A look into the Mobile Messaging Black Box

33rd Chaos Commmunication Congress #33c3

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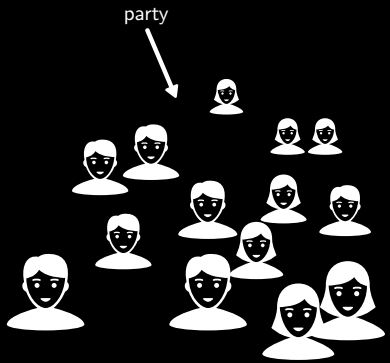
Hamburg University of Technology
Security in Distributed Applications

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?

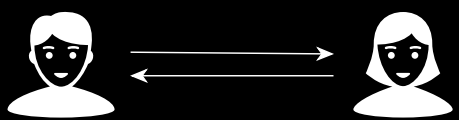


A Private Room

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

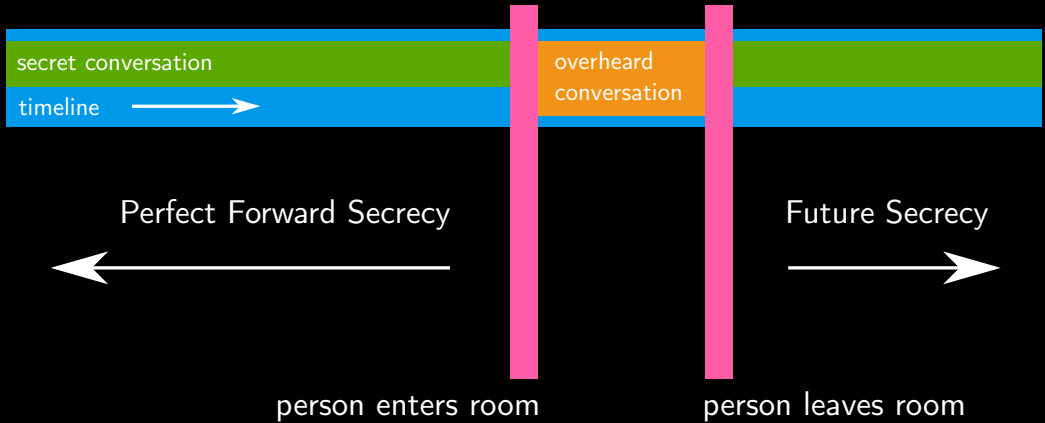
We call this forward secrecy

→ 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

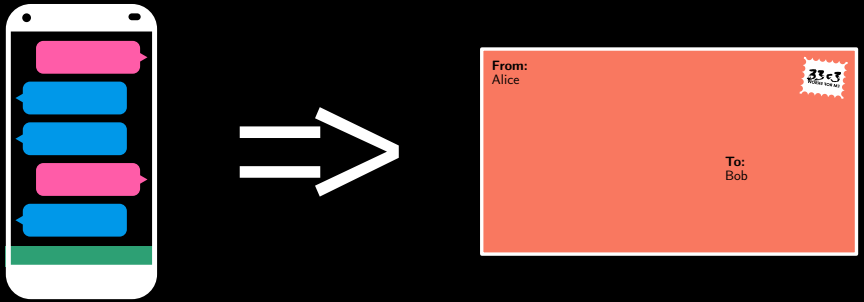
We call this deniability

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?

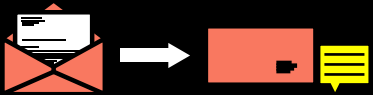
Your providers (and other people on the same network)

- 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

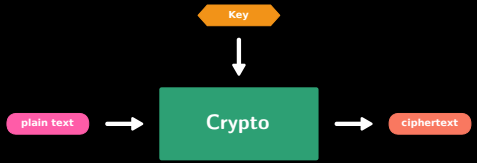
From Postcards to Letters



The Shortest Introduction to Encryption You Will Ever Get

Symmetric Encryption:

→ Encryption and decryption with the same key



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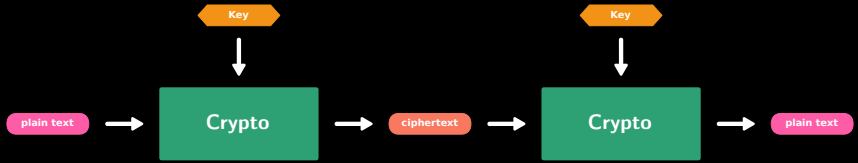

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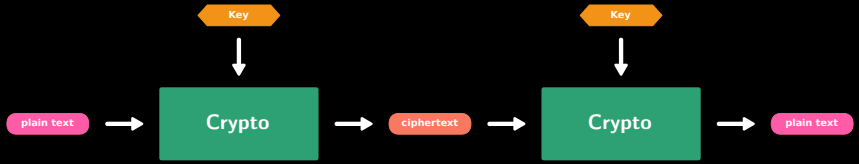

Asymmetric Encryption:

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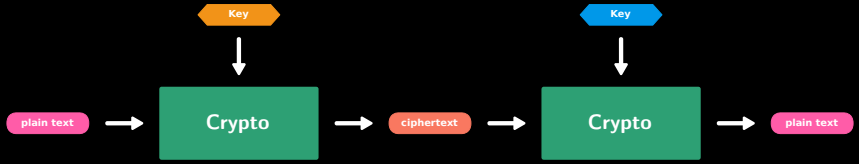

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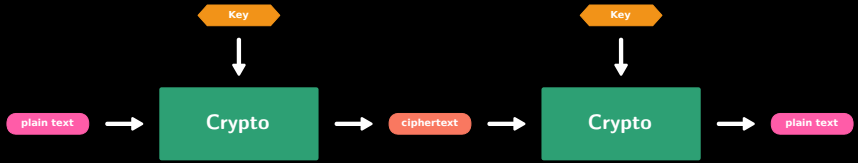

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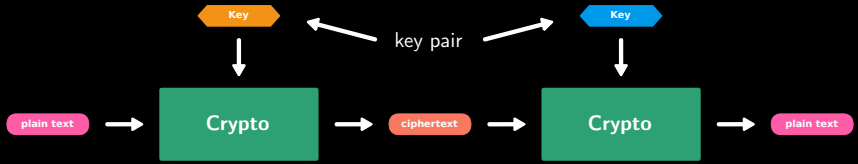
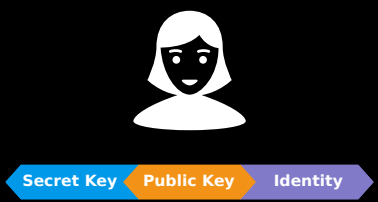
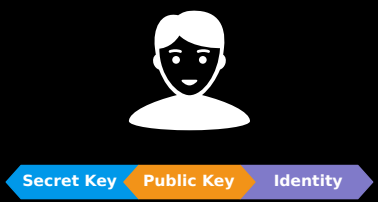


