The Ins and Outs of Anonymous Group Communication

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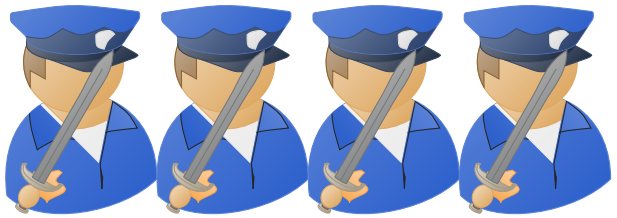
PRIVACY AND SECURITY

KASTEL

Why do we need anonymous group communication?

versus



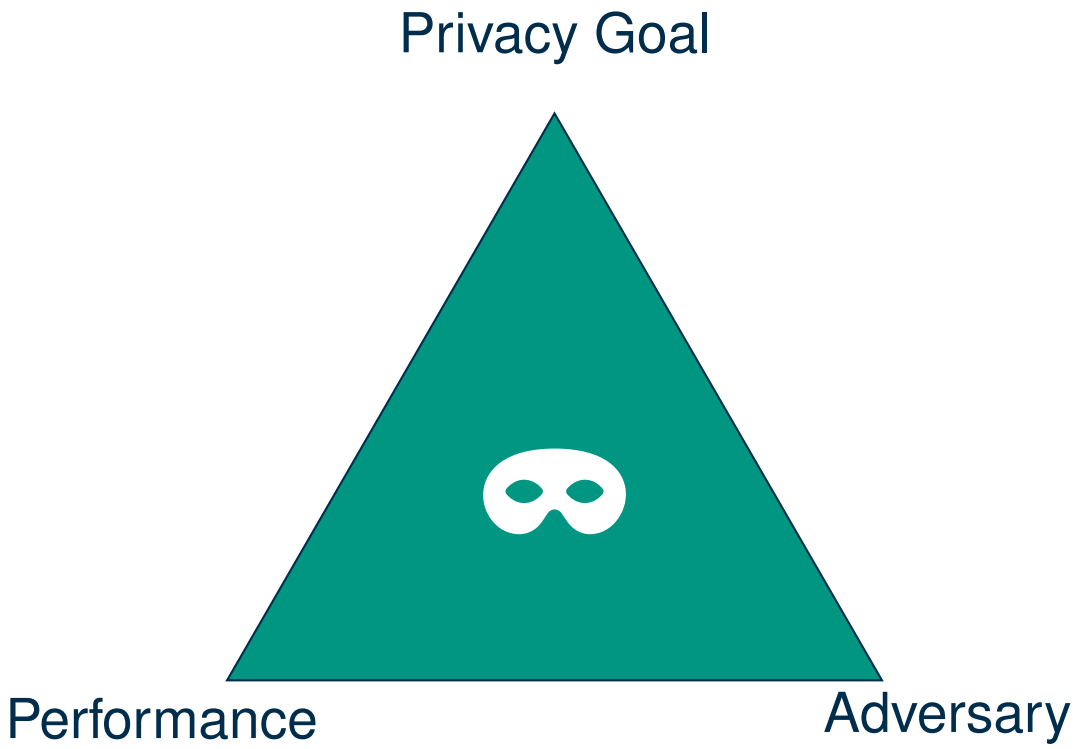
Political activists need a group chat to organize their protest

