Midterm review

CS 161

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Feb 19, 2020

Fall 18, Midterm 1

Problem 9 ***Screwups in Inserting an IV*** **(15 points)**

Alice encrypts two messages, M_1 and M_2 using the same IV/nonce and a deterministic padding scheme (when appropriate for the particular mode) using AES (a 128b block cipher). Eve, the Eavesdropper, knows the plaintext of M_1, that each block of M_1 is different, that M_1 is 120 *bytes*, and that Alice never sends any bytes she doesn't have to. Unbeknownst to Eve, it turns out that the messages differ only in the 21st byte of the two messages but are otherwise identical.

Yes, Alice screwed up. But how badly? For each possibility, select *all* which apply.

(a) If Alice used AES-ECB (Electronic Code Book), Eve is able to determine which of the following about M_2:

- ☐ That M_2 is exactly 120B long
- ☐ The entire plaintext for M_2
- ☐ The entire plaintext for M_2 except for the 2nd block
- ☐ That M_2 is less than 129B long but not the exact length
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Q: How many blocks is M1?

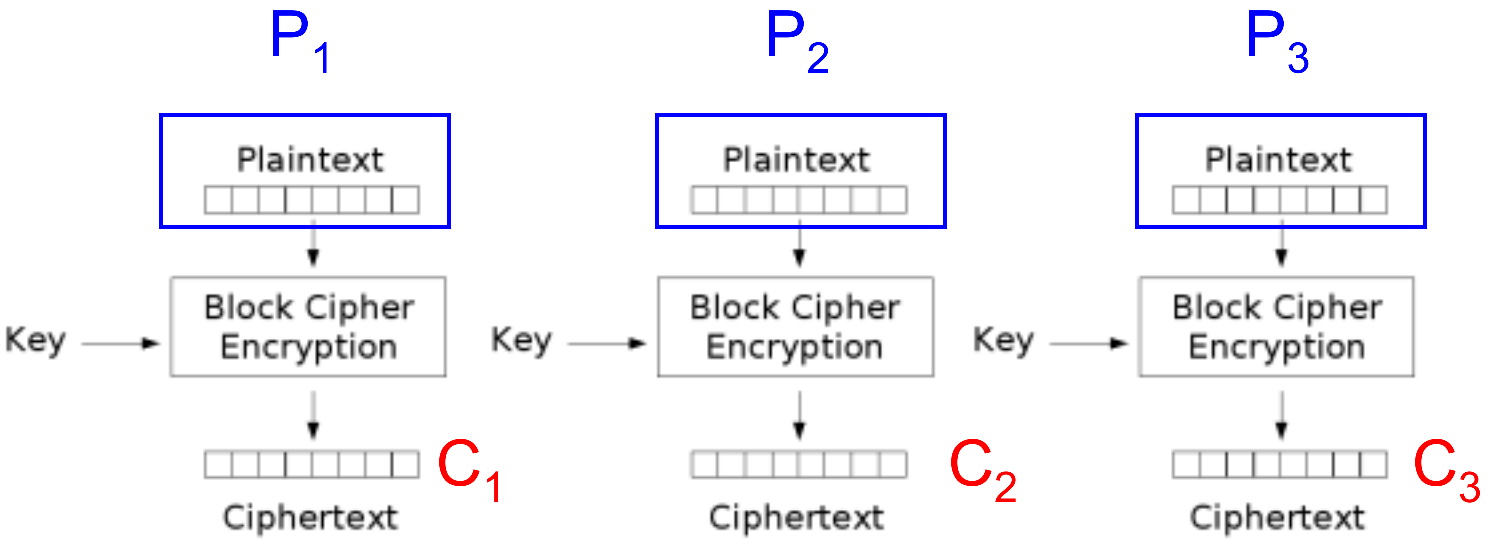
A: Each block is 128/8=16 bytes long, so M1 is more than 7 blocks: 8 blocks with padding

Q: Which block contains the 21st byte?

