E2EE

[End-to-End Encryption]

for iOS Developer.

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Introduction.

→ Graduated Master of Applied Mathematics at Odessa State `I.I.Mechnikov` University.

→ 9 years in iOS development.

→ 5 years berliner.

→ Proud father of Alexander and Daniel.

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Motivation.

Why I am giving this talk?

→ Help devs understand what the end-to-end encryption is exactly about.

→ Motivate to think about privacy when implementing the apps.

→ Inspire to create the new E2EE apps.

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[1]

[1] Image copyright: Wired magazine, all rights reserved.

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[2] Image copyright: I am sure it is copyrighted.

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WIRE
FOR WORKGROUPS™

Version 3.11

About Wire.

→ I am the part of the awesome iOS team at Wire.

→ Wire is open-source 🎉: `https://github.com/wireapp/wire-ios` and other repos.

→ Wire is one of the pioneers of End-to-End encryption: first version released in #TODO.

→ Wire is available as the encrypted Slack replacement.

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Disclaimer.

→ I am not the inventor of E2EE.

→ I am not responsible for the design of the encryption at Wire.

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Prologue: The Invention.

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Hoplite with their aspis [3]

A hoplite was primarily a free citizen who was responsible for procuring his armour and weapon. Many famous personalities, philosophers, artists and poets fought as hoplites.

[3] Public domain, Either Edward J. Krasnoborski or F. Mitchell. - website.

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Bottomline.

Forbidding encrypted messaging would not work.

It is the invention and invention is not possible to forbid. TODO

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So what is End-To-End encryption, exactly?

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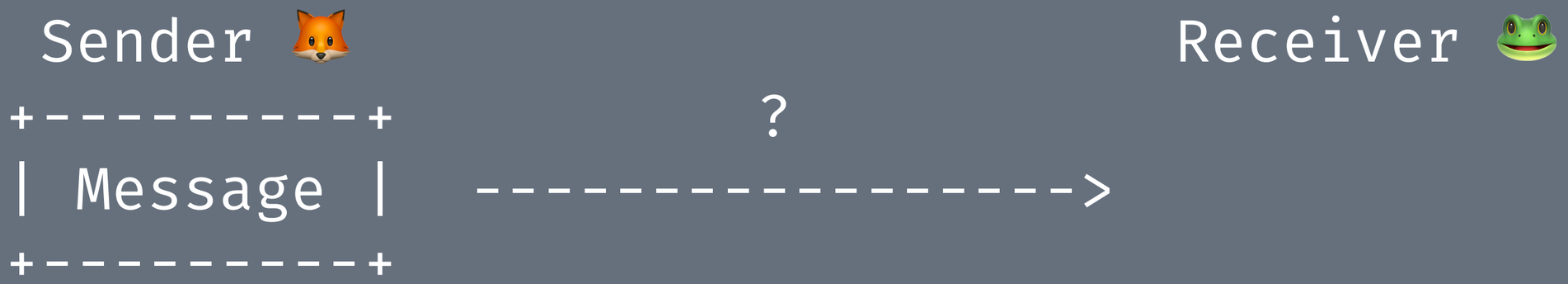
Defining the problem.



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Defining the problem: Confidentiality.

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Solution 🎉: Public-key crypto: Diffie-Hellman (DH) key exchange or RSA.

`Sender 🦊 <----- Public keys ----> Receiver 🐸`

1. Sender and receiver generate public and private key: $K^{Publ}_{🦊}, K^{Priv}_{🦊}, K^{Publ}_{🐸}, K^{Priv}_{🐸}$
2. They exchange public keys: 📱🦊 $\xrightarrow[K^{Publ}_{🦊}]{}$ 🐸,

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Public-key crypto.

Using the Diffie-Hellman (DH) procedure, the shared secret key is created: $K^{Shared}_{🦊🐸} = DH(K_{🐸}, K_{🦊})$

```
                Secure channel
Sender 🦊  <---- encrypted with the ----> Receiver 🐸
                shared secret key
```

This is how TLS (and HTTPs over it) is working.

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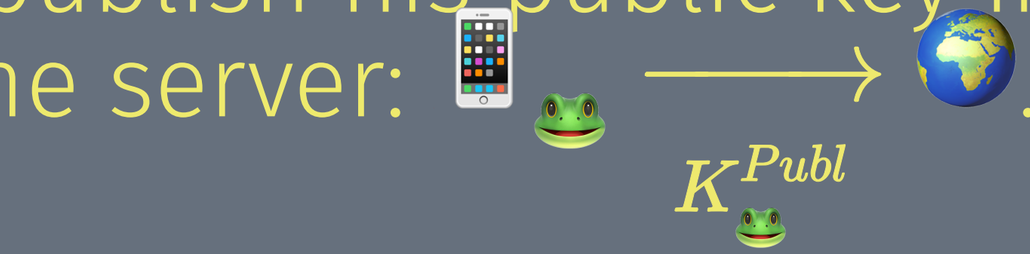
Problem 1: Receiver not online ⚠️

→ Using the DH or RSA, both participants must be online in order to perform the key exchange.

