

# 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

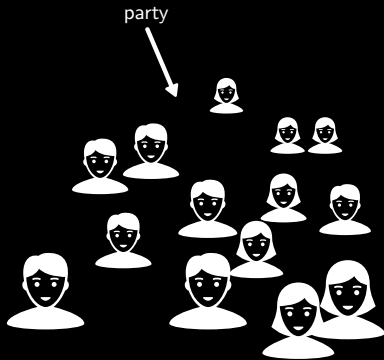
December 22, 2016

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?

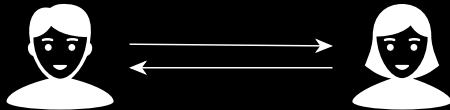


# A Private Room

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

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

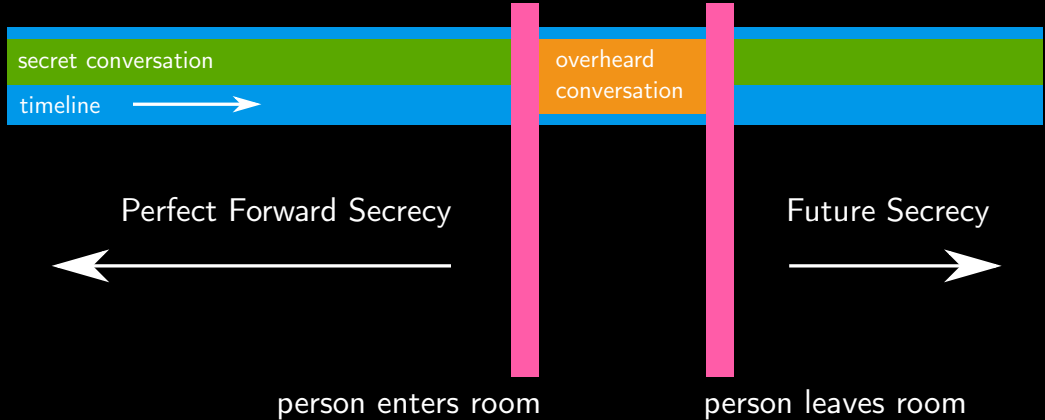
We call this **future secrecy**



# 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**



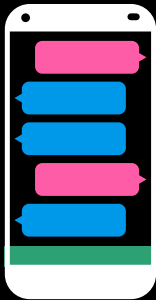
## Messaging – Reality Check



## 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**

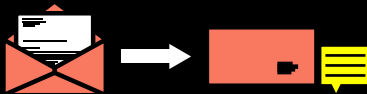
→ Messaging translates badly to our offline communication expectation



# From Postcards to Letters



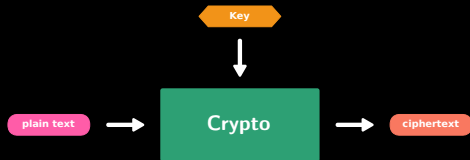
# From Postcards to Letters



# The Shortest Introduction to Encryption You Will Ever Get

Symmetric Encryption:

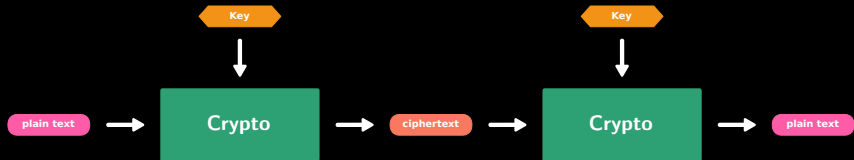
→ Encryption and decryption with the same key



# The Shortest Introduction to Encryption You Will Ever Get

Symmetric Encryption:

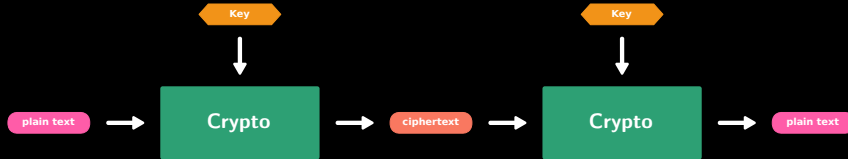
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# The Shortest Introduction to Encryption You Will Ever Get

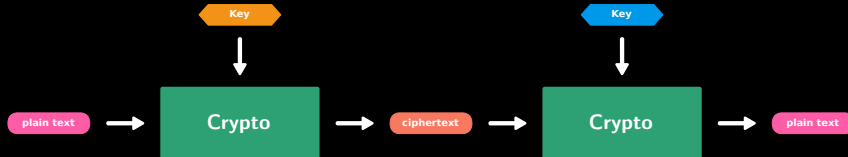
Symmetric Encryption:

→ Encryption and decryption with the same key



Asymmetric Encryption:

→ Encryption and decryption with different keys





# The Shortest Introduction to Encryption You Will Ever Get

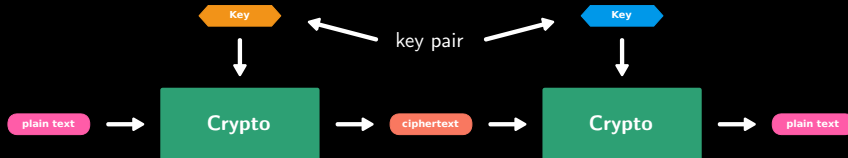
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Asymmetric Encryption:

→ 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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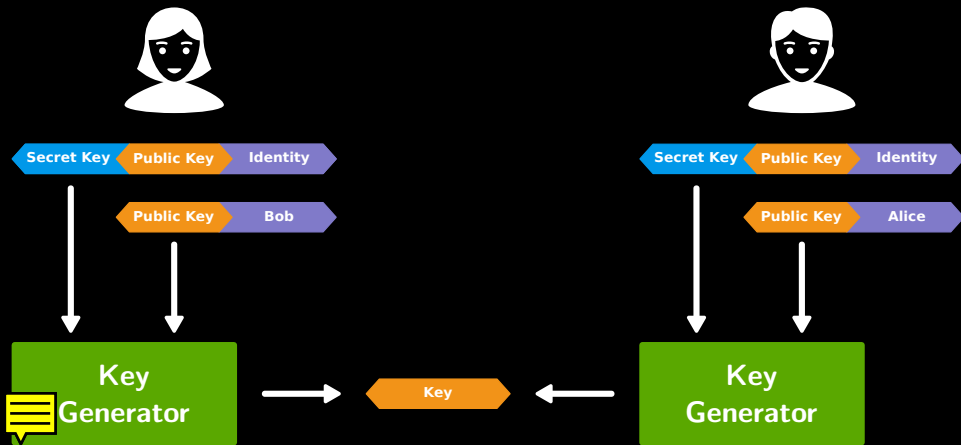
# Public-Key Cryptography – In a Nutshell



- Both parties publish their identities and public keys
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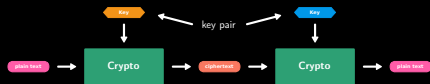


# Authenticated Encryption



# Recap

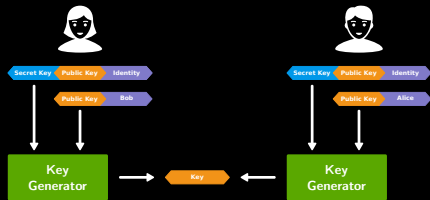
**Asymmetric Encryption** gives us IDs but is very expensive.



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

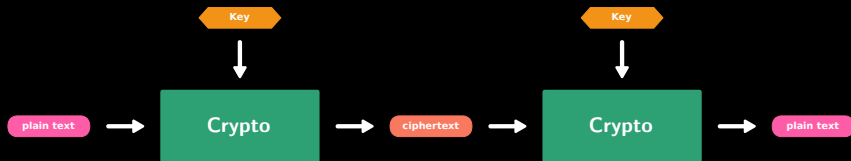


**Authenticated Encryption** allows us to create symmetric keys based on asymmetric key pairs.



But there's more...

