Maintaining cryptographic library for 11 languages

@vixentael

Maintaining cryptographic library for ~~11~~ 12 languages

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head of customer solutions,
security software engineer

OSS maintainer: Themis, Acra

focused on applied crypto
and building e2ee protocols

COSSACK
LABS

Data security solutions

We provide hard-to-misuse cryptographic tools to help companies to protect the data that is sensitive for their business.

cossacklabs.com/products

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database searchable encryption

cossacklabs.com/acra/

e2ee data collaboration

cossacklabs.com/hermes/

zero knowledge authentication

github.com/cossacklabs/themis/wiki/Secure-Comparator-cryptosystem

cossacklabs.com/whitepapers/

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IN CRYPTO

WE TRUST

USABLE

Plan for today

1. Boring Crypto & inspiration
2. The Scale: core & language wrappers
3. Easy to use VS hard to misuse
4. Security & testing
5. Community & cases

…imagine simple use case

“Let’s protect stored data”

Things to decide on:

PLATFORMS | BACKUPS

KEY ROTATION | KEY EXCHANGE | KEY REVOCATION

KEY DERIVATION | KEY STORAGE | KMS

MODE | PADDING | IV

DATA SCOPE | CIPHER | KEY LENGTH

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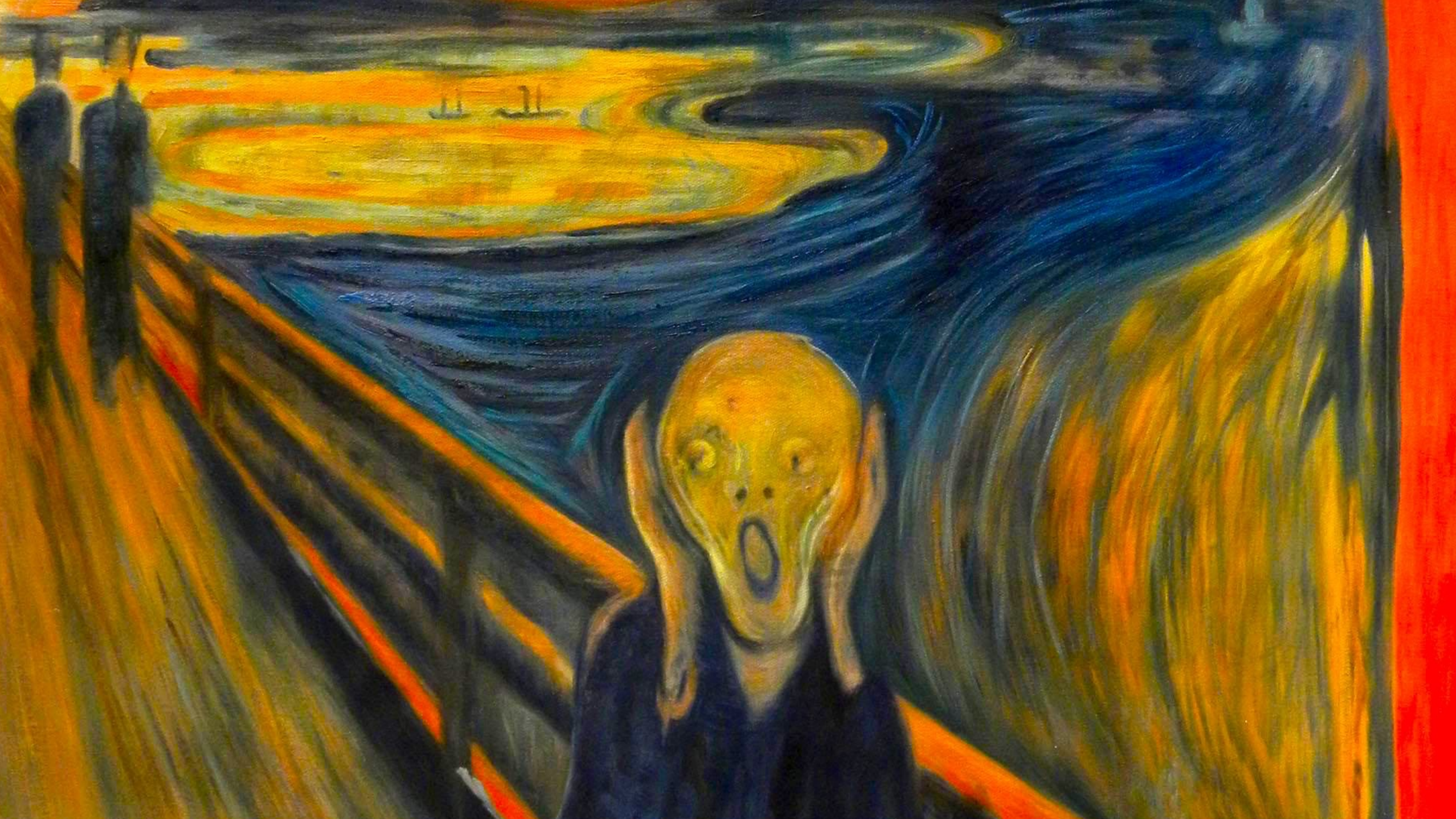

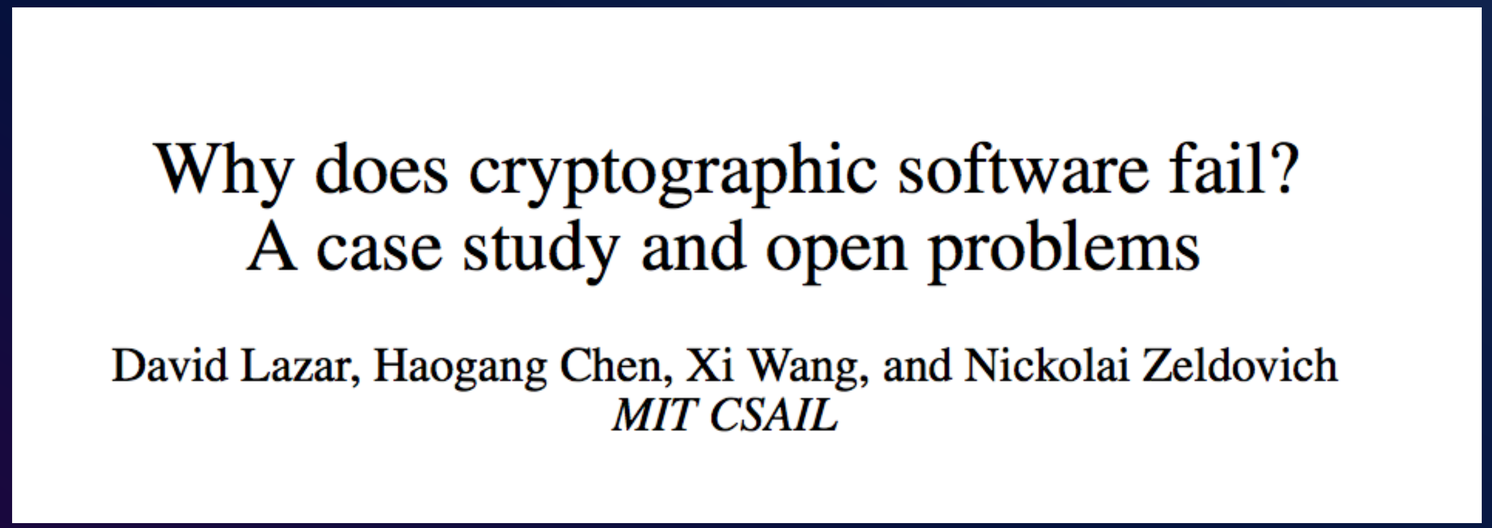
Why does cryptographic software fail?
A case study and open problems

