Q1 Team Name

0 Points

Enciphered

Q2 Commands

5 Points

List the commands used in the game to reach the ciphertext.

==> go
==> wave
==> dive
==> go
==> read

Q3 Analysis

50 Points

Give a detailed description of the cryptanalysis used to figure out the password. (Use Latex wherever required. If your solution is not readable, you will lose marks. If necessary the file upload option in this question must be used TO SHARE IMAGES ONLY.)

** Given facts **
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1. Screen suggest that, we are using block cipher
2. Size of the block is 8 bytes
3. Working finite field is $\mathbb{F}_{128}$. It is constructed using a degree 7 irreducible polynomial $x^7 + x + 1$. Arithmetic operation over $\mathbb{F}_{128}$ will be used.
4. Given two linear transformation
    - A: GIven by an invertible 8×8 key matrix with elements from $\mathbb{F}_{128}$.

○ E: An exponentiation given by 8×1 vector whose elements are numbers between 1 and 126
5. Encrypted Password: lhkrktlnhojqfhfimjmmlthhgkfhimhj
This is obtained by typing password.

Encoding Map

We have clearly observe the ciphertext belongs to the range from f to u. There are 16 letters in this range. Now we map each letters to a four-bit string. Let provide a mapping of a letter to a 4-bit binary string.

f: 0000; g: 0001; h: 0010; i; 0011 j: 0100; k: 0101; l: 0110;
m: 0111; n: 1000;
o: 1001; p: 1010; q: 1011; r: 1100; s: 1101; t: 1110; u: 1111;

So, a byte contains two characters. Thus the input was of 8-bytes, however we are working on $\mathbb{F}_{128}$. Thus, we could have inputs from "ff" to "mu" considering MSB for any letter will be 0.

"Generate-inputs.ipynb" helps to generate all the possible plaintext. We write down these all plaintext in "plaintexts.txt".

Methodology:

Structural cryptanalysis is the part of cryptography which explores the security
of cryptosystems described by generic block diagrams. It explains the syntactic
interaction between the various blocks. However it ignores their semantic definition as
particular functions. Typical examples include meet in the middle attacks on
double encryptions, the study of various chaining structures, and the properties
of Feistel structures with a small number of rounds.

In this work we are studying structural cryptanalysis of EAEAE problem. This cryptosystem takes 8×1 vector of size 8 bytes over the field as input. Here we tabled a list of observation

regarding input and output.

Input	Output
1. plaintext has all zero	ciphertext has all zero
2. first i byte of inpute plaintext were zero	first i byte of inpute ciphertext were zero were zero
3. if changed plaintext at ith bit	ciphertext at ith bit got changed

Let use explain a bit more. Suppose the plaintexts are denoted as $m_0, m_1, \cdots, m_7$ and ciphertext denoted as $c_0, c_1, \cdots, c_7$.

1. Input text: $ff\ ff\ ff\ ff\ ff\ ff\ ff\ ff \Rightarrow$ output text $ff\ ff\ ff\ ff\ ff\ ff\ ff\ ff$

2. Suppose input has a nonzero byte m_j and zero byte m_i with $\forall i \neq j$. We observed that the corresponding ciphertexts has $c_i = 0 \ \forall \ i < j$.

3. Now we change the input after k byte, then output got changed.

From these observation we draw ca conclusion that each row having zeros has at the end of that row. This statement tells us that A should be lower triangular. Suppose ($a_{i,j}$) denotes $i - j$-th elements of the matrix A and e_i stands for i-th element of the 8×1 vector E.

Generations of input plaintext follows the expression $C^{i-1}PC^{8-i}$. Here we have deployed 128×8 plaintext, all these are saved in "plaintext.txt".
[See each input had maximum one non-zero block at a time. From the encoding we know that there are 128 bit possible plaintext. So for each block, we have 128 possible plaintext values. Therefore for eight block, it needs 8×128 possible plaintext values.]

We include "Python pexpect", it helps to connect to the server after verifying the credentials. The file "sever.py" helps to

compute ciphertext from plaintext stored in plaintext.txt and write those ciphertext in ciphertext.txt.

