Deniability in Automated Contact Tracing

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PETS 2024

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FWF Austrian Science Fund

SPyCoDe

This research was funded in whole or in part by the Austrian Science Fund (FWF) 10.55776/F85.

Automated contact tracing (ACT)

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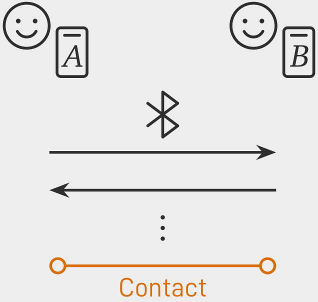
- **Automated:** Without human labor

- A lot of research & development due to Covid-19
- Google and Apple jointly deployed protocol based on DP3T (Troncoso et al.)

ACT using Bluetooth Low Energy



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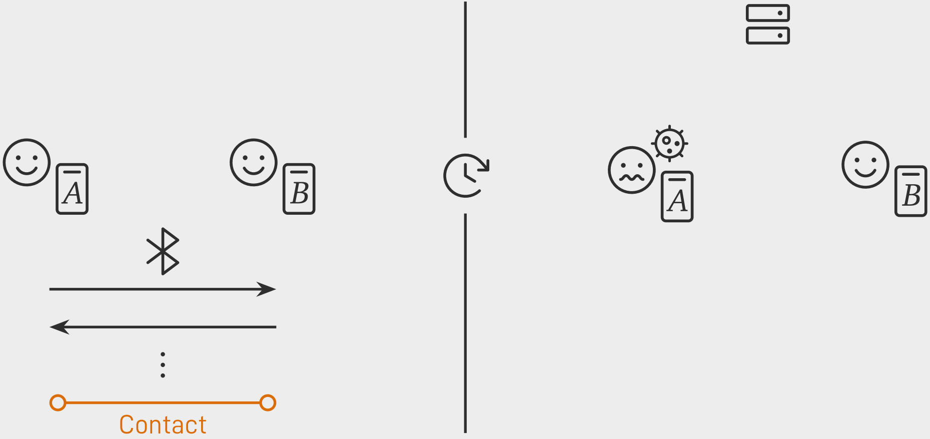

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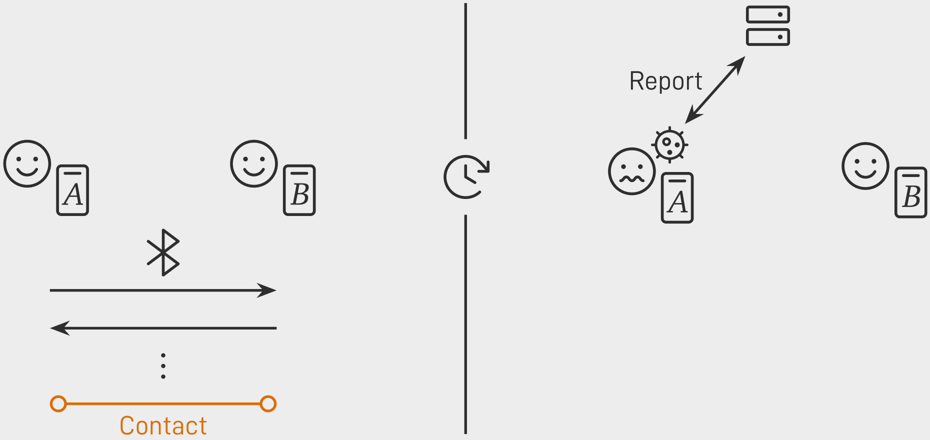