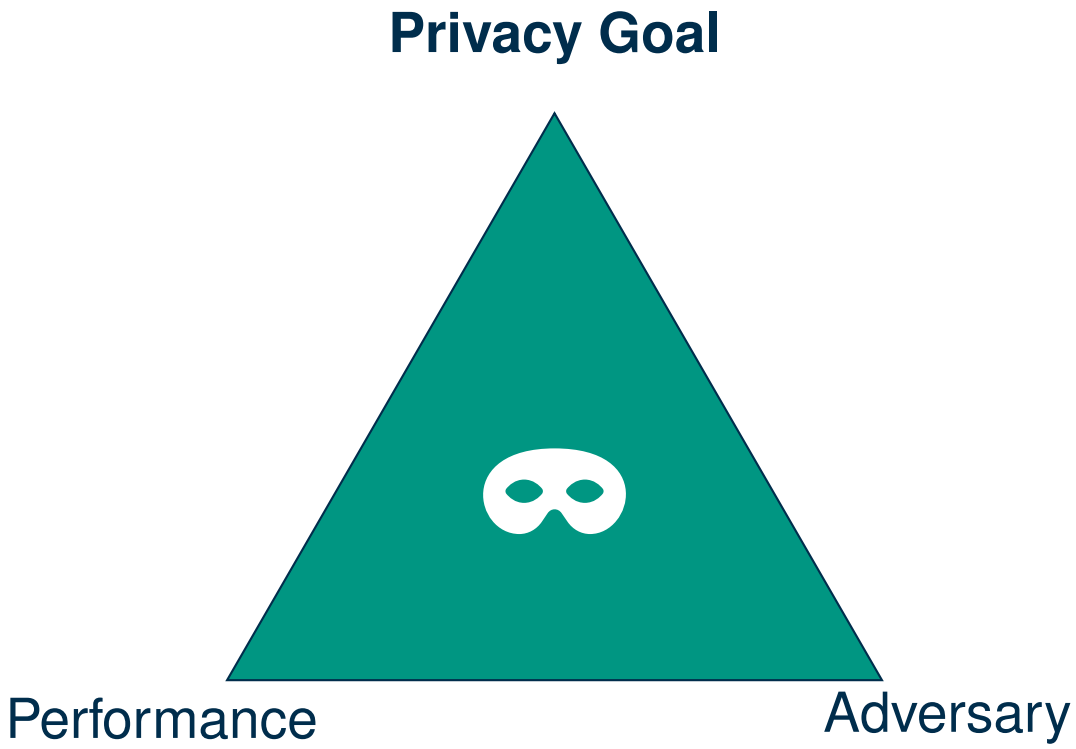
↓

Standard encrypted messengers are not sufficient, as they allow the activists to be linked based on metadata

↓

Let's build an anonymous group messenger to help them ✊


Privacy Goal
Performance
Adversary


Privacy Goal
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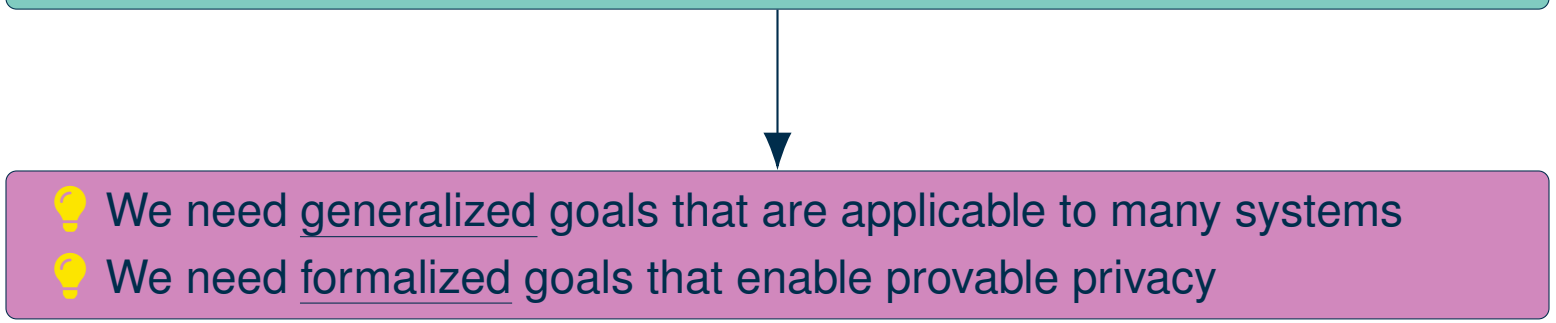
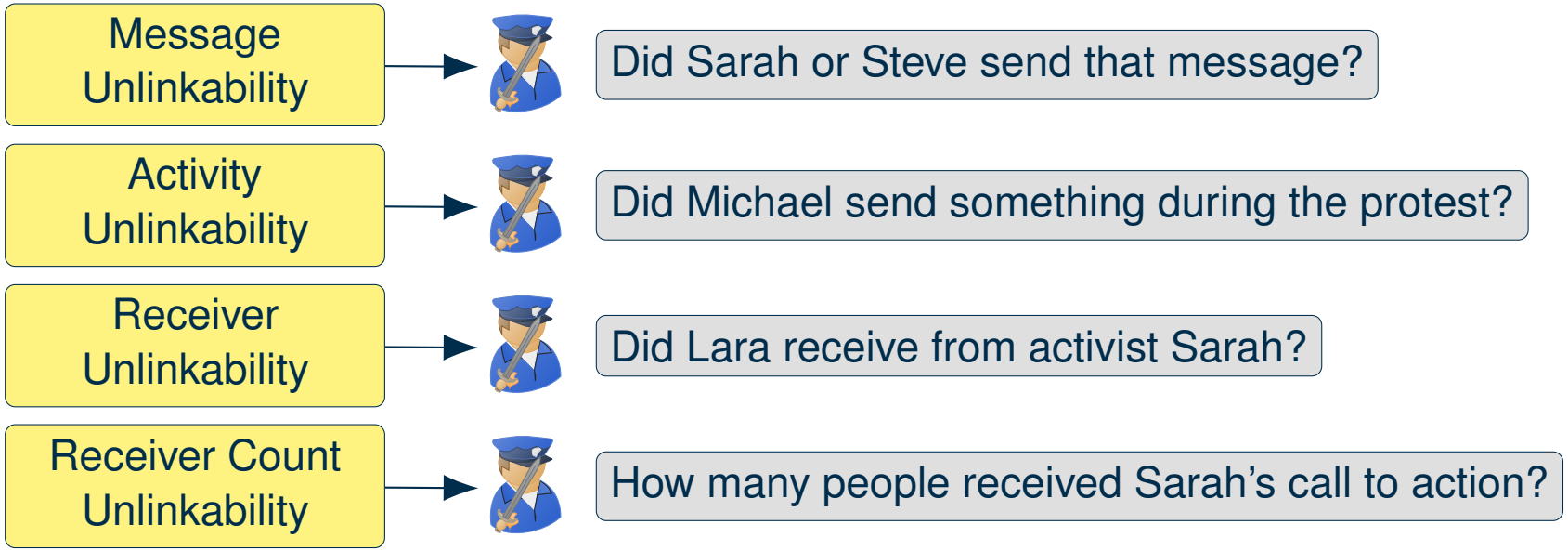
Privacy goals for anonymous communication

