Week 4 - Problem Set

测验, 10 个问题

10/10 分 (100%)

恭喜！您通过了！

下一项

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1。
An attacker intercepts the following ciphertext (hex encoded):

20814804c1767293b99f1d9cab3bc3e7 ac1e37bfb15599e5f40eef805488281d

He knows that the plaintext is the ASCII encoding of the message "Pay Bob 100$" (excluding the quotes). He also knows that the cipher used is CBC encryption with a random IV using AES as the underlying block cipher.

Show that the attacker can change the ciphertext so that it will decrypt to "Pay Bob 500$". What is the resulting ciphertext (hex encoded)?

This shows that CBC provides no integrity.

20814804c1767293bd9f1d9cab3bc3e7 ac1e3

正确回答
You got it!

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2。
Let (E, D) be an encryption system with key space K, message space $\{0,1\}^n$ and ciphertext space $\{0,1\}^s$. Suppose (E, D) provides authenticated encryption. Which of the following systems provide authenticated encryption: (as usual, we use $\|$ to denote string concatenation)

- [ ] $E'(k, m) = [c \leftarrow E(k, m),\ \text{output}\ \ (c, c)\,]$ and

$$D'(k,\ (c_1, c_2)\ ) = \begin{cases} D(k, c_1) & \text{if } c_1 = c_2 \\ \perp & \text{otherwise} \end{cases}$$

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正确

(E', D') provides authenticated encryption because an attack on (E', D')

directly gives an attack on (E, D).

- [ ] $E'\big((k_1, k_2), m\big) = E(k_2,\ E(k_1, m))$ and

$$D'\big((k_1, k_2),\ c\big) = \begin{cases} D(k_1,\ D(k_2, c)) & \text{if } D(k_2, c) \neq \perp \\ \perp & \text{otherwise} \end{cases}$$

正确

(E', D') provides authenticated encryption because an attack on (E', D')

gives an attack on (E, D). It's an interesting exercise to work out

the ciphertext integrity attack on (E, D) given a ciphertext integrity

attacker on (E', D').

- [ ] $E'(k, m) = \big(E(k, m),\ H(m)\ \big)$ and

$$D'(k,\ (c, h)\ ) = \begin{cases} D(k, c) & \text{if } H(D(k, c)) = h \\ \perp & \text{otherwise} \end{cases}$$

(here H is some collision resistant hash function)

未选择的是正确的

- [ ] $E'(k, m) = \big(E(k, m),\ E(k, m)\big)$ and

$$D'(k,\ (c_1, c_2)\ ) = D(k, c_1)$$

未选择的是正确的

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3。

If you need to build an application that needs to encrypt multiple

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messages using a single key, what encryption

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method should you use? (for now, we ignore the question of key generation and management)

- use a standard implementation of CBC encryption with a random IV.
- implement OCB by yourself
- use a standard implementation of randomized counter mode.
- use a standard implementation of one of the authenticated encryption modes GCM, CCM, EAX or OCB.

正确

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4。
Let (E, D) be a symmetric encryption system with message space M (think of M as only consisting for short messages, say 32 bytes).

Define the following MAC (S, V) for messages in M:

$$S(k, m) := E(k, m) \quad ; \quad V(k, m, t) := \begin{cases} 1 & \text{if } D(k, t) = m \\ 0 & \text{otherwise} \end{cases}$$

What is the property that the encryption system (E, D) needs to satisfy for this MAC system to be secure?

- ciphertext integrity

正确
Indeed, ciphertext integrity prevents existential forgery under a chosen message attack.

- perfect secrecy

semantic security

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semantic security under a chosen plaintext attack

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5。

In Key Derivation we discussed how to derive session keys

from a shared secret. The problem is what to do when the shared

secret is non-uniform. In this question we show that using a PRF with

a *non-uniform* key may result in non-uniform values. This shows that

session keys cannot be derived by directly using a *non-uniform*

secret as a key in a PRF. Instead, one has to use a key derivation

function like HKDF.

Suppose k is a *non-uniform* secret key sampled from the key space $\{0,1\}^{256}$

.

In particular, k is sampled uniformly from the set of all keys whose most significant

128 bits are all 0. In other words, k is chosen uniformly from a small subset of the key space. More precisely,

for all $c \in \{0,1\}^{256}$: $\quad \Pr[k=c] = \begin{cases} 1/2^{128} & \text{if } \mathrm{MSB}_{128}(c) = 0^{128} \\ 0 & \text{otherwise} \end{cases}$

Let $F(k,x)$ be a secure PRF with input space $\{0,1\}^{256}$. Which

of the following is a secure PRF when the key k is uniform in the

key space $\{0,1\}^{256}$, but is insecure when the key is sampled from the *non-uniform*

distribution described above?

$$F'(k,x) = \begin{cases} F(k,x) & \text{if } \mathrm{MSB}_{128}(k) \neq 0^{128} \\ 0^{256} & \text{otherwise} \end{cases}$$

正确

$F'(k,x)$ is a secure PRF because for a uniform key k the

probability that $\mathrm{MSB}_{128}(k) = 0^{128}$ is negligible.

