

A look into the Mobile Messaging Black Box

33rd Chaos Communication Congress #33c3

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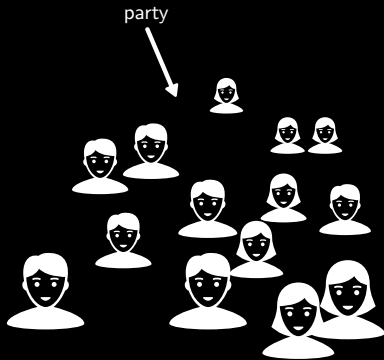
December 22, 2016

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?

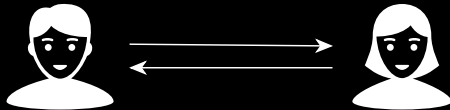


A Private Room

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

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

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

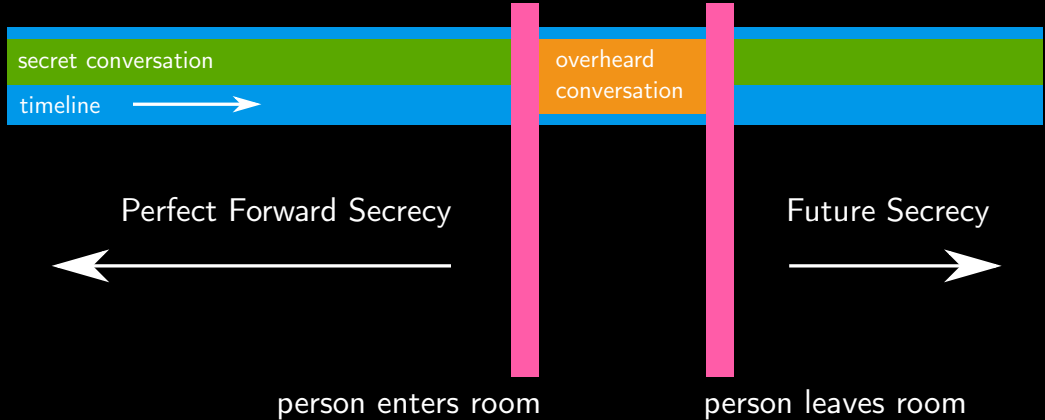
We call this **future secrecy**



It's a One-Time Talk



Perfect Forward- and Future Secrecy



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

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**

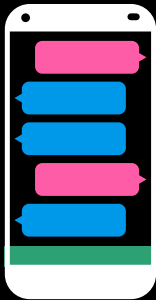
Messaging – Reality Check



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**

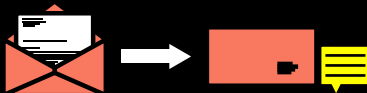
→ Messaging translates badly to our offline communication expectation



From Postcards to Letters



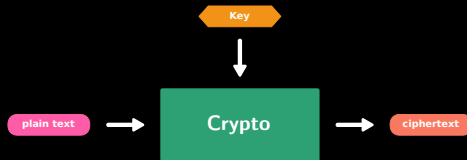
From Postcards to Letters



The Shortest Introduction to Encryption You Will Ever Get

Symmetric Encryption:

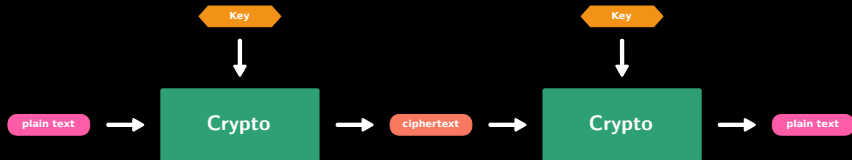
→ Encryption and decryption with the same key



The Shortest Introduction to Encryption You Will Ever Get

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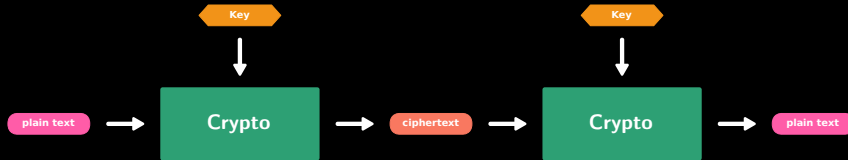
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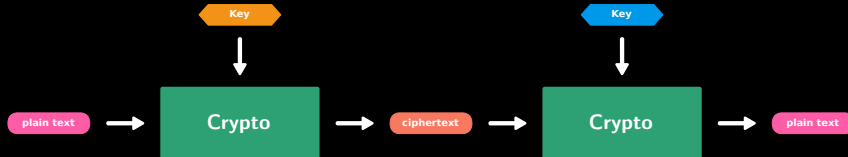
Symmetric Encryption:

→ Encryption and decryption with the same key



Asymmetric Encryption:

→ Encryption and decryption with different keys



The Shortest Introduction to Encryption You Will Ever Get

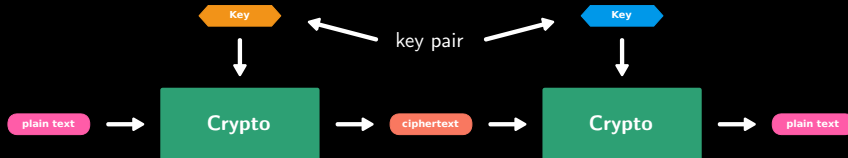
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Asymmetric Encryption:

→ 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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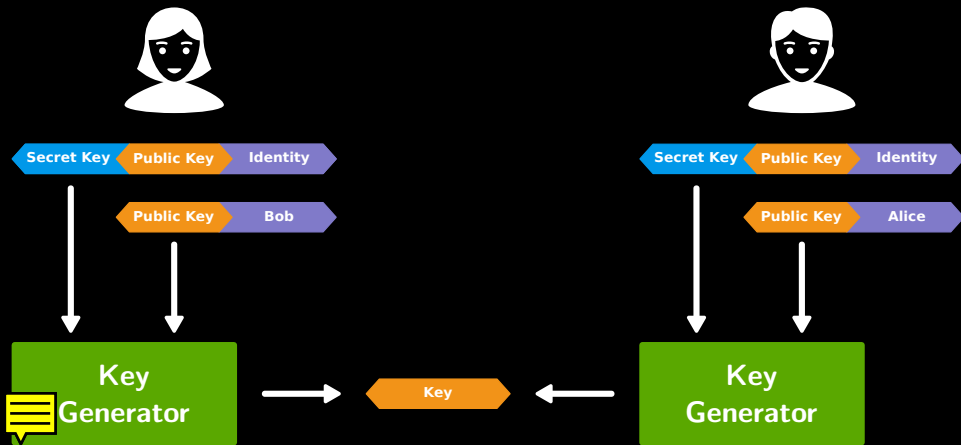
Public-Key Cryptography – In a Nutshell



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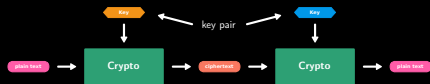


Authenticated Encryption



Recap

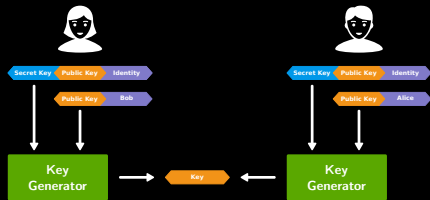
Asymmetric Encryption gives us IDs but is very expensive.