"Anonymity" is not unambiguously defined: Protocols can aim to protect different categories of metadata.

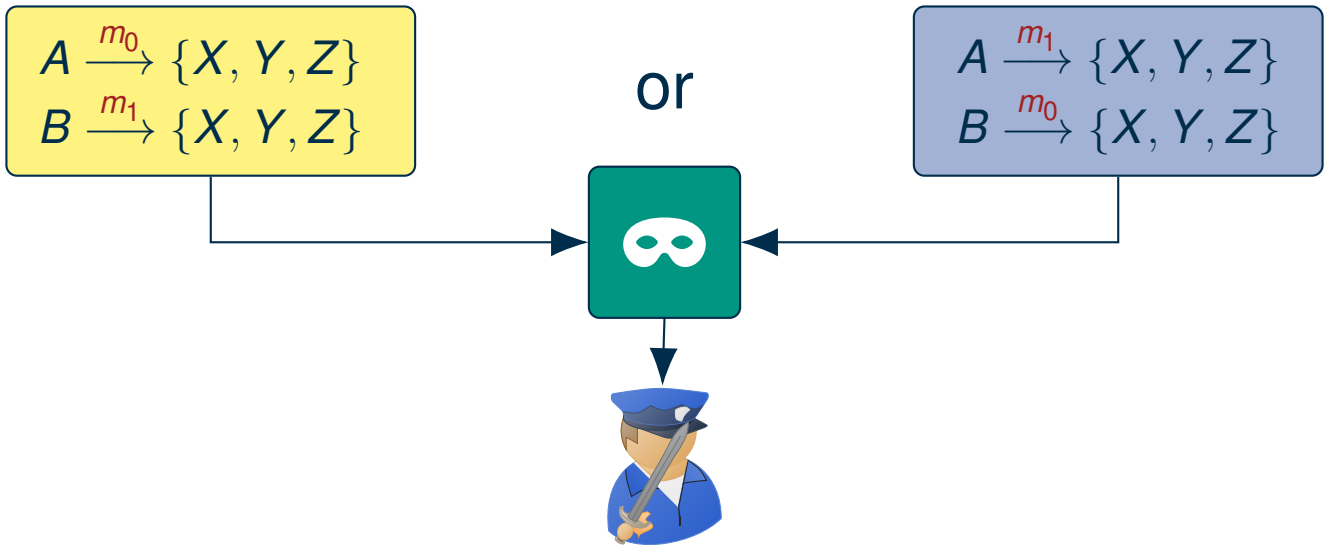


Generalized privacy goals for anonymous group communication

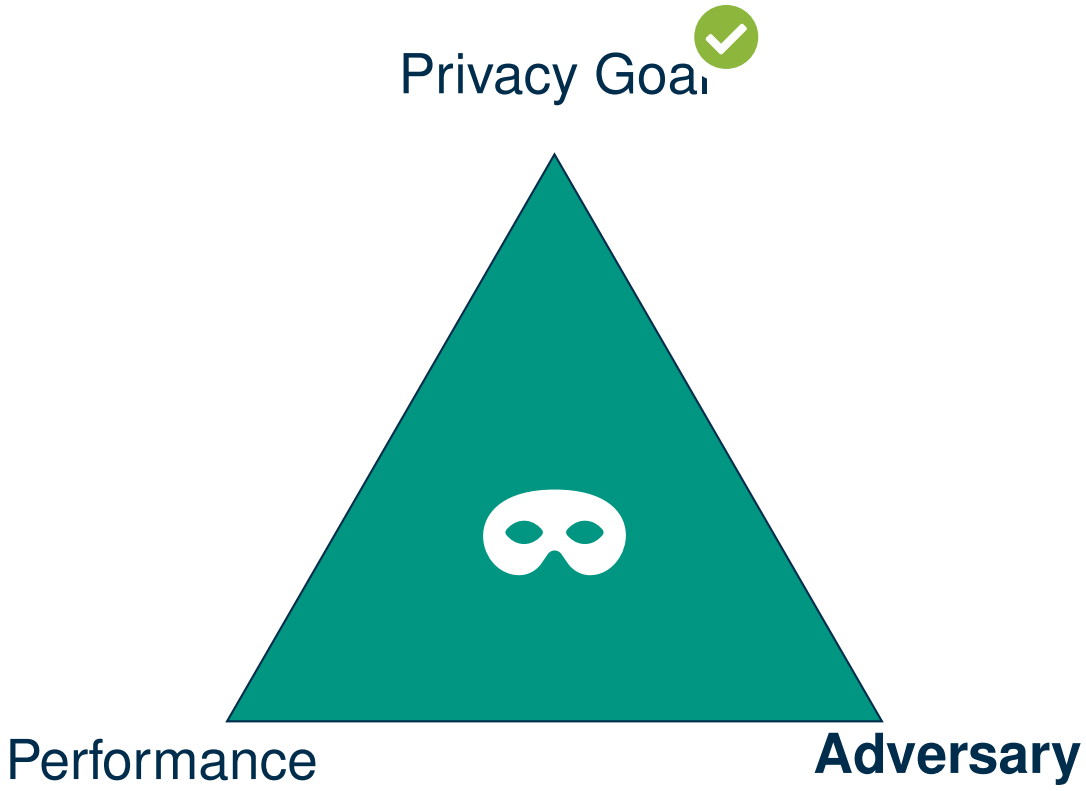
Most goals in literature can be approximated by the following four:



Formal privacy goals through an indistinguishability game



