

# A look into the Mobile Messaging Black Box

33<sup>rd</sup> Chaos Communication Congress #33c3

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Roland Schilling @NerdingByDoing

Frieder Steinmetz @twillnix

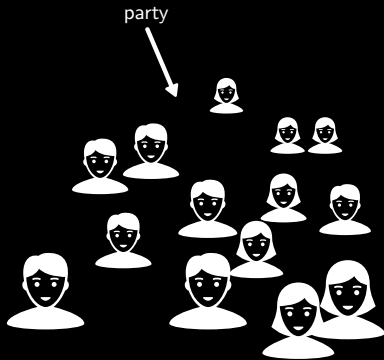
December 21, 2016

Hamburg University of Technology  
Security in Distributed Applications

# Messaging – Identifying Our Expectations

You're at a party

- Friend approaches you and needs to tell you something **in private**
- What do you expect when you say **private**?
- You enter a separate room, you trust the location
- What does a separate room offer you?

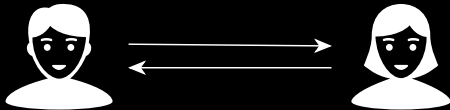


# A Private Room

You are now alone in a closed room with your Friend

- Both of you have absolute Confidentiality that you are alone
- Nobody can overhear your talk
- Your exchange is completely private

We call this **confidentiality**



# You Know Each Other

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Since you're long-time friends, you're absolutely sure, whom you're talking to

- Nobody can impersonate your friend or you, without the other noticing
- You're talking directly, without a phone or webcam in between

We call this **authenticity**

## In Sight of Each Other

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The room you're in is small enough that you can always see each other

- You know that the words you speak are received just as you spoke them
- There is no way either of you hears something other than the other says

We call this **integrity**

# It's a One-Time Talk

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Suppose somebody steps into the room

- They could overhear your conversation
- They would only learn the contents of this particular conversation
- They would not learn anything about past conversations you had

We call this **forward secrecy**

→ After leaving they would not be able to listen to any future conversations you might have

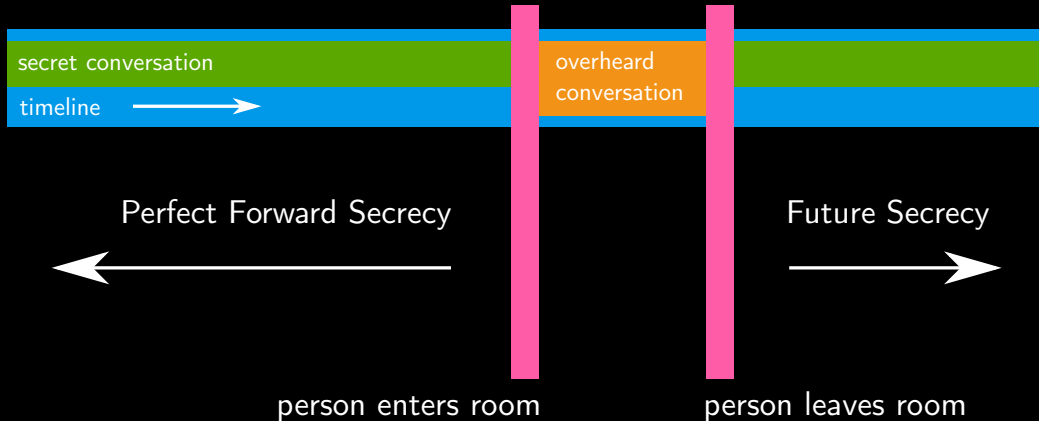
We call this **future secrecy**



# It's a One-Time Talk



Perfect Forward- and Future Secrecy



# It's a One-Time Talk Between Only You Two

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There are no witnesses in the room

- Either of you can later deny to other having made any statement
- Neither of you can prove to other that any of you have made a particular statement

We call this **deniability**



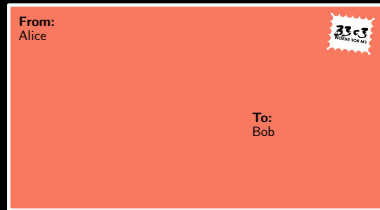
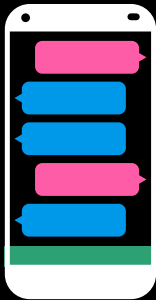
## Messaging – Reality Check



## Messaging – A More Technical Analogy

We started with a conversation analogy to identify our expectations of messaging

→ Actually **postal services** are better to look at messaging from a technical point of view.



## Example: Traditional Messaging

What if our party conversation had taken place via SMS?



Your providers (and other people on the same network)

- would know the contents of your exchange: **no confidentiality**
- could change the contents of your exchange: **no integrity**
- could reroute your messages and impersonate either of you: **no authentication**
- would know all messages you ever exchanged: **no forward Secrecy**
- would know all messages exchanged in the future: **no future secrecy**
- could store all messages and use them as proof of the exchange: **no deniability**

→ Messaging translates badly to our offline communication expectation

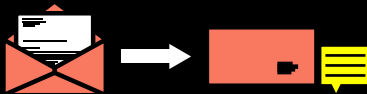


# From Postcards to Letters

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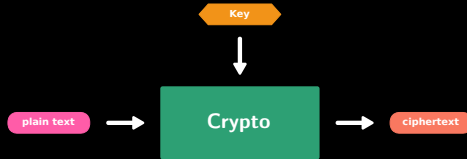
# From Postcards to Letters



# The Shortest Introduction to Encryption You Will Ever Get

Symmetric Encryption:

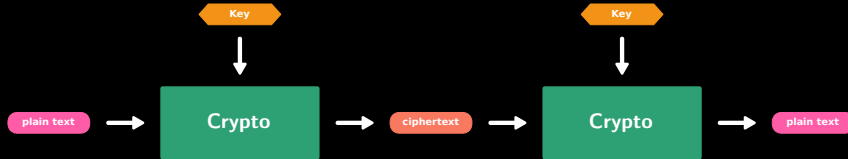
→ Encryption and decryption with the same key