# Confidentiality



# Deniability

**From:**  
either of us

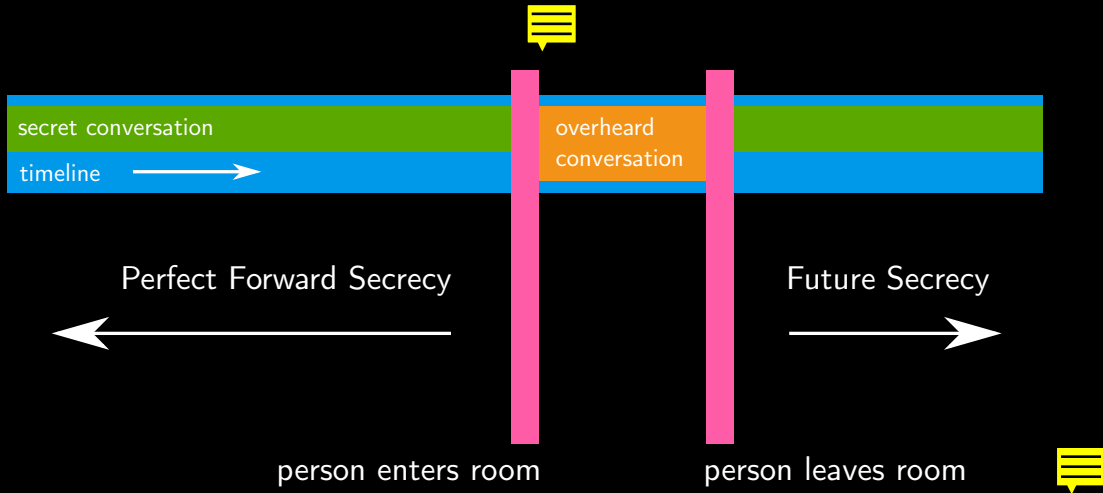


**To:**  
both of us

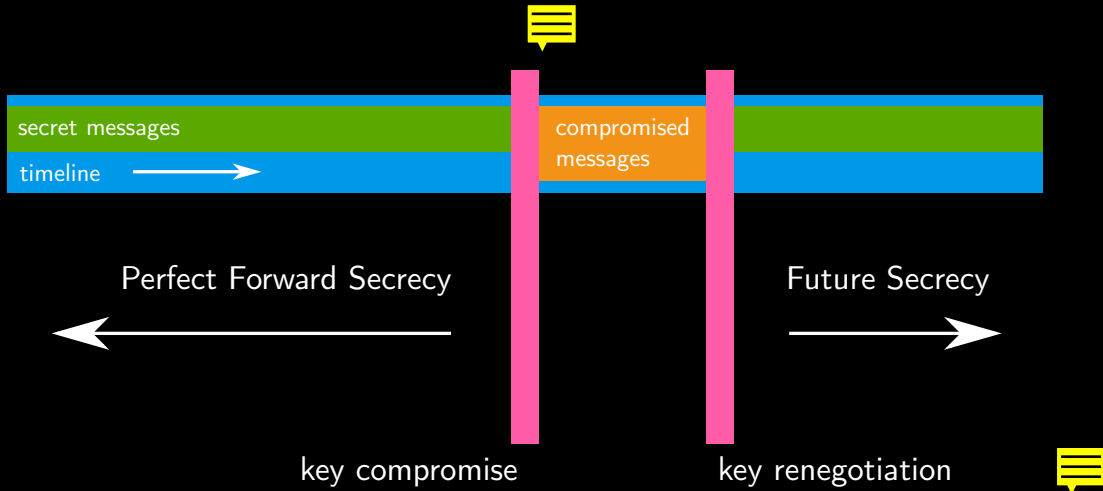




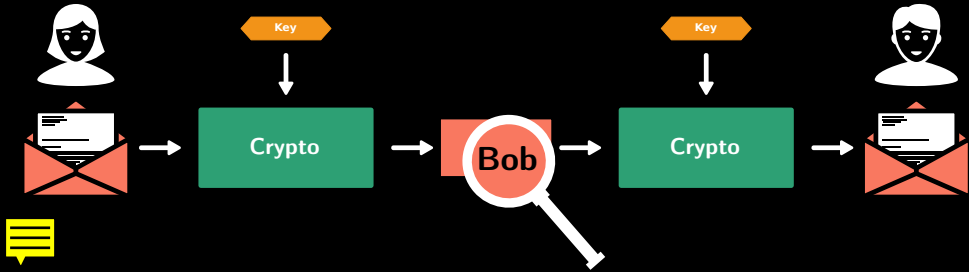
## But What About Forward- and Future Secrecy?



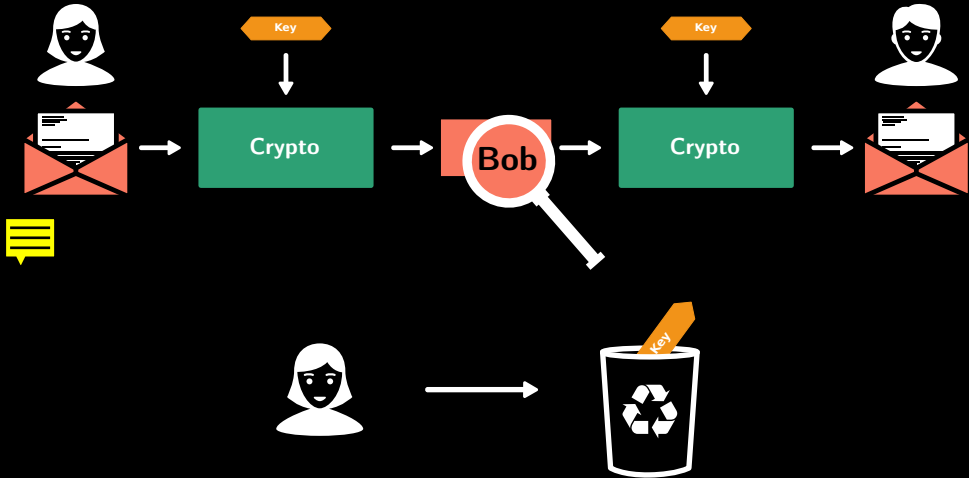
## But What About Forward- and Future Secrecy?



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# Recap

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Authenticated Encryption gives us:

- Confidentiality
- Deniability
- Authenticity

We don't have:

- Perfect Forward Secrecy
- Future Secrecy

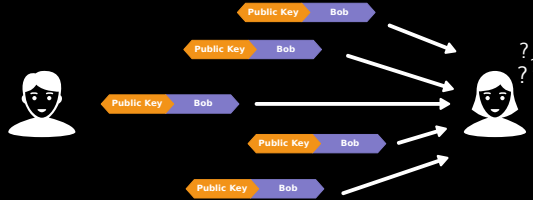
→ We are ignoring Integrity here, but we have that, too.

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.

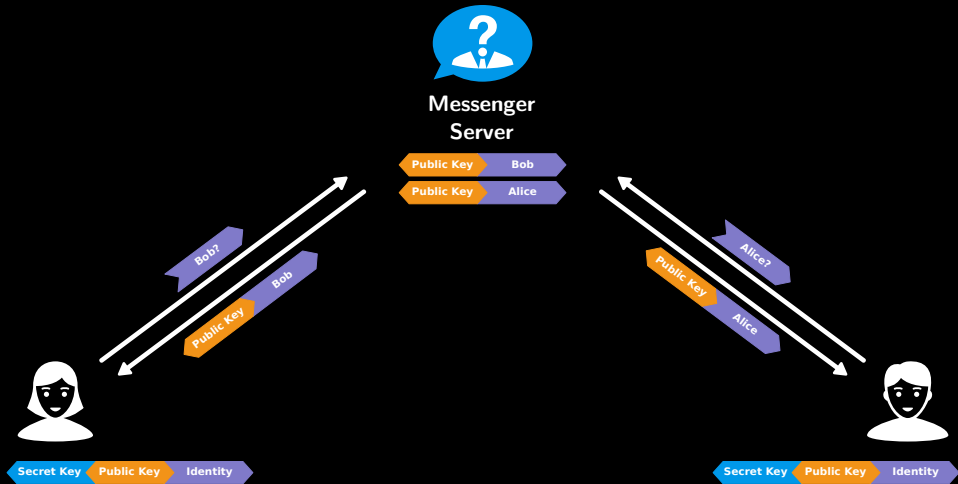
—Dieter Gollmann

# Key Management

How does Alice know which is Bob's public key?

