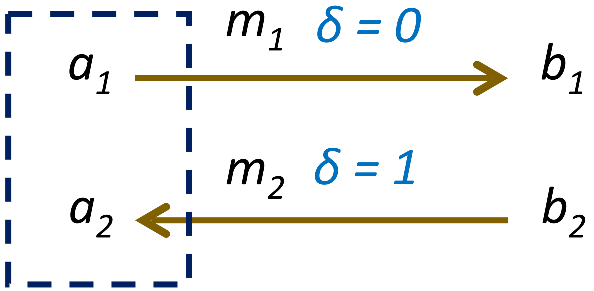

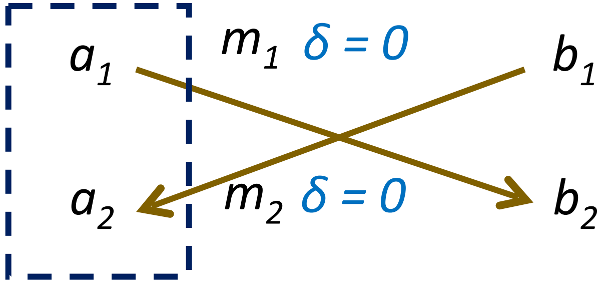

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- We formally prove that this fixed so-called causal TLS 1.3 channel is **CP-secure**.
  - Very simple fix, interesting to find practical use cases for causal TLS 1.3 channel.

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- Our fix is generic: can apply to any secure-messaging channel to gain SCP security.
  - Assume underlying channel achieves ciphertext integrity with post-compromise security.

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    - Define causality model with desired security for secure messaging (as bidirectional channel).
    - Propose provable secure fix to add causality to TLS 1.3 and Signal.
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  - Lower bound on the overhead for messaging channels to preserve causality.
  - Extend causality preservation to secure group messaging.

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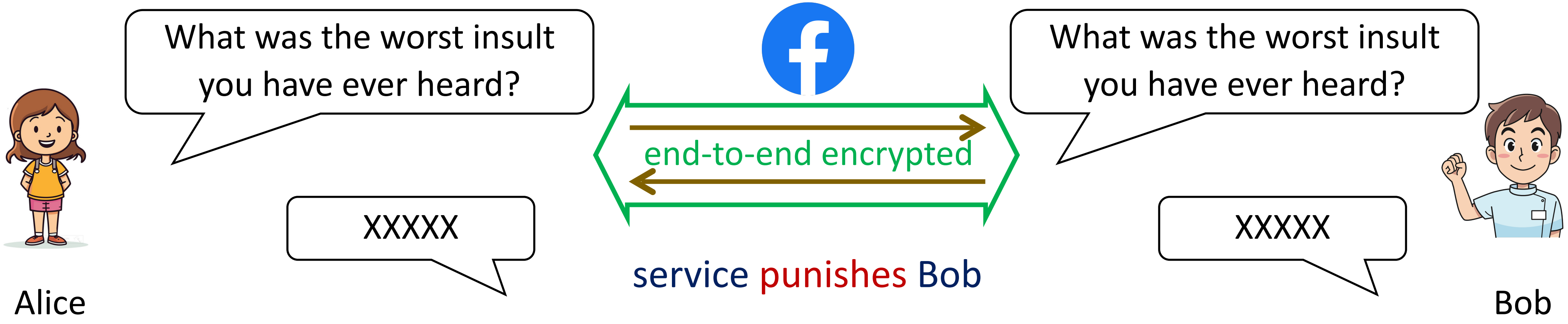
- Thanks! Questions? (Our paper: https://eprint.iacr.org/2024/362)