- **Goal:** Distinguish between two communication patterns (■ and ■) based on protocol output
- Patterns may only differ in the metadata that the goal aims to protect.
- Here: Who sends which message (Message Unlinkability)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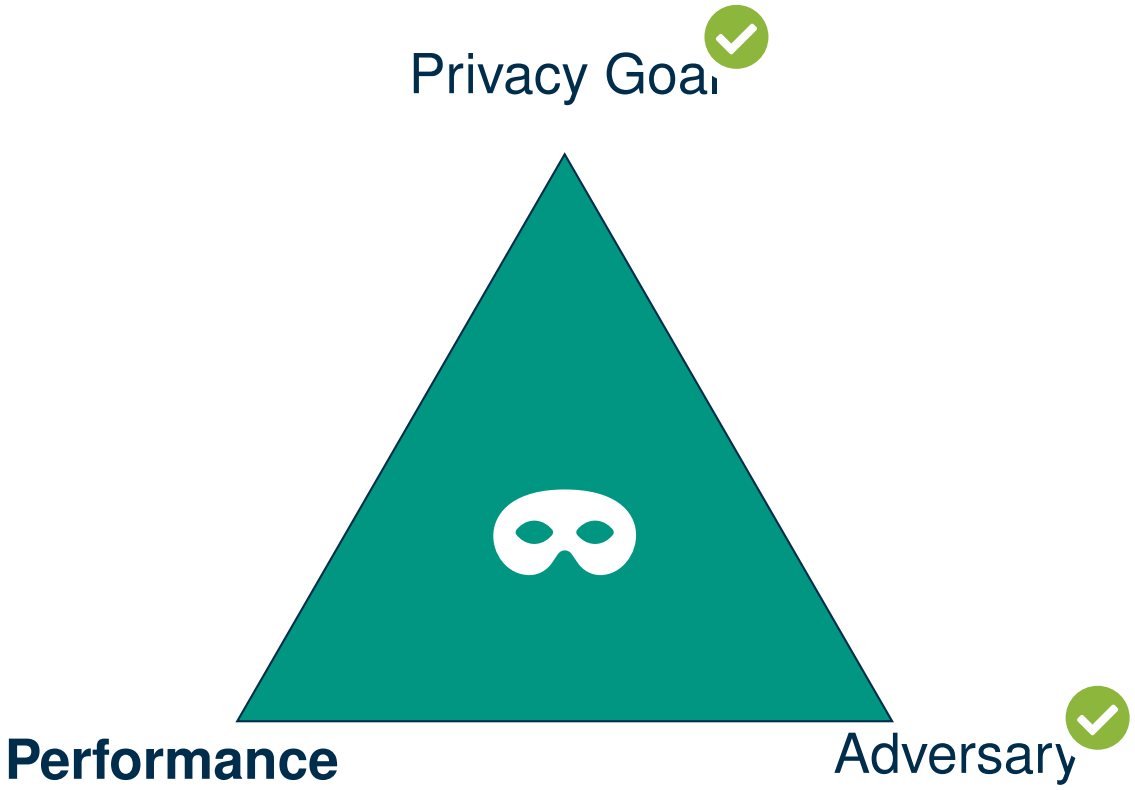
Adversaries