# The Shortest Introduction to Encryption You Will Ever Get

Symmetric Encryption:

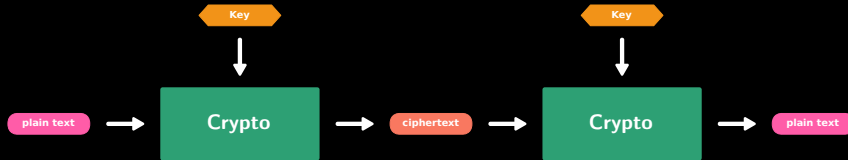
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# The Shortest Introduction to Encryption You Will Ever Get

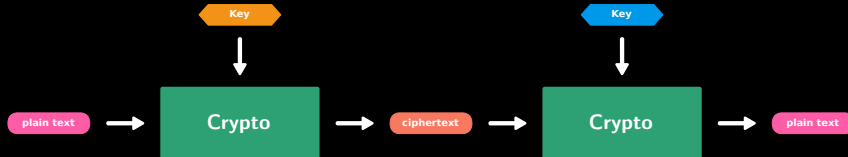
Symmetric Encryption:

→ Encryption and decryption with the same key



Asymmetric Encryption:

→ Encryption and decryption with different keys





# The Shortest Introduction to Encryption You Will Ever Get

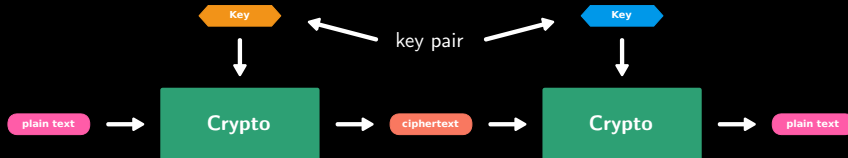
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Asymmetric Encryption:

→ Encryption and decryption with different keys



# Public-Key Cryptography – In a Nutshell



Secret Key

Public Key

Identity



Secret Key

Public Key

Identity

- Both parties publish their identities and public keys
- Any message can be encrypted with anyone's public key and only be decrypted with its corresponding secret key



# Public-Key Cryptography – In a Nutshell



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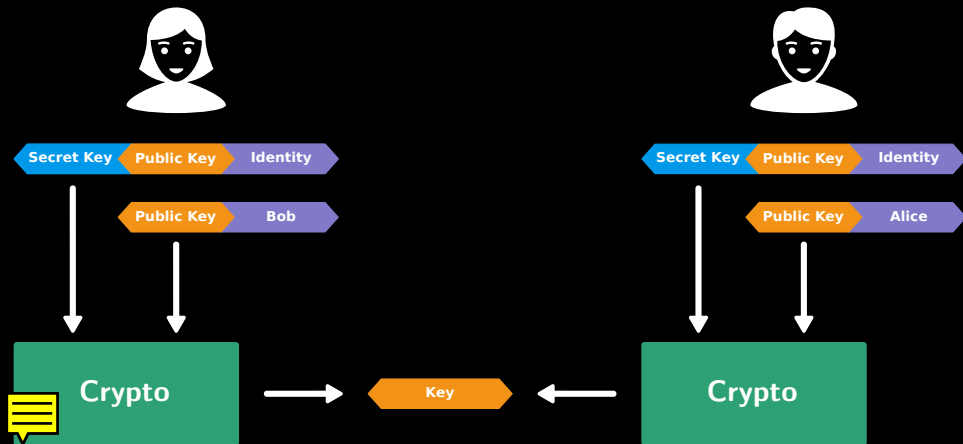
# Public-Key Cryptography – In a Nutshell



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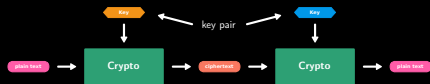


# Authenticated Encryption



# Recap

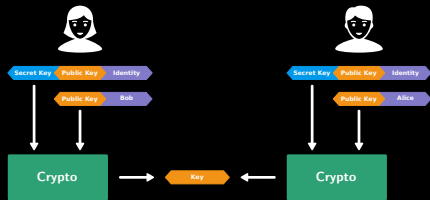
**Asymmetric Encryption** gives us IDs but is very expensive.



**Symmetric Encryption** is cheap, but a key has to be shared by all participants **before** communication starts.

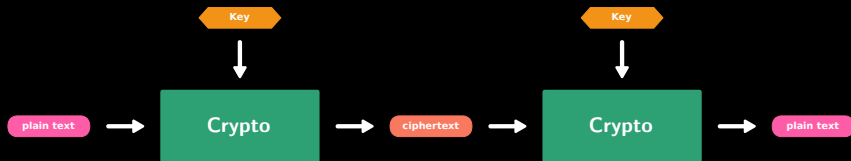


**Authenticated Encryption** allows us to create symmetric keys based on asymmetric key pairs.



But there's more...