A: The second block. So the messages differ only in the in second block.

Recall ECB Encryption

break message M into $P_1|P_2|\ldots|P_m$ each of n bits (block cipher input size)



Electronic Codebook (ECB) mode encryption

$\text{Enc}(K, P_1|P_2|..|P_m) = (C_1, C_2, \ldots, C_m)$

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(b) If Alice used AES-CTR (Counter), Eve is able to determine which of the following about M_2:

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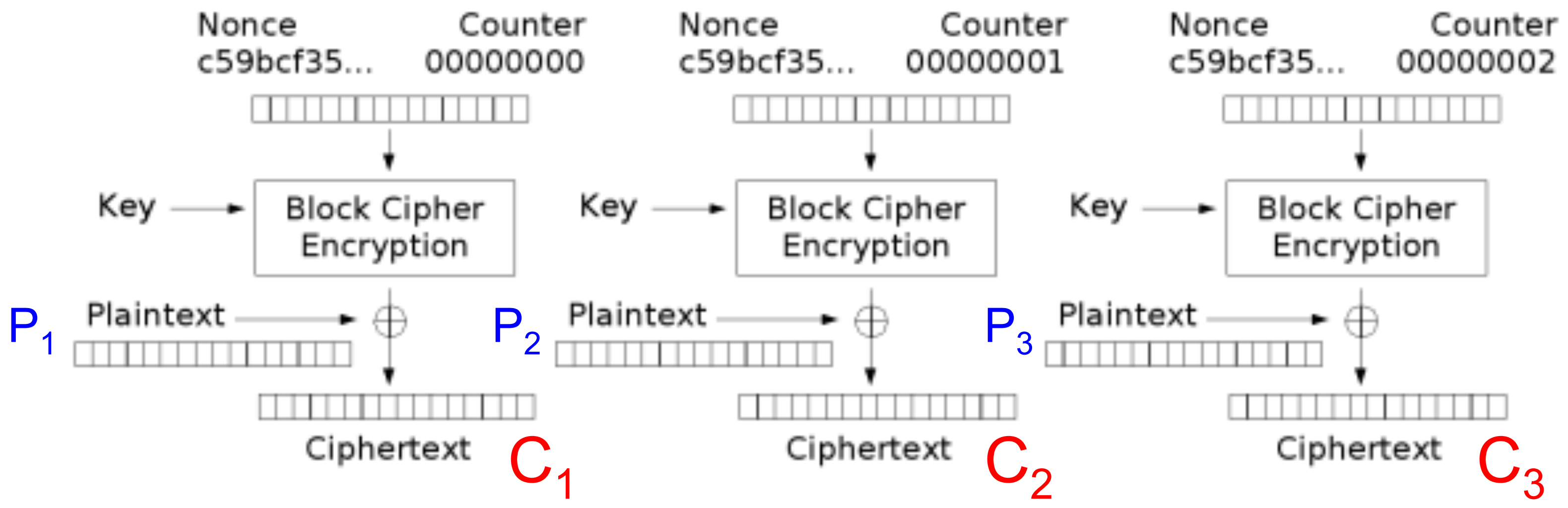
Recall CTR: Encryption

Enc(K, plaintext):

- If n is the block size of the block cipher, split the plaintext in blocks of size n: P_1, P_2, P_3,..
- Choose a random nonce
- Now compute:

(Nonce = Same as IV)
Important that nonce does not repeat across different encryptions (choose it at random from large space)



Counter (CTR) mode encryption

- The final ciphertext is (nonce, C_1, C_2, C_3)

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(c) If Alice used AES-CBC (Cipher Block Chaining), Eve is able to determine which of the following about M_2:

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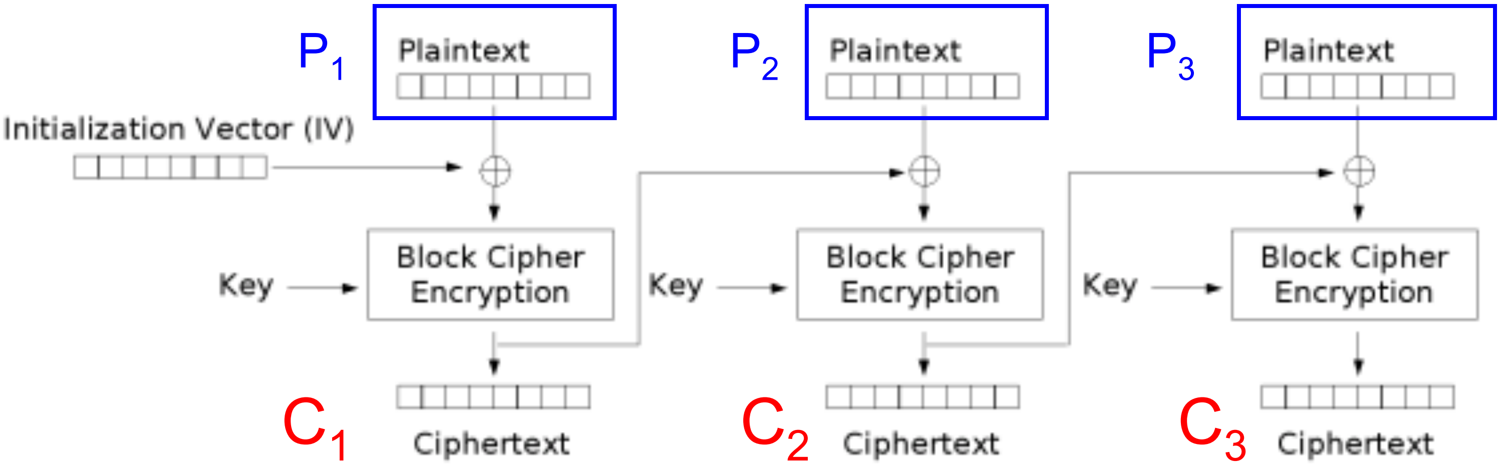
Recall CBC: Encryption

Break message M into $P_1|P_2|\ldots|P_m$

Choose a random IV (it may not repeat for messages with same P_1 , it is not secret and is included in the ciphertext)



Cipher Block Chaining (CBC) mode encryption

$$Enc(K, P_1|P_2|..|P_m) = (IV, C_1, C_2, \ldots, C_m)$$

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(d) If Alice used AES-CFB (Ciphertext Feedback), Eve is able to determine which of the following about M_2:

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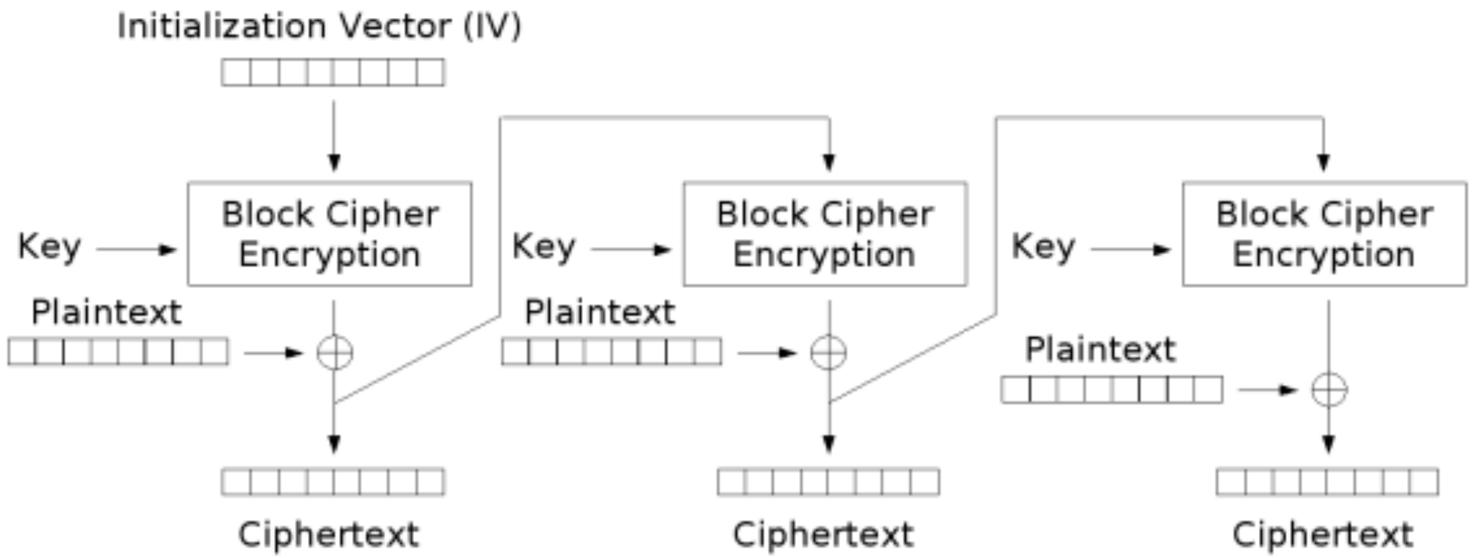
AES-CFB