- Depending on their abilities, adversaries can observe different metadata.
- Today, we focus on passive adversaries
- We distinguish between three classes


Privacy Goal
Performance
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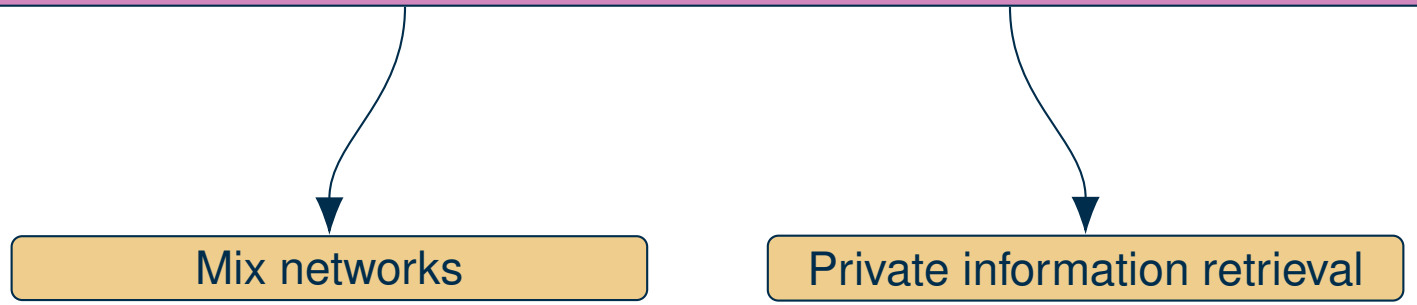
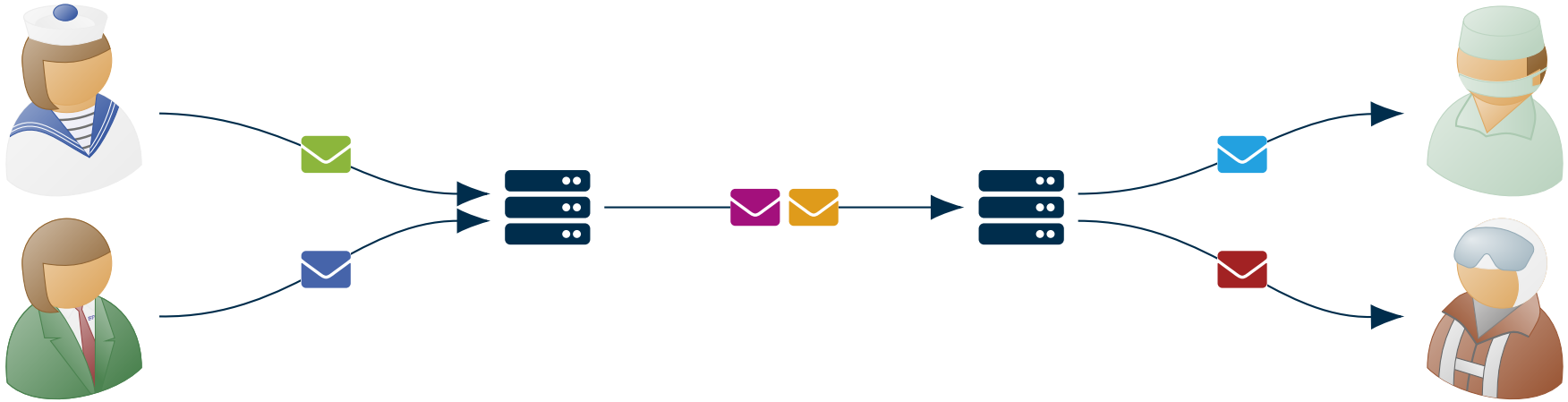
Performance