# Confidentiality



# Deniability

**From:**  
either of us

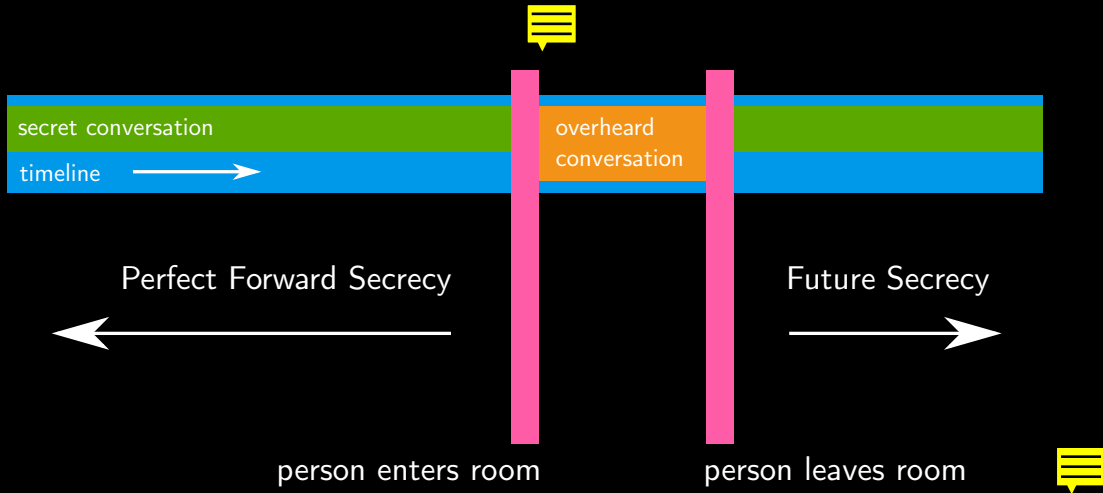


**To:**  
both of us

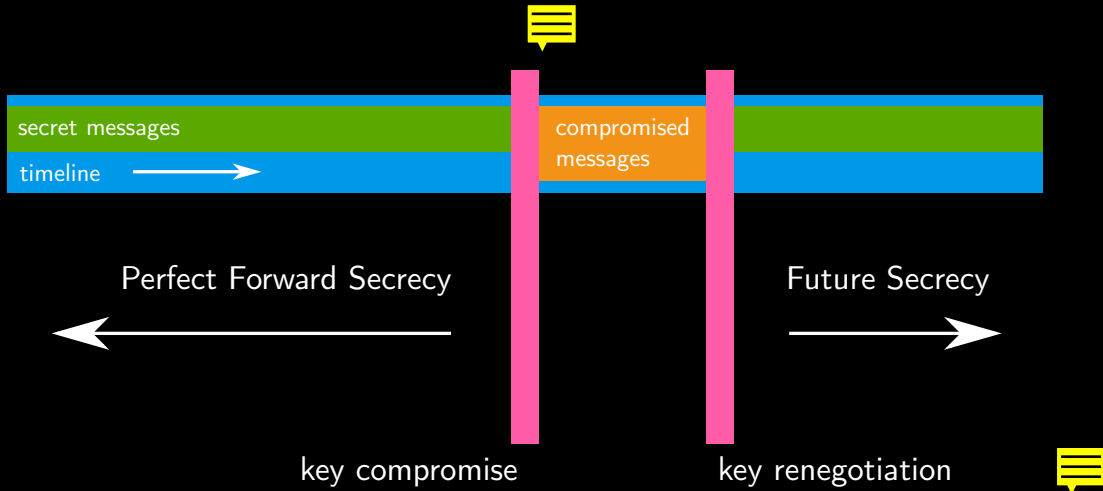




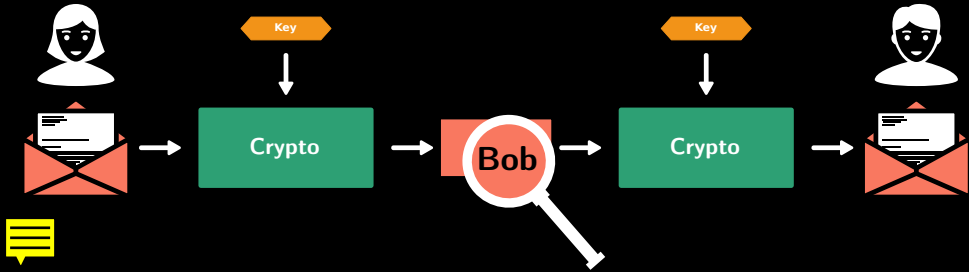
## But What About Forward- and Future Secrecy?



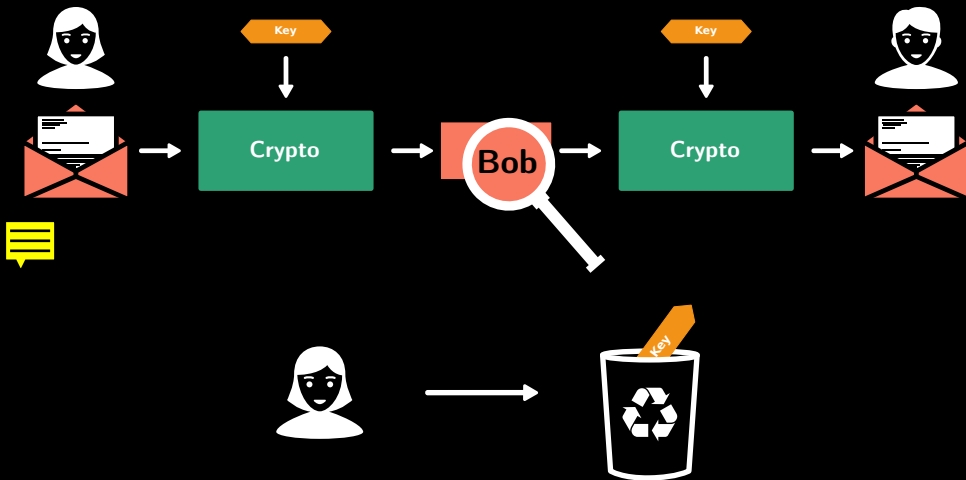
## But What About Forward- and Future Secrecy?



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## But What About Forward- and Future Secrecy?



# Recap

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Authenticated Encryption gives us:

- Confidentiality
- Deniability
- Authenticity

We don't have:

- Perfect Forward Secrecy
- Future Secrecy

→ We are ignoring Integrity here, but we have that, too.

# Key Management

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Cryptography is rarely, if ever, the solution to a security problem. Cryptography is a translation mechanism, usually converting a communications security problem into a key management problem.