→ Not possible for reasons: phone or other device is not online.

Solution.

→ Receiver can publish his public key in advance to the server: 

.

→ Next time someone wants to communicate with him it is possible to fetch the public key from the server: 

.

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In Wire

K^{Publ}

is called the Prekey.

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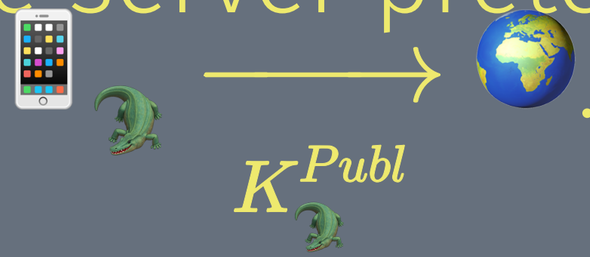
Problem 2: Authenticity ⚠️

→ What if someone generates another key pair: $K^{Priv}_{🐊}, K^{Publ}_{🐊}$.

→ Upload it to the server pretending he is 🐸:



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Problem 2: Authenticity ⚠️

→ Anyone who would like to talk with 🐸 will actually create the shared secret with 🐊!

→ Then 🐊 can decide to create the shared secret with 🦊 and relay the messages reading them.

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Problem 2: Authenticity ⚠️

→ This is called ~~crocodile~~man-in-the-middle attack.

🦊 <-- Secure channel --> 🐲 <-- Secure channel --> 🐸

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Solution: Key Verification 🔑.

→ It is possible to sign the key with another private key.

→ In HTTPs: the authority signatures (public keys) are saved in the keychain.

→ It is possible therefore to check the signature.

→ In messaging: users must check the key fingerpints of the people they are communicating

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it is called
the fingerprint
verification.

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Problem 3: Forward secrecy.

→ If the  would record all the encrypted communication between 🦊 and 🐸...

→ And then find out the $K^{Shared}_{🦊🐸}$.

→ All the previous communication can be decrypted.

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Solution: Session keys / Key rotation.

→ Generate the new key for each message.

→ Rotate the key using the Hash Key Derivation Function (HKDF) - basically hash the previous key:

$$K^{n}_{🦊🐸} = HKDF(K^{n-1}_{🦊🐸})$$

→ It is not possible to find out key $K^{n-1}_{🦊🐸}$ from $K^{n}_{🦊🐸}$.

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Problem 4: Backward / Future secrecy.

→ If 🐊 would find out the K^n 🦊🐸 ...

→ He can hash it, too, and find out the next key $n + 1$.

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Solution: DH re-negotiation, mixing the initial session keys with the new ones.

→ Every message we send, we also include the new public key signed with our initial session key.

→ Receiver also generate another key pair and restart the session.

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Problem 5: It's not me i.e. *Plausible Deniability*.

→ Remember problem 2: authenticity?

→ It is good to check if the person talking to you is the one you want to talk to.

→ It is also possible to say that only the sender can sign the message, since only sender has his private key.

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Plausible Deniability

→ So what's the issue here?

→ If the messages are getting compromised, it is possible to associate the message with the sender.

→ Can be the proof in the court 👨‍⚖️: message is fingerprinted by the sender!

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Solution: Three-way initial DH key negotiation.

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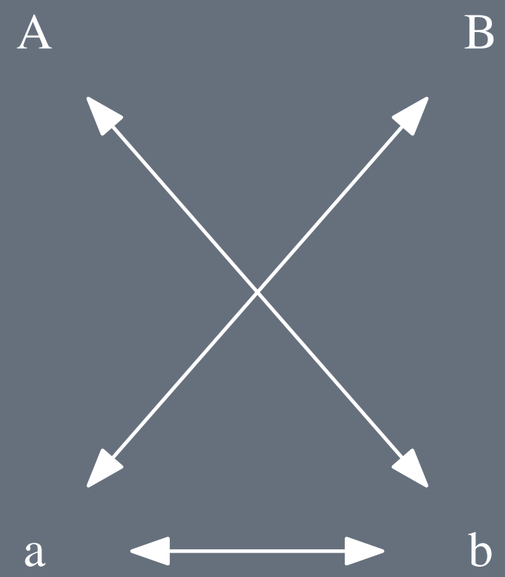

$$K_{master} = hash(dh(A, b), dh(B, a), dh(a, b))$$

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Why good E2EE was not available earlier?