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

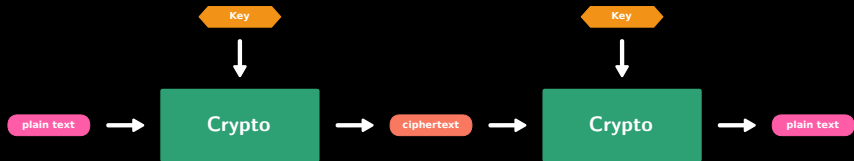


Authenticated Encryption allows us to create symmetric keys based on asymmetric key pairs.



But there's more...

Confidentiality



Deniability

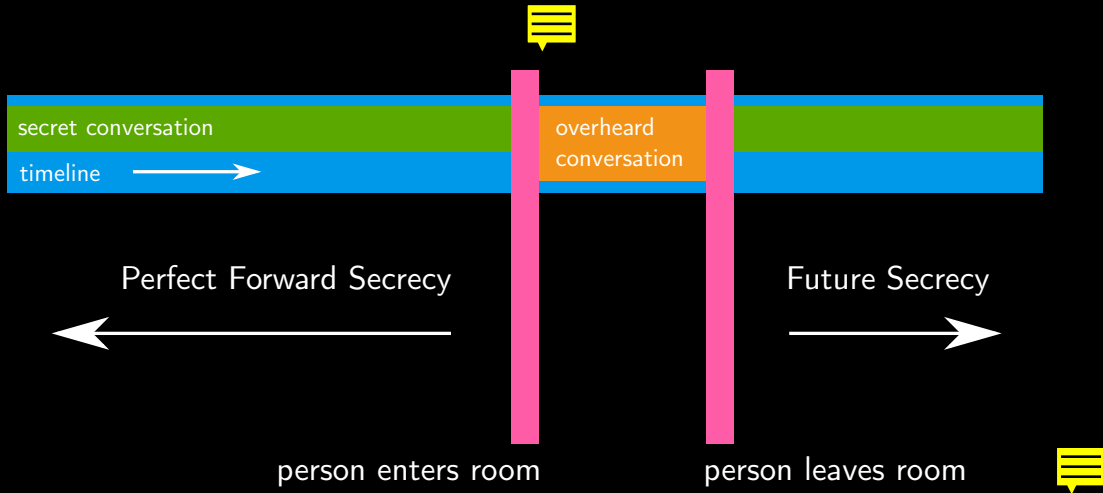
From:
either of us



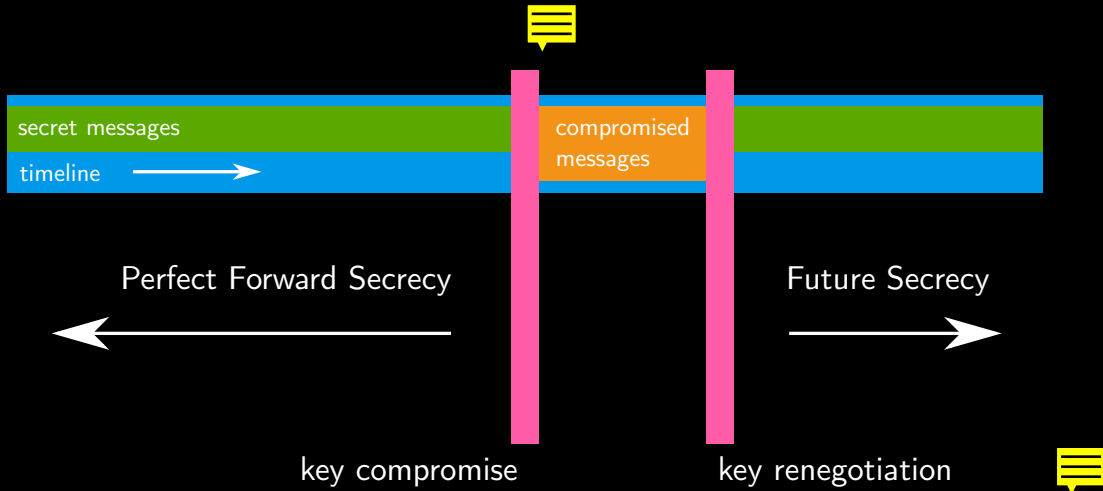
To:
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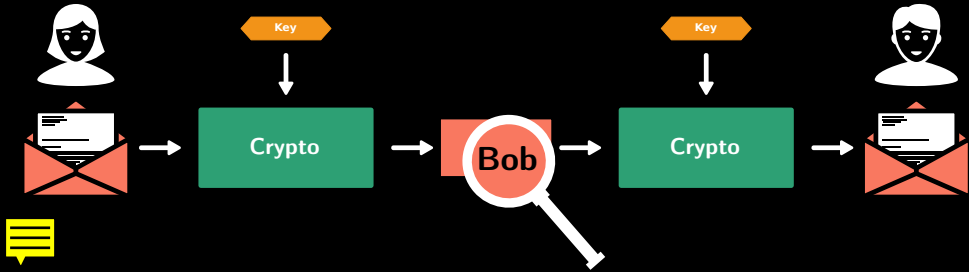
But What About Forward- and Future Secrecy?



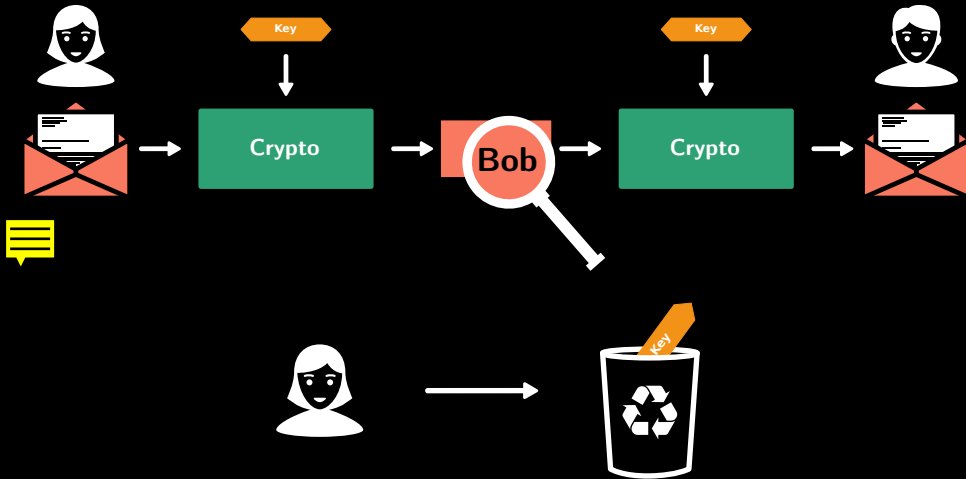
But What About Forward- and Future Secrecy?