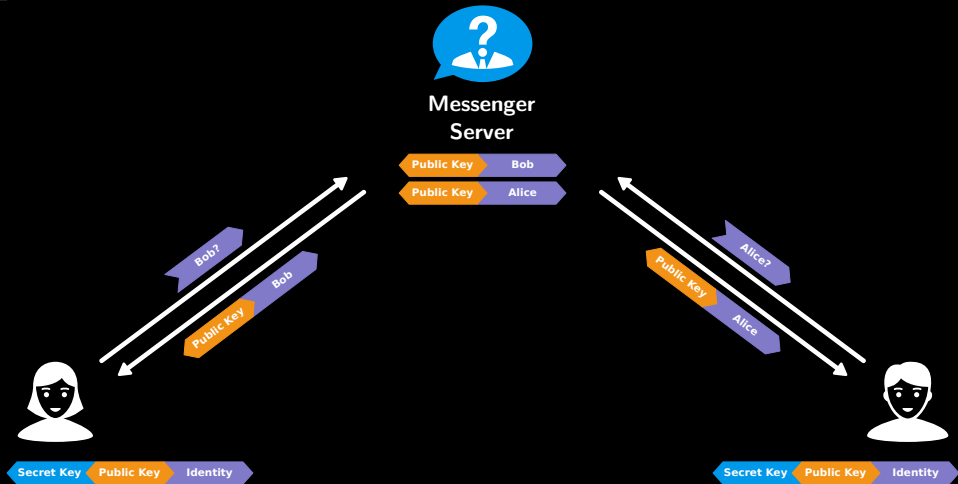
—Dieter Gollmann

# Key Management



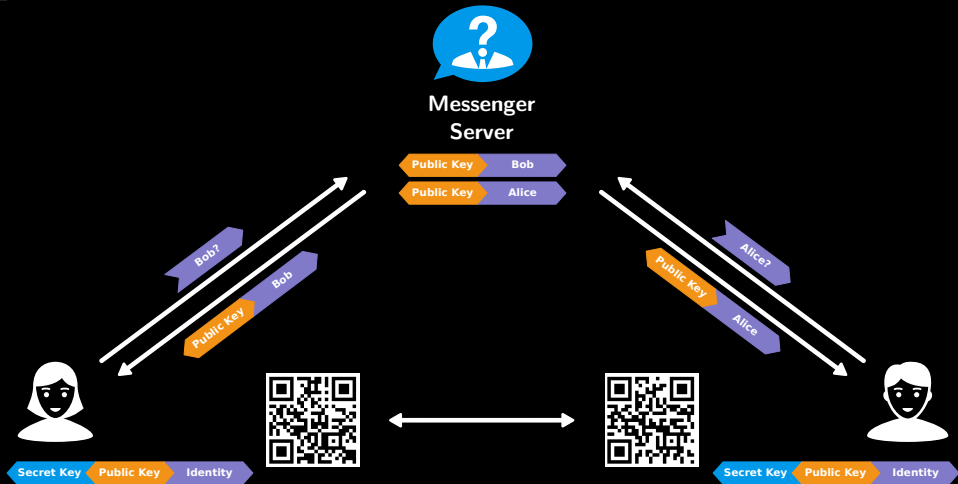
- How does Alice know which is Bob's public key?
- Identity keys stored on devices, what if stolen
- Keys for back-end communication layer hard-coded, almost impossible to replace
- How to deal with key compromise? (answer: key rotation)

# Key Management






# Key Management



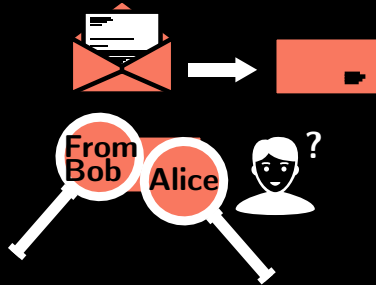
# Authenticity

- How to connect a key to a person?
  - Key signing (PGP)
  - Certificates (trusted third party)
  - (Messenger  service-based directory (based on phone numbers or email addresses))
- How to deal with changing keys?
  - warnings are annoying
  - Threema's traffic light system encourages authentication but doesn't deal with changing keys (other than new identities for known phone numbers with yellow dots)

# Metadata Handling

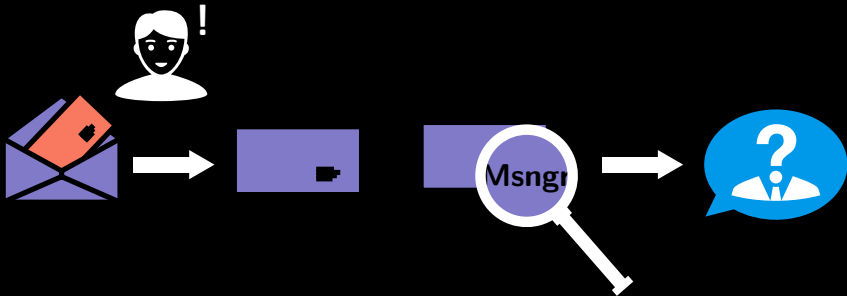
Everybody on the network can see:

- the sender of the message
- the intended receiver of the message

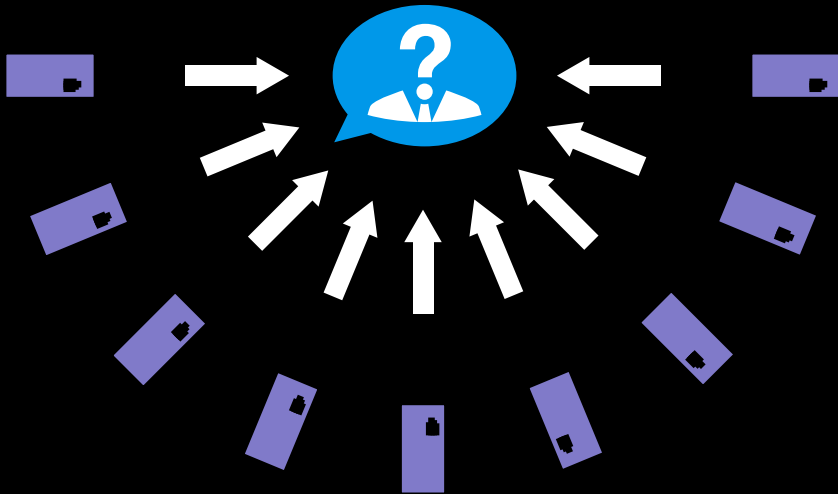


# Metadata Handling

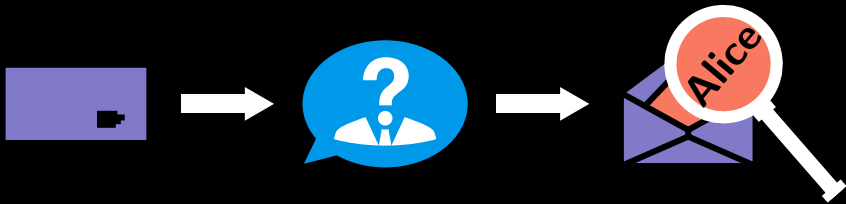
Solution: wrap encrypted message in a second layer of encryption and address it only to the message server.