→ No good protocol to solve problems 3-5.

→ The performance of the keypair $K^{Publ}_{🦊}, K^{Priv}_{🦊}$ generation improved dramatically, since:

→ Elliptic curve crypto development.

→ Mobile CPUs are way faster nowadays.

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Recap: good E2EE is:

1. Confidentiality.
2. Authenticity.
3. Forward Secrecy.
4. Backward (Future) Secrecy.
5. Plausible Deniability.

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Wire protocol that solves problems 1-5 is called Axolotl/Double Ratchet.

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How it applies to iOS.

→ Basics of not sharing the data with Apple.

→ Push Notifications (APNs) 💔 E2EE.

→ Share extension + E2EE.

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Basics of not sharing the data with Apple.

→ Apple cares about user privacy.

→ iTunes and iCloud backups.

→ CallKit 👍.

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Image and Video metadata.

Every image or video taken on the iPhone has a significant amount of embedded metadata:

- Device location 📍.
- Model 📱.
- Camera information 📷.

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Strip metadata using `ImageIO`.

Load image from `Data` to `imageSource` [4]:

```
guard let imageSource = CGImageSourceCreateWithData(data, nil),
      let type = CGImageSourceGetType(imageSource) else {
    throw MetadataError.unknownFormat
}
```

[4] Source: https://github.com/wireapp/wire-ios-images/blob/develop/Sources/Image%20Processing/NSData+MediaMetadata.swift

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Strip metadata using `ImageIO`.

Create the new image `imageDestination`:

```
let count = CGImageSourceGetCount(imageSource)
let mutableData = NSMutableData(data: self as Data)
guard let imageDestination = CGImageDestinationCreateWithData(mutableData,
                                                              type,
                                                              count,
                                                              nil) else {

    throw MetadataError.cannotCreate
}
```

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Strip metadata using `ImageIO`.

Reset the metadata:

```
for sourceIndex in 0..<count {
    CGImageDestinationAddImageFromSource(imageDestination,
                                         imageSource,
                                         sourceIndex,
                                         nullMetadataProperties)
}

guard CGImageDestinationFinalize(imageDestination) else {
    throw MetadataError.cannotCreate
}
```

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iTunes and iCloud backups.

→ The content of the backup is stored plaintext in the iTunes or (even worse) in the iCloud.

→ Since we care not to put user data on our backend, we also have to care not to put it on the Apple backend.

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iTunes and iCloud backups.

Like that[5]:

```
var resourceValues = URLResourceValues()
resourceValues.isExcludedFromBackup = true
try mutableURL.setResourceValues(resourceValues)
```

[5] Source: https://github.com/wireapp/wire-ios/blob/develop/WireExtensionComponents/Utilities/URL%2BBackup.swift

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CallKit.

→ CallKit used to sync the calls metadata between the devices.

→ iOS 11 fixed that.

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Push Notifications (APNs) 💔 E2EE.

→ The message sent via the push notification is visible to Apple.

→ APNs allows sending the "VoIP Puhs Notifications".

→ Using **VoIP** push, the iOS application can run the code while not active.

→ During this time, the application must fetch the message from the backend and display the local