Public-Key Cryptography – In a Nutshell





- 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

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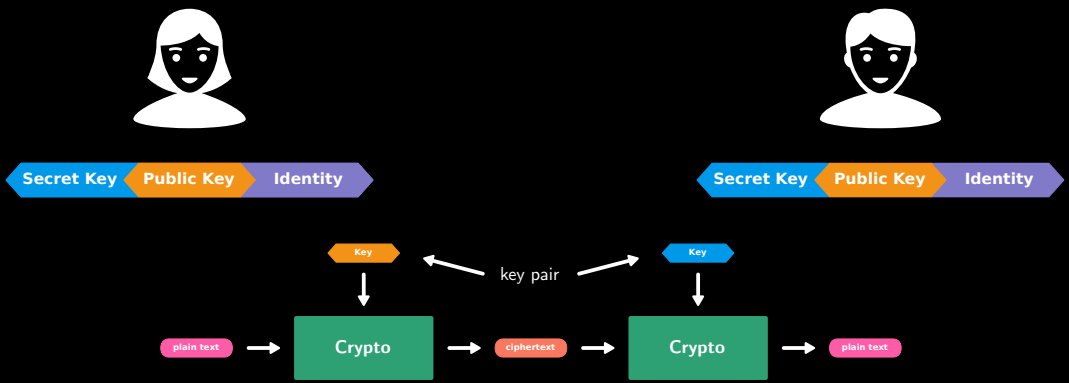

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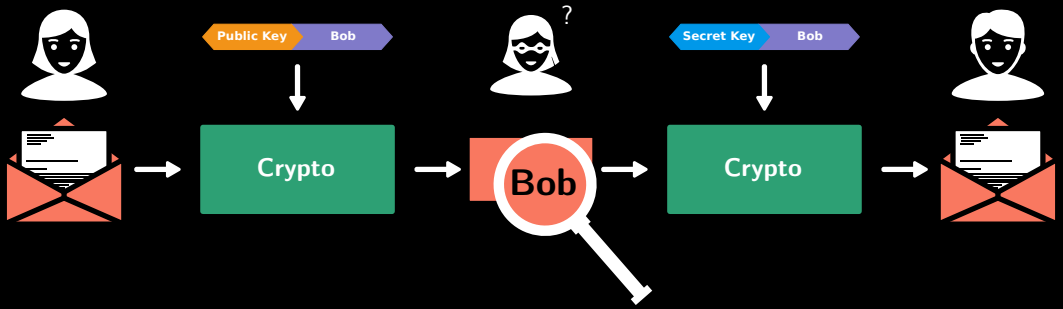

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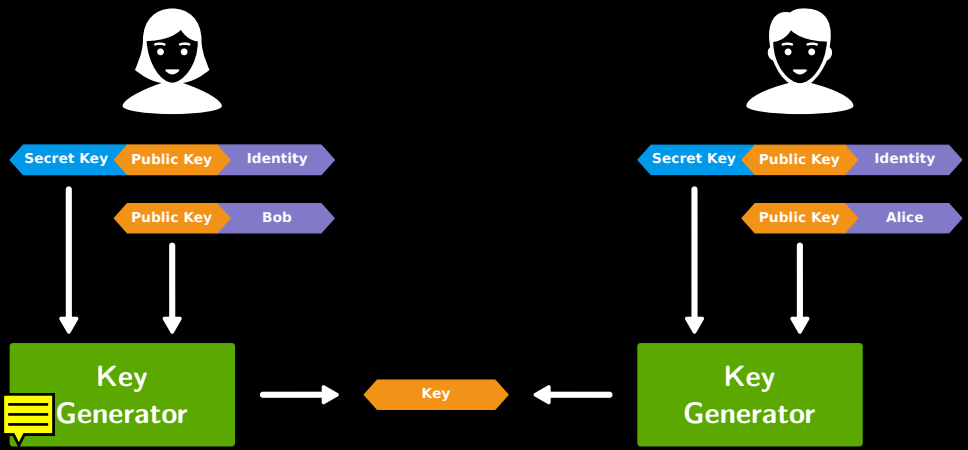
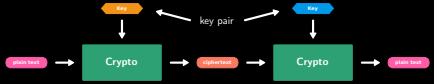
Authenticated Enryption



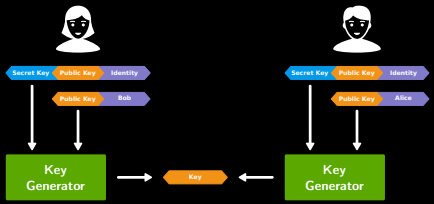
Recap

Asymmetric Encryption gives us IDs but is very expensive.



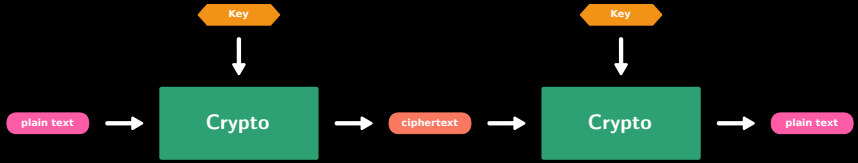
Symmetric Encryption is cheap, but a key has to be shared by all participants before communication starts.

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



But there's more...

Confidentiality

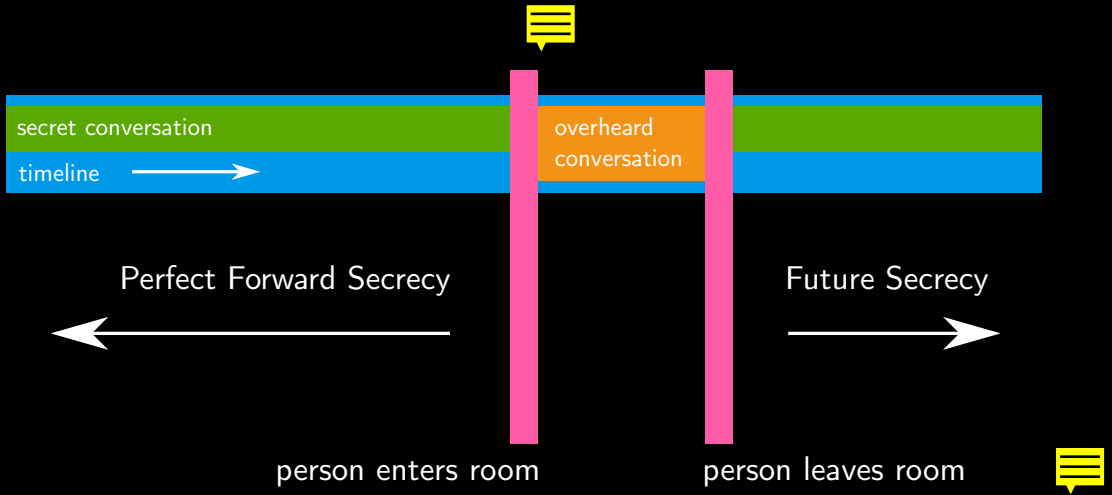


Deniability

From:
either of us

To:
both of us

But What About Forward- and Future Secrecy?