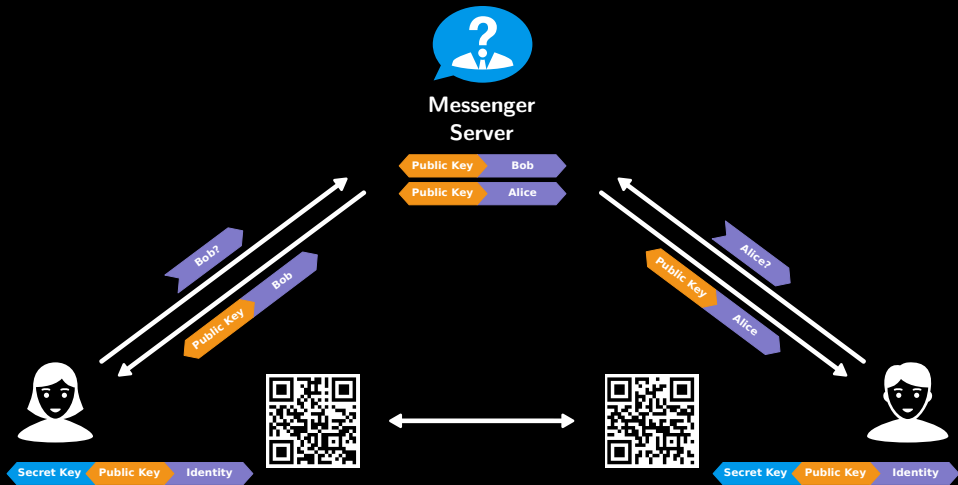


# Mobile Messaging Key Management






# Mobile Messaging Key Management



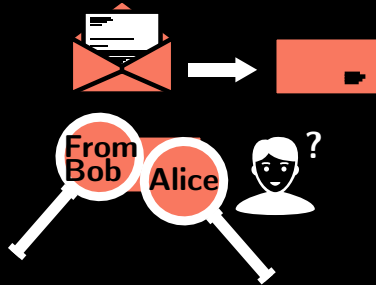
# Authenticity

- 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

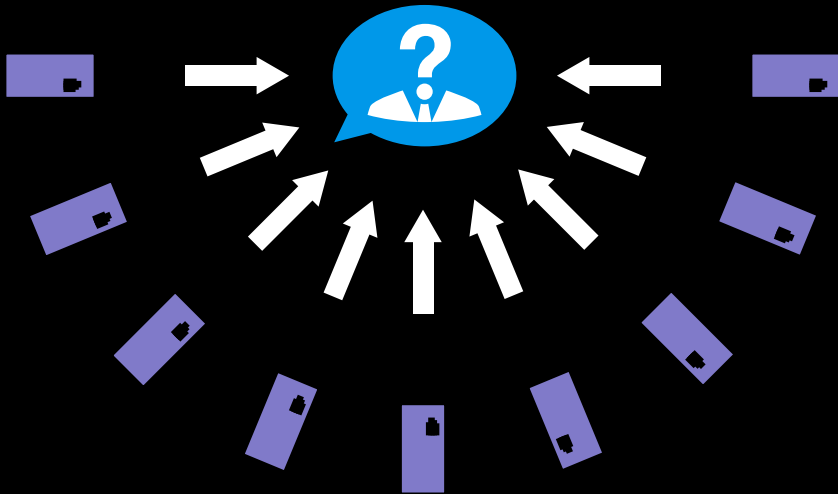


# Metadata Handling

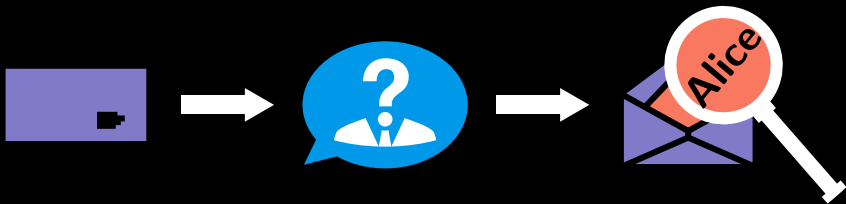
Solution: wrap encrypted message in a second layer of encryption and address it only to the message server.



