

# CS427 Final Project - Stream File Encryption & Key Management

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# Abstract

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# Stream Encryption and Decryption (enc, dec)

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## Primitives

Our design utilizes  $F$ , a Block Cipher (PRP).  $F$  will be the AES block cipher with a 256-bit key. This key will be derived using a common hashing algorithm, SHA256 based on the text password entered by the user.

- <https://www.geeksforgeeks.org/advanced-encryption-standard-aes/>
- <https://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.197.pdf>

klen = 256 TODO: types declared here	$\frac{F_{AES}(k, d):}{\text{TODO}}$
---	--------------------------------------

## Formal Scheme Definition

Our symmetric encryption mode will be a modified CTR mode.

klen = 256 TODO: types declared here	$\frac{\text{ENC}_{CTR}(k, m_1    \dots    m_l):}{r \leftarrow \{0, 1\}^{klen}}$	
	$c_0 := r$	
	for $i = 1$ to $l$ :	$\frac{\text{DEC}_{CTR}(k, c_0    \dots    c_l):}{\text{TODO}}$
	$c_i := F(k, m_i    r)$	
	$r := r + 1 \% 2^{klen}$	
	return $c_0    \dots    c_l$	

The hashing function we will use is SHA-256.

klen = 256 TODO: types declared here	$\frac{\text{HASH}_{SHA-256}(m):}{\text{TODO}}$
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## Main

```
from getpass import getpass

klen, blen = 256

# Stored persistently, in file or otherwise
s = ''
K = ''
H = ''

Init():
    k = KeyGen()
    s = KeyGen()
    print("You will make a new password.")
    H = Pass2Key()
```

```

print("You will enter the password again.")
K = EncKey()
print("Vault has been initialized.")

Main():
    if:
        Init()

    k = DecKey()
    # Decrypt vault with k
    print("Vault has been decrypted.")

    #Encryption and Decryption behavior here

    # Re-encrypt vault files with k
    # k is not persistant on shutdown

```

getpass: <https://stackoverflow.com/questions/43673886/python-2-7-how-to-get-input-but-dont-show-keys-entered/43673912>

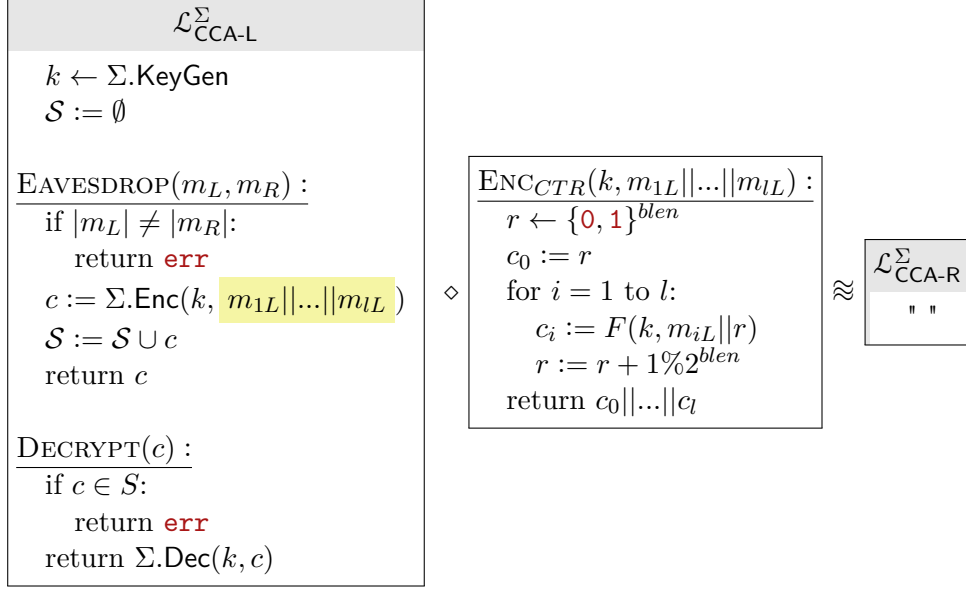
## Security Proof and Reasoning

We will prove that the encryption scheme of our key manager, a modified CTR mode, has security against chosen ciphertext attacks. We assume that  $F$  is a secure PRP.

