Designing the API for a Cryptographic Library

A Misuse-Resistant Application Programming Interface

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Outline

The Gap Between Theory and Practice

(Academic) cryptographers $\Longleftrightarrow$ (Industrial) engineers

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- provably secure
- practical systems
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when things go wrong

- *Why didn't THEY listen to us?*
- *Why didn't THEY tell us?*

Goals of this talk

- **Bridging the gap** between theory and practice
- Rise awareness of cryptographic misuse issues
- Introduce our cryptographic library (LibAdaCrypt) (`http://github.com/cforler/Ada-Crypto-Library`)
- **Collecting design features** to improve this Library

Common Flaws In Cryptographic Applications

Top Three Flaws In Cryptographic Applications

1. Buffer Overflows
2. Nonce Reuse
3. Plaintext Leaking

Buffer Overflows

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Countermeasure

Use of bounds checking programming language like Ada

Misuse? What Misuse?

- A: “Have you any problems with encryption?”
- B: “No, we are fine. We are using AES!”
- A: “Well ... what mode of operations are you using?”
- B: ???

Cryptographic ciphers must be used in a **proper mode** of operation **to ensure**

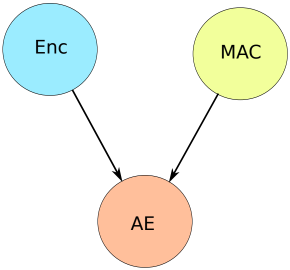
- data privacy (confidentiality)
- data integrity (authenticity)

Generic Composition

Authenticated Encryption Schemes

Modes of operations that ensure both **privacy** and **integrity**

Generic composition of **secure** encryption scheme and **secure** MAC usually leads to **insecure** AE schemes
[Bellare Namprempre 2008]



"Building a secure crypto system is easy to do badly, and very difficult to do well"
– Bruce Schneier

Authenticated Encryption Schemes

- There are a lot of beautiful AE schemes that are provably secure under **reasonable assumptions** (CWC, GCM, OCB,...)
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QA-Session

- Q: Are AE schemes misuse resistant, and will the honest developer apply it properly?

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- A: No! :-)

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Proper encryption schemes are only secure under **reasonable assumptions**

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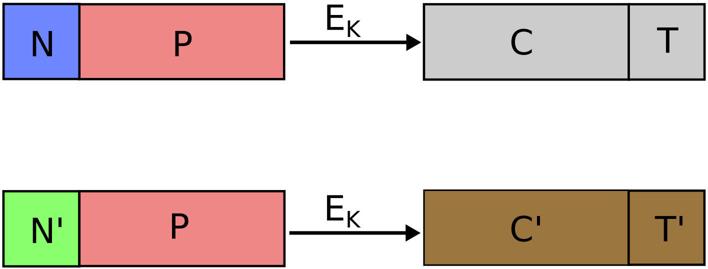
Usually, cryptographers publish this assumptions **only** in cryptographic conferences and journals

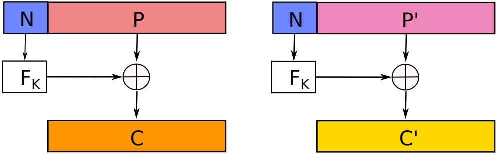
Nonce - Number Used Only Once

Modern AE schemes are not deterministic but nonce based



Nonce Misuse Issue

It is not unusual that K and N determine a keystream S



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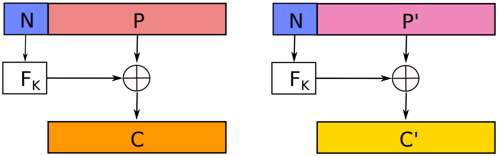

Fatal privacy issue, even for secure keystream generator F_K

$$P \oplus P' = C \oplus C'$$

(Fatal integrity issues [Fleischmann Forler Lucks 2012])

Nonce Reuse Examples

Examples of flawed implementations

- Intercepting Mobile Communications: The Insecurity of 802.11 [Borisov, Goldberg, Wagner 2001]
- The Misuse of RC4 in Microsoft Word and Excel [Wu 2005]
- Console Hacking 2010 - PS3 Epic Fail [Hotz 2010]
- ...

$\Rightarrow$ Even big players as Microsoft and Sony sometimes get it wrong

Nonce Reuse Prevention

Ada Countermeasure Against Nonce Reuse

A **limited** and **private** `type` that is *always* updated before reading

Proposed and Implemented Solution (ACL-0.5.4)

```
generic
   type Block is private;

package Crypto.Types.Nonce_Generator is

   type Nonce is abstract limited new ...

   function Update(This : in out Nonce)
                  return Block is abstract;

end Crypto.Types.Nonce_Generator;
```

Implementation of a Random Nonce Generator

```
function Update(This: in out Nonce_Rand) return ...
   Byte_Array: Bytes(0..(Block'Size / 8)-1);
begin
   Crypto.Types.Random.Read(Byte_Array);
   return To_Block_Type(Byte_Array)
end Update;
```

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Collision probability for q invocation of the function `Update`:

$$\leq \frac{q^2}{2^n} \qquad n = \text{Block'Size}$$

Supported Nonce Generators (ACL-0.5.4)

Name	Random Source	NV Memory	Update
Counter	No	Yes	Ctr
Random	Yes	No	R
Mixed-1	Yes	No	Ctr
Mixed-2	Yes	No	R and Ctr

Note that the implementation of a nonce type requires at least NV memory or a random source.

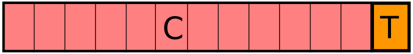
Plaintext Leaking Scenario

Definition (Plaintext Leaking)

Application stores (parts of) an unauthenticated plaintext

Plaintext Leaking Example

Decryption APIs usually process plain/ciphertext chunks




```
procedure Decrypt(C          : in   Ciphertext_Chunk;
                  P          : out  Plaintext_Chunk);

procedure Final_Decrypt(C    : in   Ciphertext_Chunk;
                        T    : in   Tag_T;
                        P    : out  Plaintext_Chunk;
                        Verified : out Boolean);
```

What happens if the Verification failed?

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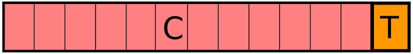


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What happens if the Verification failed?

At least $n - 1$ chunks of the invalid Plaintext have been delivered to the application

Application User Awareness

One out of five application user ignore security warnings [Egelman 2008]

Invalid Ciphertext

The validation of the ciphertext failed. The ciphertext might be modified by an evil adversary.

Proceed anyway

Delete Plaintext

Goal

Plaintext Leaking Countermeasure

Design a proper API that never leak parts of unauthenticated plaintext to a application

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Drawback

Usually, an ciphertext must processed twice

1. Authenticate ciphertext
2. Decrypt ciphertext

Our Solution (ACL-0.5.4)

```
type AE_Scheme is limited interface;

type Writer is access procedure(B : in  Bytes);

type Reader is access procedure
  (B : out Bytes; Count: out Natural);

function D_And_V(This          : in out AE_Scheme;
                 Ciphertext_F  : in Reader;
                 Ciphertext_S  : in Reader := null;
                 Plaintext     : in Writer)
                return Boolean is abstract;
```

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- A good cryptographic library should be
  - useful for non cryptographers
  - resistant to common misuse issues
- What do you think about the `Ada-Crypto-Library`? (`http://github.com/cforler/Ada-Crypto-Library`)
- We are eager to hear from you

Ände

Questions?