# Metadata Handling

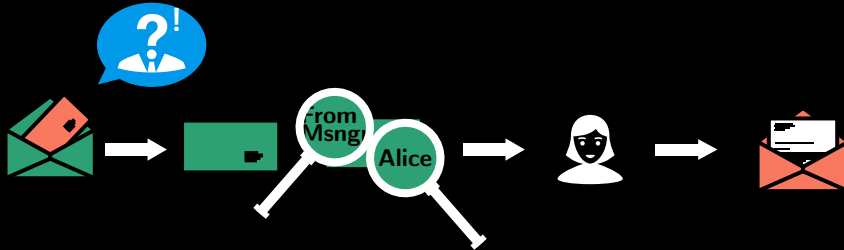


# Metadata Handling



# 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!



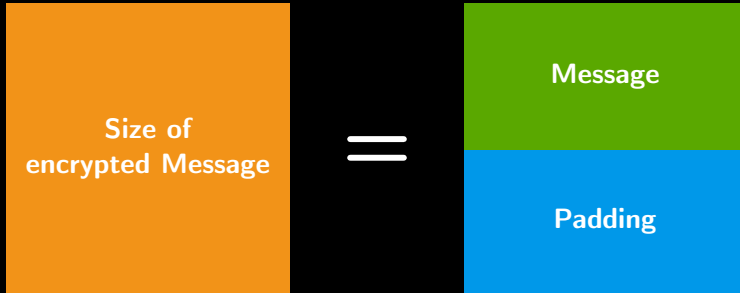
# Metadata Handling

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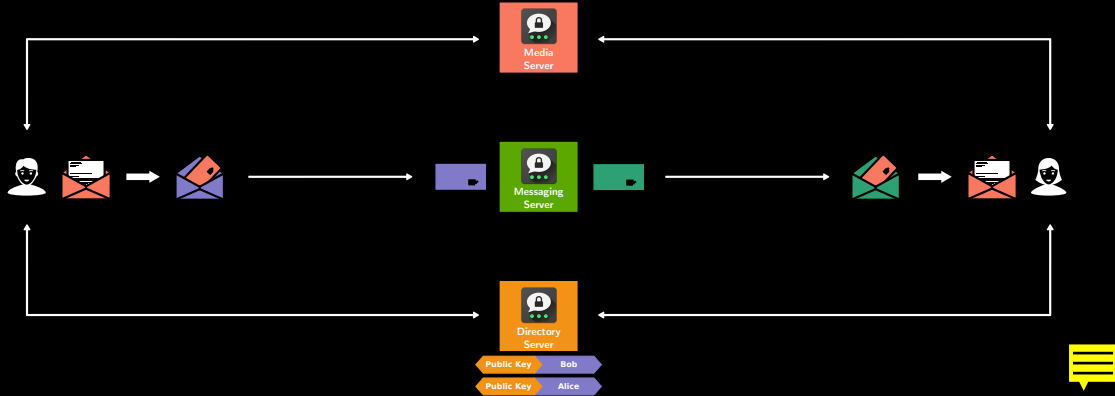
We can obfuscate the size of a message with `padding`

# Metadata Handling

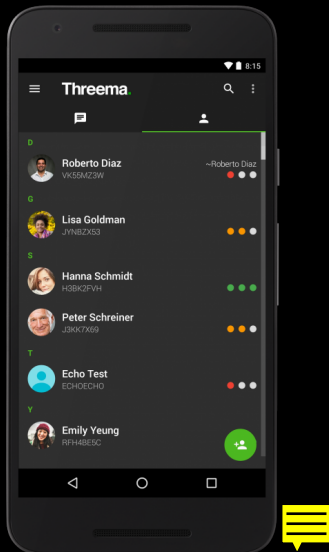
We can obfuscate the size of a message with **padding**



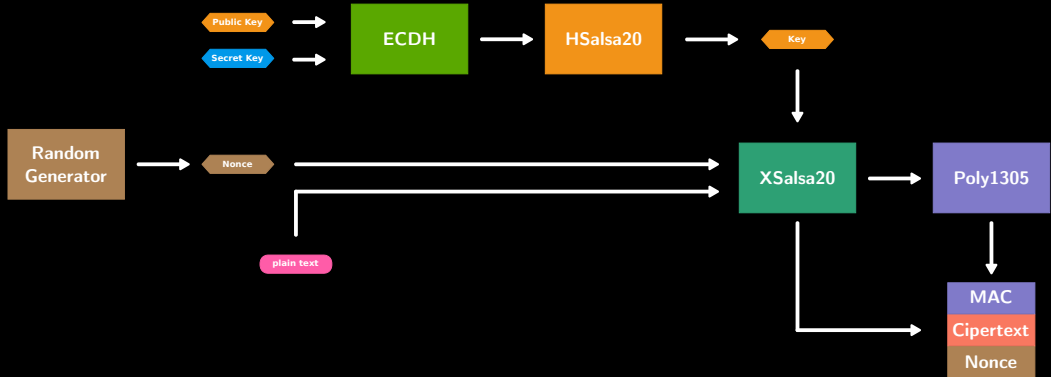
# Threema's Architecture



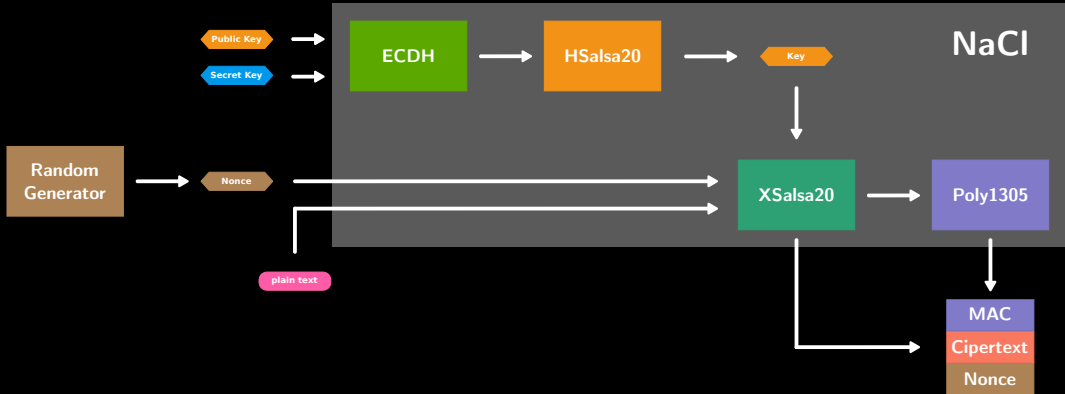
# Threema Fingerprints



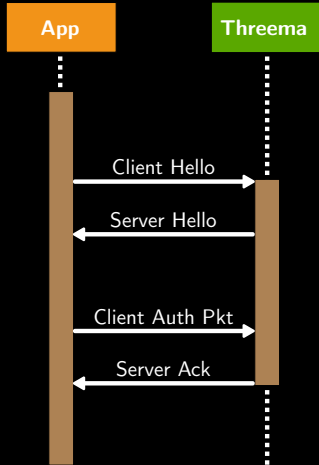
# NaCl and Threema



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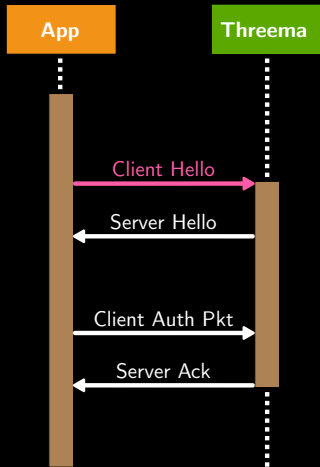