David Lazar, Haogang Chen, Xi Wang, and Nickolai Zeldovich
MIT CSAIL

269 CVEs
from 2011-2014

17% bugs inside crypto libs

83% misuses of crypto libs
by individual apps

https://pdos.csail.mit.edu/papers/cryptobugs:apsys14.pdf

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Blowfish

AES-SIV

Rabbit

Salsa20

AES

Kuznyechik

SEED

CFB

RSA

DSS

ECDSA

DES

Camelia

SEAL

CBC

DSA

3DES

SHARK

RC4

CTR

ChaCha20

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Boring crypto

— crypto that simply works, solidly resists attacks, never needs any upgrades

Daniel J. Bernstein

https://cr.yp.to/talks/2015.10.05/slides-djb-20151005-a4.pdf

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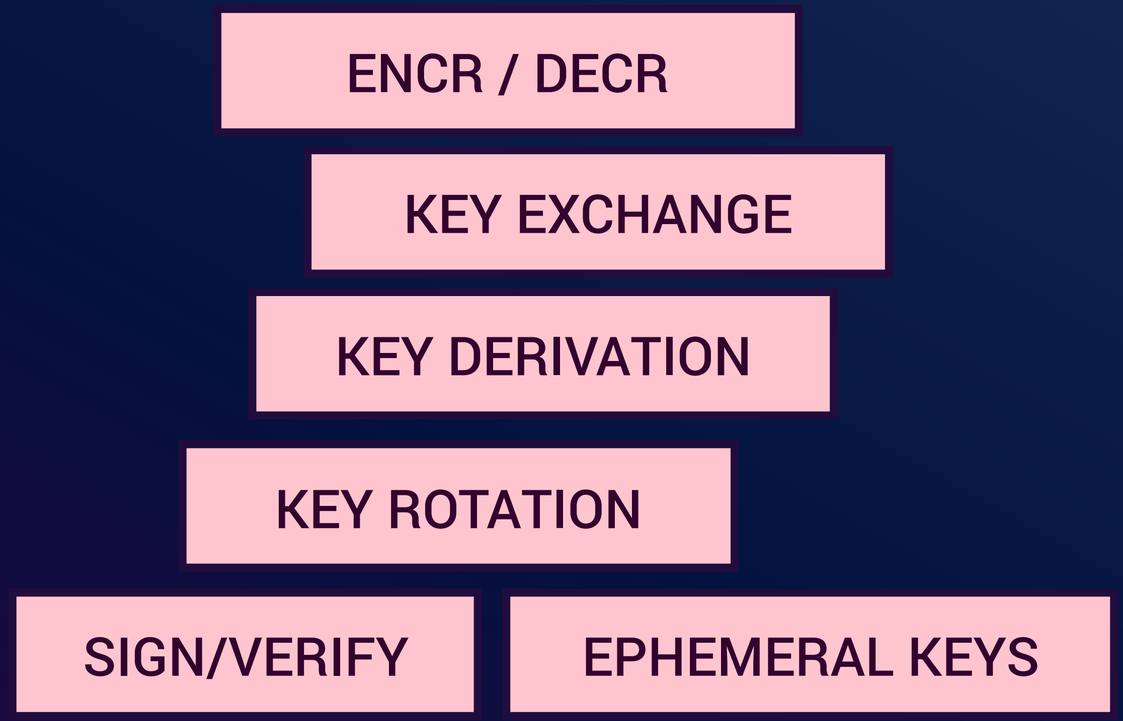
Solve use-cases

I want to **store** data securely
I want to **send** data securely
I want to **verify** data integrity

Solve use-cases

store data securely
send data securely
verify data integrity



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Themis

Themis provides strong, usable cryptography for busy people

---

release v0.12.1 | circleci passing | bitrise ✓ | platform Android | iOS | macOS | Linux | Java | WASM | coverage 90% | go report A+

General purpose cryptographic library for storage and messaging for iOS (Swift, Obj-C), Android, desktop Java, C++, Node.js, Python, Ruby, PHP, Go, Rust, WASM.

Perfect fit for multi-platform apps. Hides cryptographic details. Made by cryptographers for developers 🧡

github.com/cossacklabs/themis

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Themis: cryptosystems

store encrypted

encrypt for someone

encrypt session communication

authenticate

github.com/cossacklabs/themis

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Themis: cryptosystems

store encrypted

encrypt for someone

encrypt session communication

authenticate

SecureCell

AES GCM /
AES CTR

built in KDF

github.com/cossacklabs/themis

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Themis: cryptosystems

store encrypted

encrypt for someone

encrypt session communication

authenticate

SecureCell

SecureMessage

AES GCM / AES CTR

ECC + ECDSA / RSA + PSS + PKCS#7

built in KDF

built in key gen

github.com/cossacklabs/themis

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Themis: cryptosystems

store encrypted	encrypt for someone	encrypt session communication	authenticate
SecureCell	SecureMessage	SecureSession	
AES GCM / AES CTR	ECC + ECDSA / RSA + PSS + PKCS#7	ECDH + ECC + AES	
built in KDF	built in key gen	ephemeral keys	

github.com/cossacklabs/themis

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Themis: cryptosystems

store encrypted	encrypt for someone	encrypt session communication	authenticate
SecureCell	SecureMessage	SecureSession	SecureComparator
AES GCM / AES CTR	ECC + ECDSA / RSA + PSS + PKCS#7	ECDH + ECC + AES	OTR SMP + ECC
built in KDF	built in key gen	ephemeral keys	ZKP

github.com/cossacklabs/themis

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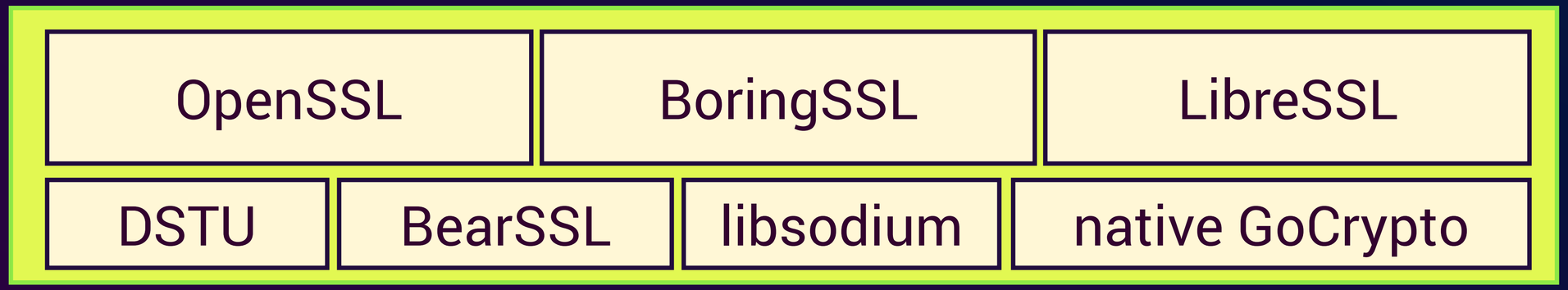
Themis



crypto-backends

stable

experimental

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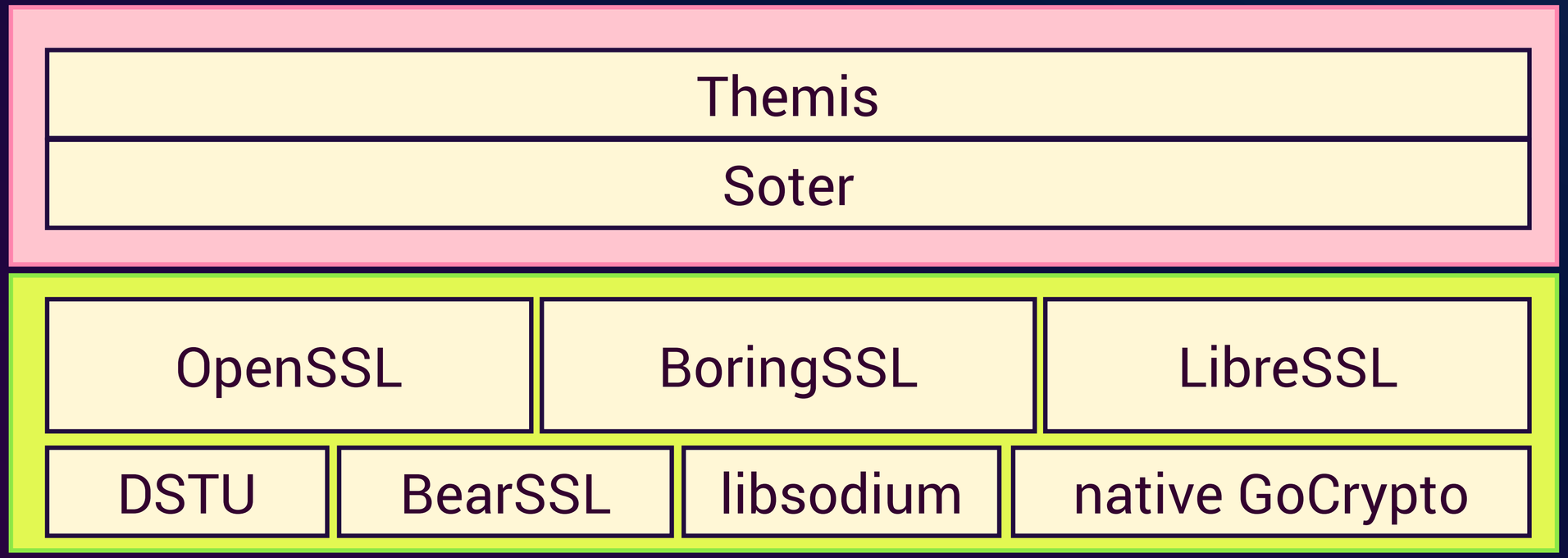
Themis