- Anonymous group communication networks hide metadata through cryptographic means
- Hiding metadata requires computational and/or network overhead, which impacts performance
- Concrete system performance is mainly determined by the underlying privacy primitive:



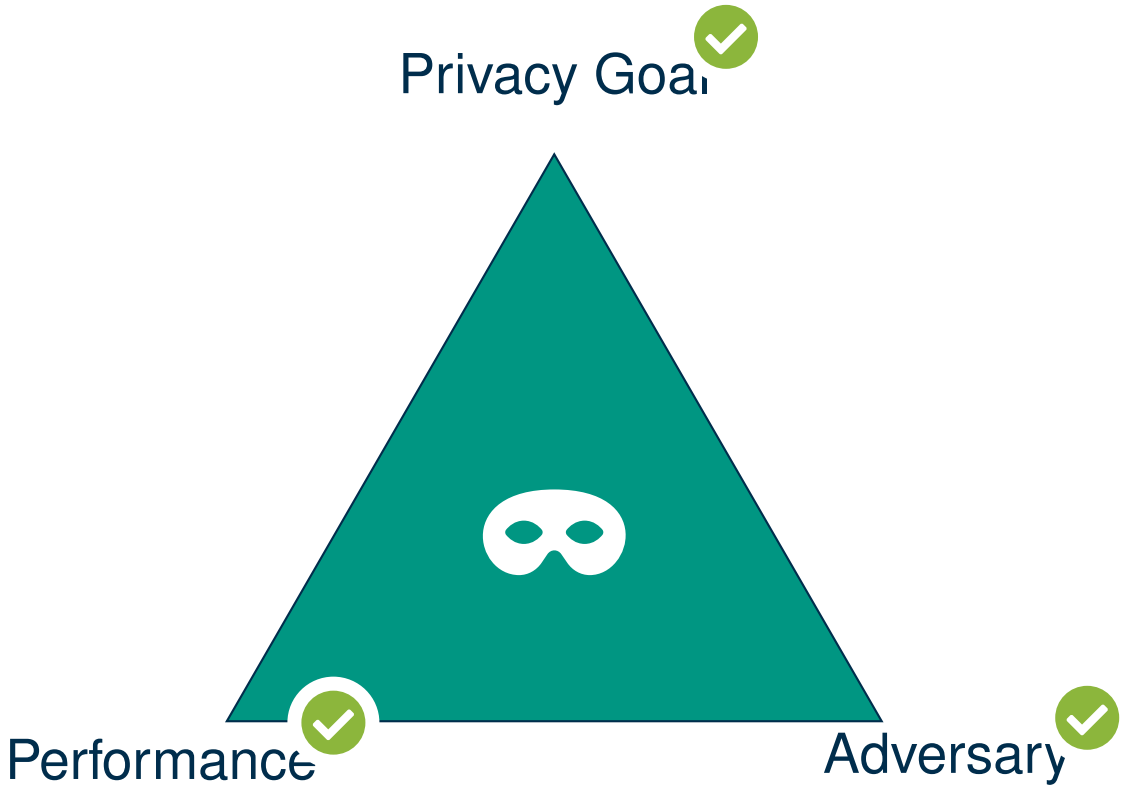
Primitive: Mix Networks



- Messages from multiple senders pass through a chain of servers
- Each server unlinks incoming from outgoing messages

Primitive: Private Information Retrieval

- Clients request items by index from server with remote database
- Server does not learn which item the client wants


Privacy Goal
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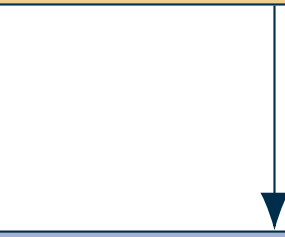
Toy protocol ∞Mix

∞Mix: Anonymous group communication based on mix networks.



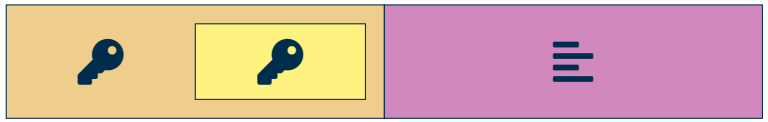
⚠ Servers need to unlink incoming from outgoing messages