But What About Forward- and Future Secrecy?



But What About Forward- and Future Secrecy?



Recap

Authenticated Encryption gives us:

- Confidentiality
- Deniability
- Authenticity

We don't have:

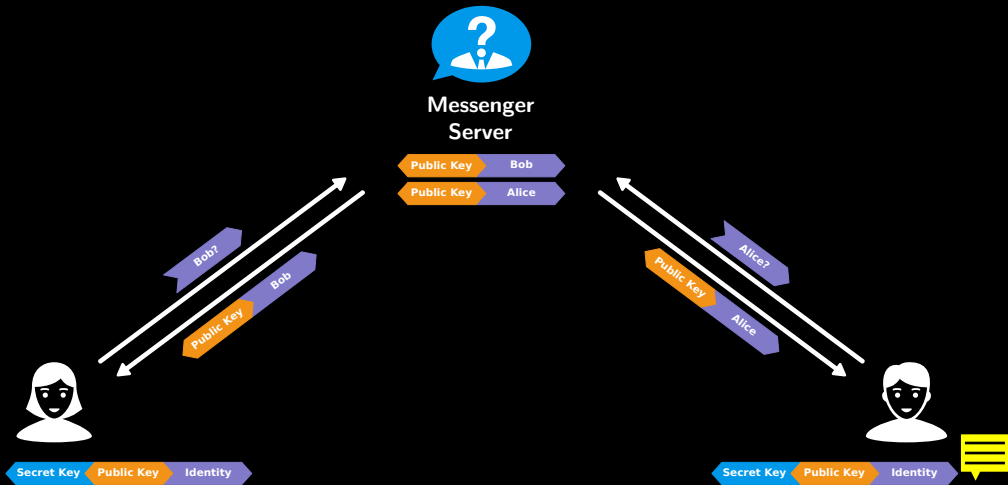
- Perfect Forward Secrecy
- Future Secrecy

→ 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 and ID Management



Key and ID Management

We can ask for IDs, but what is an ID?

- A phone number?
- An email address?
- Something else?

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 - Dedicated IDs offer anonymous usage, but ID ownership must be verifiable.

Key and ID Management

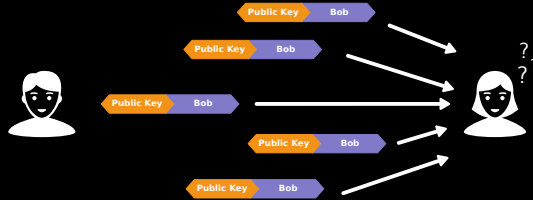
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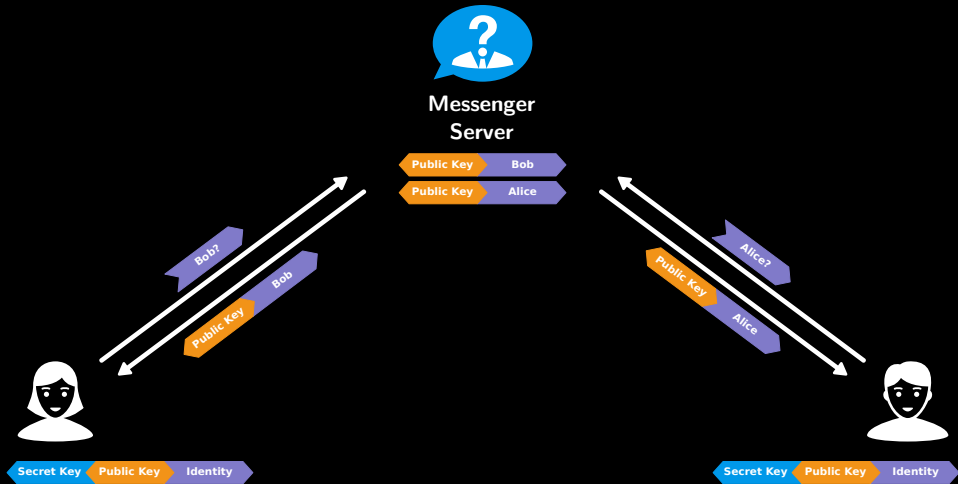
→ Dedicated IDs are preferable. But only if we find a way to verify ID ownership

Key and ID Management

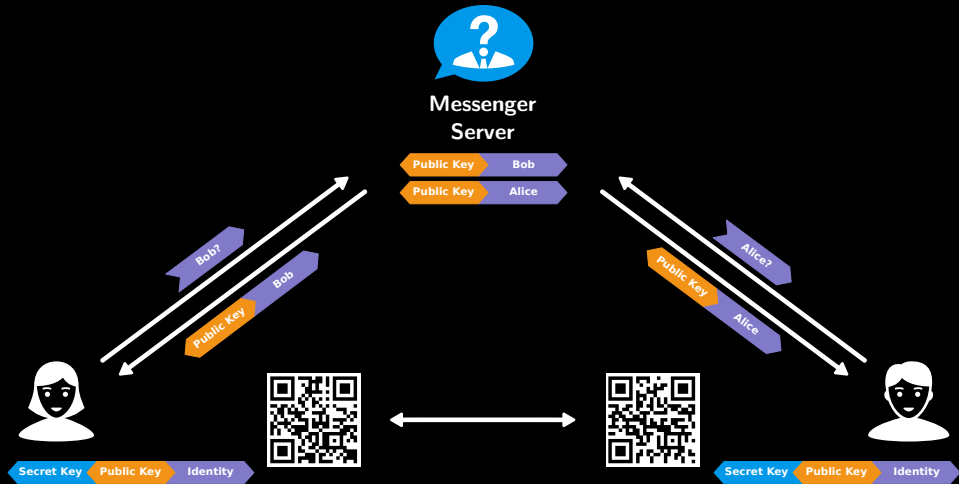
How does Alice know which is Bob's public key?




