Lab 4: Block Ciphers

(From **Lab 4_2025.pdf)**

Deadline: 29 June 2025 11:59PM

Objectives

- Implement the ultra-lightweight PRESENT block cipher

PRESENT

Read on PRESENT: an Ultra-lightweight Block Cipher:

• https://www.iacr.org/archive/ches2007/47270450/47270450.pdf - This is a publication on PRESENT.

• PRESENT: An Ultra-Lightweight Block Cipher | SpringerLink https://link.springer.com/chapter/10.1007/978-3-540-74735-2_31 - This is a conference presentation on PRESENT.

• Read Netpbm image format: http://en.wikipedia.org/wiki/Netpbm_format

You will be able to get all the needed information from the resources above. To aid you, some additional explanation is provided below.

PRESENT Overview

• PRESENT is an example of an SP-network and consists of 31 rounds (and 32 keys). SP refers to substitution-permutation https://en.wikipedia.org/wiki/Substitution%E2%80%93permutation_network .

• Each of the 31 rounds consists of XOR to introduce a round key, a non-linear substitution (S-Box) layer and a linear bitwise permutation (pLayer).

• Last (32nd) key is used at the end for post-whitening https://en.wikipedia.org/wiki/Key_whitening

S-Box

- S-box: substitution-box aka performs substitution
- In PRESENT, number of input bits = number of output bits = 4
- S-box can be implemented as a fixed lookup table.
- Every word of 4 bits (a nibble) is substituted according to a fixed lookup table.
- https://en.wikipedia.org/wiki/S-box

pLayer

- Move bits around (permutation of bits) according to values given in a fixed table
- https://en.wikipedia.org/wiki/Permutation_box

Round Key

- There are a series (key schedule) of 32 keys to be used in PRESENT, to be generated from the 80-bit input key
- The output of each round of key schedule is called round key (key of the round, get it?)
- Schedule for each round i:
    - Rotate left 80-bit key by 61 bits
    - Pass the 4 bits [79...76] through S-box
    - XOR the bits [19...15] with LSB of round_counter (i)
- "Add" round key refers to XOR with round key

Decryption

- Run PRESENT backwards to decrypt. This requires you to be able to invert or "undo" S-box, pLayer, and run the loop in the reverse order as well.

Implementing PRESENT

- Use Python script `present.py` as a template to implement PRESENT block cipher with 80-bit key and 64-bit block length.
- You need to implement both the encryption and decryption portion.
- Check your result using Appendix 1 of the above linked paper. Note that `present.py` provides those test cases at the end of the file.

Implementing ECB Mode

We are going to encrypt an image (`Tux.pbm`). Check if you are able to open it.

Your `present.py` in the previous section is for a plaintext of 64-bit length. In this section, you need to extend your code so that it can work with plaintext larger than 64-bit. Use Electronic Codebook Mode (ECB) method for this purpose.
Tasks

1. Use your ECB mode block cipher to encrypt the file `Tux.ppm`.
2. Decrypt the file and see whether you can still see the same image.

Use `ecb.py` and run the file as the following:

```
python ecb.py -i [input filename] -o [output filename] -k [key filename] -m [mode]
```

Limitation of ECB Mode

ECB mode reveals some side-channel information about the plaintext pattern in the ciphertext. In this section, we will try to learn information about the plaintext image from its ECB ciphertext.

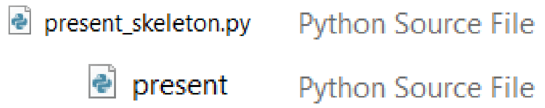
1. Download `letter.e`. This is a secret image, encrypted in ECB mode, with a secret key.
2. Your task is to recover the plaintext of the original image. The image is stored in PBM format and has its header information stored in the file header `header.pbm`, that is known to the attacker, i.e. you.
3. Write a Python script to extract the image pattern from letter.e. You can use `extract.py` as a starting point.

```
python extract.py -i letter.e  -o op.txt -hh header.pbm
```

Hint: You can ignore the first few characters which represent the header as it has already been given. The plaintext PBM image is black and white, i.e. the format only has two values, either 0 or 1. You can assume that there is no space between the data values.

Part I: Implementing PRESENT

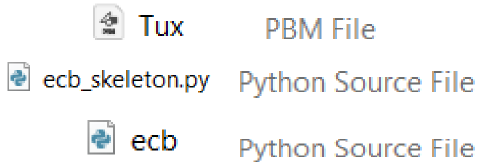
Essential file: present_skeleton.py
Expected result file: present.py



present_skeleton.py	Python Source File
present	Python Source File

Part II: Implementing ECB Mode

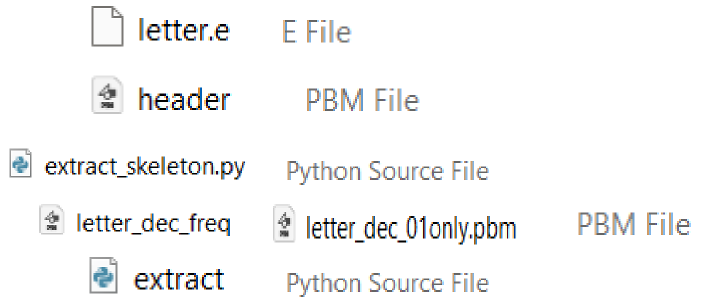
Essential files: Tux.pbm
ecb _skeleton.py
Expected result file: ecb.py



Tux	PBM File
ecb_skeleton.py	Python Source File
ecb	Python Source File

Part II: Limitation of ECB Mode

Essential files: letter.e
header.pbm
extract _skeleton.py
Expected result file: Decrypted letter.e
extract.py



letter.e	E File	
header	PBM File	
extract_skeleton.py	Python Source File	
letter_dec_freq	letter_dec_01only.pbm	PBM File
extract	Python Source File	

Submission

eDimension Submission

Lab 4 submission: Upload a zip file with the following: file name format: **lab4_name_studentid**

Upload a **zip file** with the following:

- `present.py`
- `ecb.py`

- `extract.py`
- Decrypted `letter.e`
- `Jupyter Notebook report (with the outputs saved) in (.ipynb) or (.pdf)`

Deadline: : 29 June 2025 11:59 PM

If you have read carefully through the paper for the PRESENT cipher, you will know that the cipher uses 32 round keys, numbered from 1 to 32 inclusive. In other words, the indices used for the round keys range from 1 to 32 inclusive.

Some of you have noticed that the test vector for the key schedule ("keysTest" in the present.py file) is a dictionary with 33 key-value pairs with "0: 32" as the first key-value pair. As a consequence, even if you have properly coded the genRoundKeys(key) function as described in the "key schedule" section of the paper, you may not be able pass the assertion test for the key schedule in the present.py file. To remedy this, you can do one of two things (not both!):

1. Remove the "0: 32" key pair from the "keysTest" test vector. Keep in mind that if you do this, you will need to be careful with how you use your key indices. Note that the paper uses key index 1 as the first round key, but in Python, the first element in a list is at index 0.

2. Explicitly add a key with value 32 to your list of keys before you actually start to derive the round keys in your genRoundKeys(key) function. In other words: suppose at the beginning of the genRoundKeys(key) function, you decide to declare an empty list called "roundKeys". Then make sure that you type a "roundKeys.append(32)" line before you actually start to derive and append your round keys to the "roundKeys" list.