# Metadata Handling

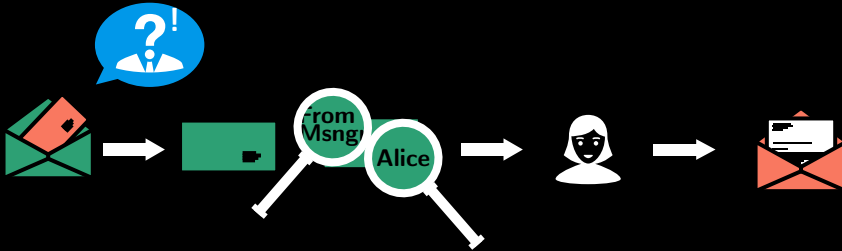


# Metadata Handling



# Metadata Handling

The message server will remove the outer layer and add a new one, targeted at the receiver.



# Metadata Handling

This leaves us with an encrypted **end-to-end tunnel**, transmitted through two **transport layer** encryption tunnels.



The message server still knows both communication partners!



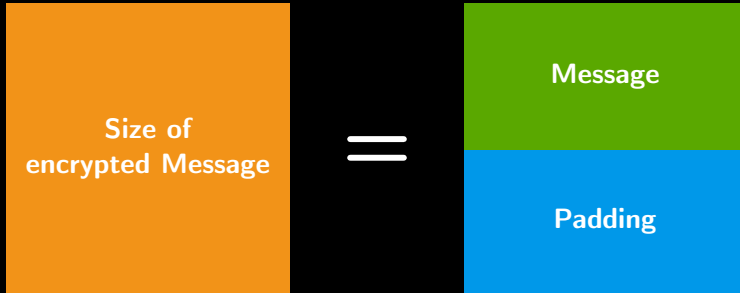
# Metadata Handling

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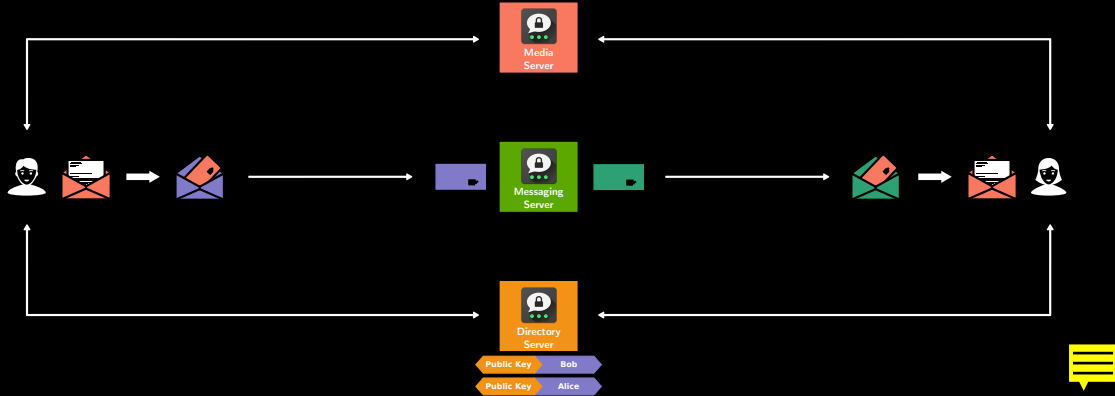
We can obfuscate the size of a message with `padding`