Mobile Messaging Key Management



Mobile Messaging Key Management



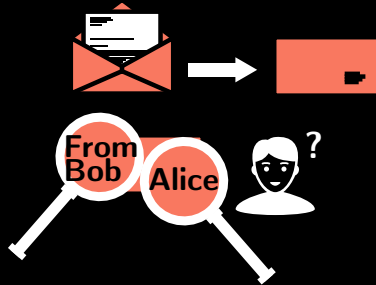
Authenticity

- 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

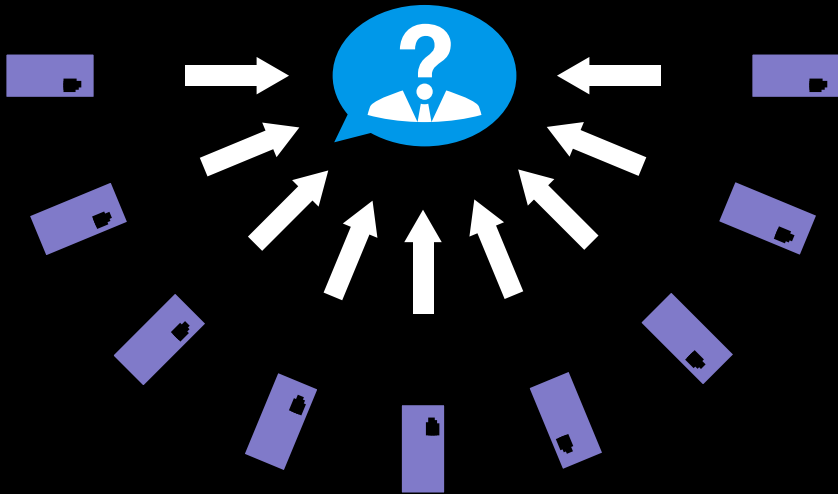


Metadata Handling

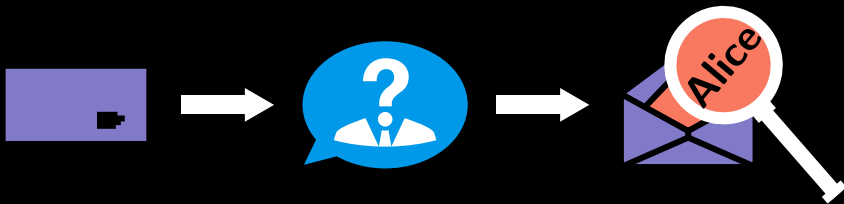
Solution: wrap encrypted message in a second layer of encryption and address it only to the message server.



Metadata Handling

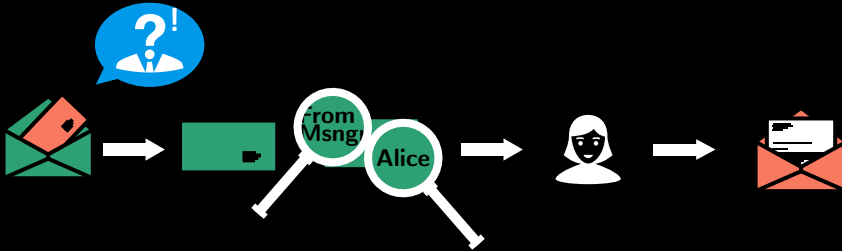


Metadata Handling



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.



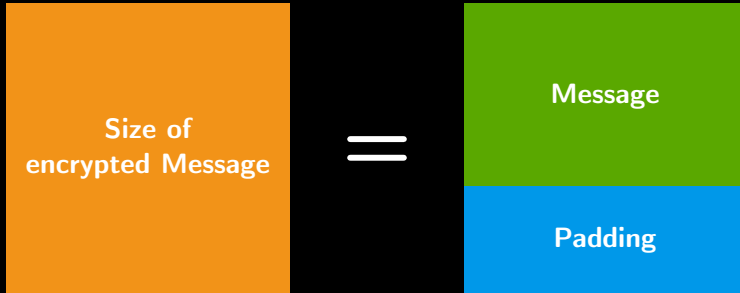
The message server still knows both communication partners!

Metadata Handling

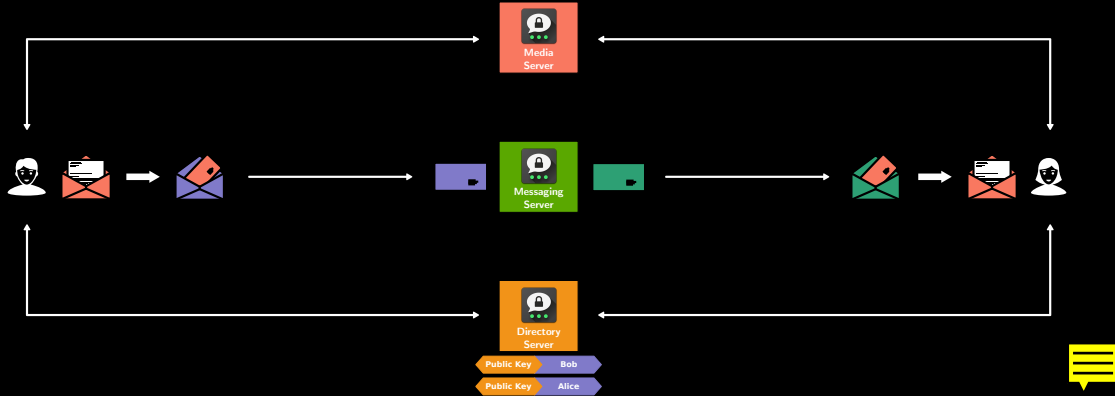
We can obfuscate the size of a message with `padding`

Metadata Handling

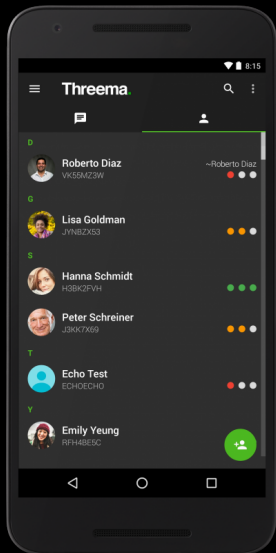
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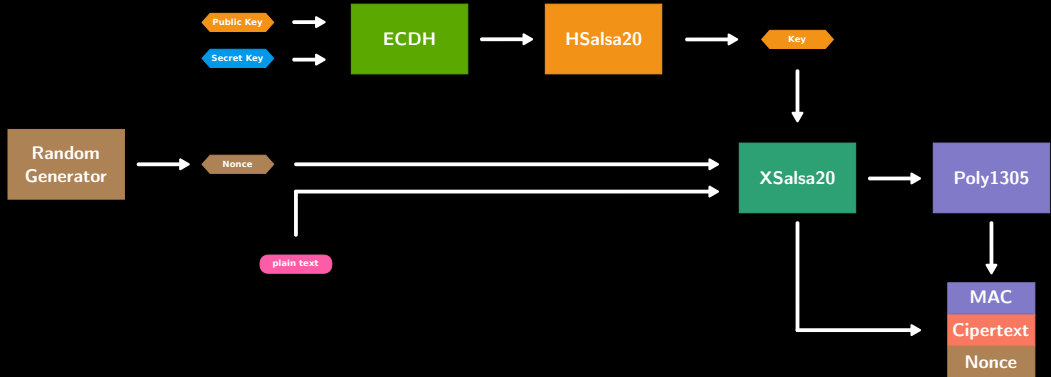
Threema's Architecture