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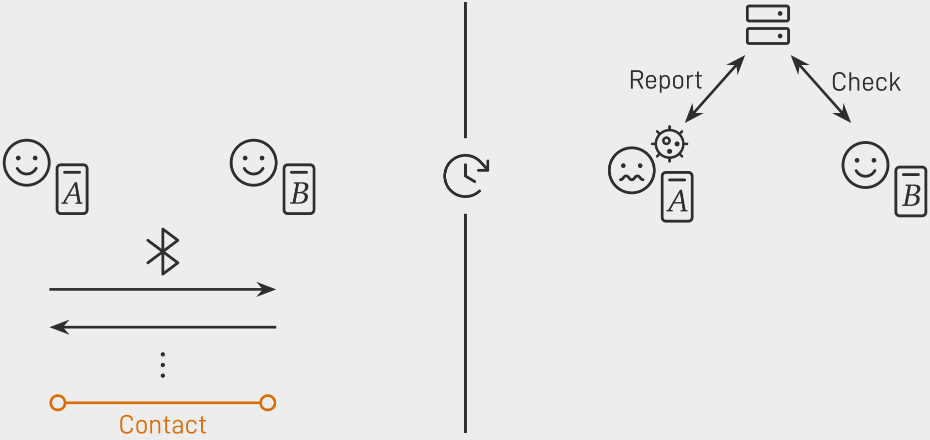

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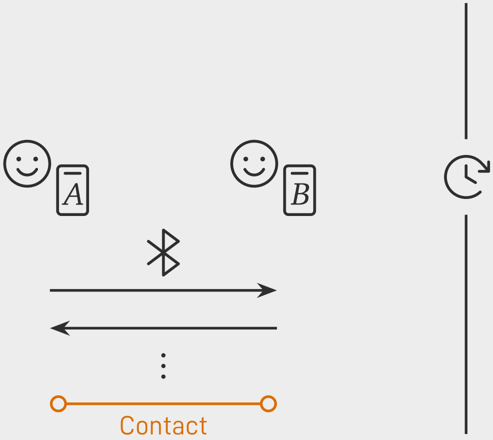

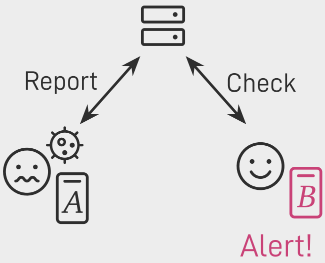

Contact and A reported sick

$\Rightarrow$

B's check causes an alert

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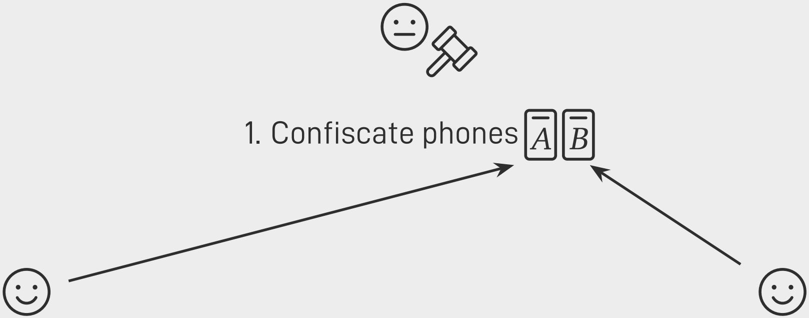
Privacy?

Digital evidence

Did A and B meet?

Digital evidence

Did A and B meet?



1. Confiscate phones

Digital evidence

Did A and B meet?

1. Confiscate phones A B
2. Report A

Digital evidence

Did A and B meet?

1. Confiscate phones A B
2. Report A
3. Check B

Digital evidence

Did A and B meet?

1. Confiscate phones A B
2. Report A
3. Check B

B got an alert $\Leftrightarrow$ A and B have met

Deniability

- User cannot deny having met by definition of ACT

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- Misuse of the protocol!

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Contact-time deniability

Did A and B meet at time t?

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- Misuse of the protocol!

Contact-time deniability

Did A and B meet at time t?

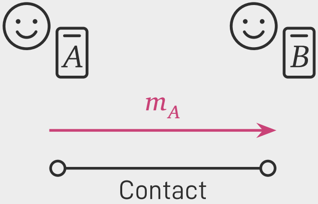
Impossibility result

Dilemma between contact-time deniability and security for a large class of protocols capturing many practically relevant ones