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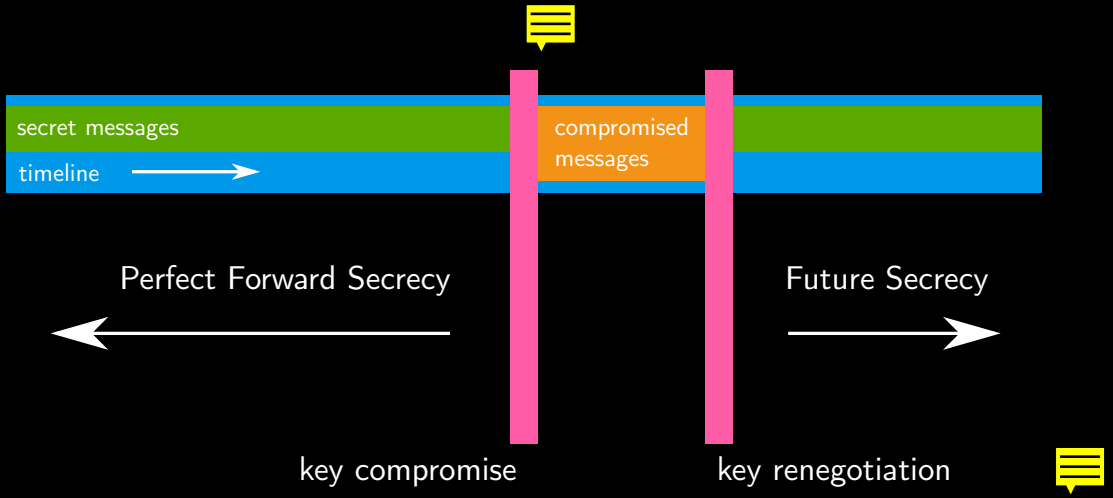

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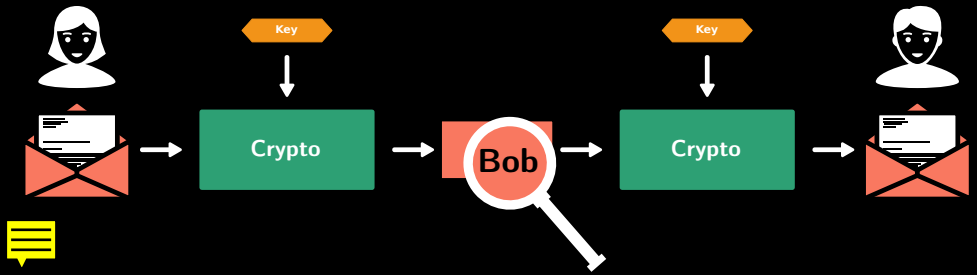

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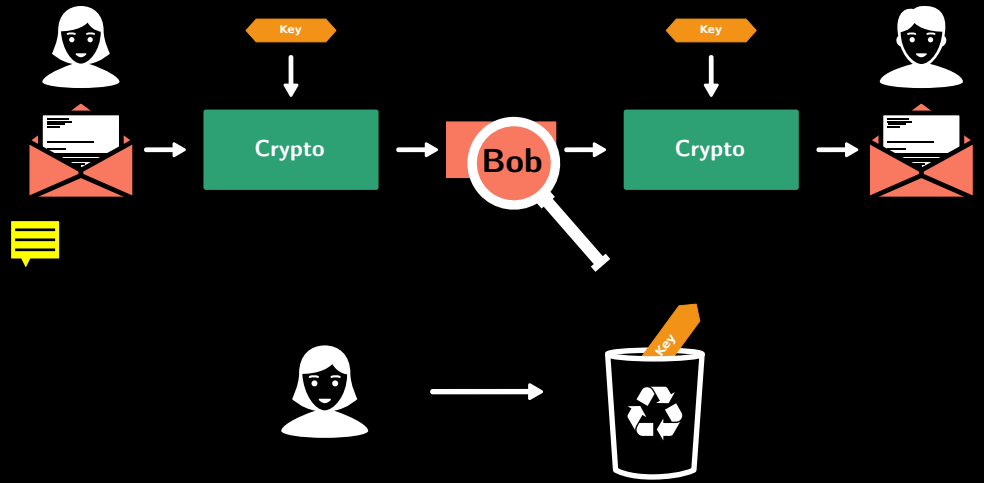


Recap

Authenticated Encryption gives us:

- Confidentiality
- Deniability
- Authenticity

We don't have:

- Perfect Forward Secrecy
- Future Secrecy

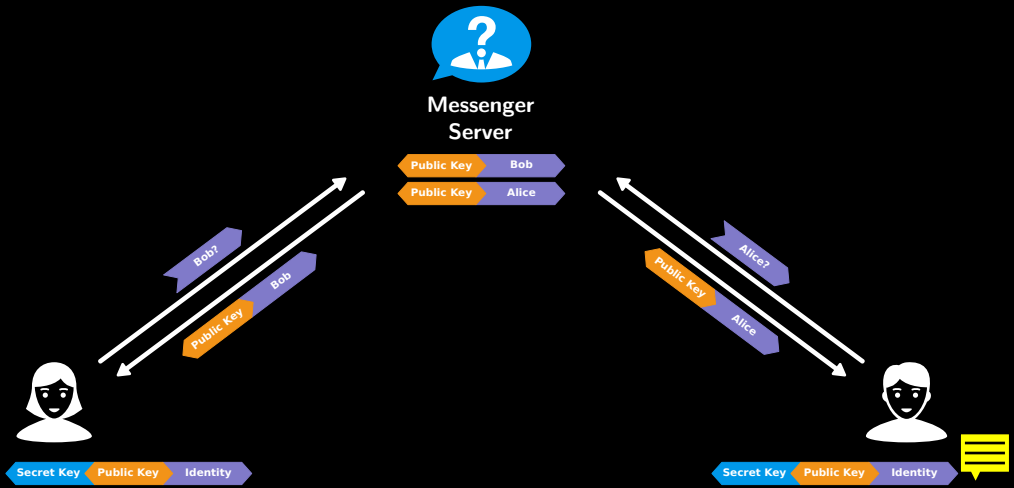
→ We are ignoring Integrity here, but we have that, too.

Key and ID Management

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?
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- Something else?

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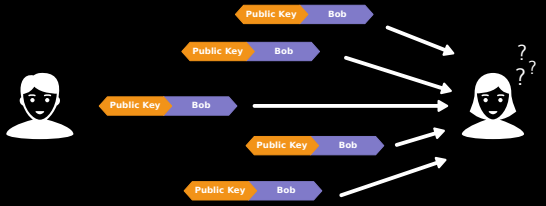
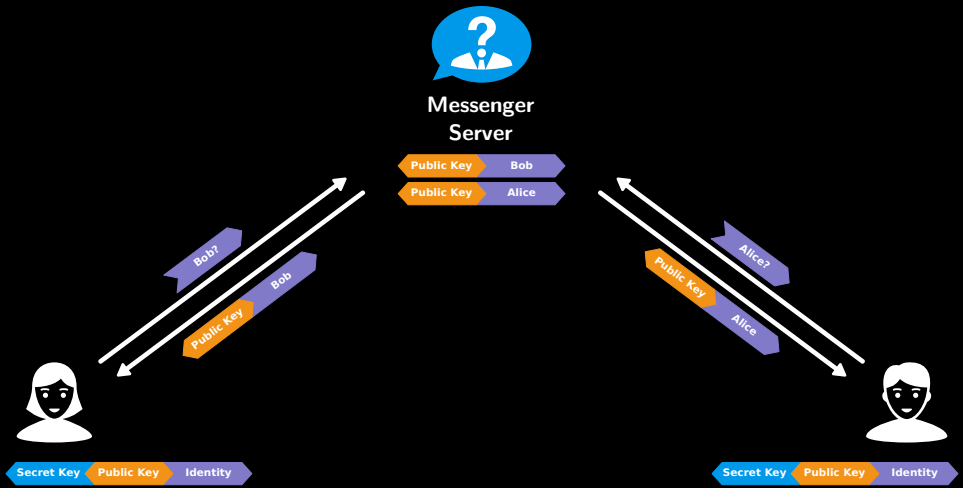
→ Dedicated IDs are preferrable. But only if we find a way to verify ID ownership