# Threema's App-to-Server Handshake

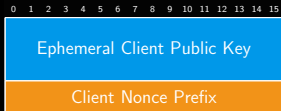


Initial Text goes here

# Threema's App-to-Server Handshake



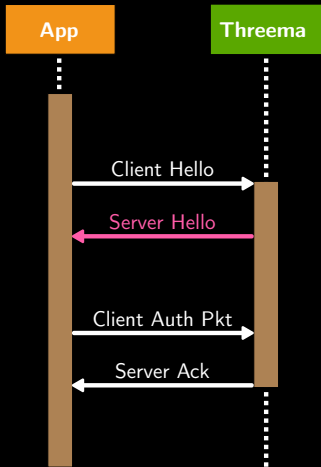
## Client Hello Packet



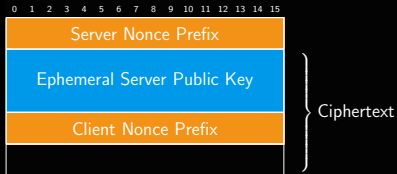
- Client generates a **ephemeral** key pair
- Client generates random nonce prefix



# Threema's App-to-Server Handshake



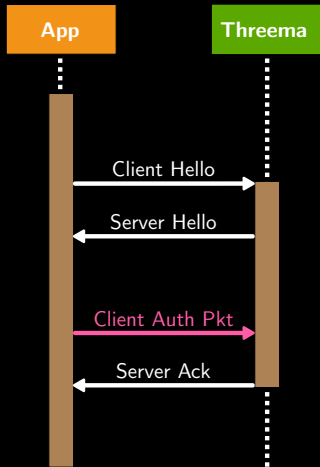
## Server Hello Packet



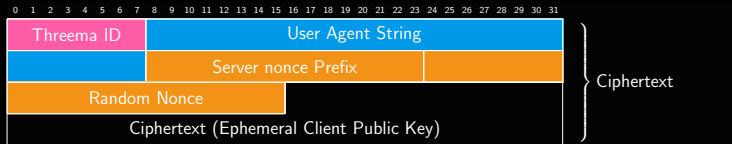
- Server generates ephemeral key pair
- Server generates random nonce
- Ciphertext encrypted with Server Nonce, Client Ephemeral Key and Server Long-Term Key



# Threema's App-to-Server Handshake

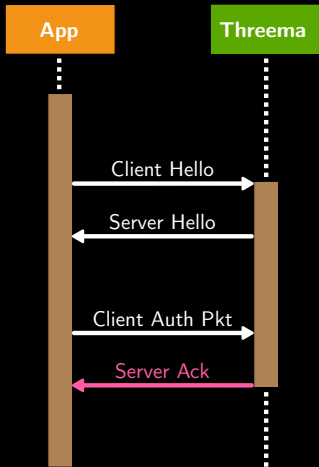


## Client Authentication Packet

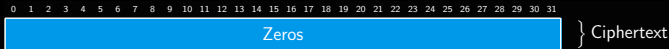


- Outer Encryption with ephemeral Keys
- Ciphertext links clients ephemeral key pair to it's long term key pair

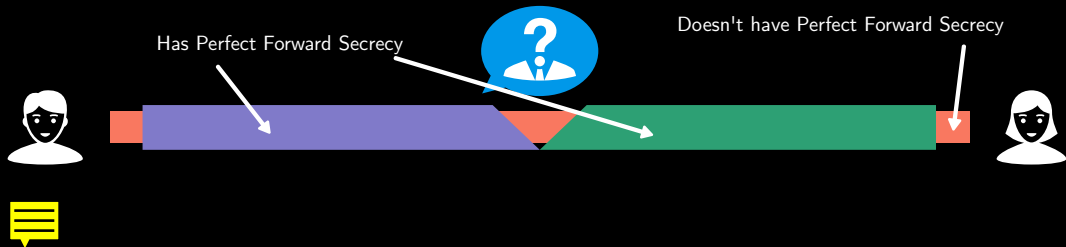
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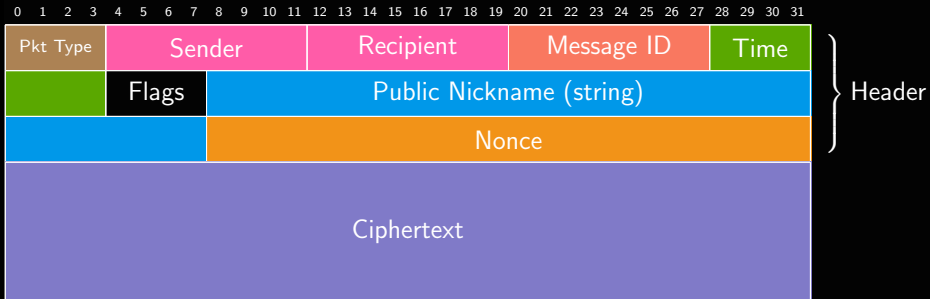
## Server Acknowledgement Packet



