NATIONAL UNIVERSITY OF SINGAPORE

CS2107 – Introduction to Information Security

(AY2018/9 Semester 1)

Mid-Term Quiz

Date: 1 Oct 2018 Time: 2:15 - 3:30PM

STUDENT NUMBER : | **A** | | | | | | | | |

NAME :

TUTORIAL GROUP : **DAY:** **TIME:**

(Write your Name and Student Number legibly with **a pen** to prevent accidental erasure.)

INSTRUCTIONS TO CANDIDATES

1. This question paper consists of **NINETEEN (19)** questions in **THREE (3)** parts; and comprises **NINE (9)** printed pages, including this page.
2. Fill in your Student Number, Name, and Tutorial Group information above with a pen.
3. This mid-term quiz has **30 marks**, and is worth **15%** of your final mark.
4. Answer **ALL** questions.
5. You may use pen or pencil to write your answers, but please erase cleanly, and write legibly. Marks may be deducted for illegible handwriting.
6. Write your answers on this **question paper**.
7. This is an **OPEN BOOK** assessment.
8. You are allowed to use **NUS APPROVED CALCULATORS**. Yet, you should be able to work out the answers without using a calculator.

5

Part A (5 marks): Multiple Choice Questions

Instructions: Choose the ***best answer***, and circle/cross the corresponding letter choice below. No mark is deducted for wrong answers.

A1. Alice needs to ensure confidentiality with a high diffusion level. Which cryptographic technique should she use?

a) Block cipher
b) Stream cipher
c) Hash
d) MAC
e) Digital signature

A - Block cipher can ensure confusion only

A2. Bob wants to ensure the integrity of his messages sent to Charlie in the presence of active attackers. A secure channel between Bob and Charlie is, however, *not* available. Yet, Bob and Charlie share a secret key, and want to use this key to achieve the security requirement. Which cryptographic technique should both use in this case?

a) Block cipher
b) Stream cipher
c) Hash
d) MAC
e) Digital signature

D - Since have symmetric key, can use MAC

A3. Bob wants to protect the authenticity of his messages sent to Charlie. Charlie now also requires an assurance that Bob cannot deny his previously-sent messages. Both of them insist on solely using their shared secret key. Which cryptographic technique can be used?

a) Block cipher
b) Stream cipher
c) Hash
d) MAC
e) None of the above

E - none

A4. Which statement regarding classical cipher(s) below is *false*:

a) Substitution cipher is insecure under known-plaintext attack
b) Substitution cipher is insecure under ciphertext-only attack
c) Permutation cipher even with a large block size is still considered insecure
d) Since one-time-pad cipher failed in the “Venona Story”, it is thus considered a broken cipher and must not be used
e) Modern ciphers, instead of classical ciphers, should be used in general practical use cases in today’s computing and Internet age

D - that one is only cause reuse key.

A5. The criminal practice of using social engineering over the (*voice-based*) *telephone system* to gain access to private personal and financial information is specifically known as:

a) Phishing
b) Vishing
c) Smishing
d) Pharming
e) Scanning

B

Part B (10 marks): Security Terminology

Instructions:

The next ten questions (B1 to B10) give security-related descriptions. Below is a list of security terms. Fill in the blanks in the next ten questions with the ***most appropriate*** terms from the list. Put only one choice per blank. You may ignore any grammatical rules on plural forms. Note that it is possible for some choices to appear more than once in your answers in this part.

Cryptography Objects:
Block cipher
Stream cipher
Initial Value (IV)
Pseudo random sequence
One-time-pad
Symmetric key
Public key
Private key
Signature
Certificate
Certification Authority
Self-signed certificate
Hash
MAC
Authenticated encryption
Nonce
Mode-of-operation

Cryptography Notions:
Symmetric Key Cryptography
Public Key Cryptography
Public Key Infrastructure
Kerckhoffs's principle

Attacks:
Denial of Service
Man-in-the-middle
Chosen-plaintext
Known-plaintext
Frequency analysis
Brute-force
Side-channel
Phishing
Skimming
Birthday
Typo squatting

Miscellaneous:
2FA
Covert channel
Bring-your-own-device
Botnet
Worm

B1. A Certificate Revocation List (CRL) must be signed by the [CA] that previously issued the revoked certificates.

B2. A/an [Block Cipher] operates on a fixed-sized block of input, and can provide high diffusion and confusion properties.

B3. An attacker registered for the domain name “www.dbsbank.com", and then set up a maliciously-spoofed DBS bank website. The attacker was hoping that some Internet users would visit the website and mistakenly believe that they visit the website of DBS bank. This is an example of a/an [Typo Squatting] attack.

