Karlsruhe Institute of Technology

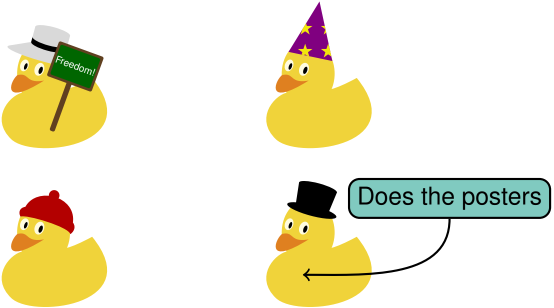
KASTEL

NEC

Panini – Anonymous Anycast and an Instantiation

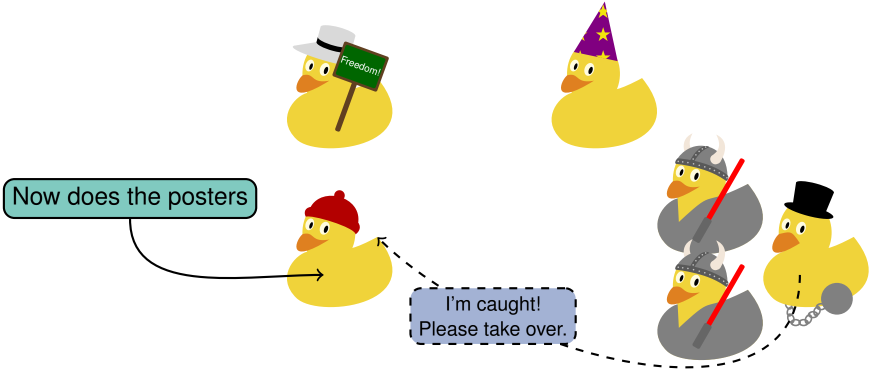
Christoph Coijanovic, Christiane Weis, and Thorsten Strufe | 09/25/2023

Motivation



Political activists

Motivation



Requirements

Hidden Receiver

even from sender

Caught activist cannot disclose their successor if they do not know them.

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chosen by sender

The successor has to be one of the activists.

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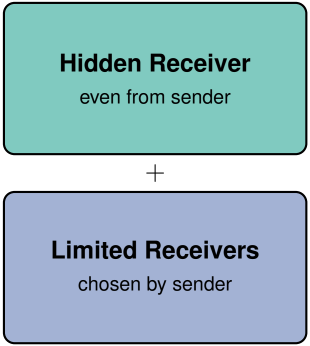
Easy Setup

for sender & receivers

Expensive setup limits adoption.



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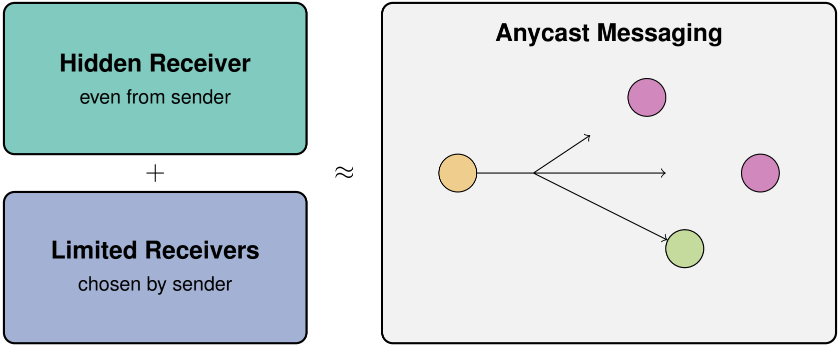

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$+$

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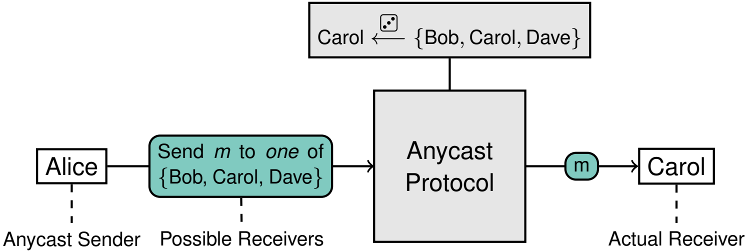
$\approx$

Anycast Messaging

Functionality & Adversary


Carol $\xleftarrow{⚂}$ {Bob, Carol, Dave}
Anycast Protocol
Alice
Send *m* to *one* of {Bob, Carol, Dave}
m
Carol
Anycast Sender
Possible Receivers
Actual Receiver