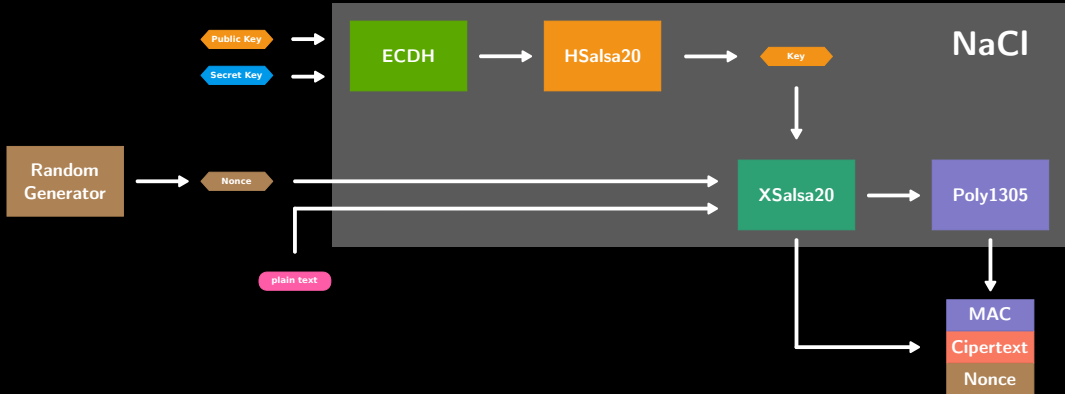
Threema Fingerprints



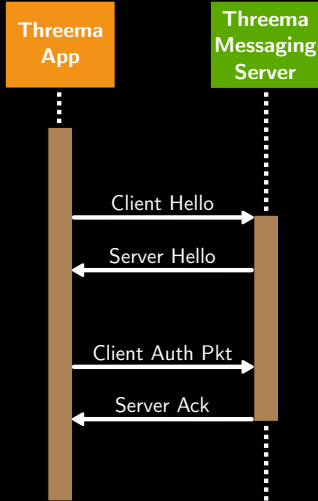
NaCl and Threema



NaCl and Threema

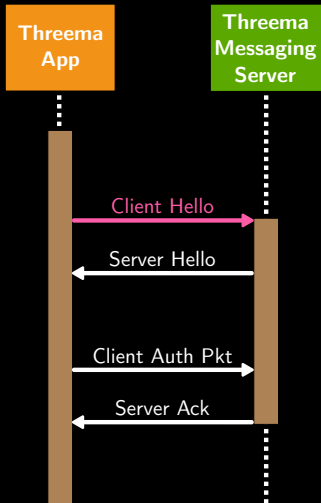


Threema's Handshake Between the App and the Messaging Server

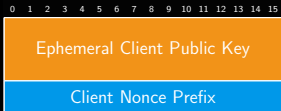


Exchange a set of **ephemeral keys** and verify each others long term identity keys.

Threema's Handshake Between the App and the Messaging Server

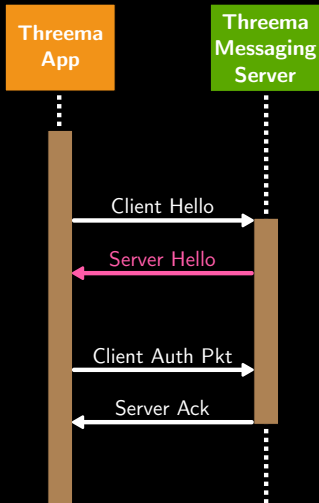


Client Hello Packet

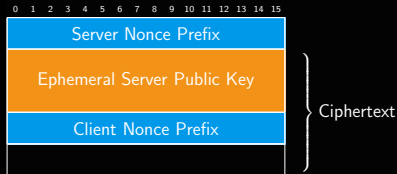


- Client generates a **ephemeral key** pair
- Client generates random nonce prefix

Threema's Handshake Between the App and the Messaging Server



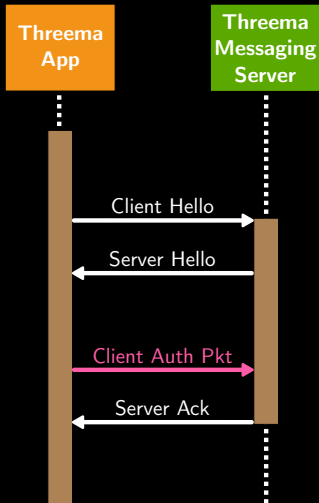
Server Hello Packet



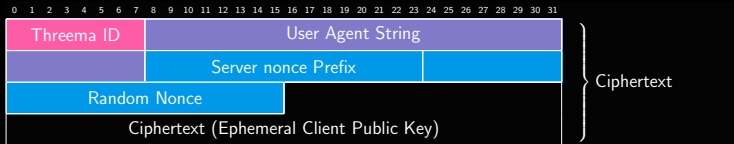
- Server generates ephemeral key pair
- Server generates random nonce
- Ciphertext encrypted with Server Nonce, Client Ephemeral Key and Server Long-Term Key



Threema's Handshake Between the App and the Messaging Server

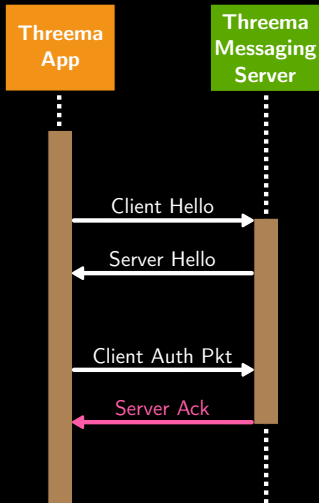


Client Authentication Packet

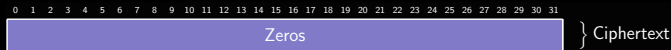


- Outer Encryption with **ephemeral Keys**
- Ciphertext links clients **ephemeral key** pair to it's long term key pair