Impossibility result

Practical protocols are often…

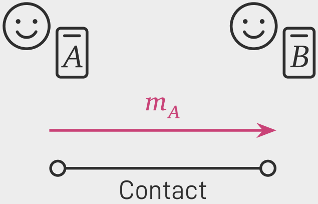
Unidirectional



Contact

Practical protocols are often…

Unidirectional



A

B

m_A

Contact

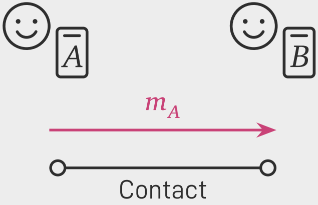
B received m_A and A reported sick

$\Rightarrow$

B's check causes an alert

Practical protocols are often…

Unidirectional

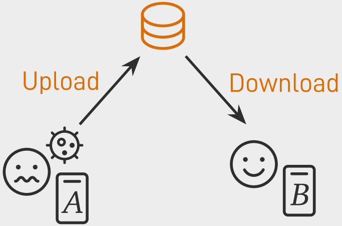


B received m_A and A reported sick

$\Rightarrow$

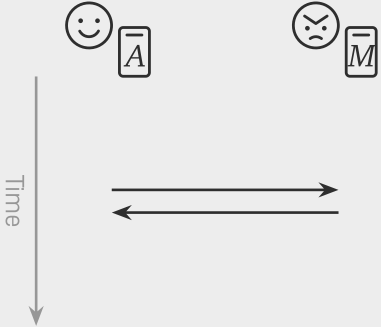
B's check causes an alert

Decentralized

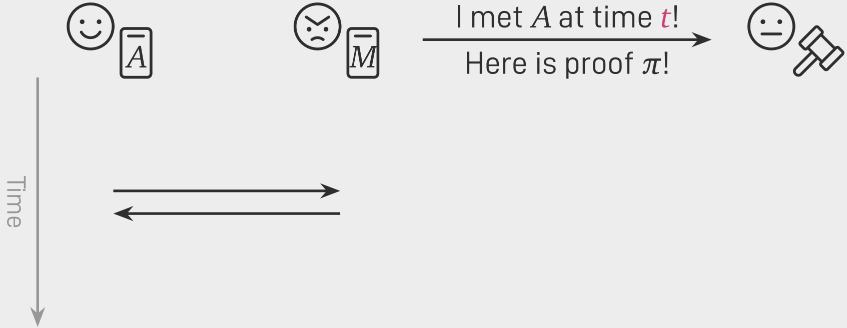


Server is a database

Contact-time deniability



Contact-time deniability



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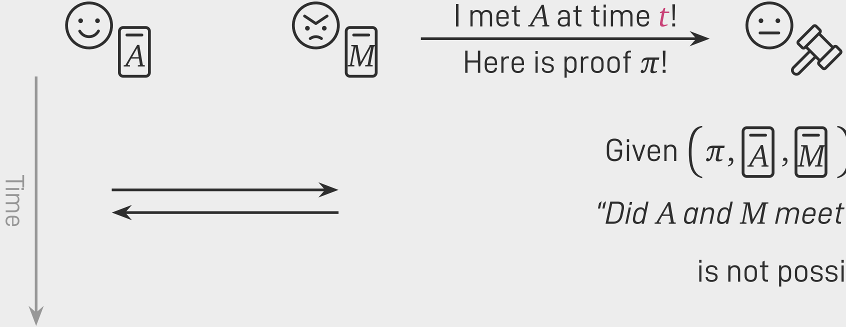


I met A at time t!

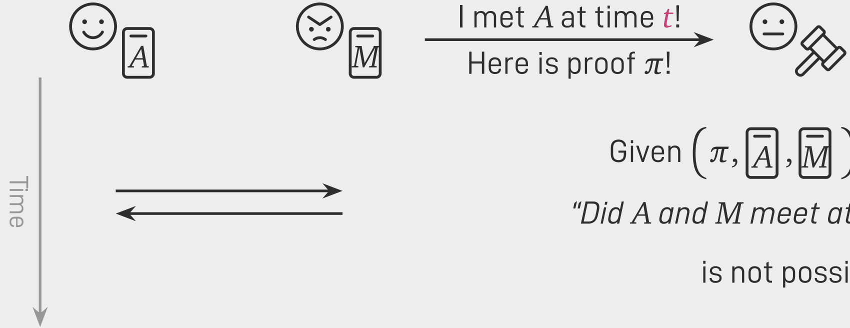
Here is proof π!