Themis Core

crypto-backends

stable

experimental

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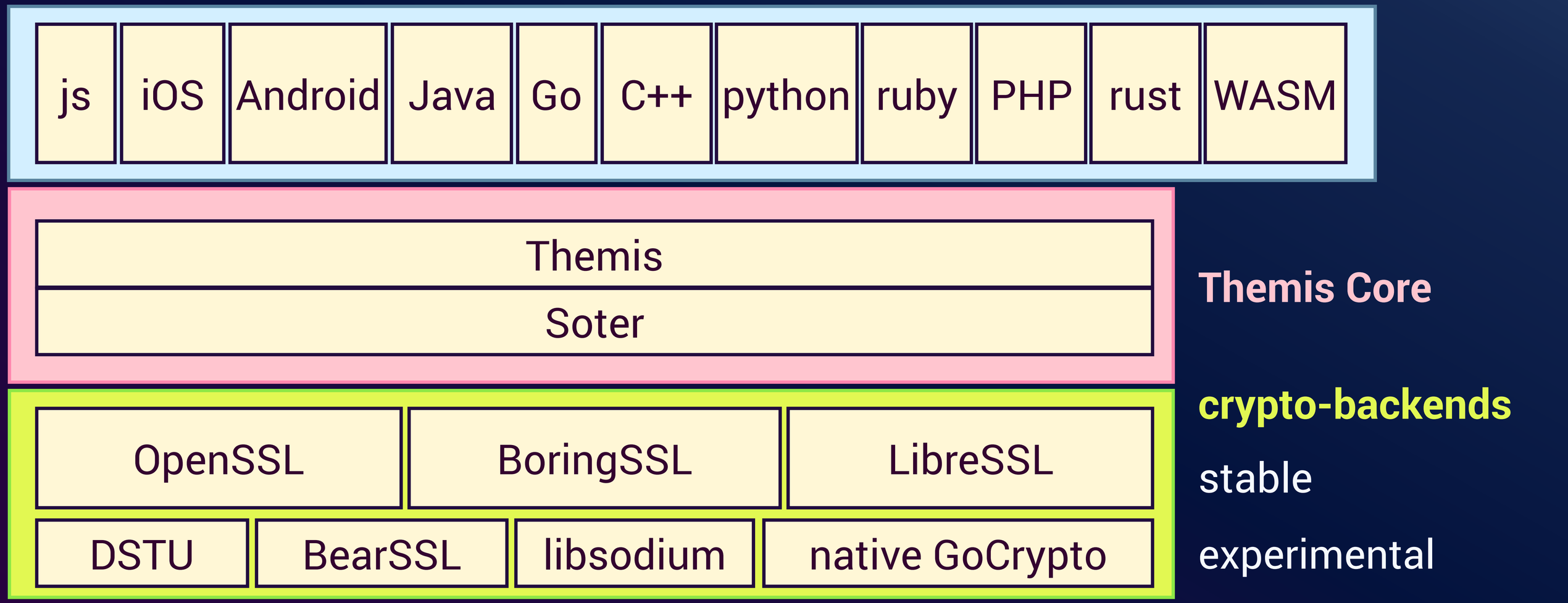
Themis



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Themis Core (server & desktop OS)

- Ubuntu
- Debian
- CentOS / RHEL
- macOS
- Windows

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Themis Core (server & desktop OS)

Ubuntu 18.04 x64	Ubuntu 16.04 x64	Ubuntu 16.04 x32	
Debian 9 x32	Debian 9 x64	Debian 8 x64	Debian 8 x32
CentOS 7 x64			
macOS 10.13	macOS 10.14	macOS 10.15	
Windows			

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Themis OSs

Ubuntu 18.04 x64	Ubuntu 16.04 x64	Ubuntu 16.04 x32	Debian 9 x32
Debian 9 x64	Debian 8 x64	Debian 8 x32	CentOS 7 x64
macOS 10.13	macOS 10.14	macOS 10.15	Windows
iOS 9	iOS 10	iOS 11	iOS 12
iOS 13	Android SDK 16 - 29		

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Cryptographic tools should be

easy to use or hard to misuse?

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Easy to use

```
make

make test

sudo make install
```

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Easy to use

noone cares about your lib if they can’t install it using their fav package manager

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Themis Core: install

Ubuntu	`apt-get install libthemis-dev`
Debian	`apt-get install libthemis-dev`
CentOS / RHEL	`yum install libthemis-devel`
macOS	`brew install libthemis`
Windows	`make nsis_installer`

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Package managers

```
npm install jsthemis

pip install pythemis

pip3 install pythemis

npm install wasm-themis

gem install rbthemis
```

```
[dependencies]
themis = "0.12"

pod themis
pod install

github “cossacklabs/themis"
carthage update
```

```
maven { url "https://dl.bintray.com/cossacklabs/maven/" }

go get github.com/cossacklabs/themis/gothemis/...
```

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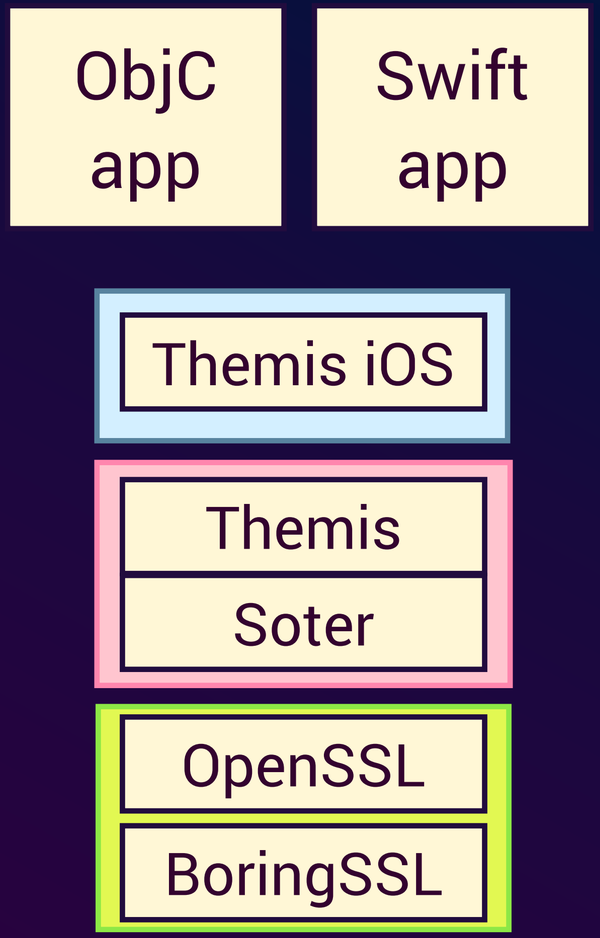
iOS specifics



ObjC <> Swift interoperability

ObjC

C lang

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iOS specifics

ObjC <> Swift interoperability

ObjC

C lang

package managers

- CocoaPods
- Carthage
- ~~SPM~~
- manually

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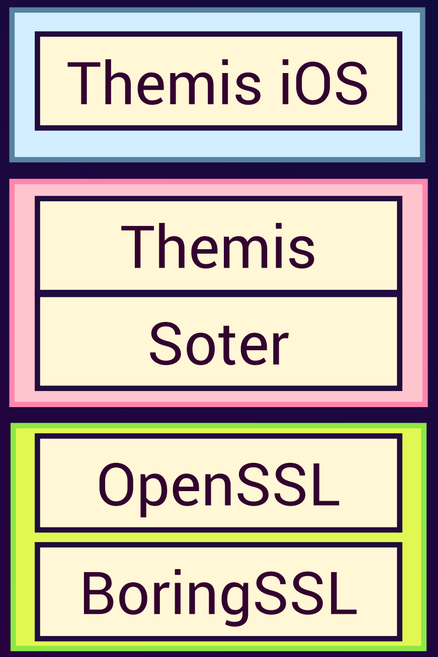
iOS specifics

ObjC app

Swift app

ObjC <> Swift interoperability



ObjC

C lang

Xcode/Swift update

iOS update

device update

package manager update

Open/BoringSSL update

package managers

- CocoaPods
- Carthage
- ~~SPM~~
- manually

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iOS specifics

Header not found when adding Themis as dependency in a new development cocoapod O-iOS

#411 by popaaaandrei was closed

Themis Carthage: fix linking issue with OpenSSL 1.0.2.18 ✕ O-iOS

#483 by vixentael was merged on Jun 25

Themis 0.10.2 doesn't compile on iOS device due to bitcode O-iOS bug

#406 by popaaaandrei was closed on Mar 4

Themis iOS and B… O-iOS question

#336 by CodeTeamLab

Update iOS wrapper header structure to compile Swift framework ● O-iOS

#415 by vixentael was merged on Mar 6 • Approved

Can't archive Xcode project with themis installed O-iOS

#538 by chrisleversuch was closed on Sep 26 2 of 4

Cannot install Themis via Cocoapods O-iOS installation

#481 by drewpitchford was closed on Jun 18 0 of 2

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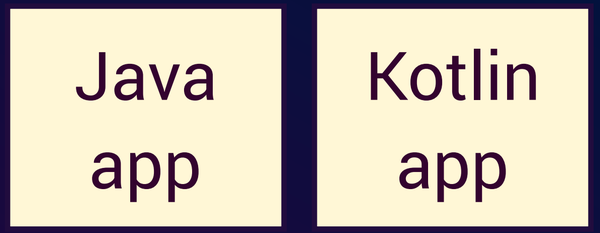
THIS IS FINE.