However, for the *non-uniform* key k this PRF always outputs 0

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and is therefore completely insecure. This PRF cannot be used as a

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key derivation function for the distribution of keys described in the problem.

- $F'(k,x) = \begin{cases} F(k,x) & \text{if } \mathrm{MSB}_{128}(k) \neq 1^{128} \\ 0^{256} & \text{otherwise} \end{cases}$
- $F'(k,x) = F(k,x)$
- $F'(k,x) = \begin{cases} F(k,x) & \text{if } \mathrm{MSB}_{128}(k) \neq 1^{128} \\ 1^{256} & \text{otherwise} \end{cases}$

1 / 1 分

6。
In what settings is it acceptable to use *deterministic* authenticated

encryption (DAE) like SIV?

- when the encryption key is used to encrypt only one message.

正确
Deterministic encryption is safe to use when the message/key pair

is never used more than once.

- when a fixed message is repeatedly encrypted using a single key.
- to individually encrypt many packets in a voice conversation with a single key.
- to encrypt many records in a database with a single key when the same record may repeat multiple times.

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7。

Let $E(k,x)$ be a secure block cipher. Consider the following

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tweakable block cipher:

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$$E'\left((k_1,k_2),t,x\right) = \ E(k_1,x) \bigoplus E(k_2,t) \ .$$

Is this tweakable block cipher secure?

- [x] no because for $t \neq t'$ we have

  $$E'((k_1,k_2),t,0) \bigoplus E'((k_1,k_2),t,1) = E'((k_1,k_2),t',0) \bigoplus E'((k_1,k_2),t',1)$$

正确

since this relation holds, an attacker can make 4 queries to E'

and distinguish E' from a random collection of one-to-one functions.

- [ ] no because for $t \neq t'$ we have

  $$E'((k_1,k_2),t,0) \bigoplus E'((k_1,k_2),t',1) = E'((k_1,k_2),t',1) \bigoplus E'((k_1,k_2),t',0)$$

- [ ] no because for $x \neq x'$ and $t \neq t'$ we have

  $$E'((k_1,k_2),t,x) \bigoplus E'((k_1,k_2),t',x) = E'((k_1,k_2),t,x') \bigoplus E'((k_1,k_2),t',x)$$

- [ ] no because for $x \neq x'$ we have

  $$E'((k_1,k_2),0,x) \bigoplus E'((k_1,k_2),0,x) = E'((k_1,k_2),0,x') \bigoplus E'((k_1,k_2),0,x')$$

- [ ] yes, it is secure assuming E is a secure block cipher.

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8。

In Format Preserving Encryption we discussed format preserving encryption which is a PRP on a domain $\{0, \ldots, s-1\}$ for some pre-specified value of s.

Recall that the construction we presented worked in two steps, where the second step worked by iterating the PRP until the output fell into the set $\{0, \ldots, s-1\}$.

Suppose we try to build a format preserving credit card encryption system from AES using *only* the second step. That is, we start with a PRP with domain $\{0,1\}^{128}$ from which we want to build a PRP with domain 10^{16}. If we only used step (2), how many iterations of AES would be needed in expectation for each evaluation of the PRP with domain 10^{16}?

- 2^{128}
- $2^{128}/10^{16} \approx 3.4 \times 10^{22}$

正确

On every iteration we have a probability of $10^{16}/2^{128}$ of falling into the set $\{0, \ldots, 10^{16}\}$ and therefore in expectation we will need $2^{128}/10^{16}$ iterations. This should explain why step (1) is needed.

- 10^{16}
- 2

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9。

Let (E, D) be a secure tweakable block cipher.

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Define the following MAC (S, V):

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$$S(k, m) := E(k, m, 0) \quad ; \quad V(k, m, \text{tag}) := \begin{cases} 1 & \text{if } E(k, m, 0) = \text{tag} \\ 0 & \text{otherwise} \end{cases}$$

In other words, the message m is used as the tweak and the plaintext given to E is always set to 0.

Is this MAC secure?

- no
- it depends on the tweakable block cipher.
- yes

正确
A tweakable block cipher is indistinguishable from a

collection of random permutations. The chosen message attack on the

MAC gives the attacker the image of 0 under a number of the

permutations in the family. But that tells the attacker nothing about

the image of 0 under some other member of the family.

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10。
In CBC Padding Attacks we discussed padding oracle attacks. These chosen-ciphertext attacks can break poor implementations of MAC-then-encrypt.

Consider a system that implements MAC-then-encrypt where encryption is done using CBC with a random IV using AES as the block cipher. Suppose the system is vulnerable to a padding oracle attack. An attacker intercepts a 64-byte ciphertext c (the first 16 bytes of c are the IV and the remaining 48 bytes are the encrypted payload). How many chosen ciphertext queries would the attacker need *in the worst case* in order to decrypt the entire 48 byte payload? Recall that padding oracle attacks decrypt the payload one byte at a time.

- 48
- 256

12288

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正确

Correct. Padding oracle attacks decrypt the payload one byte at a time. For each byte the attacker needs no more than 256 guesses in the worst case. Since there are 48 bytes total, the number queries needed is $256 \times 48 = 12288$.

1024

16384