Given $\left(\pi, \boxed{A}, \boxed{M}\right)$, deciding

"Did A and M meet at time t?"

is not possible

Δ-contact-time deniability



I met A at time t!

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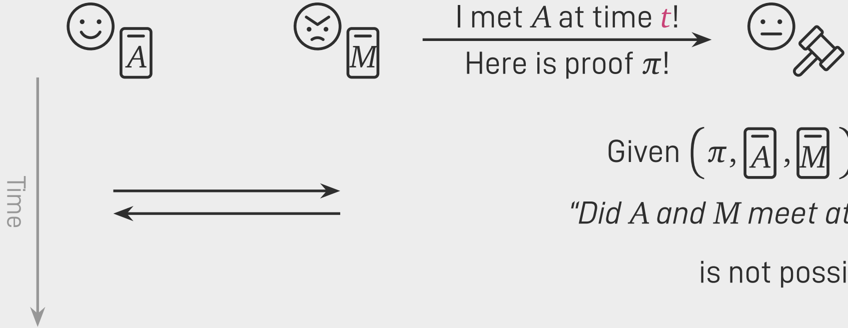
Given $\left(\pi, \boxed{A}, \boxed{M}\right)$, deciding

“Did A and M meet at time $t \pm \Delta$*?”*

is not possible

Δ-contact-time deniability



I met A at time t!

Here is proof π!

Given $\left(\pi, \boxed{A}, \boxed{M}\right)$, deciding

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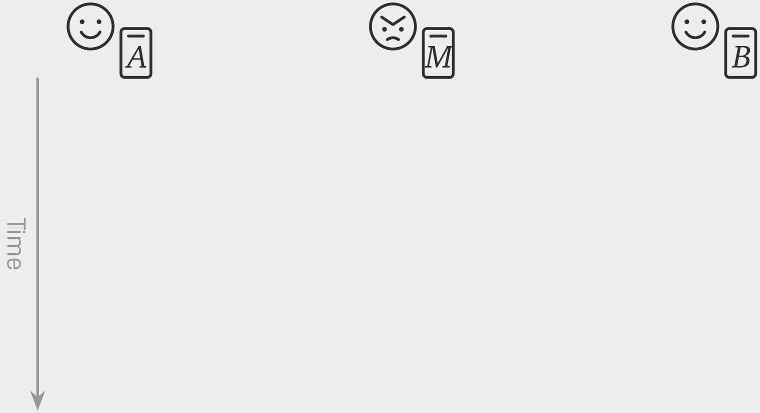
is not possible

Meaningful if large (e.g., a week)

Δ-replay security



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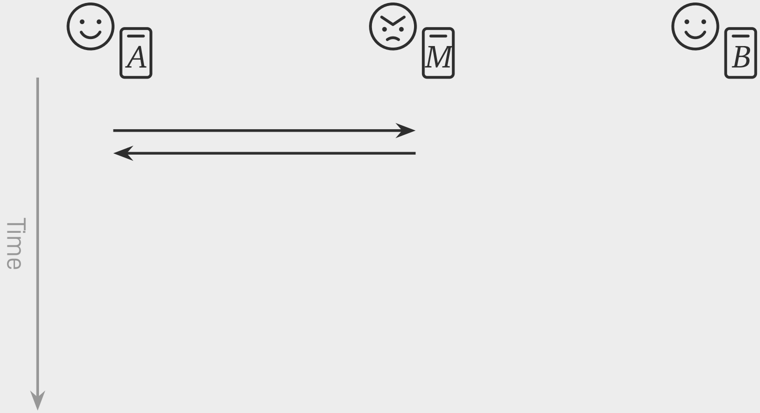