Android specifics



Java <> Kotlin
interoperability

Java <> C

C lang

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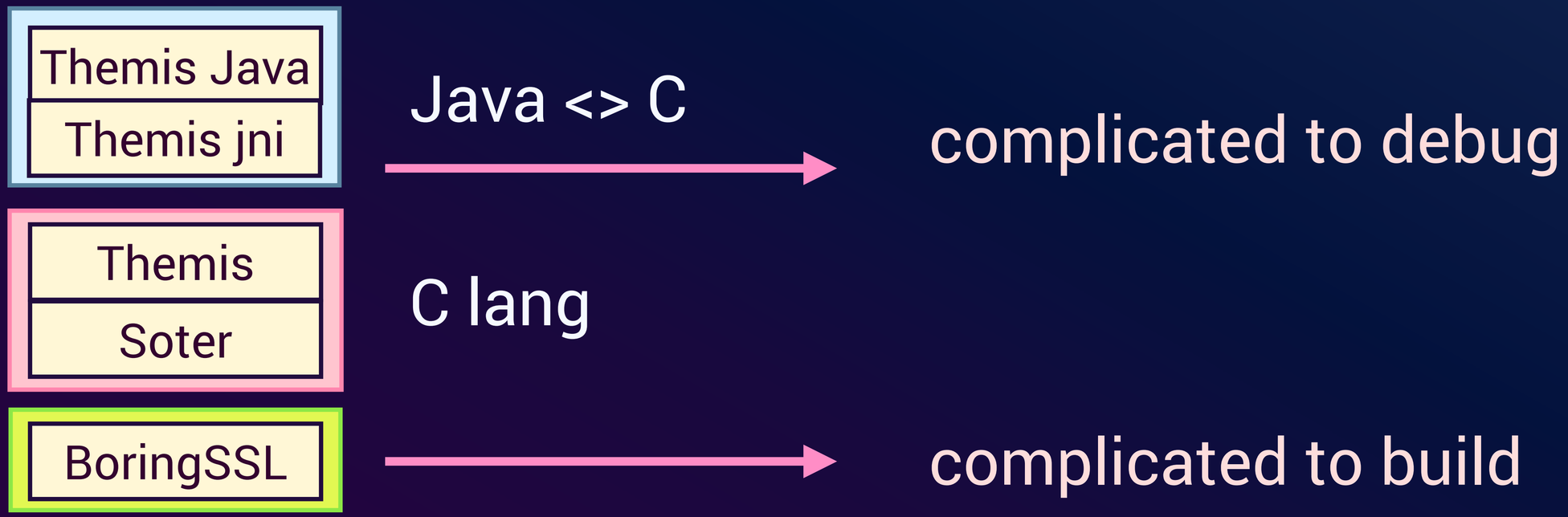
Android specifics

Java app

Kotlin app

Java <> Kotlin interoperability



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BoringSSL

```
CMake Error at /home/user/android-sdk/ndk-bundle/build/cmake/
android.toolchain.cmake:169 (message): GCC is no longer supported.

See https://android.googlesource.com/platform/ndk/+/master/docs/
ClangMigration.md.
```

github.com/cossacklabs/themis/pull/352

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BoringSSL

```
CMake Error at /home/user/android-sdk/ndk-bundle/build/cmake/
android.toolchain.cmake:169 (message): GCC is no longer supported.

See https://android.googlesource.com/platform/ndk/+/master/docs/
ClangMigration.md.
```

```
cmake {
    arguments "-DCMAKE_TOOLCHAIN_FILE=" + android.ndkDirectory +
              "-DANDROID_NATIVE_API_LEVEL=21",
              "-DANDROID_TOOLCHAIN=gcc",
              "-DCMAKE_BUILD_TYPE=Release",
              "-GNinja"
}
```

gcc -> clang

github.com/cossacklabs/themis/pull/352

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BoringSSL

why so slow 🤔

```
$ time ./gradlew --no-daemon --no-parallel --max-workers=2 assembleDebug

real    34m46.028s
user    29m9.580s
sys     6m39.280s
```

github.com/cossacklabs/themis/pull/447

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BoringSSL

```
@$(MAKE) -C $(BIN_PATH)/boringssl
@$(MAKE) -C $(BIN_PATH)/boringssl crypto decrepit
```

don’t build examples

```
$ time ./gradlew --no-daemon --no-parallel --max-workers=2 assembleDebug

real    34m46.028s
user    29m9.580s
sys     6m39.280s
```

```
real    12m46.028s
user    9m1.880s
sys     2m52.020s
```

github.com/cossacklabs/themis/pull/447

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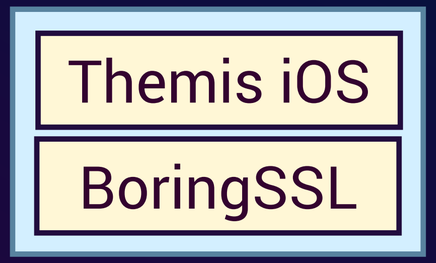
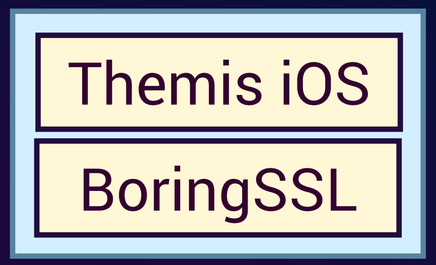
Multi-platform is hard



BoringSSL is used in iOS libs
by Google (Firebase)

Multi-platform is hard



BoringSSL is used in iOS libs
by Google (Firebase)

no AES XTS in BoringSSL iOS CocoaPod

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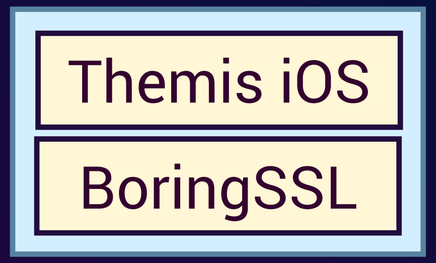
Multi-platform is hard



BoringSSL is used in iOS libs
by Google (Firebase)

↓

no AES XTS in BoringSSL iOS CocoaPod

↓

```
#define SOTER_BORINGSSL_DISABLE_XTS
```

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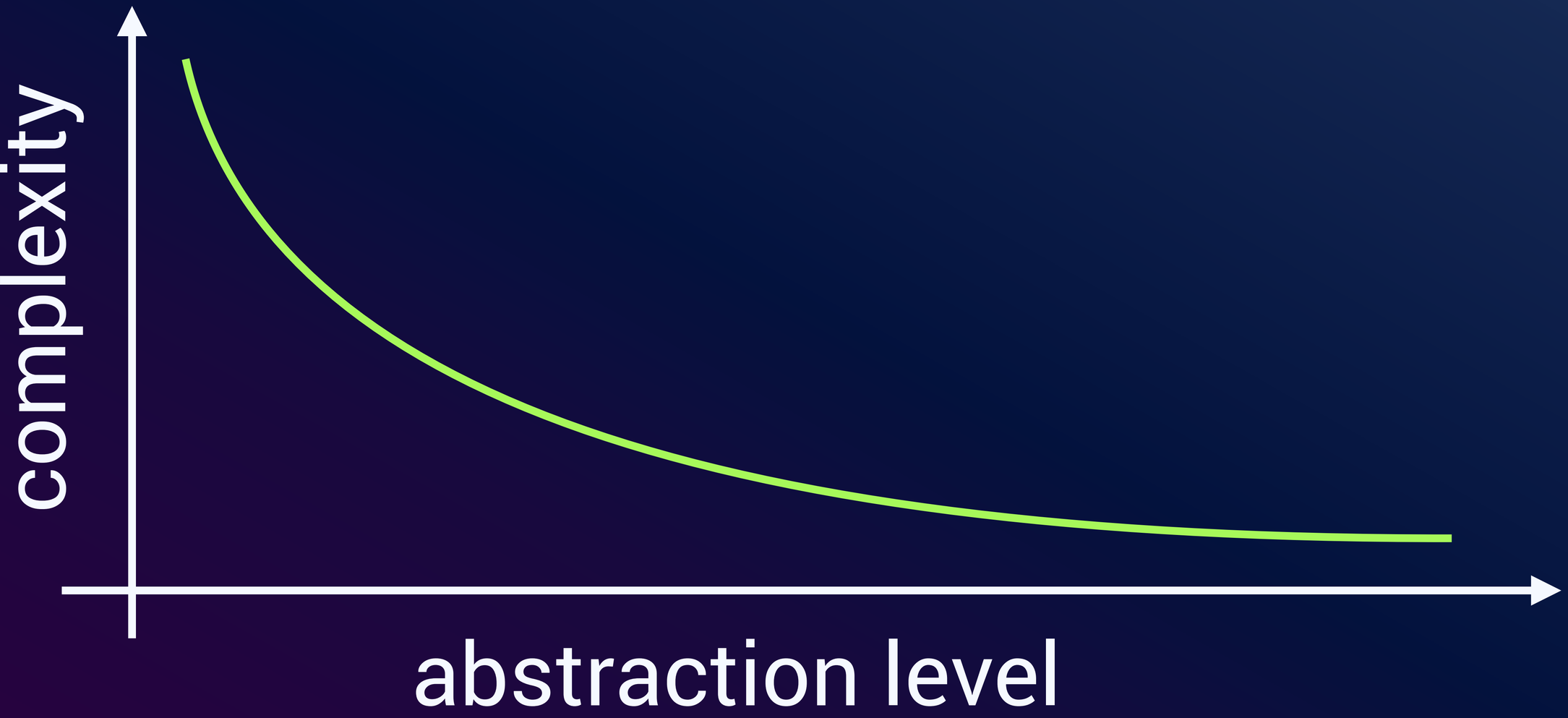
Hard to misuse