B4. Stream ciphers aim to simulate the [One Time Pad], which has a perfect secrecy property, since its ciphertext gives absolutely no additional information about the plaintext.

B5. One type of [Side Channel Attack] is timing attack, which measures how much time various computations (e.g. comparing an attacker's given password with the victim's unknown one) take to perform, without knowing the performed computations.

B6. MiFare Crypto 1 is a stream cipher used in London's Oyster card, Netherland's OV-Chipcard, and in numerous wireless access control and ticketing systems world-wide. Researchers were able to recover this algorithm by reverse engineering. The encryption uses a 48-bit key, which could be recovered in seconds on a PC given a known IV (from one single encryption). The card manufacturer failed to apply [Kerckhoff principle].

B7. A different [IV] must be chosen for encrypting a plaintext, and will be sent in clear as part of the generated ciphertext.

B8. A/An [Signature] [Authenticated Encryption] simultaneously provides confidentiality, integrity, and authenticity assurances on the data, by outputting both ciphertext and authentication tag during its encryption process.

B9. To encrypt a plaintext longer than its block size, a block cipher needs to employ a good [Mode of Operation] such Cipher Block Chaining (CBC), and not a weak one like Electronic Codebook (ECB).

B10. When a transfer of information objects between two separate processes is not supposed to be allowed by the applicable computer security policy, a/an [Covert Channel] is sometimes created by an attacker.

Part C (15 marks): Structured Questions

Instructions: Write your answers in the spaces provided.

C1. *Usage of multiple cryptographic keys* (4 marks)

a) (2 marks) Bob knows that DES has a rather short key length of 56 bits. He, however, still wants to employ DES due to its widespread availability. Bob thinks that he has found a good way of addressing the limited key length of DES by randomly selecting *three* different keys K_1, K_2 and K_3. Bob then performs his DES encryption as follows:

$$C = E_{K_1 \oplus K_2 \oplus K_3}(P).$$

Decryption process is then performed using $K_1 \oplus K_2 \oplus K_3$ as its key. Bob argues that his method significantly increases the key space size. Is Bob's argument correct? Argue concisely by comparing the key space size of using one and three keys above.

Key space size is the number of bits to represent a particular key. This hence the new key would still have 56 bits and have the same key space size.

Same length

b) (2 marks) Bob now uses only two secret keys K_1 and K_2. However, he modifies his encryption as follows:

$$C = E_{K_2}(E_{K_1}(P)).$$

Bob now believes that his double-encryption method indeed doubles the key space size to $2^{2 \cdot 56} = 2^{112}$, and brute-forcing correspondingly requires 2^{112} cryptographic operations. How can you tell Bob that, under the known-plaintext attack, there is a way to find his two keys by performing $2 \cdot 2^{56} = 2^{57}$ cryptographic operations only?

By performing a meet in the middle attack. By doing 2^56 encryptions with a known plaintext and 2^56 decryptions with a known ciphertext with K1 and K2 respectively. When we find a match, we will find the key.

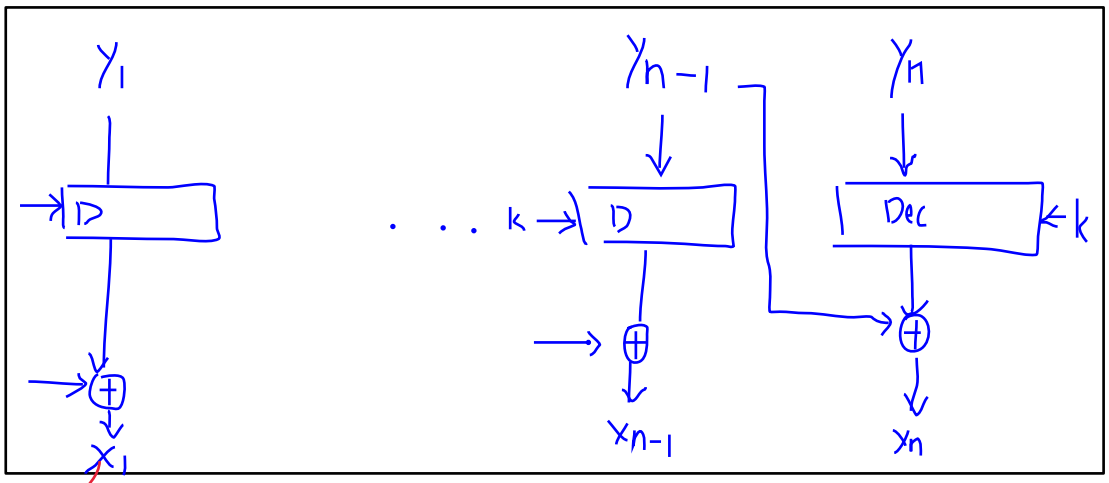
C2. *Mode-of-Operation* (4 marks)

Cipher Block Chaining (CBC) mode-of-operation is commonly used to encrypt a plaintext longer than a cipher's block. In CBC, each plaintext block is XOR-ed with the previous ciphertext block before being encrypted. An IV is used in encrypting the first plaintext block.