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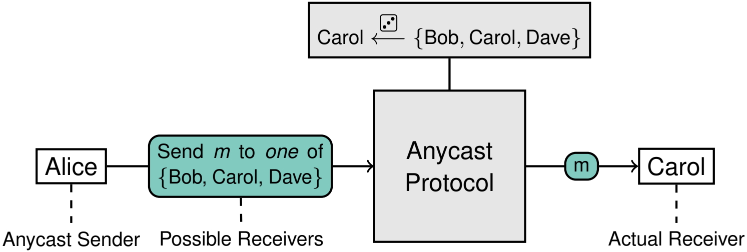
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Adversary

- Global passive observation
- Active interference on all network links
- honest-but-curious sender
- honest-but-curious fraction of possible receivers

Goals Overview

Message Confidentiality

Outside of sender and receiver, nobody shall learn information about the message.

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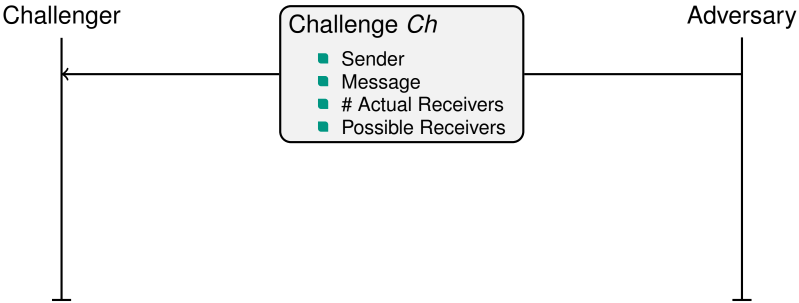
Goal: Guess an actual receiver.



Challenge *Ch*

- Sender
- Message
- # Actual Receivers
- Possible Receivers

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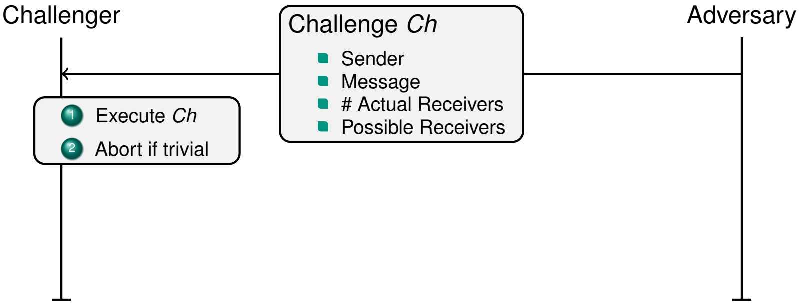

Challenger

Adversary

Challenge *Ch*

- Sender
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1. Execute *Ch*
2. Abort if trivial

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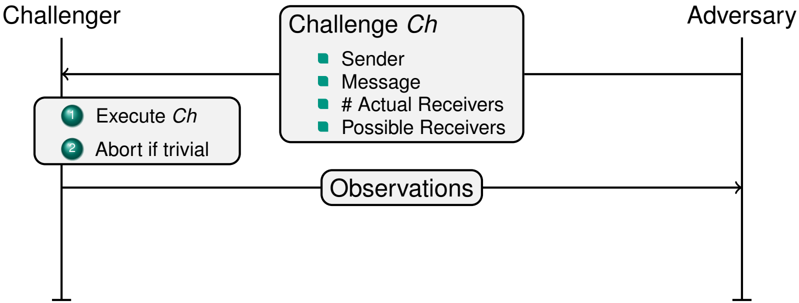

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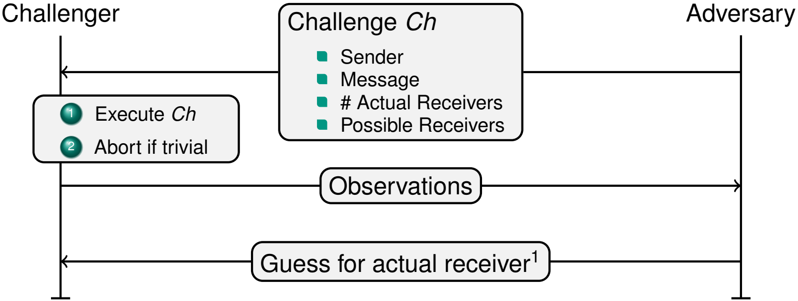

[1] **Or** unveil and try again.