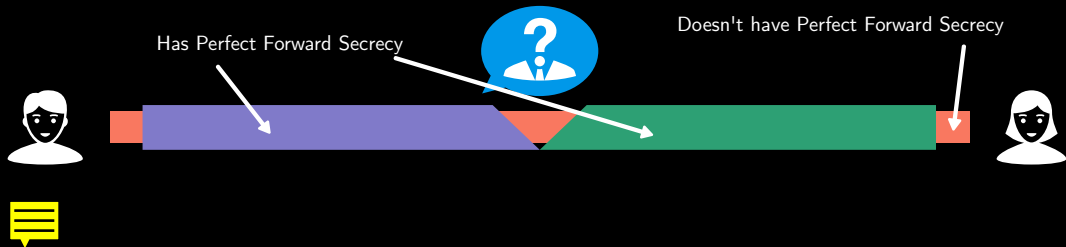
Threema's Handshake Between the App and the Messaging Server



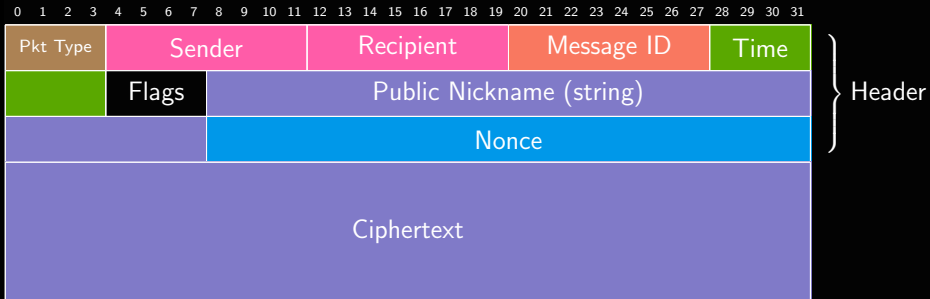
Server Acknowledgement Packet



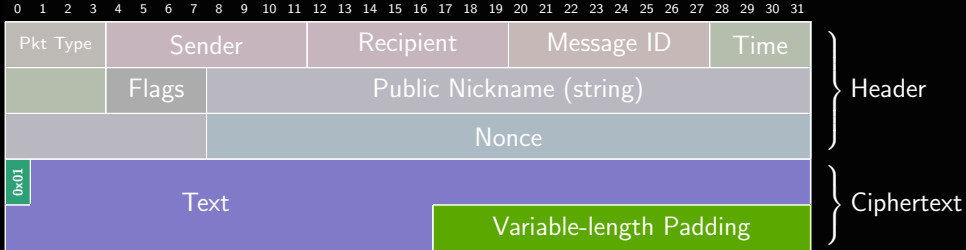
- Server confirms everything worked fine by encrypting something with both **ephemeral keys**
- We have established a forward secure channel between app and messaging server.