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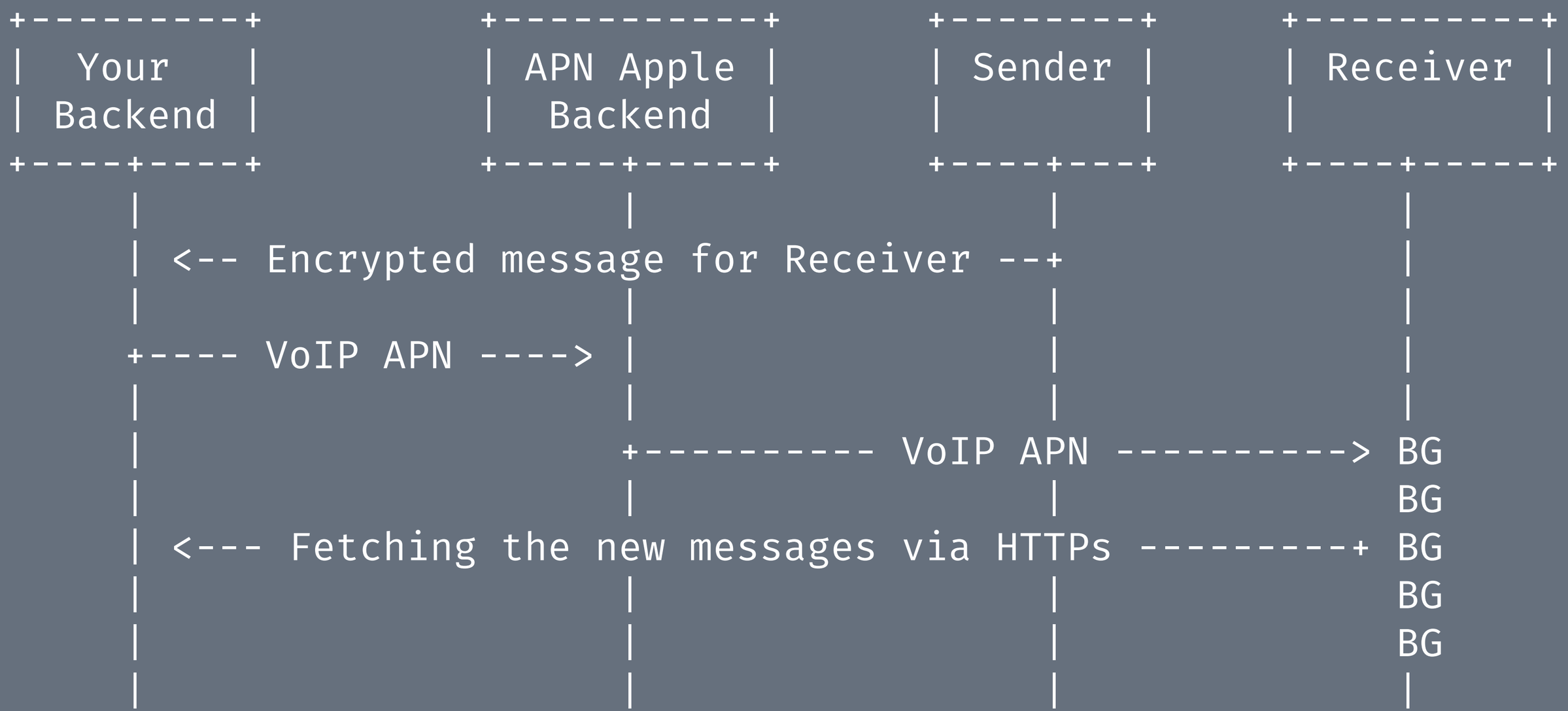

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Problems.

→ If the client cannot manage to fetch the message content from the backend in time, the push notifications are not going to be delivered.

→ If the push notification receiver is offline, then the push notification scheduler can drop some notifications, so the client would not have a chance to fetch messages.

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Possible solution: Background Fetch.

→ It is possible to enable the background fetching, so when the device comes online the app would have the chance to fetch messages.

```
application.setMinimumBackgroundFetchInterval(timeInterval)
```

Share Extensions 💔💔💔 E2EE.

→ On iOS, the share extension is the separate process.

→ Database and the crypto material must be moved to the shared container.

→ File sync is necessary: read up here [6].

[6] https://medium.com/@wireapp/the-challenge-of-implementing-ios-share-extension-for-end-to-end-encrypted-messenger-dd33b52b1e97

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Big chats 🤕 E2EE.

→ The message must be delivered to each participant.

→ To the each participant's device!

→ So when you send one message, say 1 Kilobyte of data in the conversation with N participants where each participant has K devices you actually have to send $1Kilobyte \times N\ timesK$ messages.

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Is it worth it?

As every tech out there, E2EE has it pros and cons.
- Harder to implement.
- Need to think.
- Less points of failure.

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Points of failure.

→ Probability of the data leak $0 < P(💧) \ll 1$.

→ For N points: total probability is $\bigcup_{i=1}^{N} P(💧_i) = P_{💦}$.

→ Let's remove the point N: $\bigcup_{i=1}^{N-1} P(💧_i) = P'_{💦}$.

→ $P_{💦} > P'_{💦}$.

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Sneak peek: MLS.

→ MLS stands for the message `Messaging Layer Security`.

→ IETF initiative to develop the common protocol for secure instant messaging.

→ The protocol is being developed in cooperation between IETF, Twitter, Mozilla, Google, Facebook and Wire.

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MLS: Stay tuned!

→ Improves the message sending in the big (>100) group conversations.

→ One standard that can potentially unify the different messengers.

→ https://www.ietf.org/mailman/listinfo/MLS

→ https://datatracker.ietf.org/doc/draft-omara-mls-architecture/

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Thanks!

Wire Security Whitepaper

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