Panini – Prerequisites

Secure Channel

- Anycast sender ↔ all possible receivers
- Confidential and authenticated
- Example: Anything with encryption and signatures, e.g., Email + S/MIME

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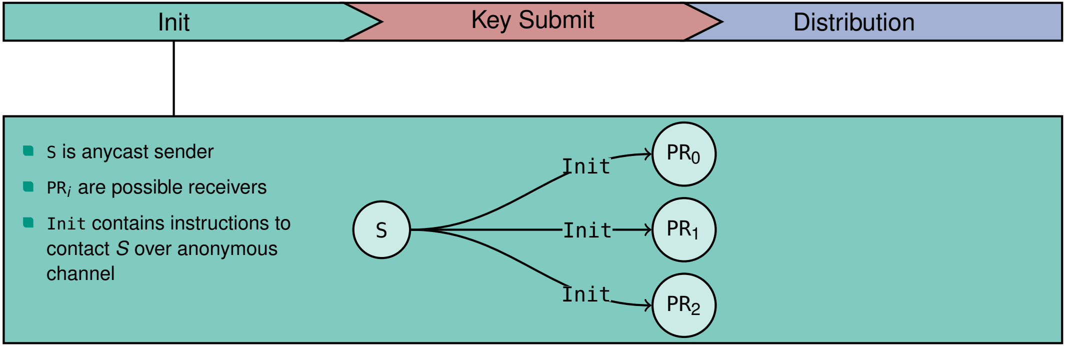
Anonymous Channel

- Every possible receiver → anycast sender
- Unlinks senders from their messages
- Example: Tor[a] against non-global adversaries or Nym[b]

[a] torproject.org

[b] nymtech.net

Panini – Base Protocol



- S is anycast sender
- PR_i are possible receivers
- Init contains instructions to contact S over anonymous channel

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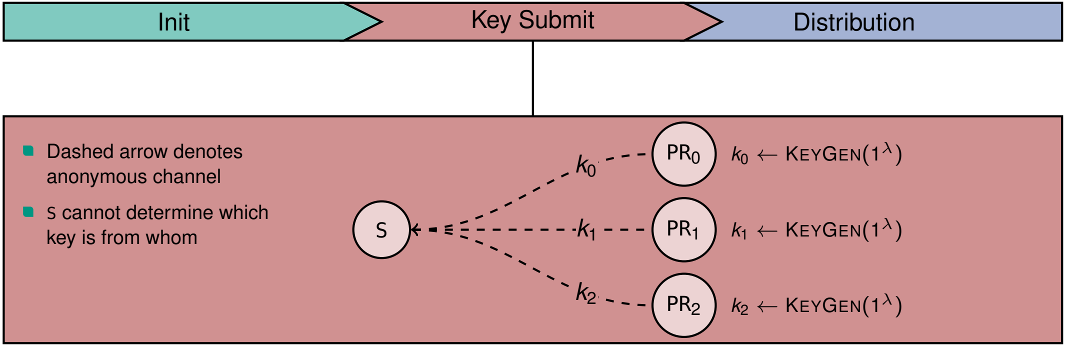
Init
Key Submit
Distribution
S
k_0
k_1
k_2
PR_0
PR_1
PR_2
$k_0 \leftarrow \textsc{KeyGen}(1^\lambda)$
$k_1 \leftarrow \textsc{KeyGen}(1^\lambda)$
$k_2 \leftarrow \textsc{KeyGen}(1^\lambda)$

- Dashed arrow denotes anonymous channel
- S cannot determine which key is from whom

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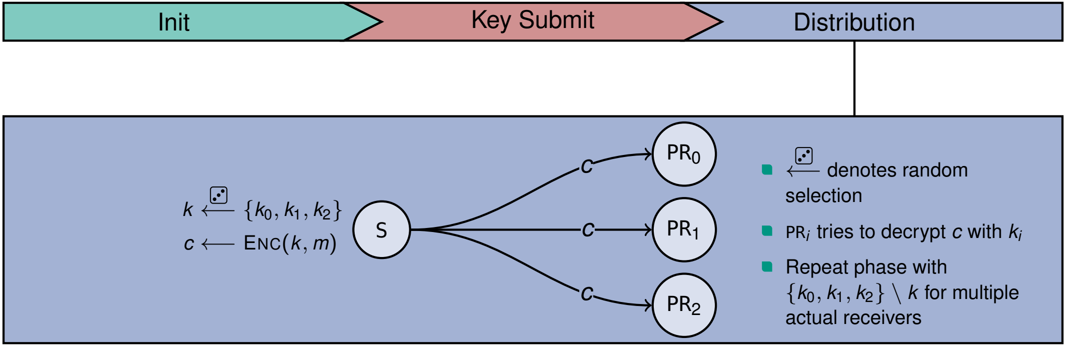