Key and ID Management

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



Mobile Messaging Key Management



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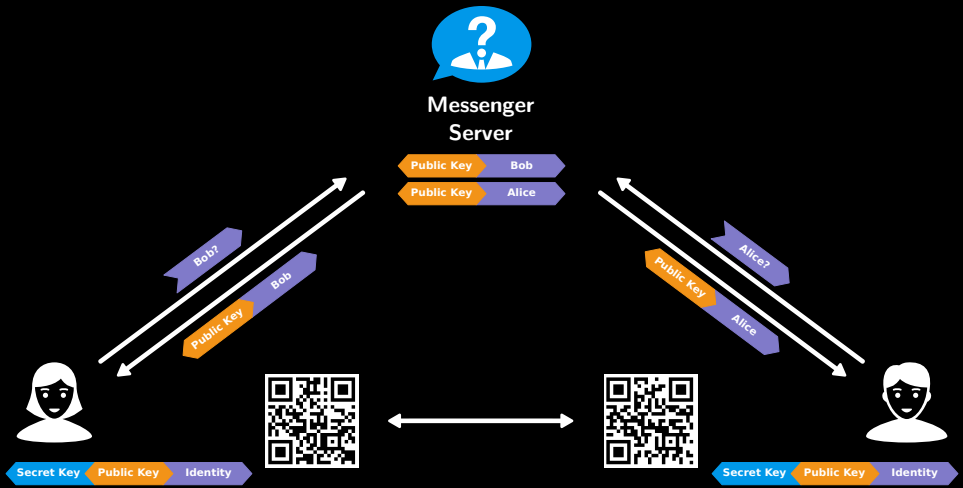


Authenticity

We have now solved the Authentiticy problem

- User can be identified by their phone number or email address
  - → But they have dedicated IDs.
  - → Personal verification is possible.

The remaining unsolved problem is a user changing their ID.

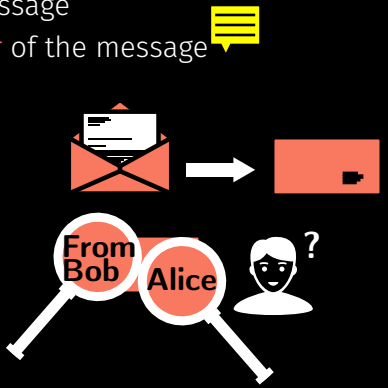
→ At this point, the problem starts anew.

→ We will get back to that later.

Metadata Handling

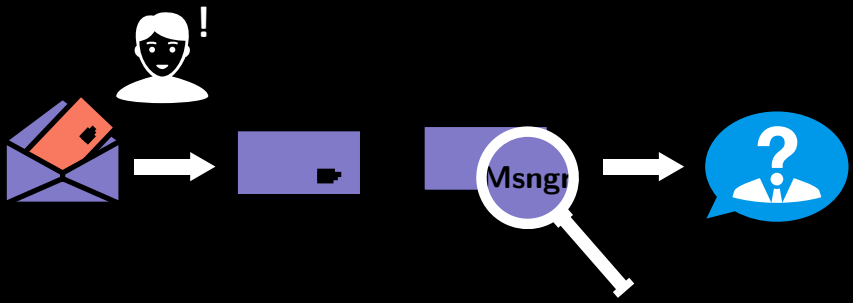
Everybody on the network can see:

- 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.



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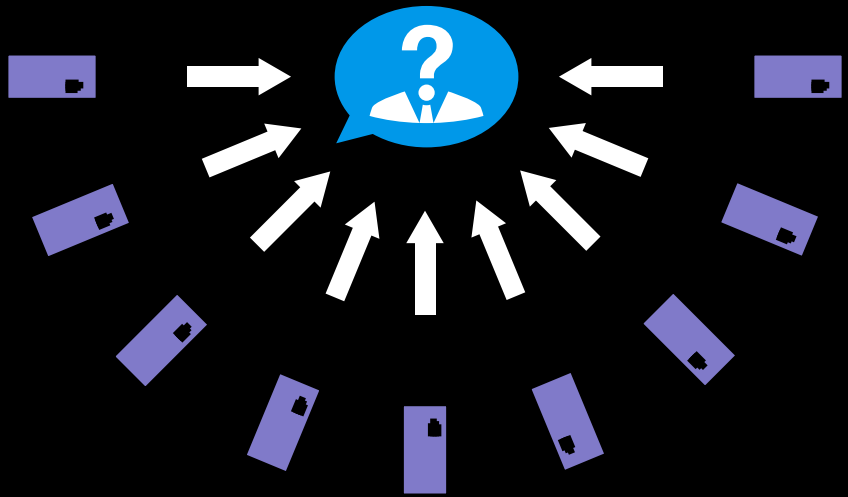

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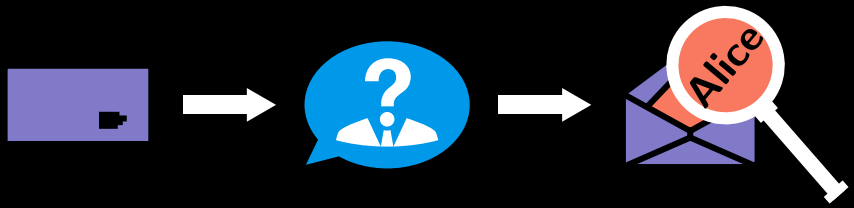
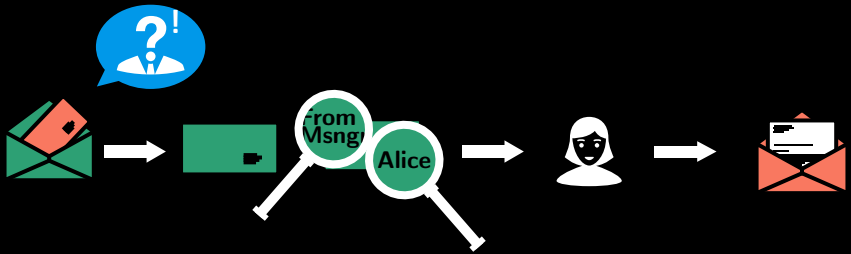


Metadata Handling

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

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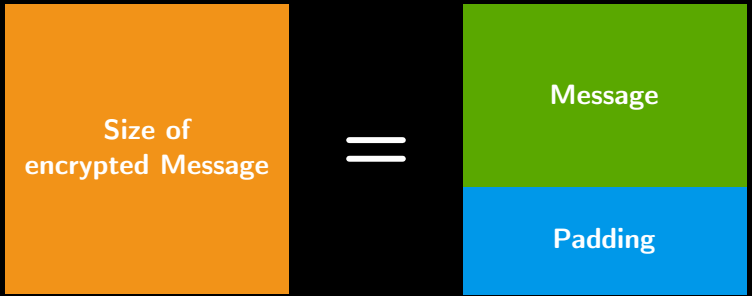
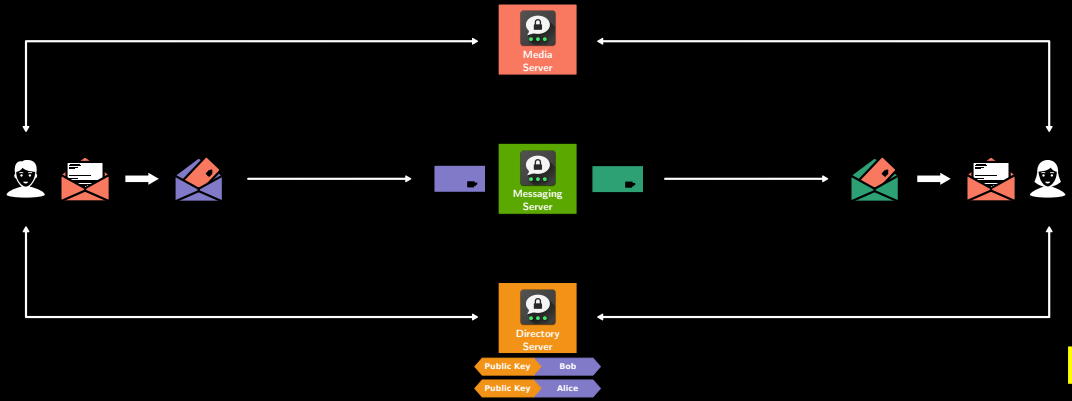
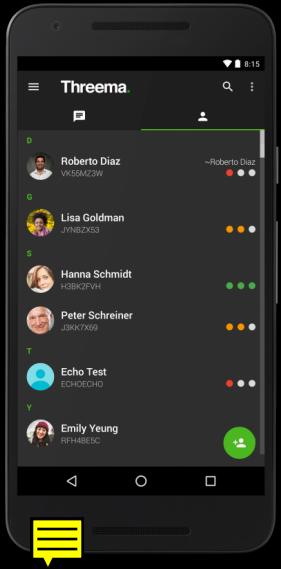