encryption integration



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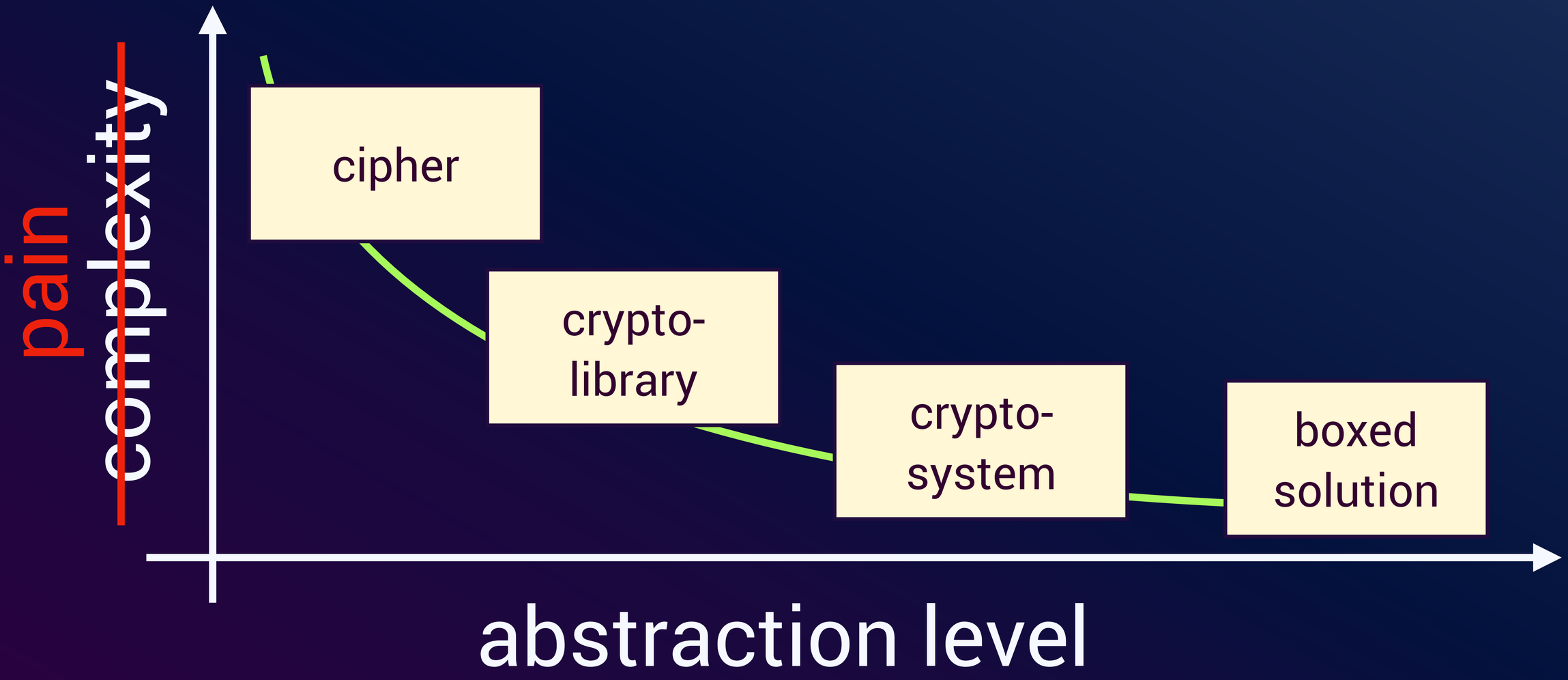
encryption integration



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CommonCrypto AES

```
status = CCCrypt(operation,
                 CCAlgorithm(kCCAlgorithmAES128),
                 CCOptions(kCCOptionPKCS7Padding),
                 keyBytes,
                 key.count,
                 ivBytes,
                 encryptedBytes,
                 input.count,
                 &outBytes,
                 outBytes.count,
                 &outLength)
```

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Easy to make mistakes

```
do {
    let aes = try AES(key: "keykeykeykeykeyk", iv: "drowssapdrowssap") // aes128
    let ciphertext = try aes.encrypt(Array("Nullam quis risus eget urna mollis ornare vel eu leo.".utf8))
} catch { }
```

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Easy to make mistakes

should use KDF(key)

should be random

```
do {
    let aes = try AES(key: "keykeykeykeykeyk", iv: "drowssapdrowssap") // aes128
    let ciphertext = try aes.encrypt(Array("Nullam quis risus eget urna mollis ornare vel eu leo.".utf8))
} catch { }
```

uses AES CBC, not AES GCM

padding? salt?

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Themis: hard to make mistakes

```
do {
    let cellSeal = TSCellSeal(key: UUID().uuidString.data(using: .utf8)!)!
    let encryptedMessage = try cellSeal.wrap("message".data(using: .utf8)!,
                                             context: nil)
} catch {}
```

github.com/cossacklabs/themis

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Themis: hard to make mistakes

built-in KDF to make keys stronger

```
do {
    let cellSeal = TSCellSeal(key: UUID().uuidString.data(using: .utf8)!)!
    let encryptedMessage = try cellSeal.wrap("message".data(using: .utf8)!,
                                             context: nil)
} catch {}
```

hides cryptographic details: salt, IV, KDF, padding

uses AES-256-GCM

github.com/cossacklabs/themis

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One API to rule them all!

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```
import themis

do {
    let cellSeal = TSCellSeal(key: UUID().uuidString.data(using: .utf8)!)
    let encryptedMessage = try cellSeal.wrap("message".data(using: .utf8)!,
                                             context: nil)
} catch {}
```

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```rust
use themis::secure_cell::SecureCell;

let cell = SecureCell::with_key(key)?.seal();
let encrypted = cell.encrypt(b"source data")?;
```

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```
from pythemis.scell import SCellContextImprint

scell = SCellContextImprint(key)
encrypted_message = scell.encrypt(b'message')
```

```rust
use themis::secure_cell::SecureCell;

let cell = SecureCell::with_key(key)?.seal();
let encrypted = cell.encrypt(b"source data")?;
```

```ruby
require 'rbthemis'

scell_seal = Themis::Scell.new(key, Themis::Scell::SEAL_MODE)
encrypted_message = scell_seal.encrypt(message, context)
```

```javascript
var themis = require('jsthemis')

var scell = new themis.SecureCellSeal(key)
var encrypted_message = scell.encrypt('message', context)
```

```java
import com.cossacklabs.themis.*;

SecureCell cell = new SecureCell(key, SecureCell.MODE_SEAL);
SecureCellData cellData = cell.protect(context, data);
```

```cpp
#include <themispp/secure_cell.hpp>

themispp::secure_cell_seal_t sm(key);
try {
    std::vector<uint8_t> encrypted_message = sm.encrypt(mes
} catch (const themispp::exception_t& e) {
    e.what();
}
```

```go
import "github.com/cossacklabs/themis/gothemis/cell"

secureCell := cell.New(secretKey, cell.ModeSeal)
protectedData, _, err := secureCell.Protect(data, context)
```

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Themis API incapsulates

✅ 1. Cipher suit, mode, padding, IV, key, memory.

✅ 2. KDF, key management.

✅ 3. Authentication, ephemeral keys.

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Testing

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Testing

```
cloc src

328 text files.
SUM: 35737
```

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Testing