$k \xleftarrow{⚂} \{k_0, k_1, k_2\}$

$c \longleftarrow \textsc{Enc}(k, m)$

- $\xleftarrow{⚂}$ denotes random selection
- PR_i tries to decrypt c with k_i
- Repeat phase with $\{k_0, k_1, k_2\} \setminus k$ for multiple actual receivers

Defending against Active Adversaries

Active Key Replacement Attack

- Goal: Gain knowledge of anycast message

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- Approach:
  - Key Submit Replace possible receiver's keys with own keys
  - Distribution Intercept and decrypt ciphertext

Defending against Active Adversaries

External Adversary can insert keys!

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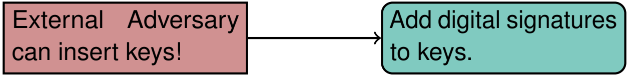

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Add digital signatures to keys.

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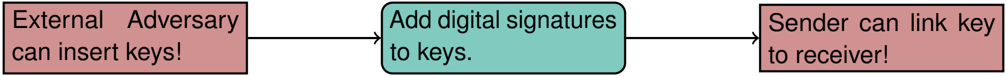

External Adversary can insert keys!

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Sender can link key to receiver!

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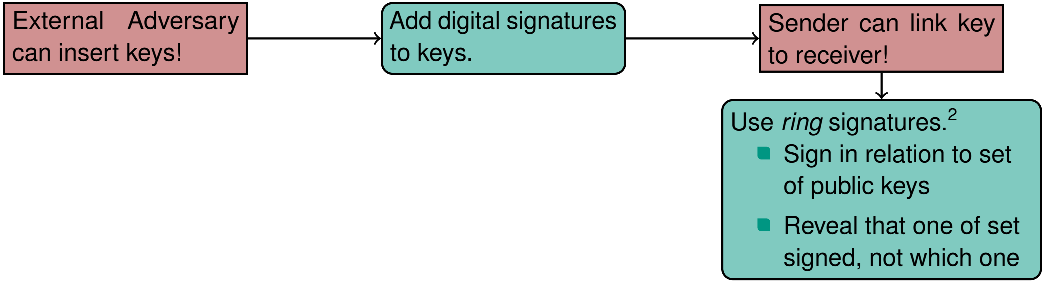

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Sender can link key to receiver!

Use *ring* signatures.[2]

- Sign in relation to set of public keys
- Reveal that one of set signed, not which one

[2] Rivest, Ronald L. et al. “How to Leak a Secret.” ASIACRYPT 2001.

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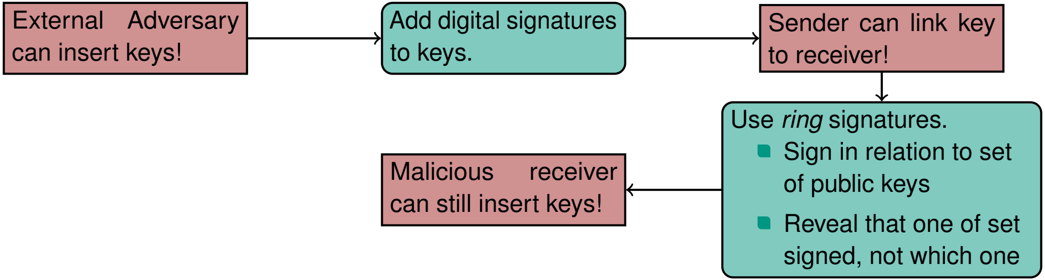

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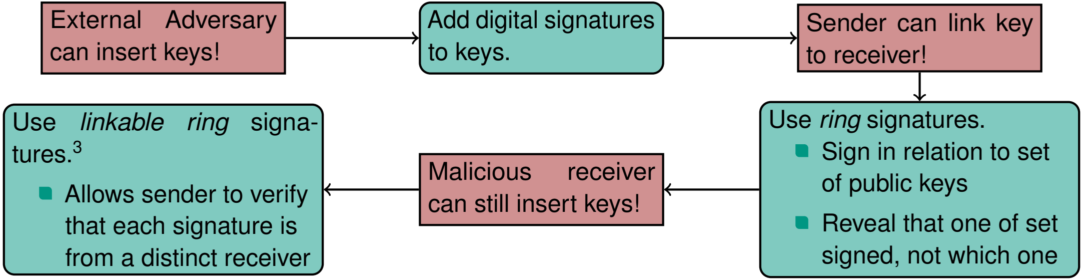

