ITIS 6200/8200 Principles of Information Security and Privacy

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Homework 2

Hand out: September 12th, 2018

Due time: September 21st, 2018 before 11:00 am

1. We have a symmetric encryption algorithm $E_K(M)=C$. Here K is the secret key, M is the plaintext, and C is the ciphertext. We (and the attacker) know that the key length is 192 bits. The attacker eavesdrops on the communication line and gets a copy of the ciphertext C1. Now the attacker decides to conduct the brute force attack and try every possible key to get the plaintext M1 (that means, every possible key of the 2^{192} keys). Let us assume that there is only one possible M1 and if the attacker sees it, he will know that this is the correct one. The attacker has 1,000,000 machines, with each machine having the capabilities to try 6,000,000 decryption of C1 with different keys per second. If one machine finds the right key, it will automatically notify the attacker. Now please answer, how many years (roughly) does the attacker need to try 10% of the keys?

   Hint: Note that Google has around 3 million servers. So, we assume that the attacker is as powerful as 1/3 Google. Also, check the Internet and see what the expected life time of the Sun is. Can you crack the key before that? This question is to show that after a certain key length, brute force is not the best way of cracking it. Side channel, or some other mechanisms will serve the purpose better.

   Answer:
   - Total number of possible combinations = 2^{192} bits
   - If 1 computer performs $6 * 10^6$ keys/second, then number of operations performed by 1000000 machines per second = $6*10^{12}$ keys/second.
   - Time required to calculate 2^{192} bits using all the machines = $(2^{192})/6*10^{12}$ seconds
   - Therefore, time required to calculate 10% of the keys ($0.1*2^{192}$ keys) = $0.1*(2^{192})/6*10^{12}$ seconds
   - Number of years to calculate 10% of the keys = $365*24*60*60 *0.1*(2^{192})/(6*10^{12}) = 3153600*(2^{192})/(6*10^{12}) = 0.5256*2^{192}/10^6$ years

   Since the time required to crack the key is $0.5256*2^{192}/10^6$ years. However, remaining life time of sum is five billion years, so the attacker won't be able to crack the key before life time of sun.

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2. 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. So, she sends out the message as: [Alice, E_{pub_Bob}(message)] to Bob. Basically, she first sends out her name in clear text, then encrypts the message with Bob's public key. Please discuss,

can an attacker M impersonate Alice and send out a packet in Alice's name? How can he do it? Here we assume that M also has the public key of Bob. For the same question, if Alice sends out [E_{pub_Bob} (Alice, message)], can M still impersonate Alice? (Here Alice puts her name in the encryption.)

Answer:

- Since Alice sends her name in text, attacker can track that communication using Replay attack. Also, attacker can send packets to bob which may contain malicious resources, documents etc. that is how the attacker can act as Alice.
- When Alice encrypts her identity, and the attacker has the public key of Bob, still the attacker M can impersonate Alice using dictionary or a rainbow table attack.

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3. 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. Please describe what the attacker needs to do so that the next time Alice login, the machine will not detect the changes. Also, please discuss how we should improve the mechanism to detect such changes.

   Hint: this is actually directly related to how to use hash functions to protect integrity of data. The defense capability of a hash function and that of a keyed hash function are actually different.

   Answer:
   When hacker tries to hack Alice's computer and modify the hashed files which are calculated using the Hash function, Alice gets to know only when she logs into her computer next time as the hash values are changed. However, attacker got to know the hash value he can modify it to the previous one and still make sure that Alice won't get notified since both hash values are same. To overcome this problem, we can use MAC which uses a secret key and hash to produce the tags by the operating system which makes it difficult for the attacker since attacker won't be knowing the secret key to change the tag. Even though an attacker changes the hash, Alice get notified because attacker can't modify the secret key.

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4. Please draw a binary Merkle's hash tree with 10 leaf nodes. The leaf nodes are labeled as Leaf1 to Leaf10, which correspond to the hash values of the files F1 to F10, respectively. Now please answer:

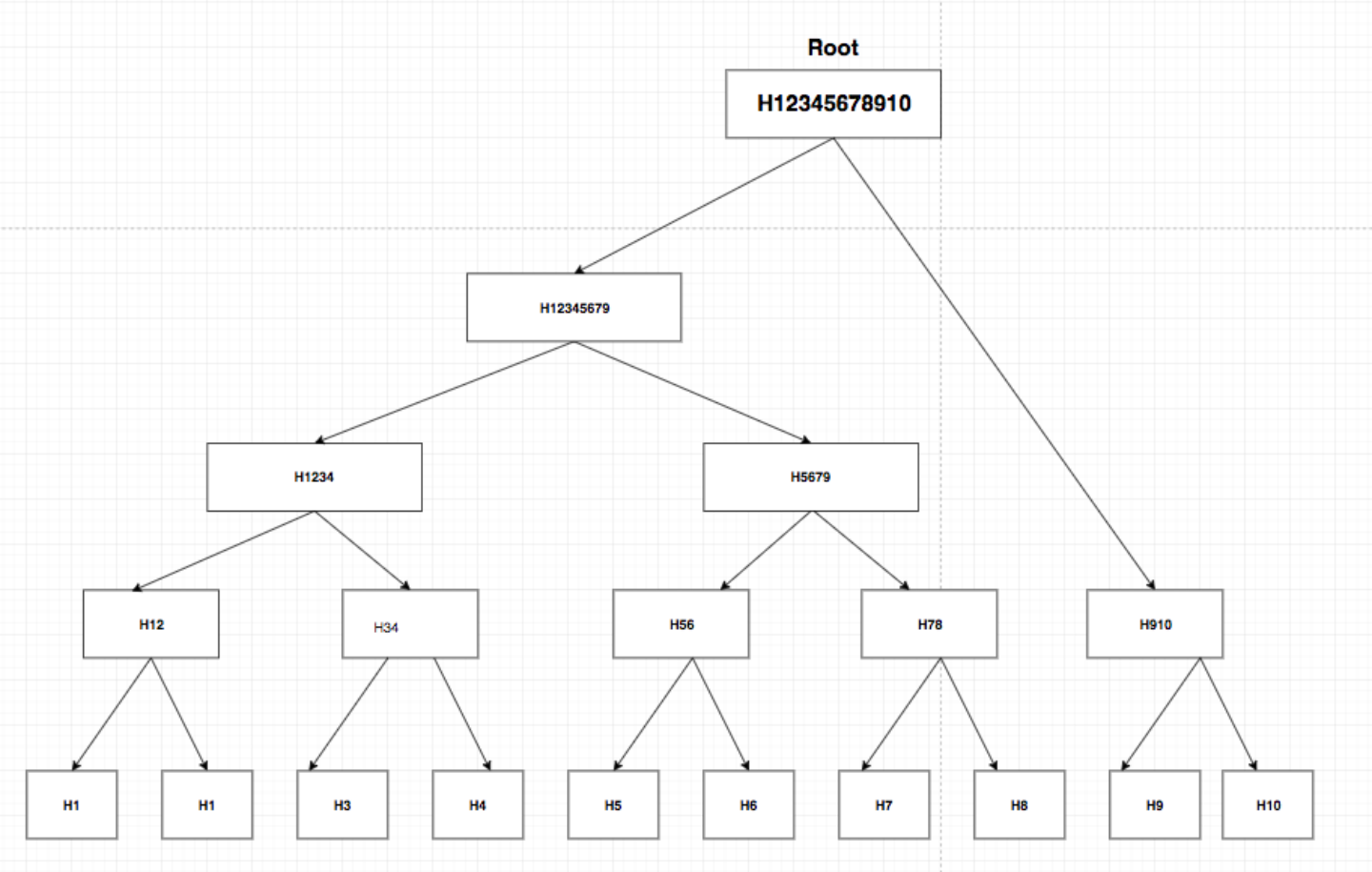
   (1) For each node in the tree, please label clearly how the hash value is calculated based on its children; Please note that the number of leaf nodes is not power of 2. Therefore, you may need

to change the way in which intermediate nodes are calculated. There are different ways to handle this. Please label clearly how you calculate each node.

(2) Now the creator of the file F7 needs to verify that his file's hash value is integrated in the root of the tree. Please show the minimum number of hash values in the tree that the creator needs to accomplish the task. Please also show how the verification is accomplished.

Answer:

1.



2.

Creator needs L8, L56, L1234, L910 hash values to verify that F7 is in root.

Step 1 – Creator hashes file F7 to get the hash value L7.
Step 2 – creator concatenates result L7 with given hash value L8 to form L78.
Step 3 – Creator uses the result L78 & concatenates with another hash value received L56 to L5678.
Step 4 – This result will be concatenated with L1234 to form L12345678.
Step 5 – This result(L12345678) concatenated with given hash value L910 to form L12345678910.
Step 6 – Now, creator compares the calculated hash value L12345678910 with given hash value L12345678910.

Step 7 – If both hash values match its concluded that F7 is integrated root.