Threema's Architecture



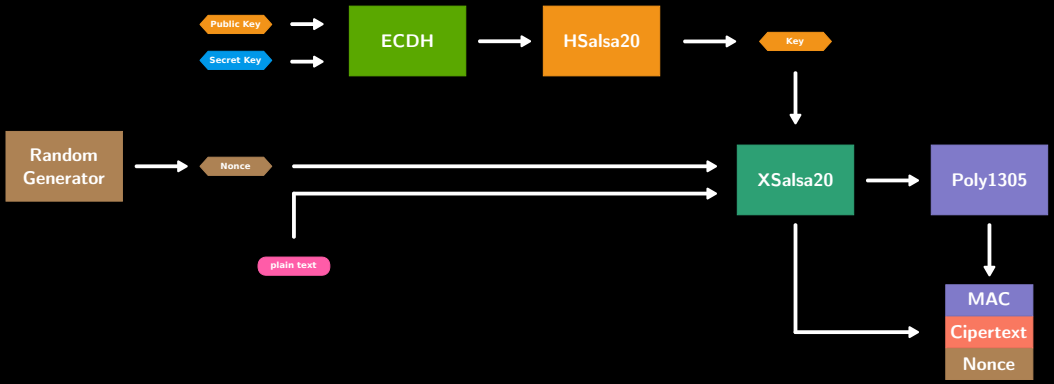
Threema Fingerprints



Threema offers dedicated IDs

- Users may provider their phone number and email.
- If provided, phone number and email are used for identification with the directory server.
- If no additional data is provided, IDs can only be exchanged manually.
- In either case, manual verification using QR codes is encouraged.
- The app permanently tracks the verification status of each peer ID.

NaCl and Threema



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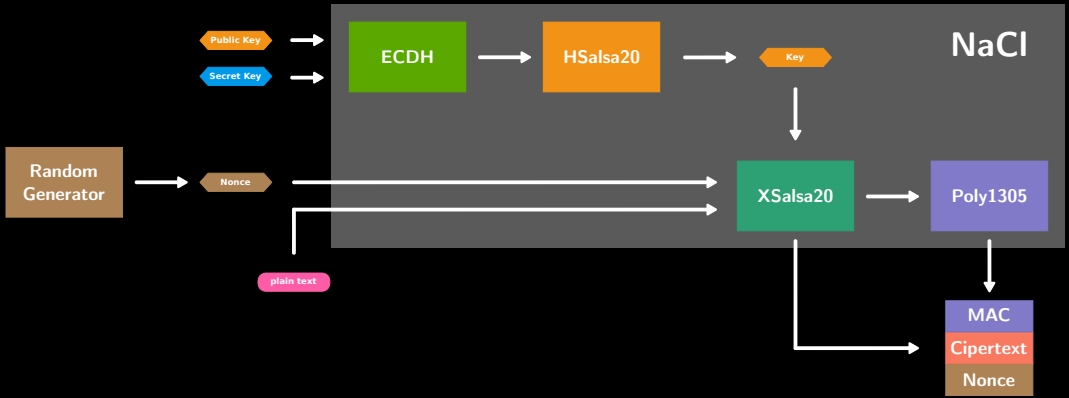
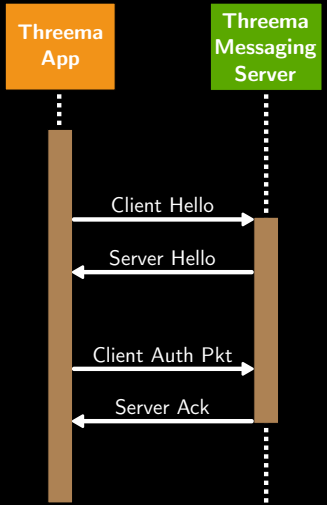


Threema's Handshake Between the App and the Messaging Server



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

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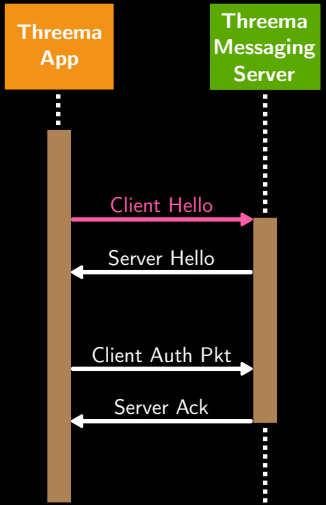
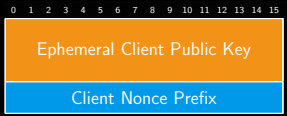


Client Hello Packet



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

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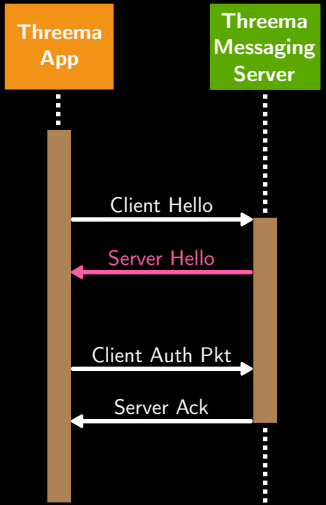
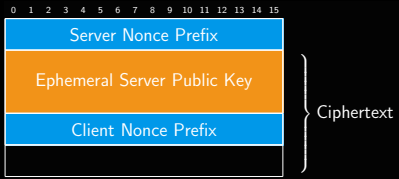
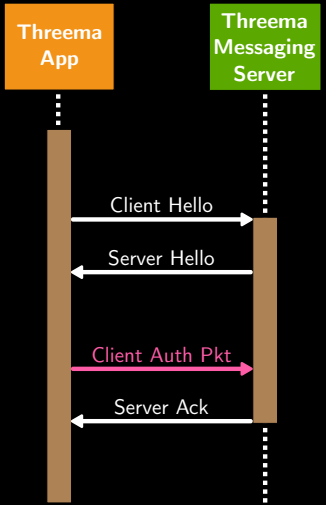


Server Hello Packet

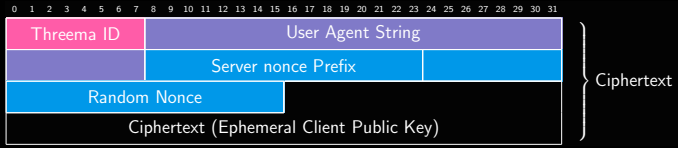


- Server generates ephemeral key pair
- Server generates random nonce
- Ciphertext encrypted with Server Nonce, Client Ephemeral Key and Server Long-Term Key