Earlier we mentioned that A should be a lower triangular matrix. Our input format suggests that one block is nonzero per input block. Suppose the value of the nonzero per input, suppose the value of the nonzero block i of a input is x. Now one can run over all possible values of diagonal elements and exponents. At the end, the output block has the value

$$v = (a_{i,i} \times (a_{i,i} \times x^{e_i})^{e_i})^{e_i} \qquad \cdots \quad (i)$$

Deploying the above equation, we able to compute the diagonal entries of A and all entries of E-vector. Earlier we mentioned that the linear transformation is lower triangular, this implies that for $i > j$, i-th input block is relies on the j-th output block.

During the brute force attack, multiplication and exponent operations are performed in alternative manner to verify the encrypted data is same as ciphertext or not.

Right now, a list of plaintext, ciphertext pairs we have in our hand. Now performed the computation for all possible diagonal entries $a_{i,i}[0, 2]$ and $e_i[0, 2]$ and observes if input maps to the outputs. We maintain a list in this regard.

Block Number	Possible values of $a_{i,i}[0, 2]$	Possible values of $e_i[0, 2]$
0	$[84, 67]$	$[20, 108]$
1	$[8, 115, 70]$	$[46, 96, 112]$
2	$[43, 78, 87]$	$[36, 42, 49]$,
3	$[12, 8, 104]$	$[78, 85, 91]$,
4	$[118, 112, 20]$	$[40, 89, 125]$
5	$[11, 41, 127]$	$[53, 83, 118]$
6	$[27, 71, 92]$,	$[23, 48, 56]$,
7	$[104, 38, 38]$	

$[1, 19, 107]$

Next task is to discard some pairs from the above list and compute non-diagonal entries of the matrix A. For this purpose we deploy more plaintext and ciphertext pair and repeat over the above pairs for computing the element within the range $[0, 127]$ so that it fulfills the equation (1). The method proceeds in a triangular manner so that the value of $a_{i,i}$ and $a_{j,j}$ helps to compute $a_{i,j}$. Therefore at the end we able to compute elements next to each diagonal entries and one entry at every diagonal position of A and the vector E.

Block Number	Possible values of $a_{i,i}[0, 2]$	Possible values of $e_i[0, 2]$
0	$[84]$	$[20]$
1	$[70]$	$[112]$
2	$[43]$	$[36]$,
3	$[12]$	$[78]$,
4	$[112]$	$[89]$
5	$[11]$	$[53]$
6	$[27]$,	$[23]$,
7	$[38]$	$[19]$

The above procedure bring down all possible pairs to one element each as only for some . We provide element next to the diagonal entry. Thus we have successfully computed every element of the matrix by running over all possible values (0 to 127) and applying the final values of E vector and the above computed the values of L.T. matrix and verified the validity of the equation (i).

The linear transformation matrix is

E vector: $[20, 112, 36, 78, 89, 53, 23, 19]$

A matrix:

$$
\begin{bmatrix}
[84, 0, 0, 0, 0, 0, 0, 0], \\
[114, 70, 0, 0, 0, 0, 0, 0], \\
[16, 16, 43, 0, 0, 0, 0, 0], \\
[127, 21, 25, 12, 0, 0, 0, 0], \\
[98, 39, 13, 116, 112, 0, 0, 0], \\
[30, 52, 19, 46, 101, 11, 0, 0], \\
[3, 121, 10, 105, 0, 93, 27, 0], \\
[89, 14, 83, 23, 22, 69, 24, 38]
\end{bmatrix}
$$

Thus the task is almost done. In similar fashion we may proceed further to decrypt the password. Just run over all possible values for a block and verify with the output of given EAEAE function is same as the current password block we have .