⚠ Message replication should occur within the network

Toy protocol Mix

⚠ Servers need to unlink incoming from outgoing messages

💡 Prevent linking based on content



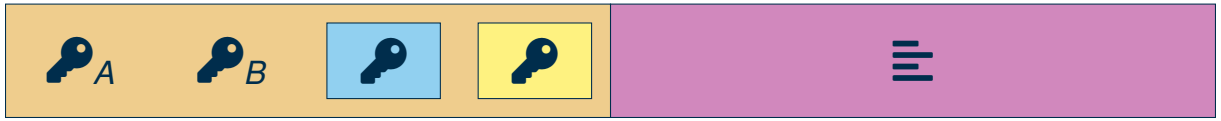
- Incoming = header + payload
- header is encrypted for current server
- header = key material + next header
- Outgoing = next header + encrypted payload

💡 Prevent linking based on order

- Collect incoming messages until threshold is reached
- Apply random permutation
- Release all at once

Toy protocol Mix

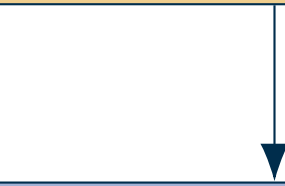
⚠ Message replication should occur within the network (without losing unlinkability!)



- Incoming header contains multiple sets of key material and next headers
- Outgoing A = next header + payload encrypted under A
- Outgoing B = next header + payload encrypted under B

Toy protocol ∞_{PIR}

∞_{PIR}: Anonymous group communication based on private information retrieval.

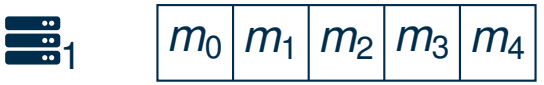


⚠ Prevent the server from learning information about the retrieved index
⚠ Clients need to know what to retrieve

Toy protocol PIR

⚠ Prevent the server from learning information about the retrieved index

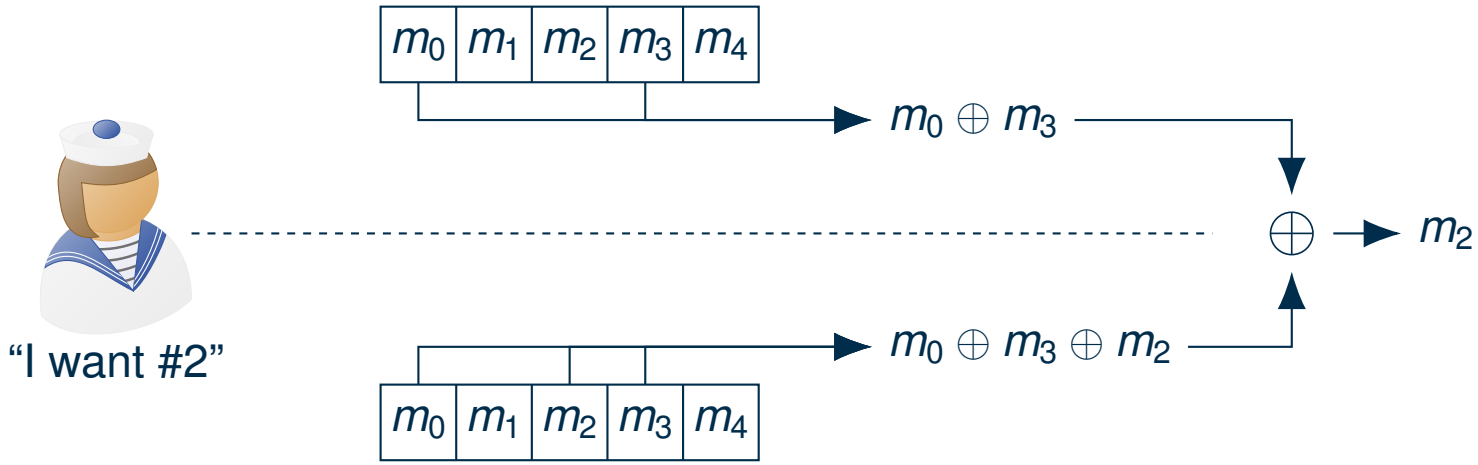
Duplicate database between two non-colluding servers



