ITIS 6200/8200 Principles of Information Security and Privacy

Midterm

**Question 1. Security Principle (10 points)**

We have learned 11 security principles in the class. Name two of them that you like/familiar with, and give real-life examples. Don’t use examples from our slides and assignment #2.

**Question 2**. **Block Cipher Design (15 points)**

One student in our class suggests the following design of block cipher operating mode. The same IV is used for every block. The message M is split into j plaintext blocks M1 … Mj each of size *n*. The encryption mode outputs (IV, C1, …, Cj) as the overall ciphertext. Assume that IV is randomly generated per encryption.

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(a) Write down the encryption formula. That is, what is the formula for Ci (0 < i <= j) given (1) plaintext M1 … Mj (2) encryption algorithm Enc(K, M) which takes a key K and message M as inputs, and (3) a randomly generated IV.

(b) Write the decryption formula for Mi (0 < i <= j) using this mode. That is, how to get M1 and Mi (0 < i <= j) given (1) ciphertext (IV, C1, …, Cj) and (2) encryption algorithm Enc(K, M).

(c) Is this mode IND-CPA secure? If yes, explain why; if not, describe how an attacker can break IND-CPA. (Hint: find two example messages that if Eve sends to Alice for encryption and Alice randomly chooses one for encryption and sends back to Eve. Then Eve can tell which message Alice encrypts with a probability > 0.5)

**Question 3**. **Public-Key Encryption (15 points)**

Bob has a public-private key pair (pub\_Bob, pri\_Bob). Alice needs to send some information to Bob. She wants to make sure that when Bob opens the message, he can verify that this is from Alice but not anyone else.

(a) If Alice sends out the message as: [ Alice || Epub\_Bob(message) ] to Bob. Basically, she sends out her name in clear text, followed by ciphertext of the message encrypted with Bob’s public key. Can powerful attacker Mallory impersonate Alice and send out a packet in Alice’s name? How can he do it? Assume that Mallory also has the public key of Bob.

(b) If Alice sends out [ Epub\_Bob(Alice || message) ], where Alice puts her name in the encryption. Can Mallory still impersonate Alice?

(c) Can you design a way that Bob can ensure the message comes from Alice?

**Question 4**. **Diffie-Hellman Key Exchange (15 points)**

In Diffie-Hellman key exchange, there are values of a, b, g and p. Alice computes ga mod p and sends it to Bob; Bob computes gb mod p and sends it to Alice. Then Alice computes (gb mod p)a mod p, and Bob computes (ga mod p)b mod p.

(a) Which of these values (a, b, g, and p) are publicly known and which must be kept private?

(b) Mallory is powerful attacker that can eavesdrop, intercept, and modify messages sent between Alice and Bob. Alice and Bob use Diffie-Hellman to agree on a shared symmetric key K. After the exchange, Bob feels somethings is wrong and calls Alice. He realizes his K is different from Alice’s K. Explain what Mallory has done.

(c) In Diffie-Hellman key exchange, p should be a large prime. What happens if p is a small number? If the exchanged key is used in symmetric key encryption, how would that affect the security of the encryption?

**Question 5**. **RSA Signature (15 points)**

To use RSA signatures on messages, we first create a RSA key pair: (N, e) is the RSA public key and d is the RSA private key, where N is the RSA modulus. For standard RSA signatures, we typically set e to a small prime value such as 5; for this problem, let e = 5.

(a) For RSA signatures, we often sign the hash of a message, rather than the message directly.

Why is that?

(b) Assume that we skip using a hash function, and sign the messages directly. That means, if Alice wants to send a signed message to Bob, she will send (M, S) to Bob where S = Md mod N is computed using her private signing key d. With such a scheme, how do Bob verify this message comes from Alice? What formula does Bob need?

(c) Mallory learns that Alice and Bob are using the simplified signature scheme that without using hash functions. Can Mallory find a (M, S) pair such that S will be a valid signature on M?

Assume that Mallory knows Alice’s public key N and e, but not Alice’s private key d.

**Question 6**. **Password Hashing (10 points)**

Alice’s computer stores the files in the following way: for every file F, the computer will calculate the hash value of the file hash(F) and store it after the file. Every time when Alice login, the machine will automatically hash all the files and compare the results to the stored hash values. In this way, if by accident the hard drive is mis-functioning and flips a few bits in a file, Alice can immediately detect it since the hash value will be different. Now an attacker hacks into Alice’s machine and he tries to change several files. The attacker also knows the hash function that the computer uses.

(a) Describe what the attacker needs to do so that the next time Alice login, the machine will not detect the changes.

(b) Please discuss how we should improve the mechanism to detect such changes.

**Question 7**. **Confidentiality & Integrity (20 points)**

Alice wants to send messages to Bob in an insecure channel. The attackers may eavesdrop, intercept, and modify the messages sent in the channel.

Some of techniques we have learned so far and their notations.

AES: Enc(K, M) and Dec(K, C), here K, M, and C denote the key, plaintext, and ciphertext

HMAC, Hash, RSA encryption, RSA signature, PRNG, public-key exchange, key management (certificates). Assume each technique provides its required security properties, e.g., AES

(a) By combining the techniques that we have learned in this course, develop three schemes that can ensure both integrity and confidentiality of the communications. Given a plaintext M, write down the formula of the messages, e.g., ciphertext, sent from Alice to Bob, and how Bob can access (decrypt) M. Indicate additional assumptions if you make any (threat models).

(b)

**Question 2. Symmetric encryption algorithms (10 points)**

Name at least two advantages and two disadvantages of symmetric encryption algorithms, and provide examples to explain them.

Choose between different techniques for providing integrity and confidentiality

**Question 3. Asymmetric encryption algorithms (10 points)**

Name at least two advantages and two disadvantages of asymmetric encryption algorithms, and provide examples to explain them.