Threema's Handshake Between the App and the Messaging Server

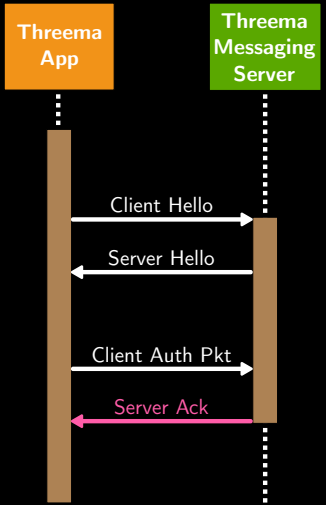


Client Authentication Packet

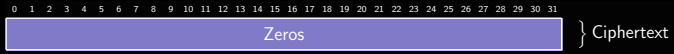


- Outer Encryption with ephemeral Keys
- Ciphertext links clients ephemeral key pair to it's long term key pair

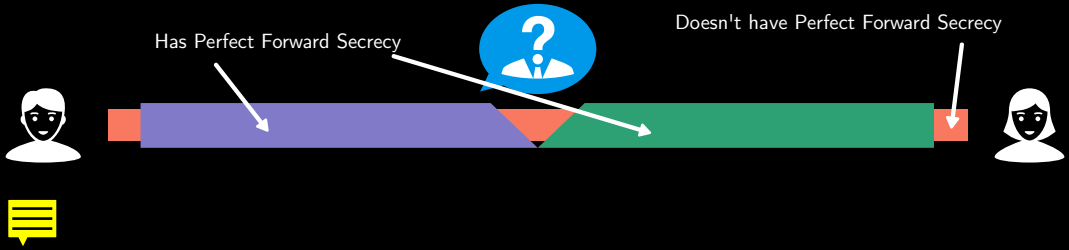
Threema's Handshake Between the App and the Messaging Server



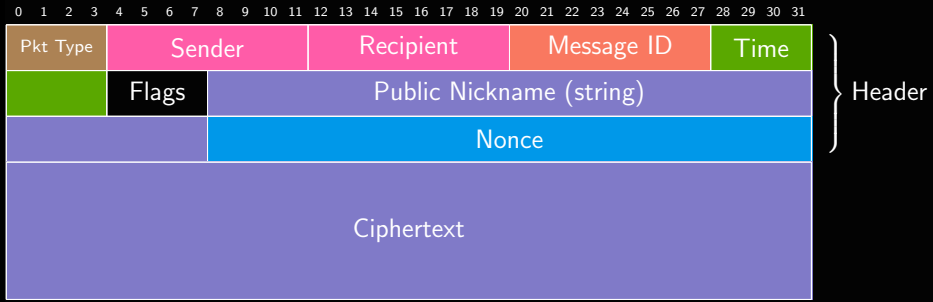
Server Acknowledgement Packet



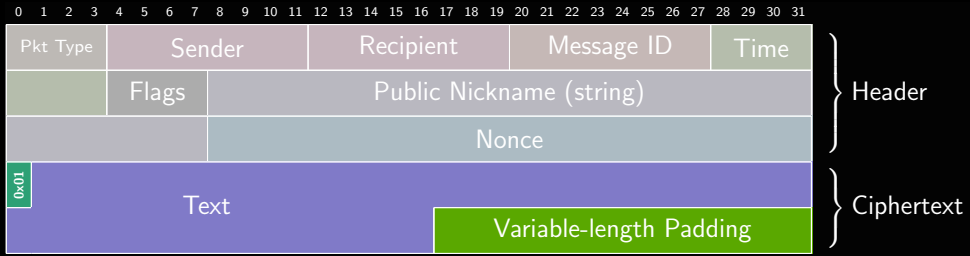
- Server comfirms everything worked fine by encrypting something with both ephemeral keys
- We have established a forward secure channel between app and messaging server.