Mathematically, the encryption can thus be expressed as follows:
Given a n-block plaintext message $x_1, x_2, x_3, \ldots, x_n$, a secret key K, and an initial value IV, CBC outputs $(n+1)$-block ciphertext message $y_0, y_1, y_2, \ldots, y_n$, where:

- $y_0 = IV$;
- $y_k = \text{Enc}_K(x_k \oplus y_{k-1})$, for $k = 1, 2, 3, \ldots, n$.

a) (2 marks) Your lecture notes show a diagram depicting how a CBC-based encryption is done. Draw a diagram of the corresponding CBC-based *decryption*.



b) (1 mark) How is decryption affected if the first ciphertext block y_0 is removed from the ciphertext?

Only the first block of plaintext x1 will be affected since the IV is missing to XOR.

c) (1 mark) Can the encryption processes of different blocks belonging to a plaintext run in parallel? How about the decryption of a ciphertext' s different blocks?

Yes if they are not side by side, since it will require the ciphertext from the previous block

The encryption process cannot run in parallel. This is since the encryption at round i to produce the ciphertext block yi does take as its input the ciphertextblock yi-1 that is generated only in the previous round i-1. The decryption process can run in parallel. This is because the decryption at round i to recover the plaintext block xidepends only on the ciphertext blocks yi and yi-1, which are both readily available from the sent ciphertext.

C3. *Hash Generation and Time-Storage Requirements* (3 marks)

A black-hat hacker managed to obtain the password file of an authentication system. Like in the 2012 LinkedIn hack case, the authentication system fails to use a salt when hashing a password entry to be stored into the password file.

Suppose the hash function *h* employed by the system takes 2^{30} clock cycles to produce the 128-bit digest of an input. Now, the hacker wants to "crack" the passwords of all users in the authentication system by using a dictionary of 16M commonly-used passwords.

a) (2 marks) Using a 4GHz single-core processor, how long does it take to exhaustively compute the digests of *all* password entries in the dictionary?
Note: 1K = 2^{10}, 1M = 2^{20}, 1G = 2^{30}, 1 year ≈ 2^{25} seconds.

$$\frac{2^{30} \times 2^{4} \times 2^{20}}{2^{2} \times 2^{30} \times 2^{25}} \simeq \frac{1}{8} y =$$

b) (1 mark) The hacker knows that he needs to quickly access his target authentication system once its password file is obtained. For his future cracking of weak salt-less authentication systems, he wants to pre-generate the digests of *all* password entries in the dictionary. For this time-memory trade-off (TMTO) effort, how much extra storage will the hacker need to store all the computed digests in his full lookup table? Express your answer in MB (megabyte) or GB (gigabyte).
Note: Please clearly differentiate bits and bytes in your answer.

1 byte = 8bit

$$\frac{16 \times 2^{20} \times \frac{128}{8}}{2^{30}} = \frac{1}{4} GB$$

C4. *Birthday Attacks (4 marks)*

a) (2 marks) A car park is having 150 parked vehicles. The license plate of each vehicle contains a 4-digit number. Assuming a uniform probability distribution of 4-digit vehicle numbers (i.e. from 0000 to 9999), is there a good probability that two of the license plates currently in the car park have the same 4 digits? Explain why.

$1.17\sqrt{10000} = 117 < \binom{150}{2}$

$\therefore$ Yes, more than 0.5 chance

b) (2 mark) Suppose Bob managed to obtain 2^{20} different digests that were generated by a hash function employed by a target system. The hash function outputs 8-byte digest of a message. Bob now wants to find a message that hashes into 1 (one) of the obtained digests. How many different messages should Bob approximately hash until there is a good probability that a generated digest will match 1 of the obtained digests? Show your working clearly and succinctly.

$m = \frac{\log(0.5)}{-2^{20}(2^{-8})\log(2.7)} = 11434.5$

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You can use the space below if you need more space for your answers.

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