```
cloc src

328 text files.
SUM: 35737
```

```
cloc tests

3508 text files.
SUM: 341312
```

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Testing

unit tests

per each language, crypto: NIST-specified for PRNG & AES

medium.com/@cossacklabs/automated-security-testing-56ee1253c1fd

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Testing

fuzzing

unit tests

AFL

per each language, crypto: NIST-specified for PRNG & AES

medium.com/@cossacklabs/automated-security-testing-56ee1253c1fd

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Testing

memory, sanitizers, SATS

fuzzing

unit tests

clang, Valgrind, Splint, Cppcheck

AFL

per each language, crypto: NIST-specified for PRNG & AES

medium.com/@cossacklabs/automated-security-testing-56ee1253c1fd

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Testing

integration tests	per OS, per language
memory, sanitizers, SATS	clang, Valgrind, Splint, Cppcheck
fuzzing	AFL
unit tests	per each language, crypto: NIST-specified for PRNG & AES

medium.com/@cossacklabs/automated-security-testing-56ee1253c1fd

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Testing

backwards compatibility tests	between versions
integration tests	per OS, per language
memory, sanitizers, SATS	clang, Valgrind, Splint, Cppcheck
fuzzing	AFL
unit tests	per each language, crypto: NIST-specified for PRNG & AES

medium.com/@cossacklabs/automated-security-testing-56ee1253c1fd

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Testing

OWASP Source Code Analysis Tools

owasp.org/index.php/Source_Code_Analysis_Tools

Clouseau – git repo inspector for keys & creds.

github.com/cfpb/clouseau

Fuzzing resources

github.com/secfigo/Awesome-Fuzzing

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Testing

integrated with Github
unit tests, memory

iOS, Android, macOS
examples and tests

everything o.o

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Security

zeroing, minimization, memory,
constant time checks, etc

cossacklabs.com/blog/macros-in-crypto-c-code.html

github.com/veorq/cryptocoding

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One readme is not enough

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1. Language-specific docs

Building Themis wrappers (11)

- Android wrapper installation
- Java wrapper installation
- iOS/macOS wrapper installation
- C++ wrapper installation
- WebAssembly wrapper installation
- Node.js wrapper installation
- PHP wrapper installation
- Go wrapper installation
- Python wrapper installation
- Ruby wrapper installation
- Rust wrapper installation

Tutorials & How Tos

About the tutorials

- Java and Android HowTo
- Swift HowTo
- Objective-C HowTo
- Python HowTo
- PHP HowTo
- Ruby HowTo
- CPP HowTo
- Go HowTo
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- Rust HowTo
- WebAssembly HowTo

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1. Language-specific docs

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- NodeJS HowTo
- Rust HowTo
- WebAssembly HowTo

“give me code!”

“too much to read”

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2. “Safe to copypaste” code snippets

```
session = SSession(b'user_id2', client_private_key, CustomSimpleTransport())
# this call is only made by the client
encrypted_message = session.connect_request()

# send connect request to the peer
response_bytes = user_communication_send_method(encrypted_message)
message = session.unwrap(response_bytes)

# establish the session
while not session.is_established():
    response_bytes = user_communication_send_method(message)
    message = session.unwrap(response_bytes)
```

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2. “Safe to copypaste” code snippets

```
session = SSession(b'user_id2', client_private_key, CustomSimpleTransport())
# this call is only made by the client
encrypted_message = session.connect_request()

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while not session.is_established():
    response_bytes = user_communication_send_method(message)
    message = session.unwrap(response_bytes)
```

“how to use it in the app?”

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3. Example applications

```
cloc docs/examples

15427 text files
SUM: 1015922
```

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3. Example applications

```
cloc docs/examples

15427 text files
SUM: 1015922
```

```
cloc src

328 text files.
SUM: 35737
```

```
cloc tests

3508 text files.
SUM: 341312
```

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3. Example applications