Toy protocol PIR

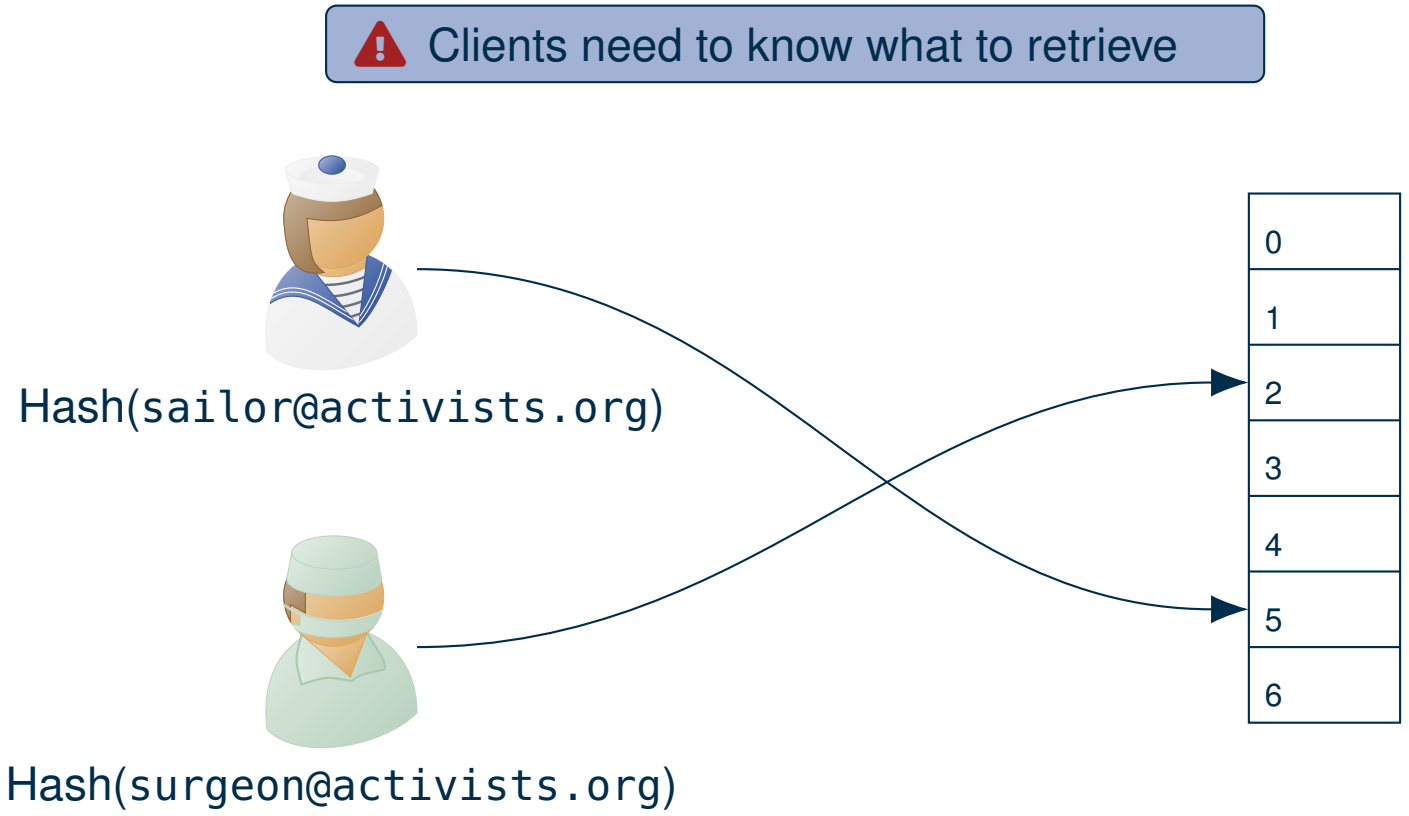
⚠ Prevent the server from learning information about the retrieved index

Request random set of indices from first server.



Request same random set with real index flipped from second server.

Toy protocol PIR



Mix versus PIR – Privacy

Mix

Message Unlinkability

- Network adversary ✓
- S – 1 servers ✓
- G – 1 group members ✓

Receiver (Count) Unlinkability

- Network adversary ✓
- S – 1 servers ✓
- G – 1 group members ✓

PIR

Message Unlinkability

- Network adversary (w/ TLS) ✓
- 1 server (w/o E2EE) ✗
- S servers (w/ E2EE) ✓
- 1 group member ✗

Receiver (Count) Unlinkability

- Network adversary (w/ TLS) ✓
- S – 1 servers (**w/o** E2EE) ✓
- G – 1 group members ✓

Activity Unlinkability is achieved against the same adversaries as Message Unlinkability if cover traffic is used.

Mix versus PIR – Performance

Mix

- ⊕ Symmetric crypto → computationally cheap
- ⊕ Adding additional servers can increase capacity
- ⊖ Shuffling incurs high end-to-end latency

PIR

- ⊖ Oblivious processing → computationally expensive
- ⊖ Adding additional servers only distributes trust
- ⊕ Low latency if sufficient computation
- ⊕ There is also PIR w/o server trust (more computationally expensive)

Conclusion

Anonymous group communication is cool!

Both ∞_{Mix} and ∞_{PIR} can protect our activists ✊

There are many (more) approaches, each with different tradeoffs.