CSE 484 / CSE M 584 - Homework 2

This homework is focused on cryptography.

Overview

- **Due Date:** Friday, November 3, 2017, 8pm.
- **Group or Individual:** Do this assignment as an **individual**. But you are allowed to talk with others in advance of actually doing the assignment.
- **How to Submit:** Submit a PDF to Catalyst. Your assignment does not need to be entirely typed / developed with computer software. You could hand-write your assignment, and hand-draw some diagrams, and then submit a PDF scan of your hand-written assignment, just make sure it is legible.
- **Total Points:** 50 (across 10 questions)

Q1 (3 points). What is the main concern cryptographers have with the Encrypt-and-MAC method for combining a symmetric encryption scheme with a symmetric MAC to create a symmetric authenticated encryption scheme?

Q2 (6 points). Your goal is to create an auction system, in which people make secret bids while the auction is open, and then later reveal those bids after the auction closes. The person who has made the highest bid will win the item. For example, Alice may secretly bid $10 for a vintage shirt with the old UW CSE logo, while Bob secretly bids $20. When the auction closes, both Alice and Bob reveal their bids, and Bob's higher bid wins the shirt.

(a) Sketch a protocol for such an auction system that relies on a cryptographically secure hash function H. Your protocol should meet the following security goals:
(1) Privacy: People should be able to make bids privately, such that other competing bidders cannot learn their bids before the end of the auction.
(2) Nonrepudiation: Once someone commits to a bid, they should not be able to change that bid before revealing it. (Hint: One way to achieve this would be to have participants publicly state their bids when they make them; however, this would violate the above privacy goal.)

(b) Explain briefly how your protocol relies on the one-wayness and collision resistance properties of H to achieve its security goals.

Q3 (2 points). Consider a group of 30 people in a room who wish to be able to establish pairwise secure communications in the future. How many keys need to be exchanged in total:
(a) Using symmetric cryptography?
(b) Using public key cryptography?

Q4 (5 points). This message was encrypted with the RSA primitive, where N=33 and e=3. Decrypt it and submit the corresponding plaintext.

Tips: You are welcome to write a program to aid in the decryption, and you might want to compute the private decryption exponent d.

For this cryptogram 'A' is encoded as a 1 before encryption, 'B' as a 2, and so on.

Here is the cryptogram: 27 17 9 27 9 12 1 14 26 27 17 3 4 27 9 9 11 3 26 28 1 24 26 19 9 24 26 31 26 12 3 27 3 9 21 28 14 17 1 5 8 24 9 27 27 9 12 3

Q5 (8 points). The following question has you use RSA, but with larger values (but still not anywhere close to the size of the numbers one would use in a secure cryptographic protocol like TLS/SSL).

You may use a program that you write, Wolfram Alpha, or any other computer program to help you solve this problem.

For all of these, it is sufficient to just include your number in the answer, unless the question explicitly asks for additional detail.

Let p = 9497 and q =7187 and e = 3.

- Compute N = p * q. What is N?
- Compute Phi(N) = (p-1)(q-1). What is Phi(N)?
- Verify that e is relatively prime to Phi(N). What method did you use to verify this?
- Compute d as the inverse of e modulo Phi(N). What is d?
- Encrypt the value P = 22446688 with the RSA primitive and the values for N and e above. Let C be the resulting ciphertext. What is C?
- Verify that you can decrypt C using d as the private exponent to get back P. What method did you use to verify this?
- Decrypt the value C' = 11335577 using the RSA primitive and your values for N and d above. Let P' be the resulting plaintext. What is P'?
- Verify that you can encrypt P' using e as the public exponent to get back C'. What method did you use to verify this?

Q6 (5 points). Suppose you, as an attacker, observe the following 32-byte (3-block) ciphertext C1 (in hex)

```
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 03
46 64 DC 06 97 BB FE 69 33 07 15 07 9B A6 C2 3D
2B 84 DE 4F 90 8D 7D 34 AA CE 96 8B 64 F3 DF 75
```

and the following 32-byte (3-block) ciphertext C2 (also in hex)

```
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 03
51 7E CC 05 C3 BD EA 3B 33 57 0E 1B D8 97 D5 30
7B D0 91 6B 8D 82 6B 35 B7 8B BB 8D 74 E2 C7 3B
```

Suppose you know these ciphertexts were generated using CTR mode, where the first block of the ciphertext is the initial counter value for the encryption. You also know that the plaintext P1 corresponding to C1 is

```
43 72 79 70 74 6F 67 72 61 70 68 79 20 43 72 79
70 74 6F 67 72 61 70 68 79 20 43 72 79 70 74 6F
```

Compute the plaintext P2 corresponding to the ciphertext C2. Submit P2 as your response, using the same formatting as above (in hex, with a space between each byte).

Q7 (5 points). Consider an insecure version of SSH that uses ECB mode for encryption. Whenever a user types a key into the ssh client, that key is immediately encrypted and sent over the wire to the server. This immediate encrypt-after-key-press procedure is what enables the interactivity of a remote shell. Now consider the following sequence of plaintext packets (written in hex):
P1 = 6C 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 // ASCII l
P2 = 73 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 // ASCII s
P3 = 20 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 // ASCII space
P4 = 2A 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 // ASCII *
P5 = 2D 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 // ASCII -
P6 = 66 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 // ASCII f
P7 = 72 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 // ASCII r
P8 = 6F 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 // ASCII o
P9 = 6D 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 // ASCII m
P10 = 0D 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 // ASCII <enter>

This corresponds to a user typing “ls *-from<enter>” into their ssh client.