The decrypted password is

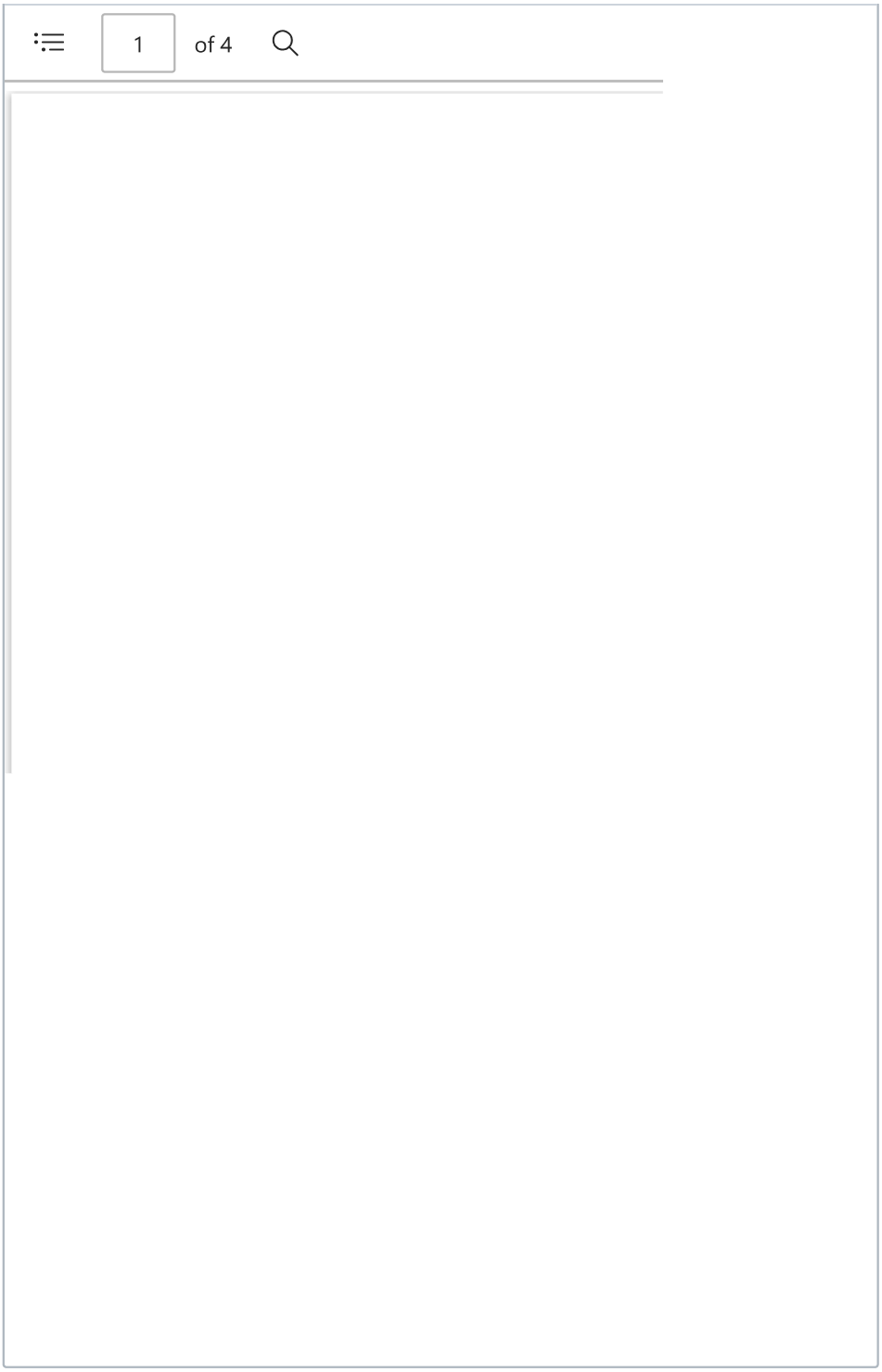
tqmtazppbc

Note: Kindly go through the attached pdf.

Reference:

1. Biryukov, Alex, and Adi Shamir. "Structural cryptanalysis of SASAS." International Conference on the Theory and Applications of Cryptographic Techniques. Springer, Berlin, Heidelberg, 2001.

Enciphered.pdf Download



Q4 Password

5 Points

What was the final commands used to clear this level?

tqmtazppbc

Q5 Codes

0 Points

It is mandatory that you upload the codes used in the cryptanalysis. If you fails to do so, you will be given 0 for the entire assignment.

Enciphered.zip Download

```
1  Binary file hidden. You can download it using the button above.
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Assignment 5

GRADED

2 DAYS, 23 HOURS LATE

GROUP

Gargi Sarkar
Anindya Ganguly
Utkarsh Srivastava

View or edit group

TOTAL POINTS

38 / 60 pts

QUESTION 1

Team Name — **0** / 0 pts

QUESTION 2

Commands — **5** / 5 pts

QUESTION 3

Analysis — R **35** / 50 pts

QUESTION 4

Password — **5** / 5 pts

QUESTION 5

Codes — R **-7** / 0 pts