To prove that a scheme has CCA security, we must prove that two random plaintexts (L & R) cannot be distinguished from each other, including any partial information, like so:

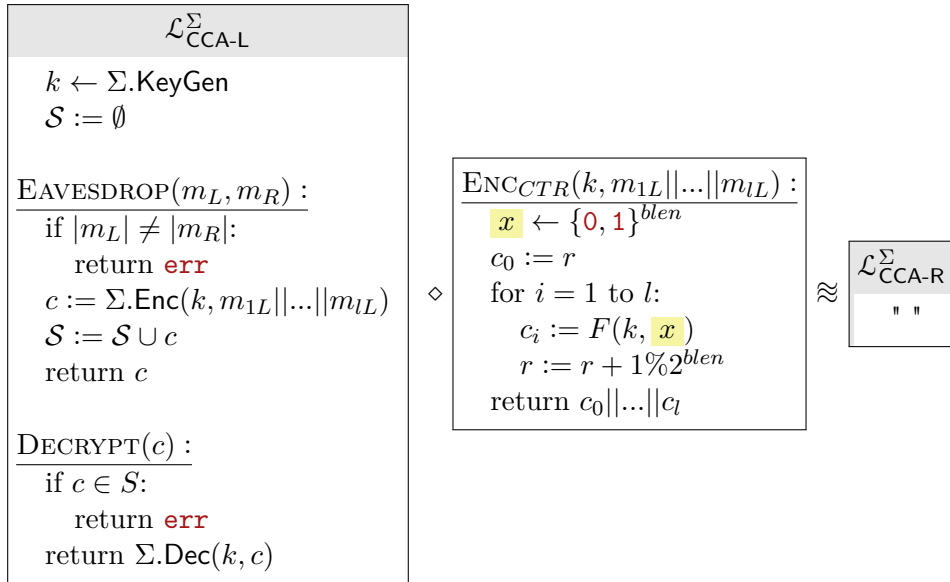
$\mathcal{L}_{\text{CCA-L}}^\Sigma$		$\mathcal{L}_{\text{CCA-R}}^\Sigma$
$k \leftarrow \Sigma.\text{KeyGen}$ $\mathcal{S} := \emptyset$		$k \leftarrow \Sigma.\text{KeyGen}$ $\mathcal{S} := \emptyset$
$\text{EAVESDROP}(m_L, m_R) :$ <div>if <math> m_L  \neq  m_R </math>:</div> <div>return <b>err</b></div> $c := \Sigma.\text{Enc}(k, m_L)$ $\mathcal{S} := \mathcal{S} \cup c$ return $c$	$\approx$	$\text{EAVESDROP}(m_L, m_R) :$ <div>if <math> m_L  \neq  m_R </math>:</div> <div>return <b>err</b></div> $c := \Sigma.\text{Enc}(k, m_R)$ $\mathcal{S} := \mathcal{S} \cup c$ return $c$
$\text{DECRYPT}(c) :$ <div>if <math>c \in \mathcal{S}</math> return <b>err</b></div> return $\Sigma.\text{Dec}(k, c)$		$\text{DECRYPT}(c) :$ <div>if <math>c \in \mathcal{S}</math> return <b>err</b></div> return $\Sigma.\text{Dec}(k, c)$

From here, we will walk through the proof for the left library.

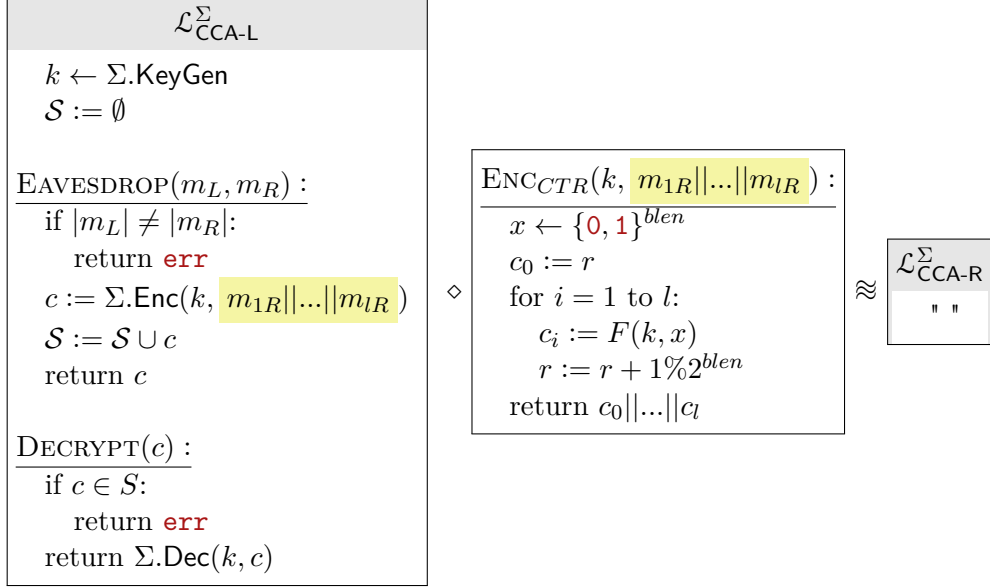


Next, we can turn our attention to the linked encryption scheme. Here we see that for each block, we calculate  $F(k, m_i || r)$  for the corresponding ciphertext block.  $r$  is sampled randomly, so the chance of collision is  $\frac{1}{2^{\text{blen}}}$ . However, we are doing counter mode, so  $r$  for each subsequent block in the message is deterministic, for  $l$  blocks in the message. Still, the rate of collision comes to  $\frac{l}{2^{\text{blen}}}$ . The  $l$  increases much slower than the  $2^{\text{blen}}$ , which means the rate of collisions is still negligible.