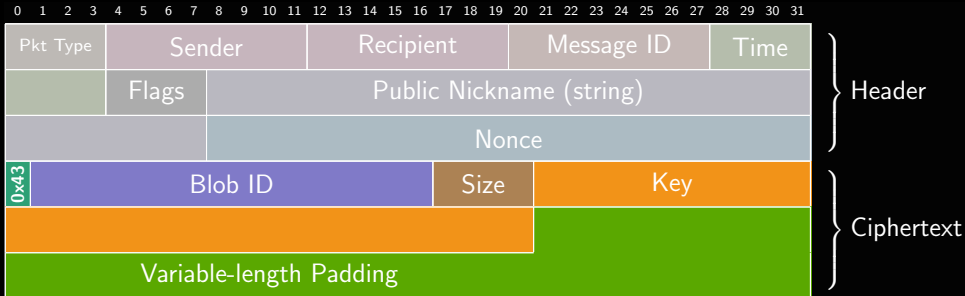
Threema Packet Format



Threema Text Messages



Threema Image Messages



Sending an Image Message

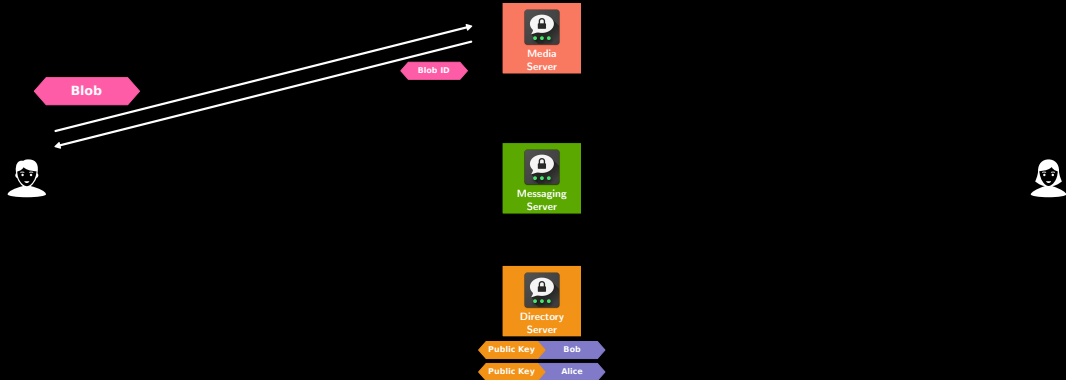


Public Key Bob

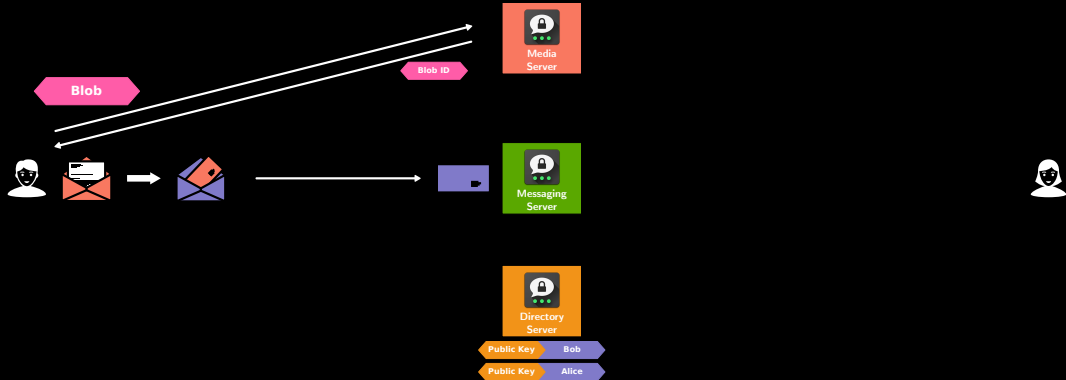
Public Key Alice



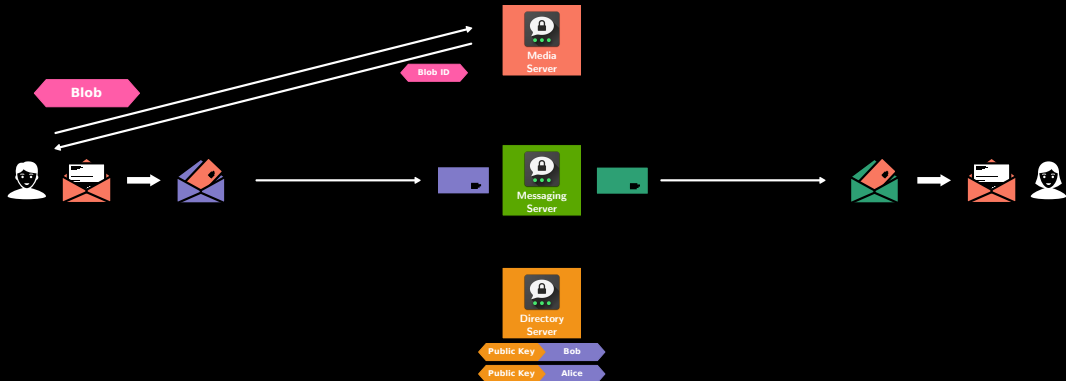
Sending an Image Message



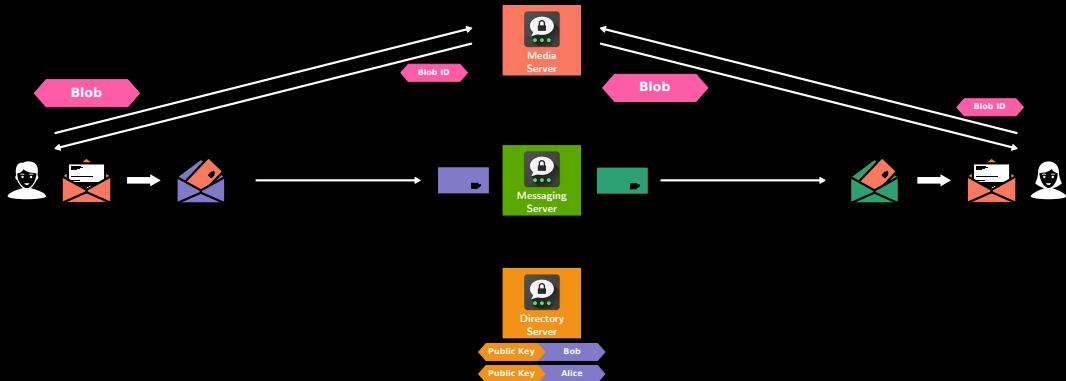
Sending an Image Message



Sending an Image Message



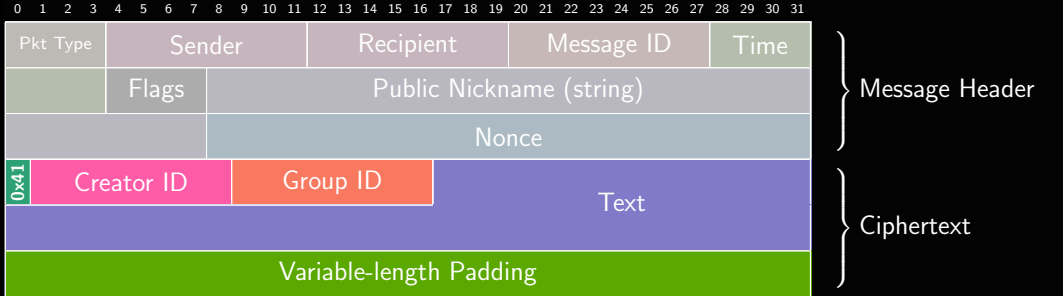
Sending an Image Message



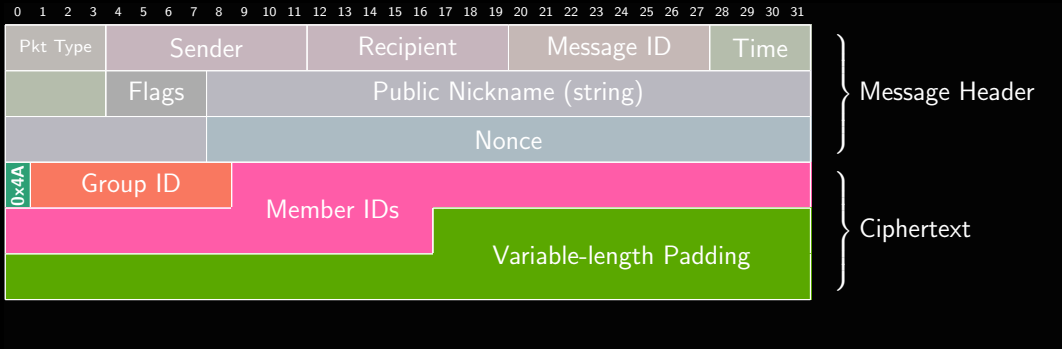
Recap

Basic messaging functionality achieved.

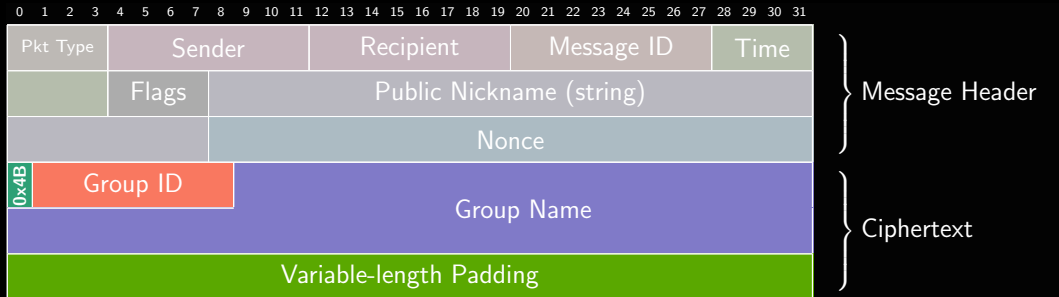
Group Messages



Group Messages



Group Messages



Implementation of Addon Features

The Devil's in the Detail

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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Frieder Steinmetz



frieder.steinmetz@tuhh.de



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

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

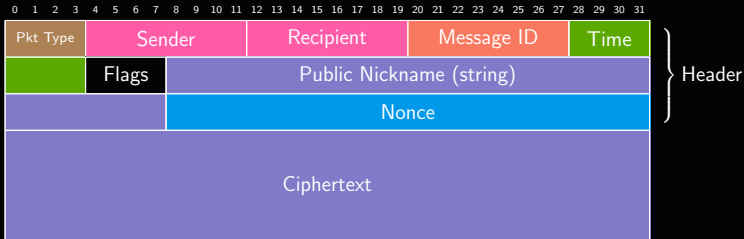
NaCl slide was adapted from a figure in Threema's [Cryptography Whitepaper](#)