```
cloc docs/examples

15427 text files
SUM: 1015922
```

“but I am building unique app!”

4. Tutorials and use case specific apps

During the development stage, we frequently do Proof-of-Concept projects to test different assumptions. They serve as interesting demos (examples) of what Themis is capable of:

Demo	Description	Repo	Blog post
0fc	Anonymous web chat * Python * webthemis (C++ + HTML/JS)	repo	blog post
Sesto	Secure storage * Python * webthemis (C++ + HTML/JS)	repo	blog post
Swift Alps demo	Secure communication (iOS app with Python server based on Secure Session) * Swift * Python	repo	slides
Zero-Knowledge Architectures workshop	iOS app for storing and sharing encrypted notes stored in Firebase database * Swift	repo	

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“your app works, but my app doesn’t”

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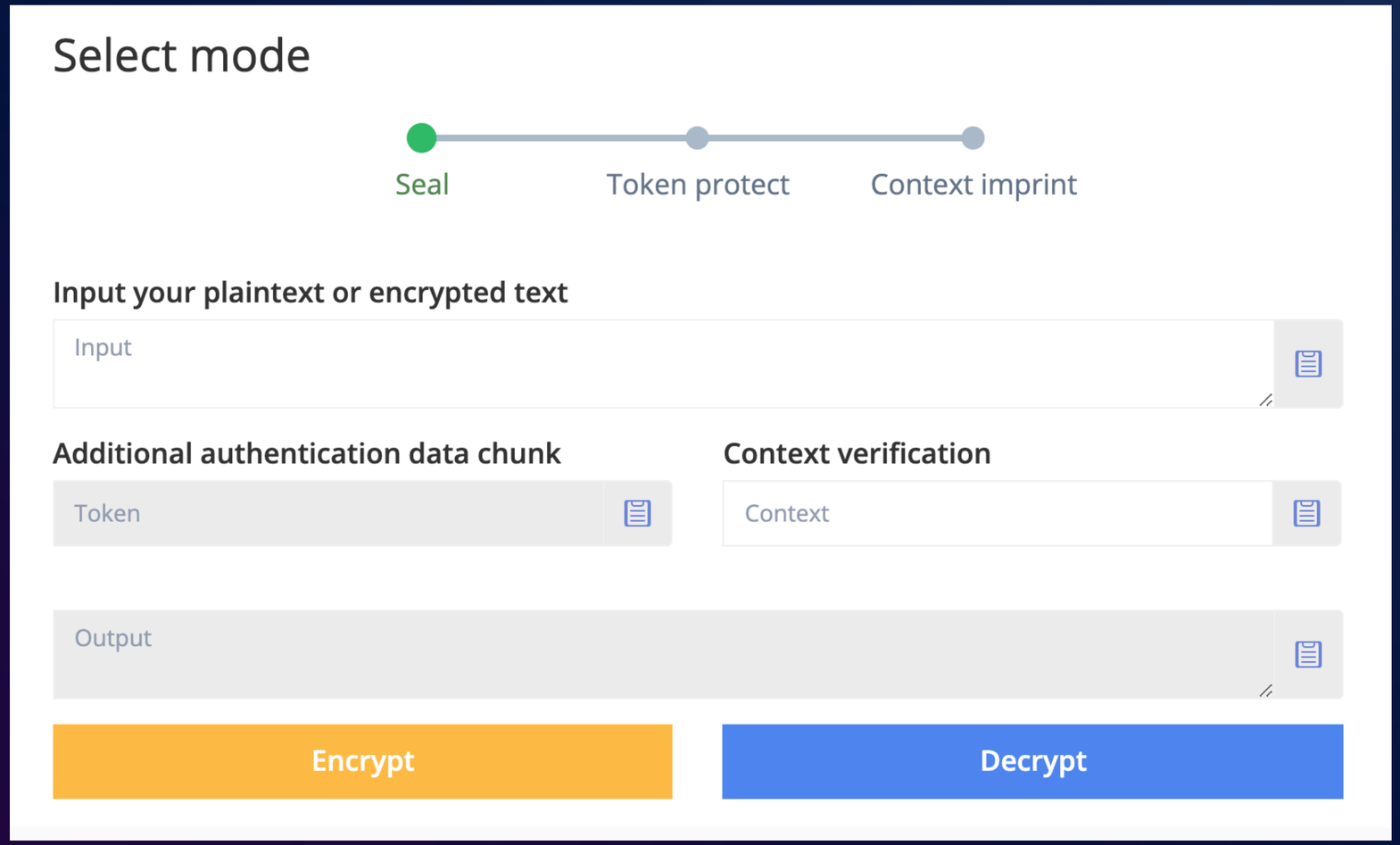
5. Codeless simulators

verify own configuration



docs.cossacklabs.com/simulator/interactive/

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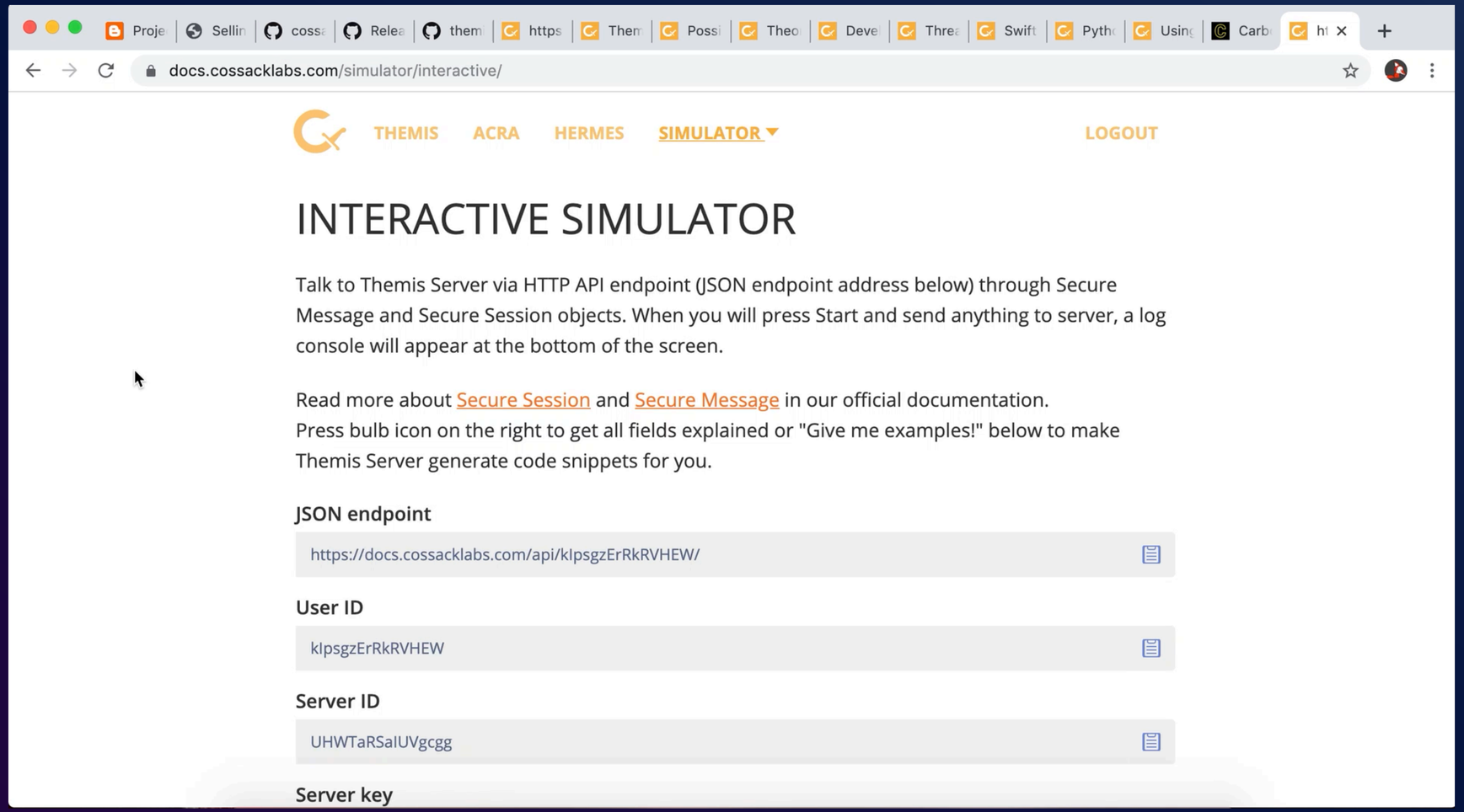
5. Codeless simulators

debug the whole flow



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One readme is not enough

1. Language-specific docs
2. “Safe to copypaste” code snippets
3. Example applications
4. Tutorials and use case specific apps
5. Codeless simulators

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Community

Are you responsible for how users use your software?

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Community

answering Q

- **Secure session vs SRP** question
  #529 by OlexandrStepanov was closed on Sep 23
- **[question] bindings for C# and .net** question
  #520 by dodikk was closed on Aug 15 1 of 1
- **Presence of 32bit native libraries without 64bit support** O-Android 🤖 question
  #479 by vanceanderson41 was closed on Jul 17 2 of 4
- **iOS - Lost key stored in Keychain when user change Device** question
  #342 by CodeTeamLabs was closed on Jan 12
- **Objective C - Store Public Key in Firebase Database and use AFNetworking SecurityPolicy** question
  #338 by CodeTeamLabs was closed on Jul 16
- **Themis iOS and BoringSSL: Objective-C Implementation** O-iOS 📱 question
  #336 by CodeTeamLabs was closed on Nov 12, 2018
- **Can I use secp256k1 keys and/or ECDH secret to encrypt using themis?** core help wanted ❤️ question
  #322 by FrankC01 was closed on Jul 16

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Community

ATTACKS ON CRYPTOSYSTEMS

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POSSIBLE ATTACKS ON CRYPTOSYSTEMS IN THEMIS

nown attacks on the cryptoalgorhitms

THREAD SAFETY

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Projects that use Themis

Themis is widely-used for both non-commercial and commercial projects. We've mentioned some of the public projects in a blog post in December 2018, and a more complete list is as follows (in alphabetical order):

Credits and honourable mentions

People

Significant contributions to Themis encryption library have been made by Ignat Korchagin (secumod) and Andrey Mnazakanov (mnaza).

A special thank you goes to the awesome contributors that help us make Themis better:

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Community

Submitting apps to the App Store

If you're using Themis as your means of encryption within your iOS/macOS app that you're submitting to the App Store, your encryption falls under the "open source" exception (although if your app is not open source/distributed free of charge, we strongly recommend that you seek legal advice).

Themis is a free cryptographic library that builds on the existing, community-tested cryptographic instruments (OpenSSL, LibreSSL, BoringSSL, depending on the target platform). It is open source and Apache 2-licensed, with its full source code publicly available online on GitHub.

This means that you should indicate that you're using encryption and only submit annual self-classification reports (use this handy table to self-check). Read more about Apple regulations on cryptography and check Apple docs.

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Where Themis is used?

mobile apps

web-first apps

other libraries

Cossack Labs software

e-commerce

fintech

chats

cossacklabs.com/blog/themis-contributors-and-projects-2018.html

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<HospitalApp>: cryptocore 130 lines

```
// ================================================================================
// AES
// ================================================================================

/// generates random AES256 key
func ___generateAES256Key(count: Int = 32) throws -> Data {

    var keyData = Data(count: count)
    let status = keyData.withUnsafeMutableBytes {
        SecRandomCopyBytes(kSecRandomDefault, count, $0.baseAddress!)
    }

    guard status == errSecSuccess else {
        throw CryptoStatus(status: status)
    }