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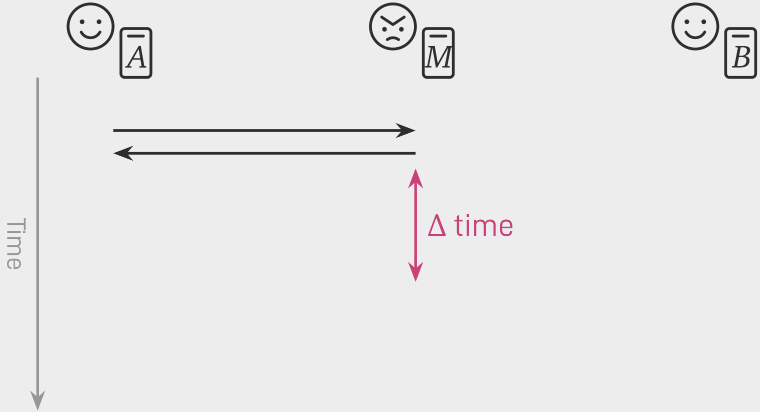

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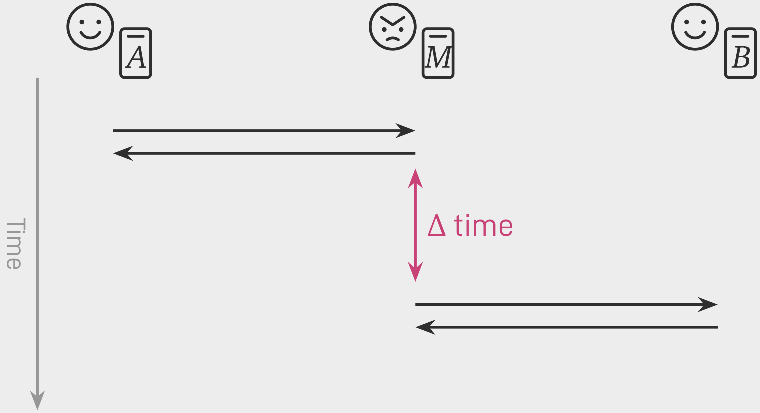

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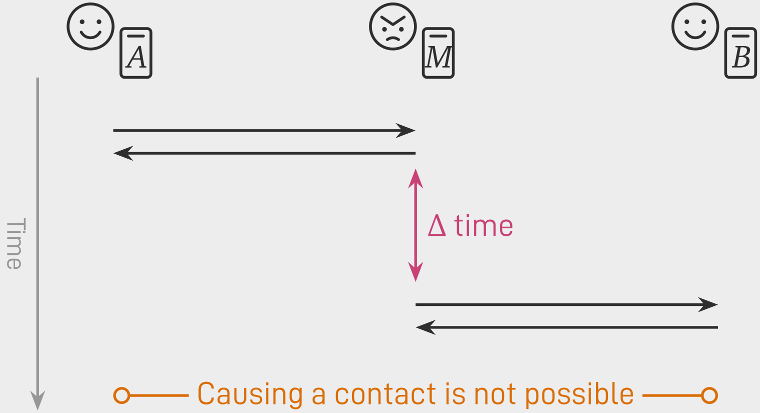

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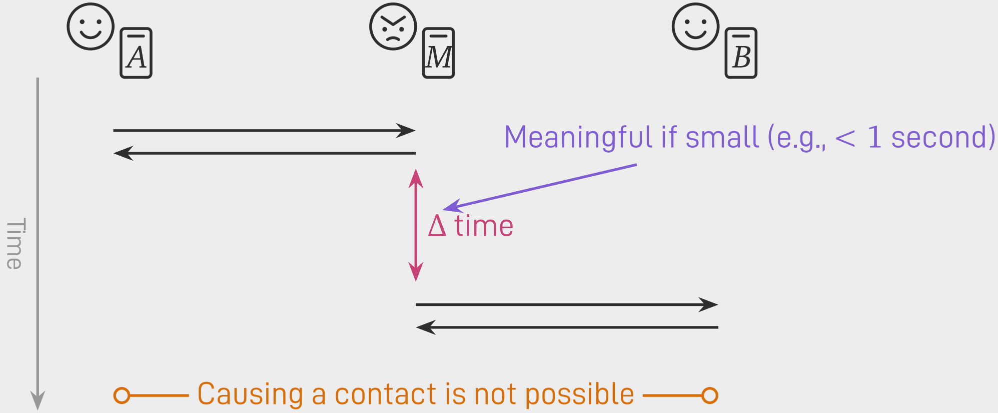

Meaningful if small (e.g., < 1 second)

Causing a contact is not possible

Main theorem

If a unidirectional, decentralized protocol is Δ-replay secure, then it can at most be Δ'-contact-time deniable with $\Delta > \Delta'$.