# Metadata Handling

We can obfuscate the size of a message with **padding**



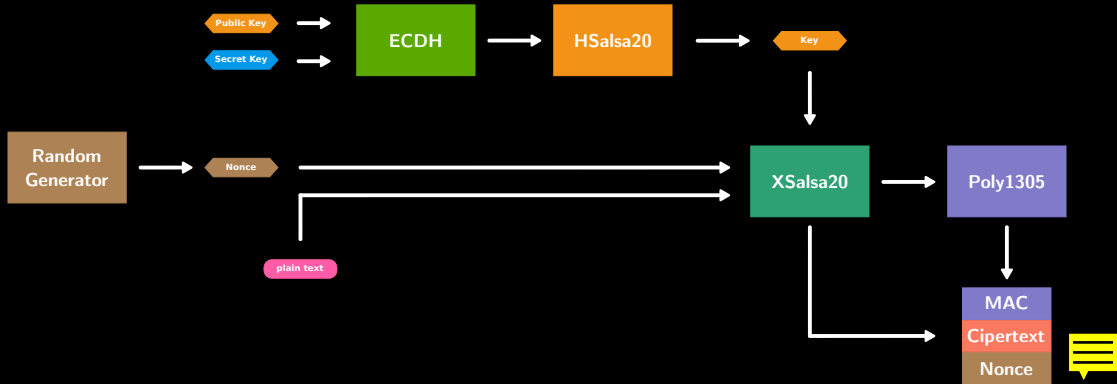
# Threema's Architecture



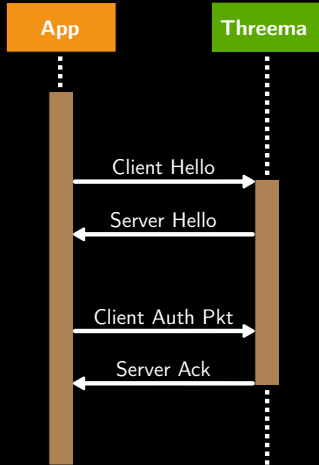
Threema Fingerprints



# NaCl and Threema

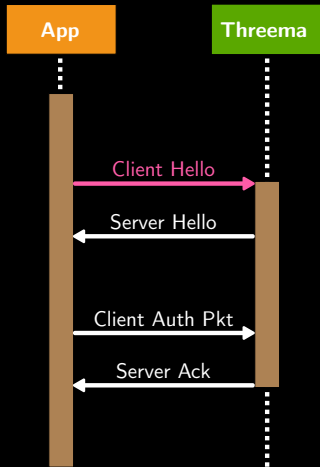


# Threema's App-to-Server Handshake

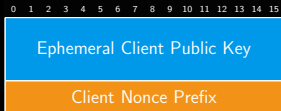


Initial Text goes here

# Threema's App-to-Server Handshake

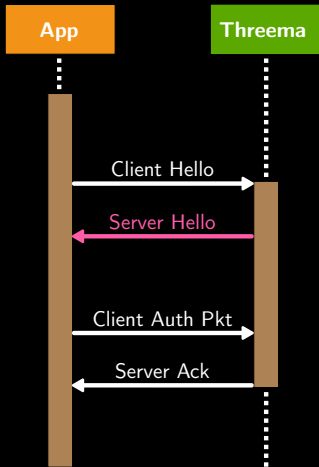


## Client Hello Packet

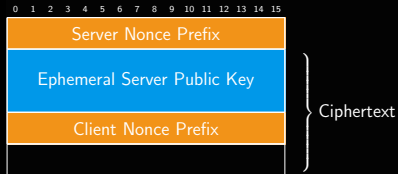


- Client generates a **ephemeral** key pair
- Client generates random nonce prefix

# Threema's App-to-Server Handshake



## Server Hello Packet

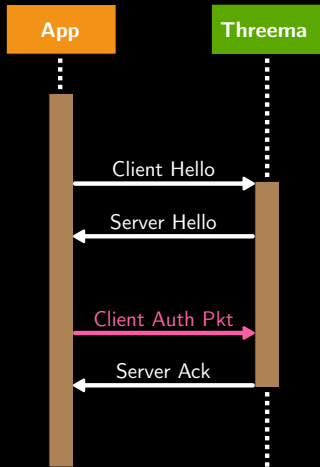


- Server generates ephemeral key pair
- Server generates random nonce
- Ciphertext encrypted with Server Nonce, Client Ephemeral Key and Server Long-Term Key

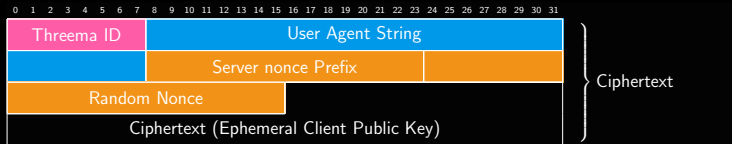




# Threema's App-to-Server Handshake

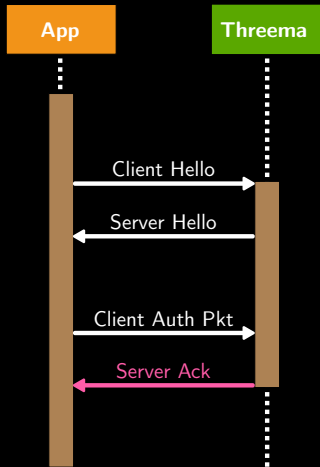


## Client Authentication Packet

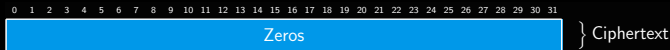


- Outer Encryption with ephemeral Keys
- Ciphertext links clients ephemeral key pair to it's long term key pair

# Threema's App-to-Server Handshake



## Server Acknowledgement Packet

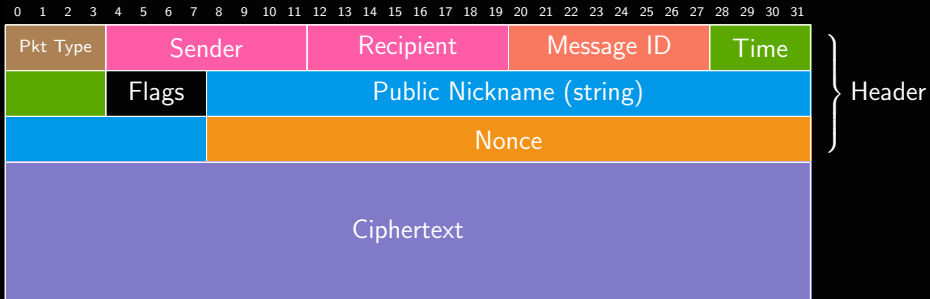


- Server confirms everything worked fine by encrypting something with both ephemeral keys