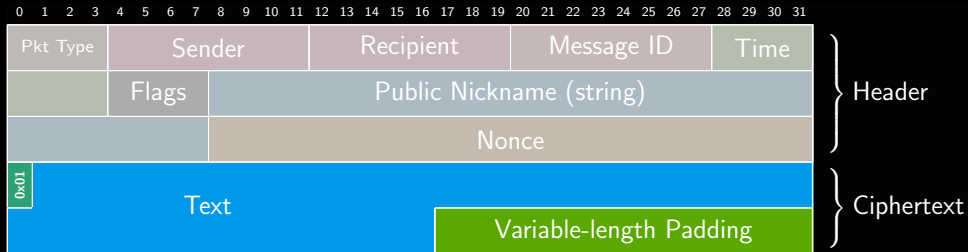
- Server confirms everything worked fine by encrypting something with both ephemeral keys



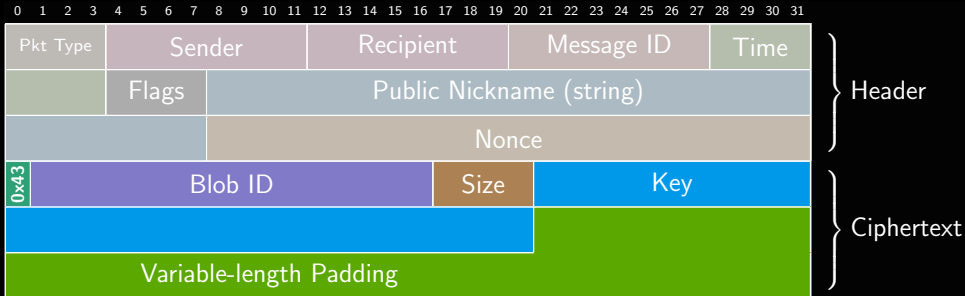
# Threema Packet Format



# Threema Text Messages



# Threema Image Messages



# Sending an Image Message



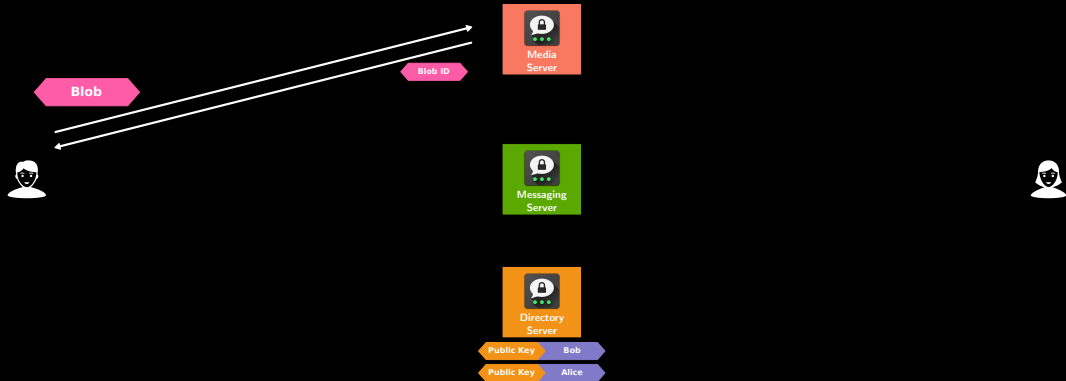
Public Key Bob

Public Key Alice

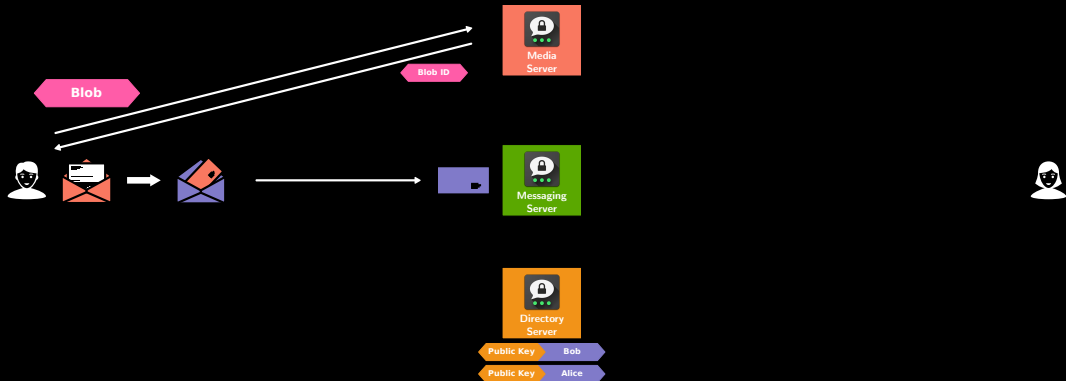




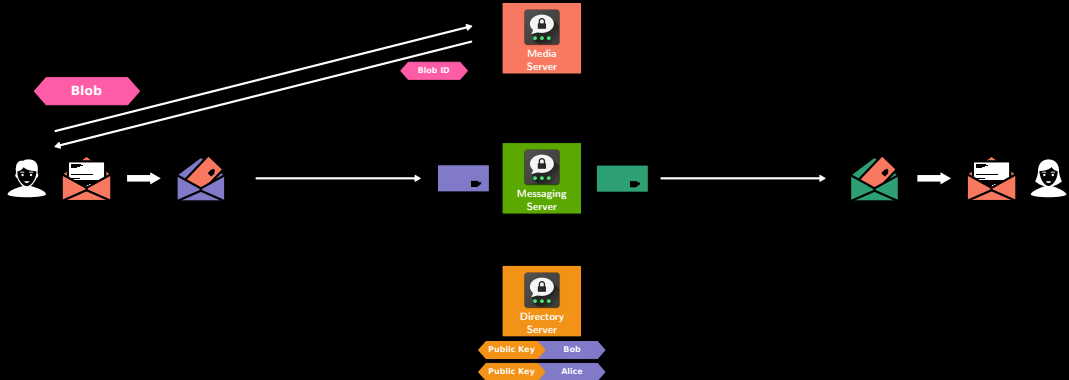
# Sending an Image Message



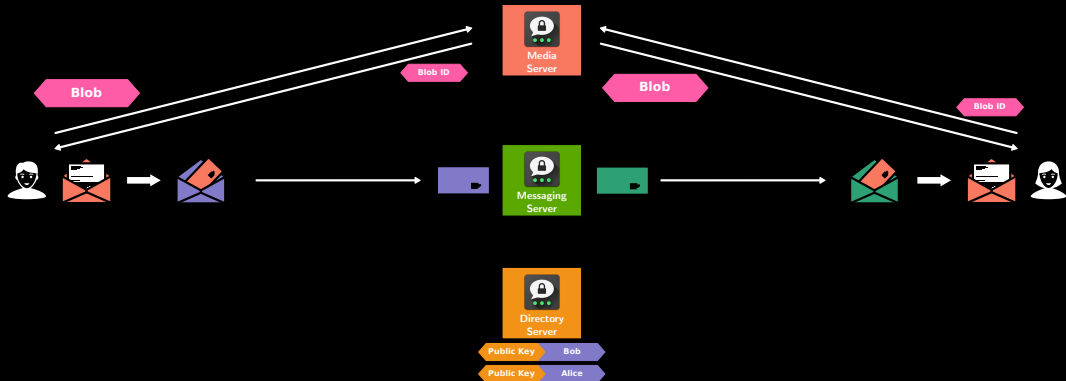
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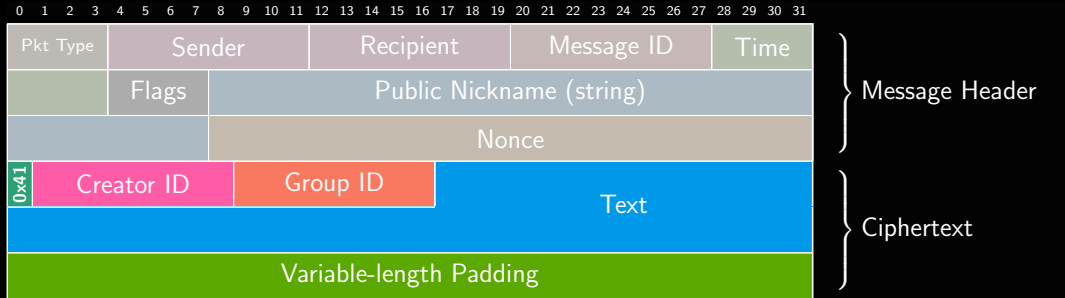


## Recap

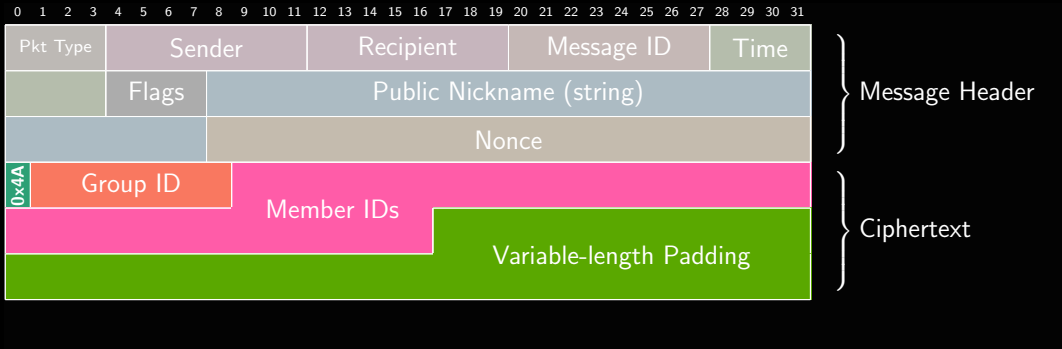
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Basic messaging functionality achieved.