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If a unidirectional, decentralized protocol is Δ-replay secure, then it can at most be Δ'-contact-time deniable with $\Delta > \Delta'$.

Problematic since

- Δ only meaningful if small
- Δ' only meaningful if large

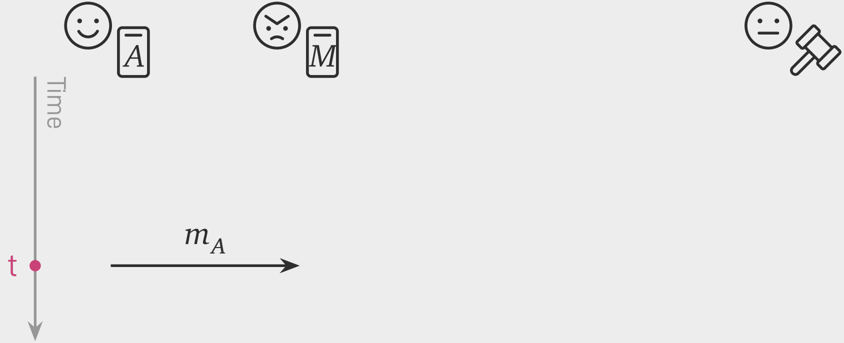
Proof

Want to show: Δ-replay secure ⇒ **not** Δ-contact-time deniable

$\bar{A}$
$\bar{M}$
Time

Proof

Want to show: Δ-replay secure ⇒ **not** Δ-contact-time deniable



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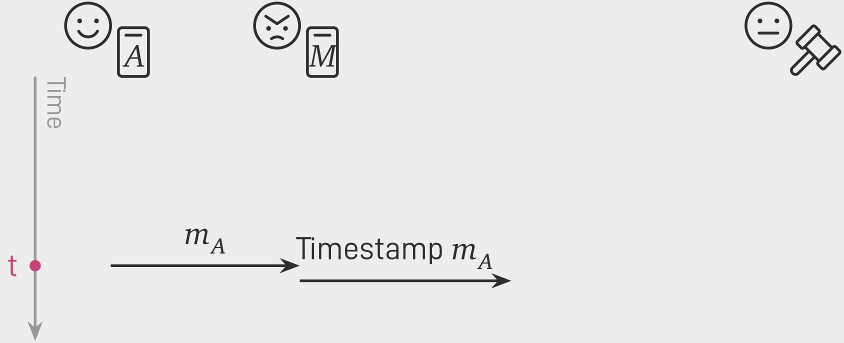

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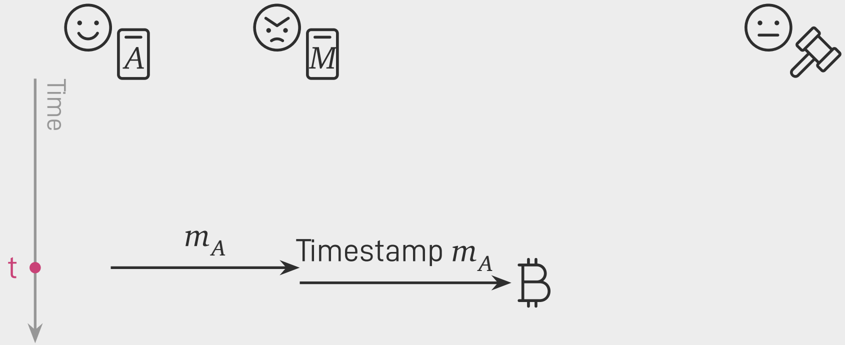