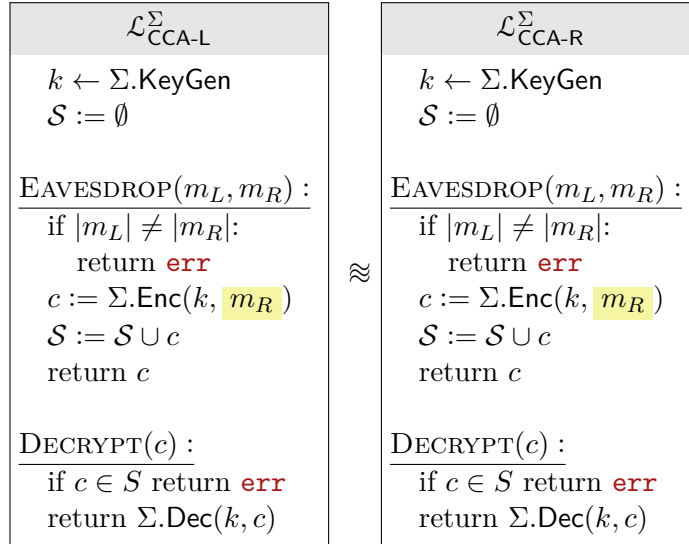
Because  $r$  is sampled randomly and has a negligible rate of collisions,  $m_i || r$  also has a collision rate of  $\frac{l}{2^{\text{blen}}}$  even when the same  $m_i$  is inputted. It does not matter what  $m_i$  is when we concatenate it and put it through the PRP  $F$ . To illustrate this, we can apply the following transformation:



Now,  $m_{1L}||...||m_{lL}$  is not being used by the  $Enc_{CTR}$  function; we can change it to some other name without disrupting the function of the encryption scheme. We can rename this to  $m_{1R}||...||m_{lR}$  and inline it into the library.



Let's inline the whole linked function, and re-consider the right library.



Here we can see in this function, the left and right libraries are indistinguishable. For any calling program  $A$ , it will not be able to distinguish between the two libraries - aka, it will not be able to obtain any partial information from the scheme.

## Key Generation and Storage (keygen)

### Primitives

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$m_1    \dots    m_l := \text{DecStore}$ $c_0    \dots    c_l := \text{EncStore}$	$\frac{\text{EncStore}(k):}{c_0    \dots    c_l := \text{ENC}_{CTR}(k, m_1    \dots    m_l)}$ return $c_0    \dots    c_l$	$\frac{\text{DecStore}(k):}{m_1    \dots    m_l := \text{DEC}_{CTR}(k, c_0    \dots    c_l)}$ return $m_1    \dots    m_l$
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### Formal Scheme Definition

$k := \text{DecKey}()$	$\frac{\text{KeyGen}():}{k \leftarrow \{0, 1\}^{klen}}$ return $k$	$\frac{\text{Pass2Key}():}{p := \text{get\_passphrase}()$ $h := \text{Hash}_{SHA-256}(p    s)$ return $h$	$\frac{\text{EncKey}(k):}{h := H}$ $K := \text{Enc}_{CTR}(h, k)$ return $K$
$s := \text{KeyGen}()$ $H := \text{Pass2Key}()$ $K := \text{EncKey}(h, k)$			

$\frac{\text{DecKey}(K):}{h := \text{Pass2Key}()}$ if $h \neq H$ : return $err$ $k = \text{Dec}_{CTR}(h, K)$ return $k$
---

TODO: Define types and formalize scheme in tex

### Security Proof and Reasoning

Here we define a library of functions that will handle the generation and storage of the Master Key that will be used to encrypt and decrypt the stored keys in the manager. The Master Key is generated with function **KeyGen**, which samples a string of length **klen**. This sampling will come from the machine's built-in random device, such as **/dev/urandom**.

This Master Key will be stored on the machine, encrypted. The encryption and decryption of the Master Key will be done with a password and in the CTR mode, as shown in the remaining two functions, **Pass2Key()** and **EncKey()**. The correct, salted hash of the password will be stored alongside the encrypted Master Key.

**EncKey()** begins with **Pass2Key()**, where it will prompt the user for the password, salt it, and then return the SHA-256 hash. **EncKey** will compare this hash with the stored, correct hash. If they do not match (it is the wrong password), then an error is returned. Otherwise, **EncKey** will call the CTR mode, using the hashed password as a key/seed to the PRP F.

## Conclusion and Discussion

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