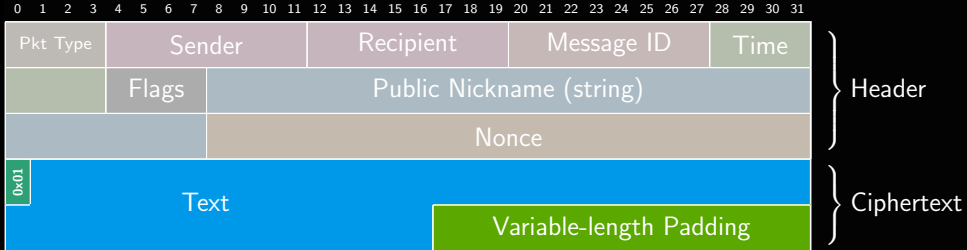


Lila und Gruen sind klar  
Jetzt noch kurz rot

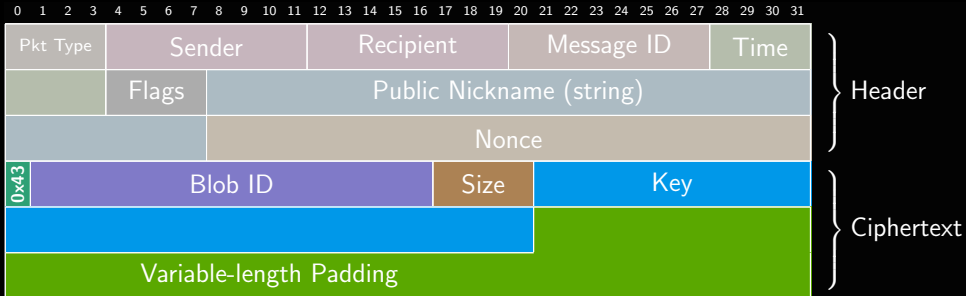
# Threema Packet Format



# Threema Text Messages



# Threema Image Messages



# Sending an Image Message

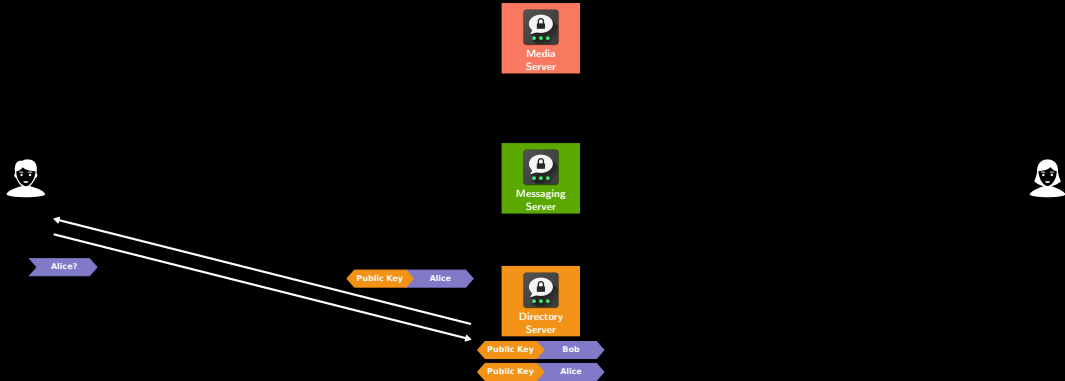


Public Key Bob

Public Key Alice

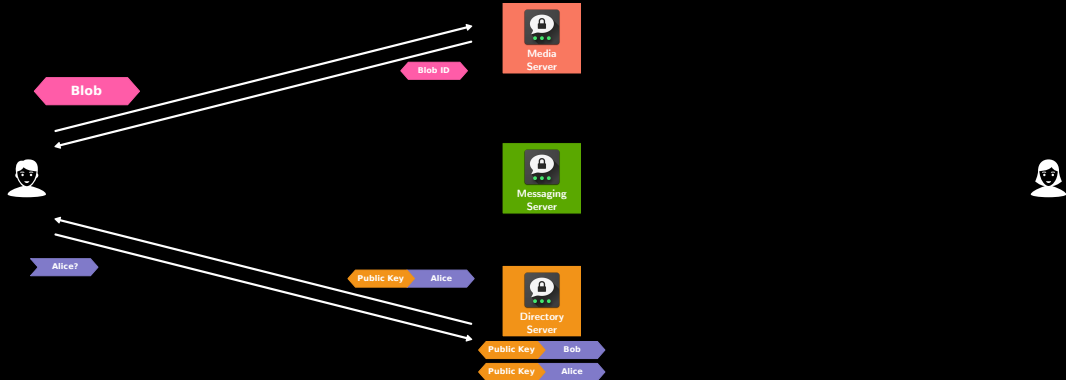


# Sending an Image Message

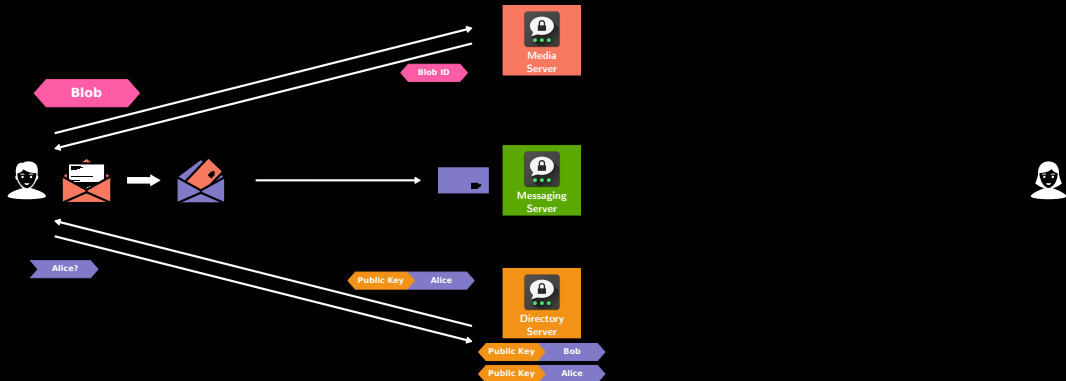




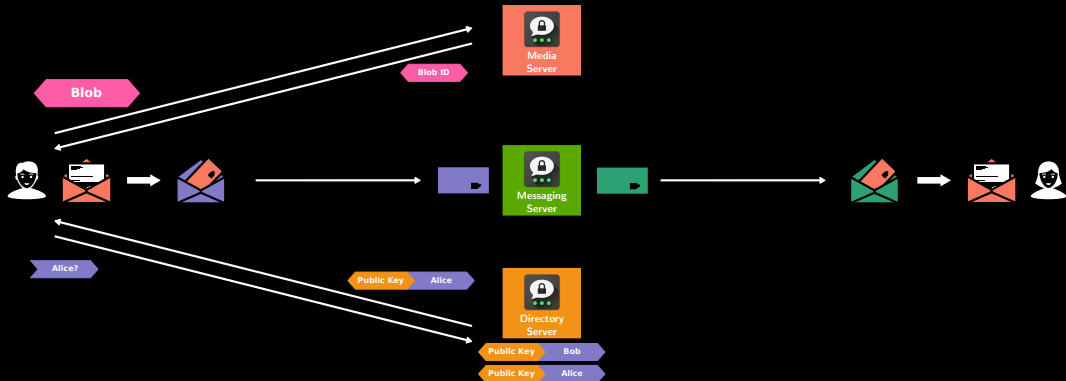
# Sending an Image Message



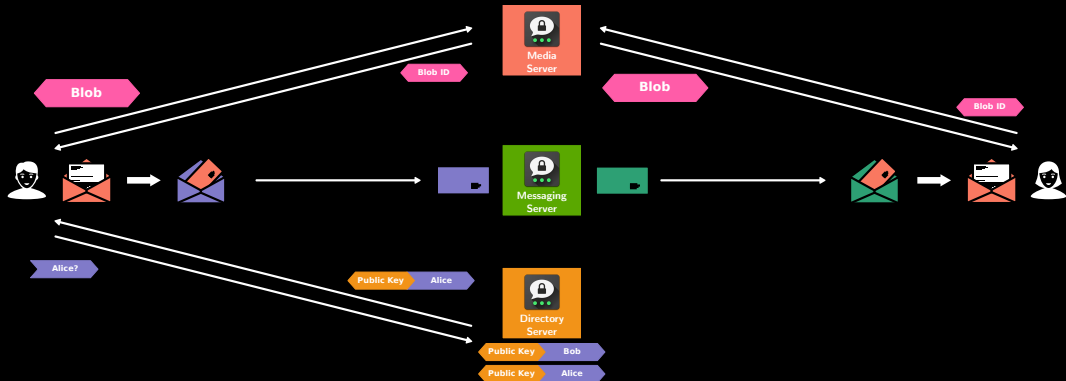
# Sending an Image Message



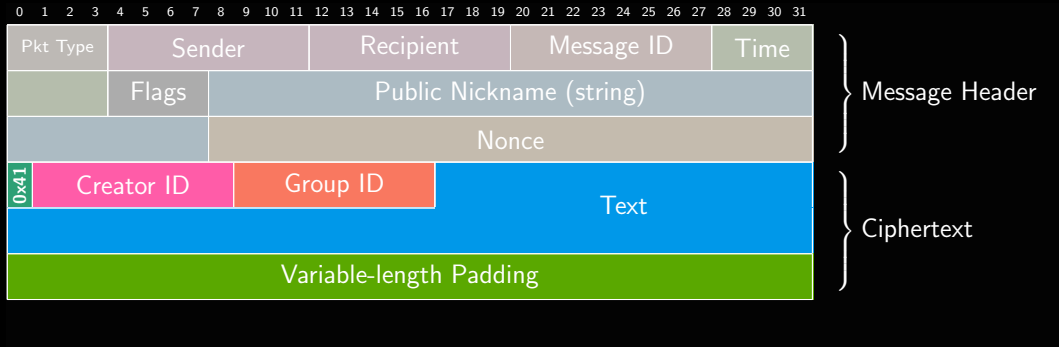
# Sending an Image Message



# Sending an Image Message



# Group Messages



## Group Messages

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- Group IDs aren't unique. They are created locally and only work together with the group creator's ID
- The structure of group messages makes it impossible for Threema to introduce multiple group administrators on a protocol level without breaking compatibility to older clients.

# The Devil's in the Detail

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Sammlung kleinerer Dinge, die uns aufgefallen sind

- Media messages could be StageFright attach vectors
- The protocol implementation looks sound to us but the message design prevents feature upgrades on the protocol (not text-protocol) level

# Threema - Notes and Open Questions

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Notes:

- PFS only on transport layer (attacker sniffing packets from the outside will not learn contents after private key acquisition)

Q:

- How often is the handshake performed?



## Signal Forward and Future Secrecy

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- If you want forward secrecy, you need to use asymmetric crypto and dispose of your keys as often as possible
- To do that you need to perform a new handshake frequently
- Since it is not always given that both parties are online for that handshake, the good people of Whispersystems have come up with this:
  1. Both parties upload a bunch of keys to the server. Those are signed identity keys as we've seen previously and a large number of **prekeys**
  2. Using a prekey, any party can perform their part of the handshake offline and end up with a new session key to use