Has Perfect Forward Secrecy
?
Doesn't have Perfect Forward Secrecy

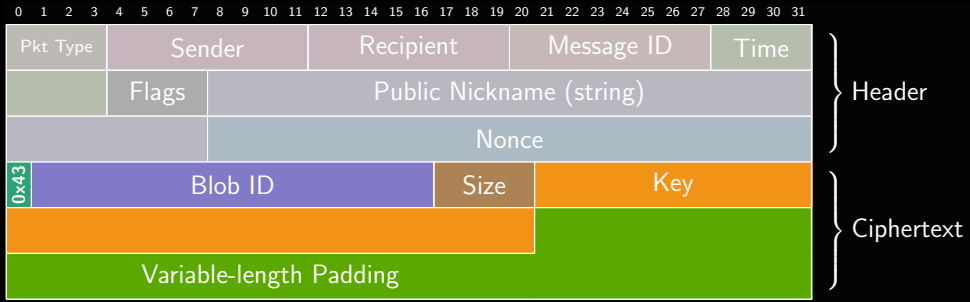
Threema Packet Format



Threema Text Messages

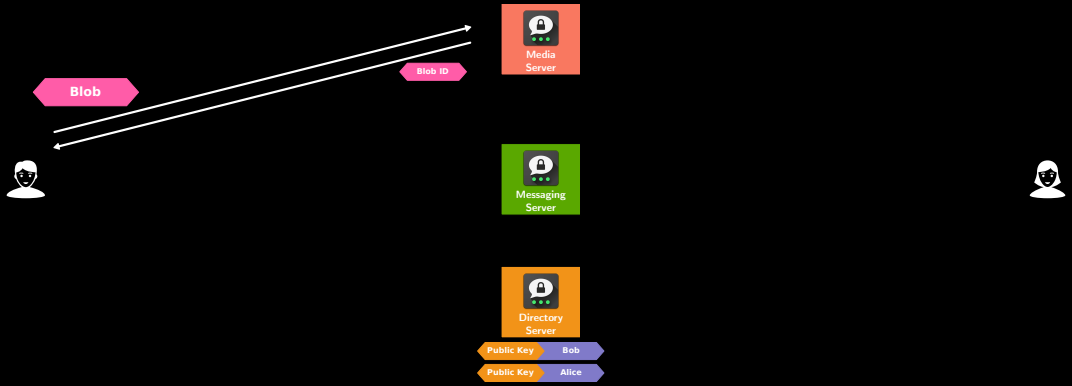


Threema Image Messages

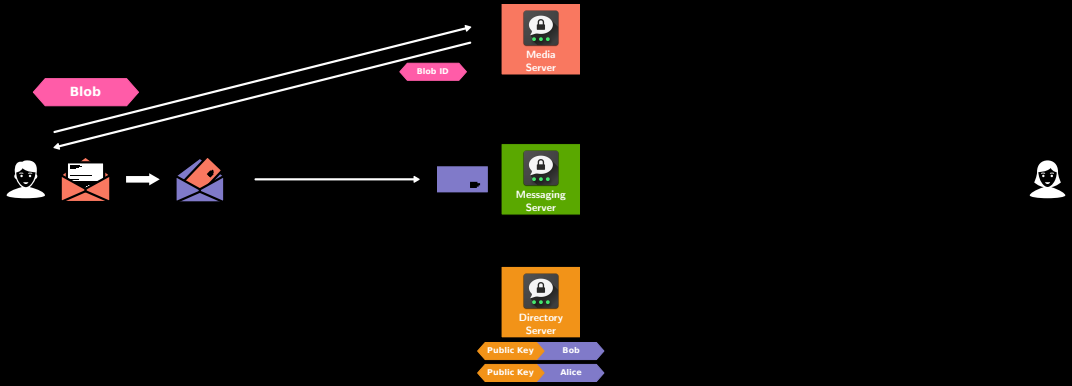


Sending an Image Message

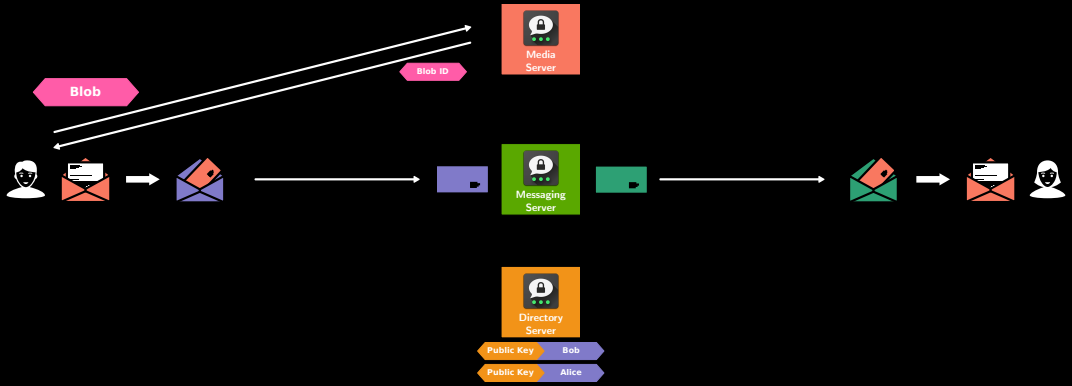
Sending an Image Message



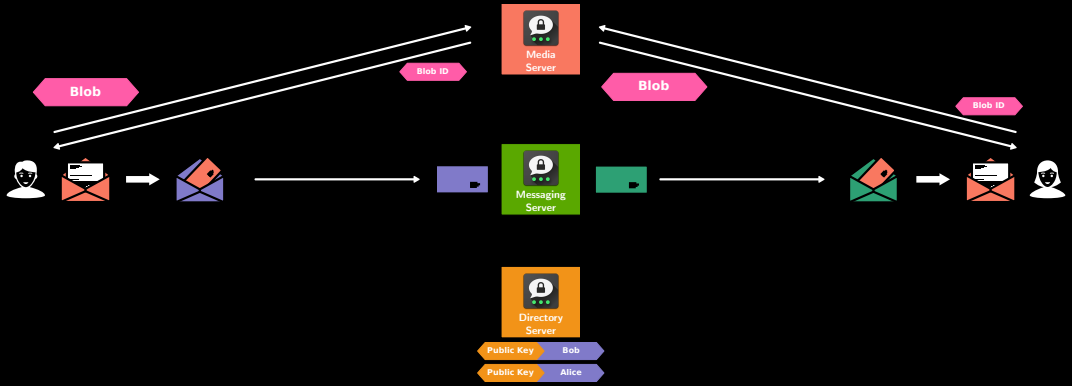
Sending an Image Message



Sending an Image Message



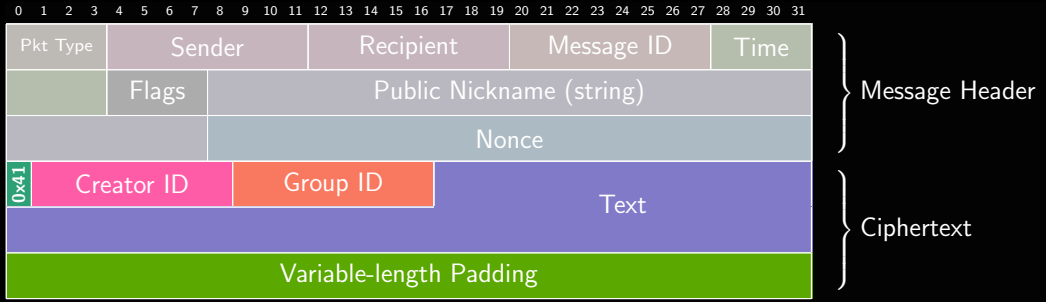
Sending an Image Message



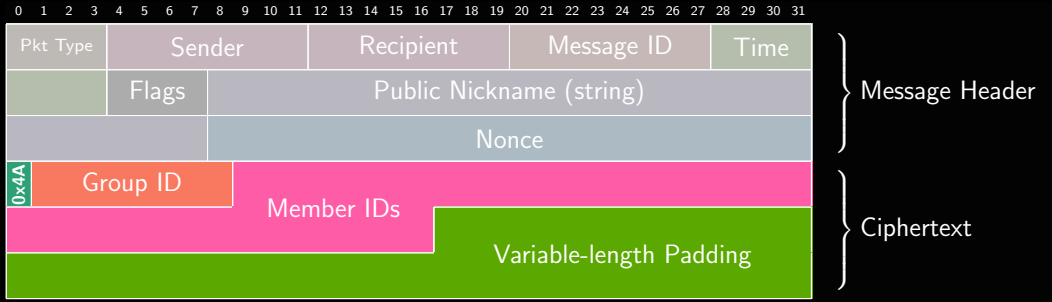
Recap

Basic messaging functionality achieved.

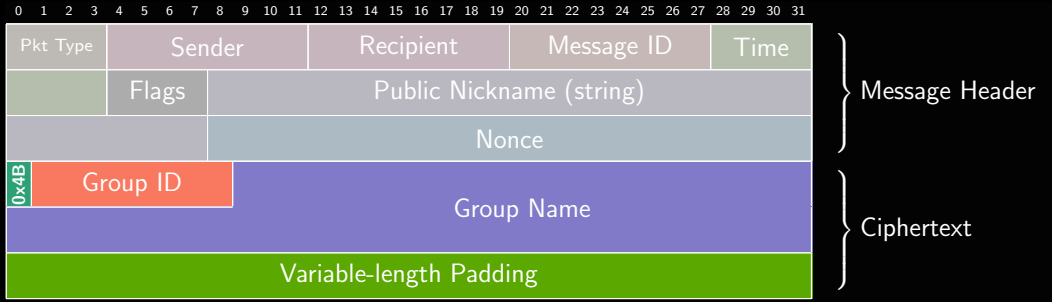
Group Messages



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

Our Library

Our reverse-engineering efforts led to a re-implementation of Threema's API.

Thank You!

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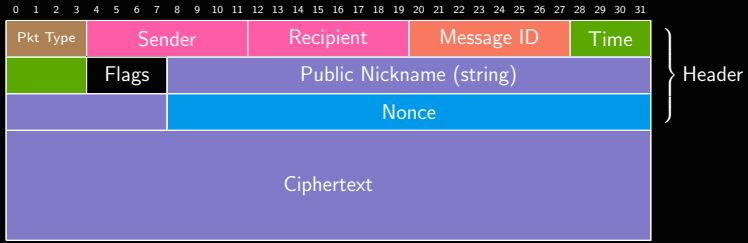
Beamer Theme: Metropolis by Matthias volgelsang
Color Theme: Owl by Ross Chirchley
Icons: The BIG collection by Sergey Demushkin
Foundation Icon Fonts 3 by ZURB
NaCl slide was adapted from a figure in Threema's Cryptography Whitepaper
Threema Screenshots taken from the Threema press package

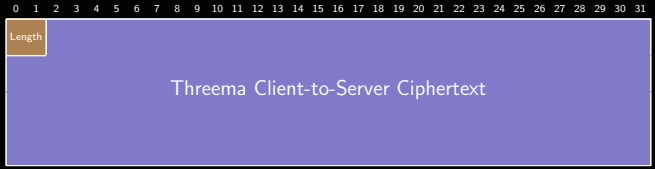
Thanks to Jan Ahrens and Philipp Berger – their work has made ours somewhat easier
Thanks to Maximilian Köstler for his initial work on Threema