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

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

Appendix

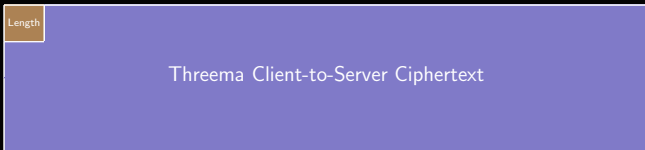
Message Packet (Threema Protocol Layer)



- Only the MSB of *Flags* is used

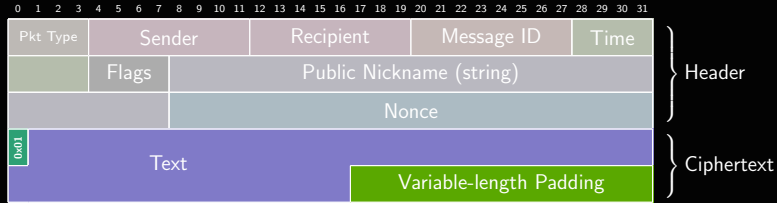
Message Packet on the Wire

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31



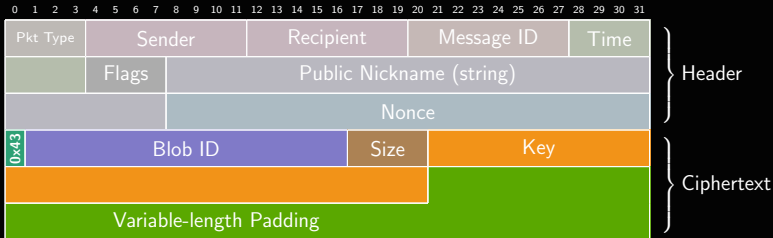
Appendix

Text Message



Appendix

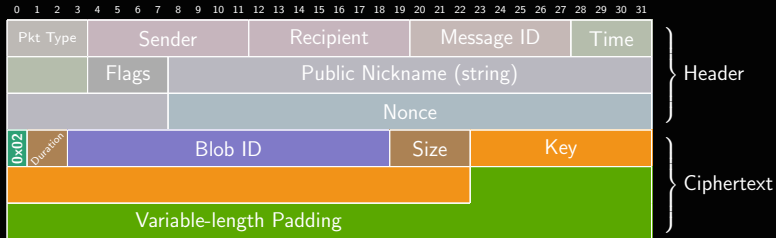
Image Message



- Blob is symmetrically encrypted using *Key* and uploaded to asset server.
- Image captions are stored inside the image's EXIF data. These data leak upon creating such an image while the "save media to gallery" option is enabled.

Appendix

Audio Message



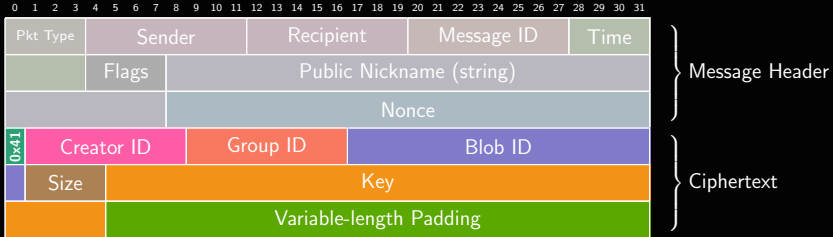
Appendix

Group Message Packet



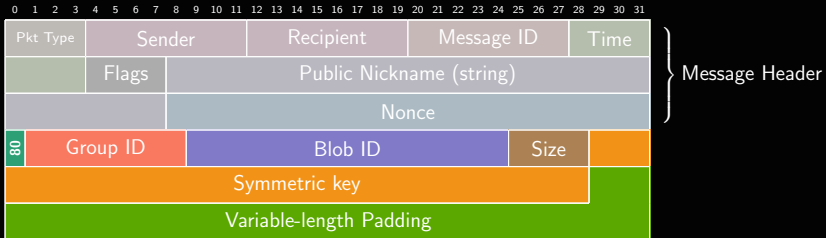
Appendix

Group Image Message

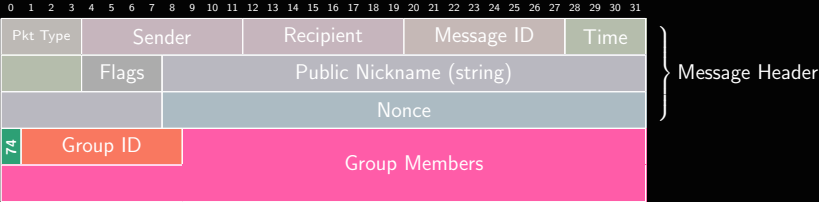


Appendix

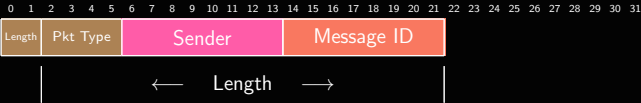
Group Picture Update



Create/Update Group (members)



Acknowledgement Packet to Server



Appendix

Client-Server Handshake

Client Hello

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Ephemeral Client Public Key

Client Nonce Prefix

Server Hello

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Server Nonce Prefix

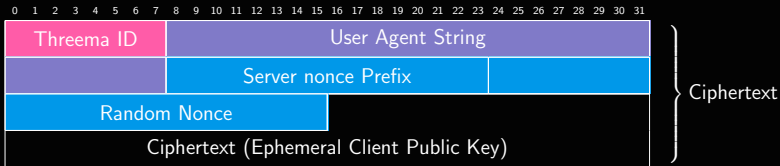
Ephemeral Server Public Key

Client Nonce Prefix

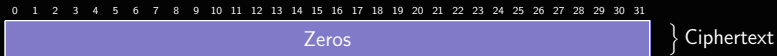
Ciphertext

Appendix

Client Authentication Packet



Server Acknowledgement

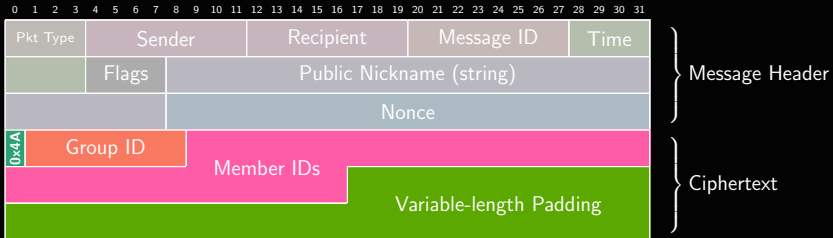


PKCS7 Padding

														03	03	03
													04	04	04	04
							08	08	08	08	08	08	08	08	08	08
16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
												05	05	05	05	05
											06	06	06	06	06	06

Appendix

Group Management Message - Add Users



Appendix

Group Management Message - Rename Group