  3. These session keys are renewed by **ratcheting** with each message transfer

## Signal - Notes

- Server-side cached short-term keys (**prekeys**) fetched by sender
- Pairwise long-lived symmetric secret key between participants
- Multiple messages without answer → perform KDF on **chaining key**
- ECDH: Curve25519, AES-CTR (no padding), AES-CBC (PKCS7 padding)
- HMAC-SHA256 for integrity
- Future secrecy only if private keys are not leaked (duh!). Since private keys go into new shared keys during ratcheting, the attacker lacks material to compromise next key after obtaining current one.
- Since shared keys are only deleted after messages are received, there is a window in which keys could be compromised before reception.
- Deniability is always a theoretical claim as long as a transmission server has the ability to log messages, their senders and recipients.

# Enter Threema

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## Threema

- Gained popularity in Germany after Facebook purchased WhatsApp
- All promise – no proof; first openly contemplating to OSS the code, later backing away from that statement
- Interest in its inner workings

## Quick Shoutouts

- Jan Ahrens for releasing his findings about the handshake before we did
- OpenMittsu for releasing the first working OSS client

## Reverse-Engineering – What to look for?

- Test for common pitfalls in implementation
  - Handling of TLS
  - Handling of keys and nonces
  - NaCl implementation errors
  - Uncommon data leaks
  - Bugs
  - ...?
- Find out how protocol is designed
  1. Understand handshakes
  2. Understand protocol
  3. decipher messages

**Positive side-note:** Threema had released a security white paper early on

Done!

# Thank You!

Roland Schilling

✉ schilling@tuhh.de

🐦 @NerdingByDoing

Frieder Steinmetz

✉ frieder.steinmetz@tuhh.de

🐦 @twillnix

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Beamer Theme: [Metropolis](#) by Matthias vorgelsang

Color Theme: [Owl](#) by Ross Chirchley

Icons: [The BIG collection](#) by Sergey Demushkin

[Foundation Icon Fonts 3](#) by ZURB

Thanks to [Jan Ahrens](#) and [Philipp Berger](#) – their work has made ours somewhat easier

Thanks to [Maximilian Köstler](#) for his initial work on Threema