Message Packet (Threema Protocol Layer)



- Only the MSB of *Flags is used*

Message Packet on the Wire



Appendix

Text Message

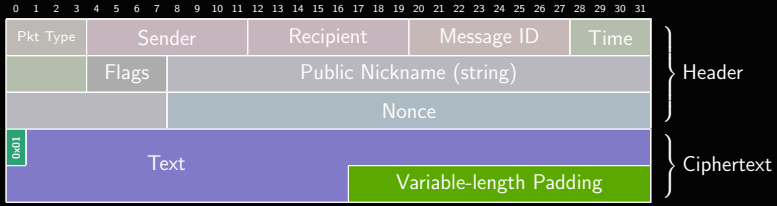
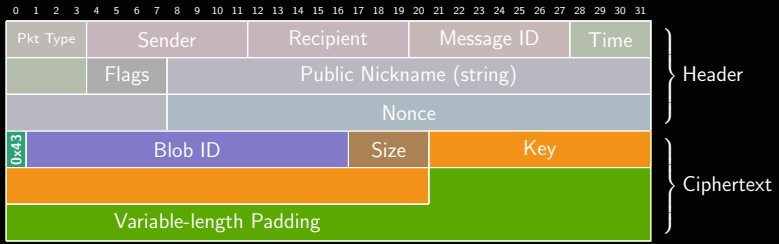
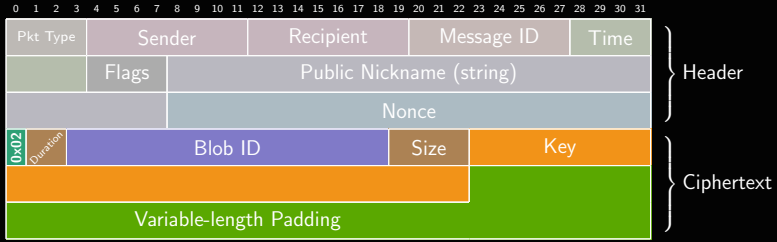


Image Message

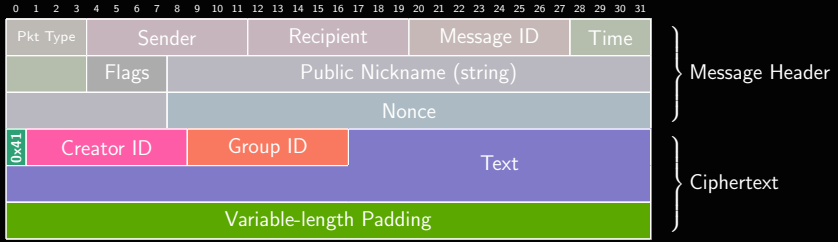


- Blob is symmetrically encrypted using *Key* and uploaded to asset server.
- Image captions are stored inside the image's EXIF data. These data leak upon creating such an image while the "save media to gallery" option is enabled.

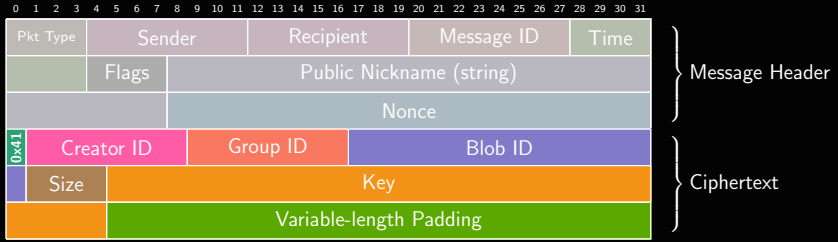
Audio Message



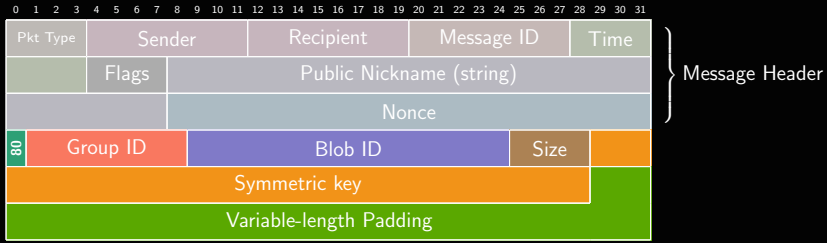
Group Message Packet



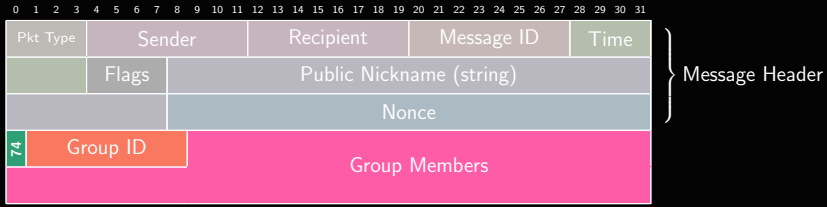
Group Image Message



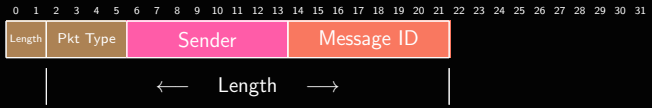
Group Picture Update



Create/Update Group (members)

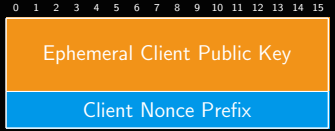


Acknowledgement Packet to Server

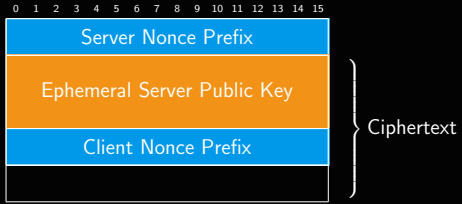


Client-Server Handshake

Client Hello

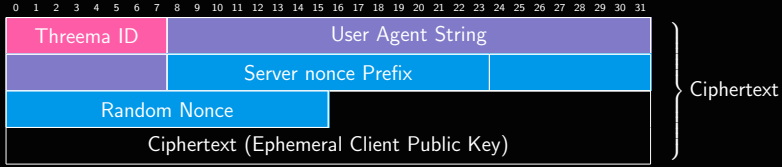


Server Hello

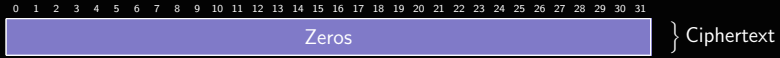


Appendix

Client Authentication Packet



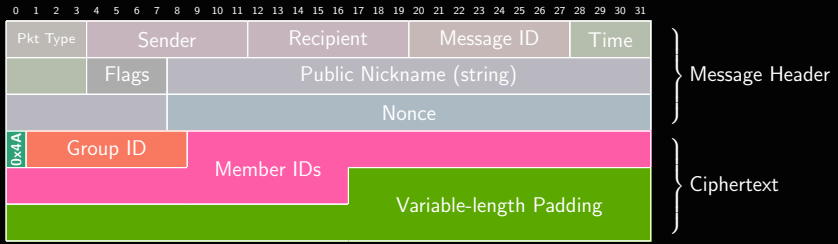
Server Acknowledgement



PKCS7 Padding

												03	03	03
											04	04	04	04
								08	08	08	08	08	08	08	08
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

Group Management Message - Add Users



Group Management Message - Rename Group