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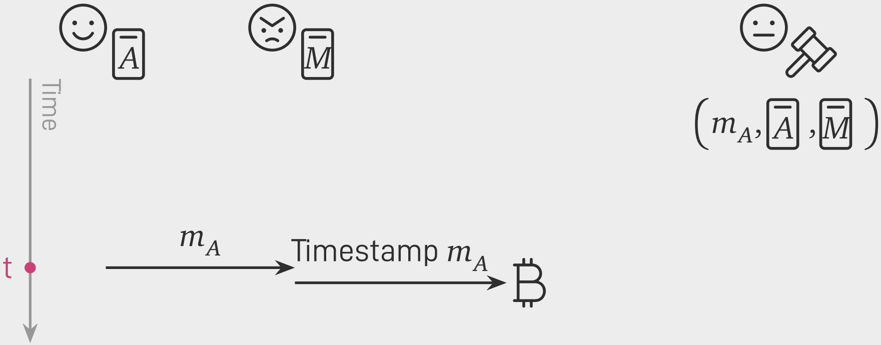

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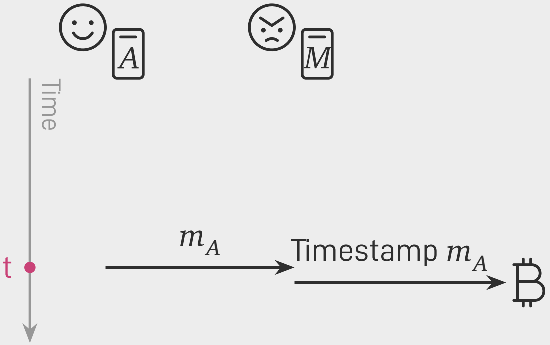
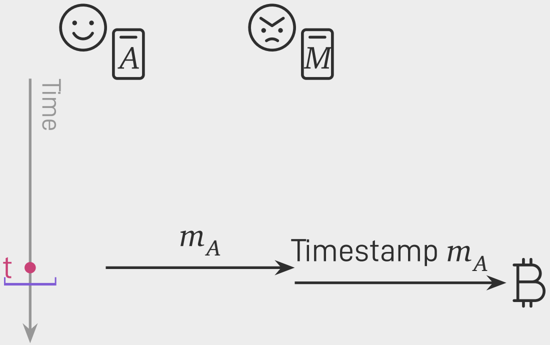


$(m_A, \boxed{A}, \boxed{M})$

1. Would receiving m_A at time t lead to contact with $\boxed{A}$?

Proof

Want to show: Δ-replay secure ⇒ **not** Δ-contact-time deniable



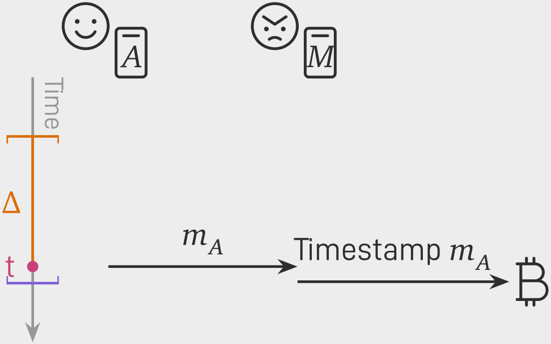
$(m_A, \boxed{A}, \boxed{M})$

1. Would receiving m_A at time t lead to contact with $\boxed{A}$?

2. $m_A \in$ ₿ at time t?

Proof

Want to show: Δ-replay secure ⇒ **not** Δ-contact-time deniable



$(m_A, \boxed{A}, \boxed{M})$

1. Would receiving m_A at time t lead to contact with $\boxed{A}$?

2. $m_A \in$ ₿ at time t?

3. Δ-replay attack not possible!

Various combinations exist

Protocol	Unidirectional	Replay-secure	Deniable
DP3T	✓	∼	∼
Challenge-Resp.	×	✓	✓
Delayed Auth.	✓	✓	×
CleverParrot	✓	✓	×
NTK	✓	∼	∼
DH-based	×	✓	✓

Table: Properties of existing decentralized protocols (cf. paper for details).

Conclusion

- Deniability not achievable for large part of the design space
- Extends to all decentralized ACT assuming stronger judge (cf. paper)
- How does this help in practice? (cf. paper)
  - Identify interesting points in the design space
  - Find creative ways to break out the theoretical model

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https://doi.org/10.56553/popets-2024-0134