Additional Slides on Message Franking

Recall: Causality in Message Franking



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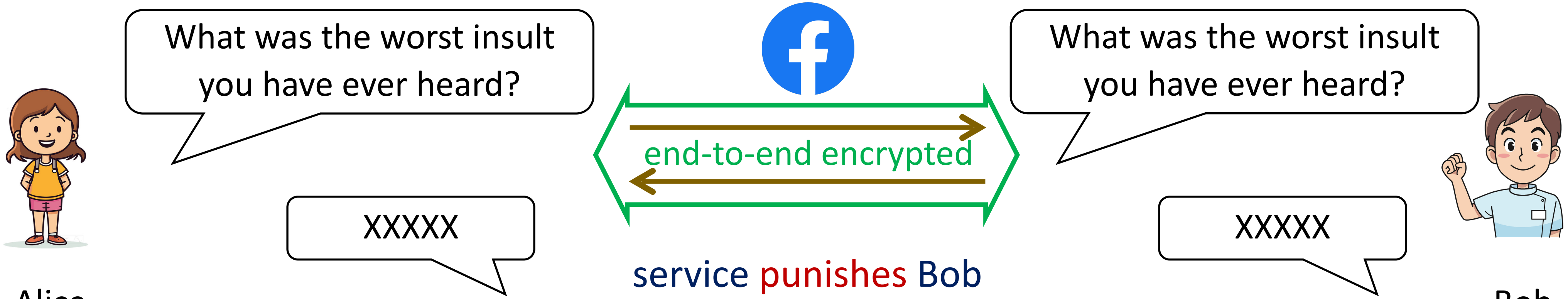

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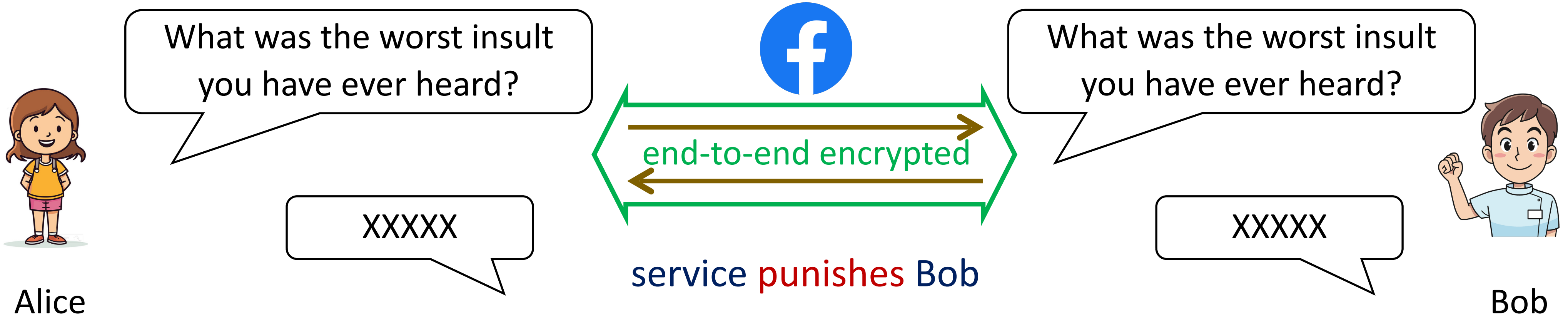
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- Would be nice if the messaging channel can provide missing causal info to server.
- Message-franking channel = secure-messaging channel + abuse reporting scheme
- Causality security guarantees for message franking channel is actually two-fold: one for end users in secure messaging and one for server in abuse reporting.

Causality Model: Security Definitions

- **Channel Causality Preservation (CCP)** for underlying secure-messaging channel:
  - **CP** and **SCP** same as before but extended to the syntax of message-franking channels.

malicious server against honest users

- **Report Causality Preservation (RCP)** for message franking (abuse reporting):
  - **RCP-S:** malicious sender cannot make the other user accept unreportable messages
  - **RCP-R:** malicious reporter (receiver) cannot report a message never sent by the other user
    + malicious reporter cannot report message with incorrect or insufficient causal info

malicious users against honest server

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- With our causality fix, abuse-reporting server can handle disputes in context.