Cipher Feedback (CFB) mode encryption

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I found the problem statement a bit confusing because it says that Alice uses a deterministic padding but later that she does not send any bytes she does not need to. Technically, with CFB you don't need to pad.
If you pad: the attacker cannot figure out the length of the last plaintext block, so it cannot tell precisely the length of M2, other than being less than 129 bytes. If you do not pad, then the attacker can tell exactly the length of M2 from the size of the ciphertext with no need for any association to M1.

Spring 19 MT 1

Problem 7 ***ElGamal and friends*** **(15 points)**

Bob wants his pipes fixed and invites independent plumbers to send him bids for their services (*i.e.*, the fees they charge). Alice is a plumber and wants to submit a bid to Bob. Alice and Bob want to preserve the confidentiality of Alice's bid, but the communication channel between them is insecure. Therefore, they decide to use the ElGamal public key encryption scheme in order to communicate privately.

Instead of using the traditional version of the ElGamal scheme, Alice and Bob use the following variant. As usual, Bob's private key is x and his public key is $\mathsf{PK} = (p, g, h)$, where $h = g^x \bmod p$. However, to send a message M to Bob, Alice encrypts M as $\mathsf{Enc}_{\mathsf{PK}}(M) = (s, t)$, where $s = g^r \bmod p$ and $t = g^M \times h^r \bmod p$, for a randomly chosen r.

(a) Consider two distinct messages m_1 and m_2. Let $\mathsf{Enc}_{\mathsf{PK}}(m_1) = (s_1, t_1)$ and $\mathsf{Enc}_{\mathsf{PK}}(m_2) = (s_2, t_2)$. For the given variant of the ElGamal scheme, which of the following is true?

- O $(s_1 + s_2 \bmod p, \quad t_1 + t_2 \bmod p)$ is a possible value for $\mathsf{Enc}_{\mathsf{PK}}(m_1 + m_2)$.
- O $(s_1 \times s_2 \bmod p, \quad t_1 \times t_2 \bmod p)$ is a possible value for $\mathsf{Enc}_{\mathsf{PK}}(m_1 + m_2)$.
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(b) In order to decrypt a ciphertext (s, t), Bob starts by calculating $q = ts^{-x} \bmod p$. Assume that the message M is between 0 and 1000. How can Bob recover M from q?

> **Solution:** If Bob knows the possible set of messages, then he can pre-compute a lookup table for values of $q = g^M \bmod p$.

(c) Explain why Bob cannot efficiently recover M from q if M is randomly chosen such that $0 \leq M < p$.

> **Solution:** Requires solving the discrete log mod$p$, which is thought to be computationally hard.