    return keyData
}

/// encrypt bytes with simmetric key
func ___encrypt(data: Data, withSimmetricKey key: Data) throws -> Data {
    // init Secure Cell in seal mode
    guard let cellSeal = TSCellSeal(key: key) else {
        throw CryptoError.encryptSeal
    }
```

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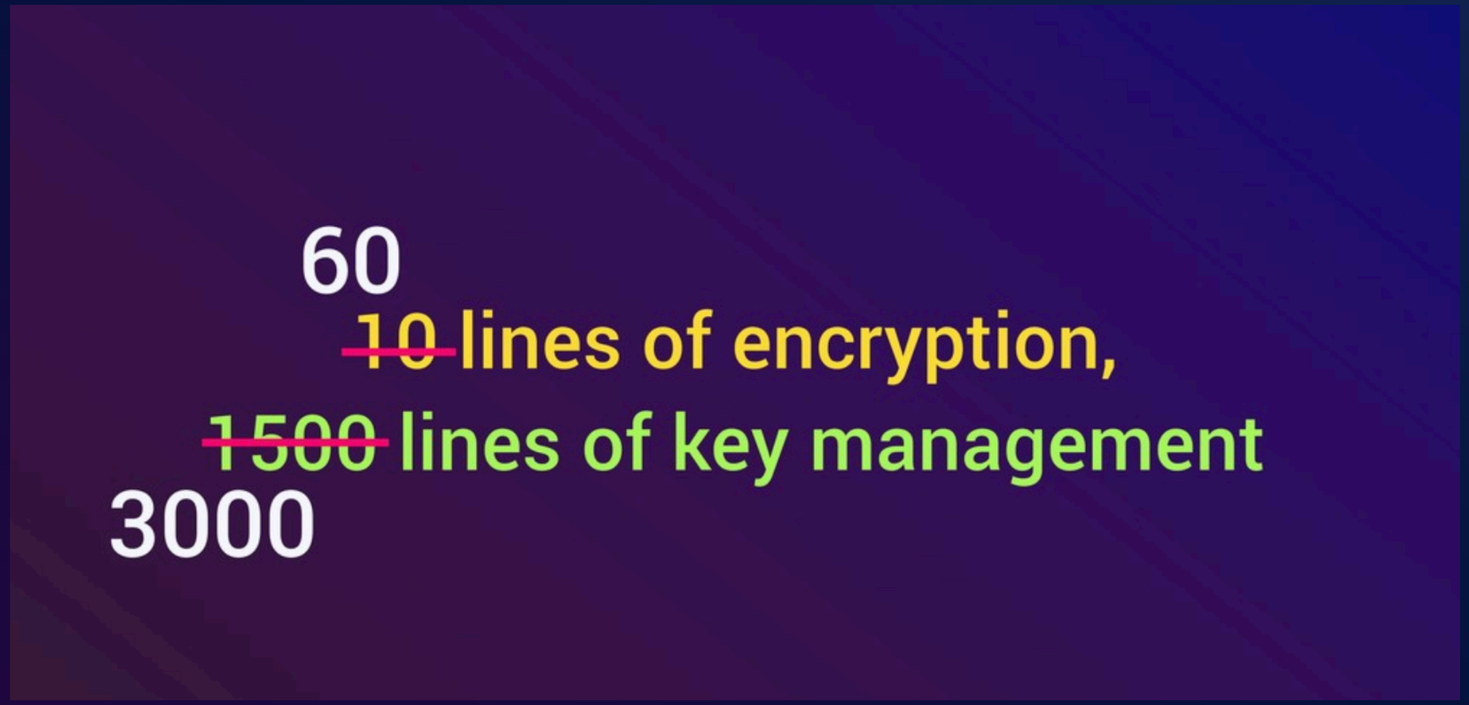
Bear: cryptocore 60 lines



speakerdeck.com/vixentael/10-lines-of-encryption-1500-lines-of-key-management?slide=42

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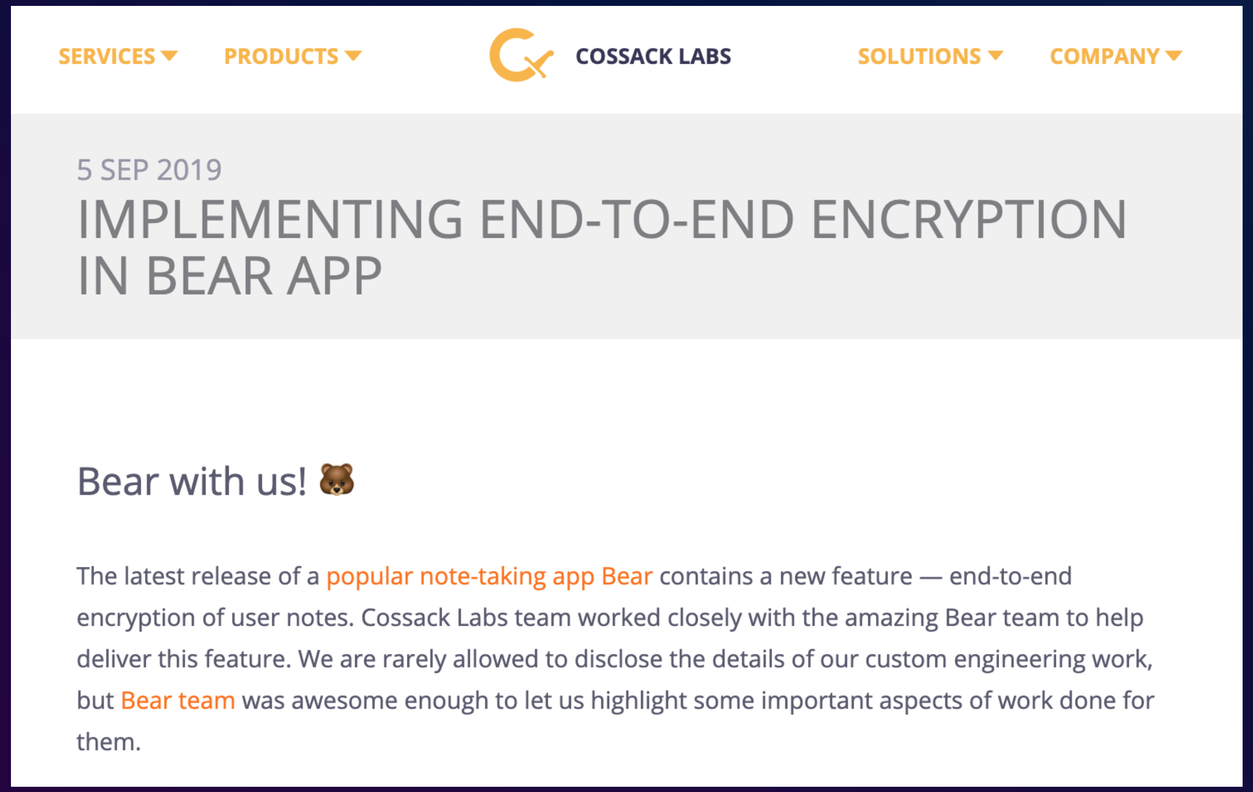
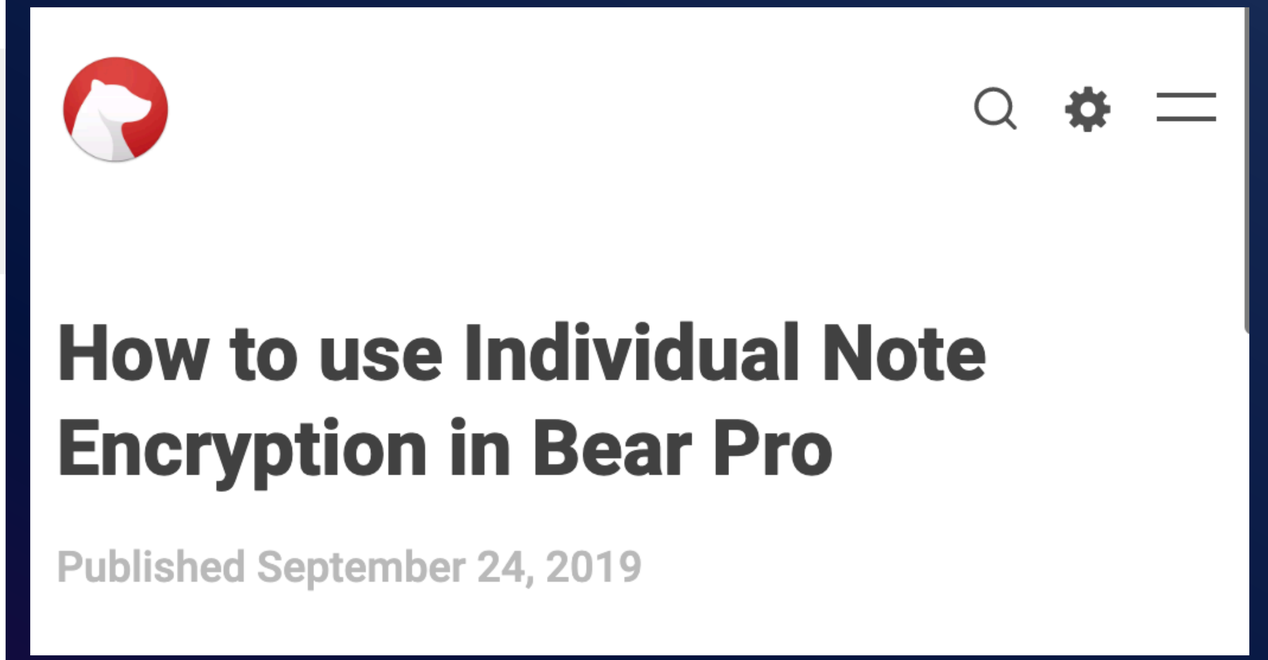
End-to-end encryption in Bear



cossacklabs.com/blog/



blog.bear.app/

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notes protection (e2ee)

passphrase KDF

auto-locking timer

obfuscation

hint encryption

encrypted user settings

anti-RE & anti-debugging

zeroing secrets

failed attempts counter

continuous improvements

TLS / certificate pinning

prepare for incidents

cossacklabs.com/blog/end-to-end-encryption-in-bear-app.html

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Key points

Good tools allow to focus on product, not on crypto code

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1. Encryption lib should be: multi-platform, maintained, secure by default, open sourced, easy to install, hard to misuse, tested.

2. Supporting libs is VERY complicated.

3. Better to spend time on features than the crypto code.

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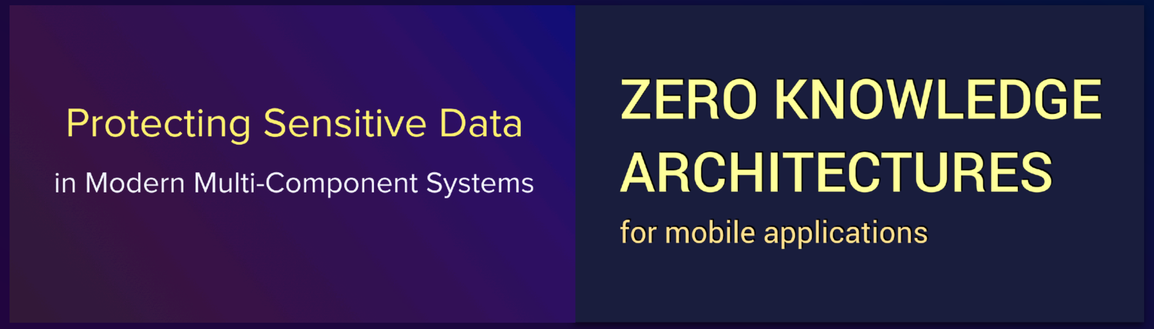
COSSACK LABS



github.com/vixentael/my-talks