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Use *linkable ring* signatures.[3]

- Allows sender to verify that each signature is from a distinct receiver

[3] Liu, Joseph K. et al. “Linkable Spontaneous Anonymous Group Signature for Ad Hoc Groups (Extended Abstract).” IACR Cryptol. ePrint Arch. 2004

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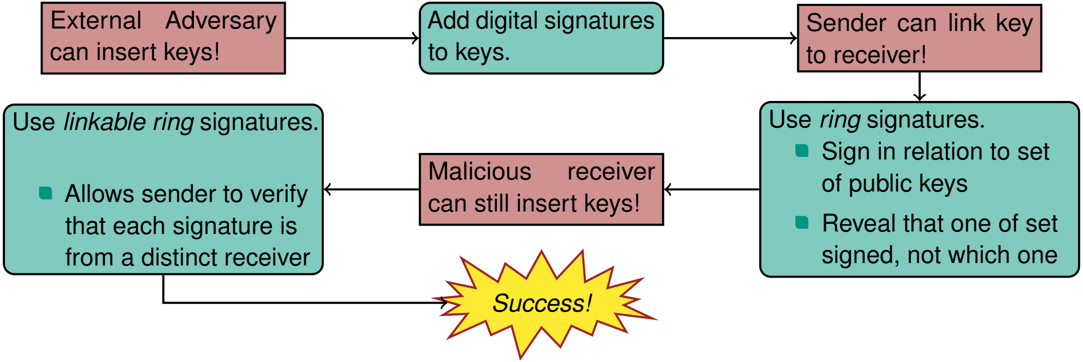

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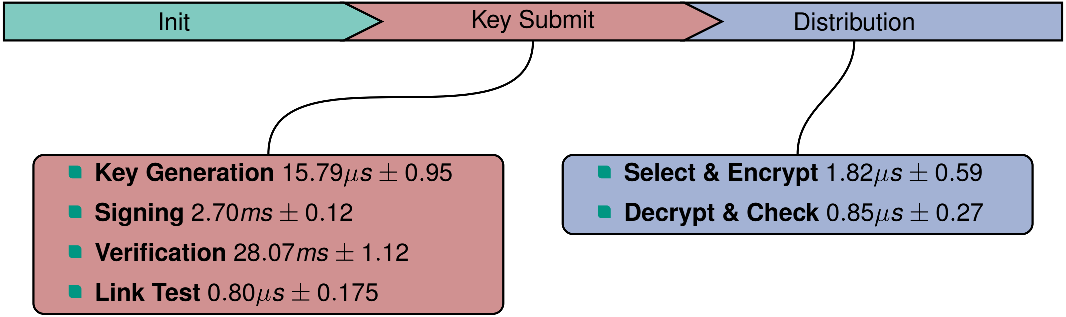
Success!

Evaluation

Computational Overhead (2 CPU cores // 10 possible receivers // 1 KB message)

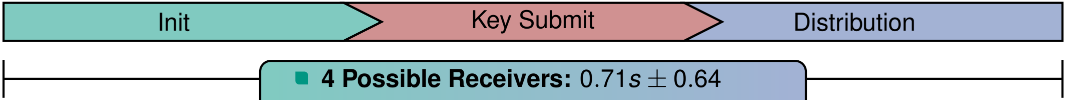


- **Key Generation** $15.79\mu s \pm 0.95$
- **Signing** $2.70ms \pm 0.12$
- **Verification** $28.07ms \pm 1.12$
- **Link Test** $0.80\mu s \pm 0.175$

- **Select & Encrypt** $1.82\mu s \pm 0.59$
- **Decrypt & Check** $0.85\mu s \pm 0.27$

Evaluation

End-to-end Latency (Secure Channel: AES+ECDSA // Anon. Channel: Nym // 512 B Message)



Init

Key Submit

Distribution

- **4 Possible Receivers:** $0.71s \pm 0.64$
- **8 Possible Receivers:** $0.76s \pm 0.34$
- **16 Possible Receivers:** $0.82s \pm 2.13$

Summary

We introduced Panini, an *anonymous anycast* protocol.

Panini is secure

First protocol to hide to hide the receiver from all entities including the sender.

Panini is efficient

<1s end-to-end latency and <30ms computation for sender.

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