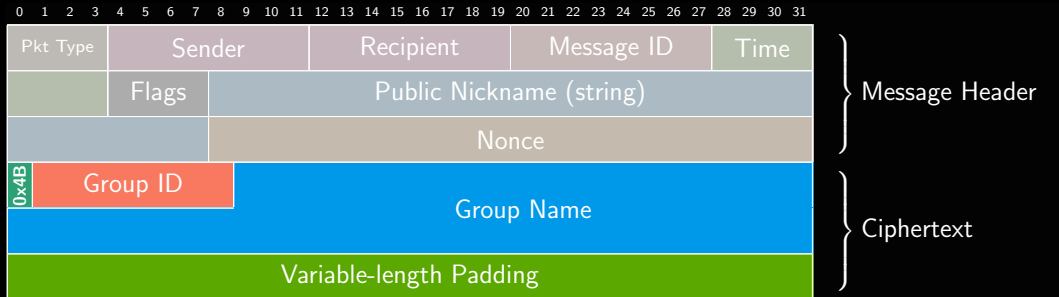
# Group Messages



# Group Messages



# Group Messages





# Implementation of Addon Features

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# 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

## 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



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[@twillnix](https://twitter.com/twillnix)

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

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

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

[Foundation Icon Fonts 3](#) by ZURB

NaCl slide was adapted from a figure in Threema's [Cryptography Whitepaper](#)

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