Suppose an attacker knows what the user is typing via some out-of-band channel (e.g., shoulder surfing) and also eavesdrops on this communications and intercepts the corresponding ciphertexts:

C1 = 4E B6 48 B2 E0 BE A5 B1 21 2F 07 54 DF CF A4 39
C2 = 11 70 78 65 88 89 06 62 82 0C 0A 6A 55 6F 87 46
C3 = EF 7F 1F 25 3E 99 98 8D 1A FC BE 7A D9 D6 ED 7E
C4 = 5B 40 2B 18 0B 94 E8 13 DA F3 DE 21 A0 27 2E C4
C5 = 93 80 19 1F 06 B4 4B 19 9D 70 86 28 34 12 26 DC
C6 = 68 74 EB 1B 16 5F 70 45 05 29 B9 66 0A CC D3 6C
C7 = 56 E8 77 E1 7E BF 01 19 27 87 03 FE E1 1D 65 A8
C8 = 9D 37 51 F0 68 C8 F7 BA 44 B2 E9 5C 09 94 1D 5A
C9 = 62 30 38 8F A4 D7 C1 68 56 88 CE 2C 29 2D F5 23
C10 = D5 89 74 7E 45 89 08 FA 5B 63 98 42 E6 B2 31 85

The attacker can now inject messages into the communications channel from the client to the server. One thing an attacker might try to do: generate a sequence of ciphertext packets that, when decrypted, are interpreted as “rm -rf *<enter>” on the server. Give such a sequence of ciphertext packets in your answer.

Q8 (3 points). Consider a Diffie-Hellman key exchange with p=29 and g=2. Suppose that Alice picks x=3 and Bob picks y=5. What will each party send to the other, and what shared key will they agree on? Show your work.

Q9 (4 points). The goal of this task is to give you a better understanding of Certificate Authorities (CA) and certificates.

Take a look at the CAs certificates that your computer trusts.

- Mac: Spotlight search ‘Keychain Access’
- Windows: Control Panel -> Search ‘Internet Options’ -> Content -> Certificates

Answer these questions:

1. How many root CA certificates does your computer have?
2. What is something that you found interesting from looking at the root CA certificates?
3. Go to google.com using your favorite browser, and find a way to look at the certificates for google.com. List the chain of certificates your browser sees.
4. What is a possible risk of trusting a CA?

Q10 (9 points). For this task, the goal is to give you experience with sending encrypted emails. To successfully complete this task, you will need to set up your email client and send/receive an encrypted email to/from the TAs. For this assignment, you can reach your super secret agent TA Charizard at charizard.thehacker@gmail.com.

Setup information

Setting up your email client to send encrypted emails is a bit complicated, and the following link is helpful if you don't want to follow the recommended setup below or you know what you are doing: How to Encrypt Your Email and Keep Your Conversations Private

Recommended setup

We found that using Mailvelope extension for the browser is easiest since you will be able to use your Gmail web client.

1. Get Mailvelope, which works with Chrome or Firefox. The rest of this guide assumes you are using Chrome.

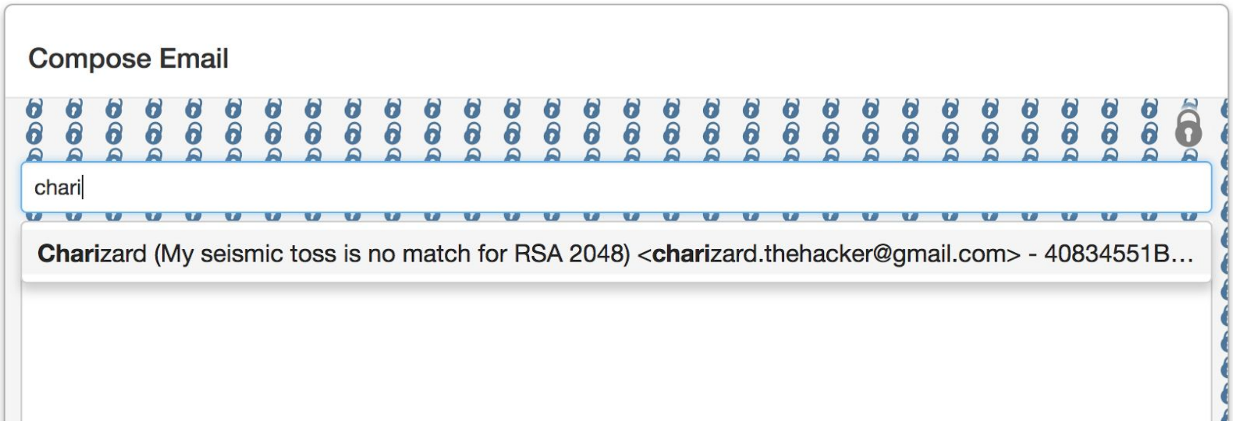
2. Once installed, you should see a 🔐 icon on the top right corner of the browser, click on it then click 'Options'

3. Generate a key for yourself
    - Name: Your name
    - Email: The email address you're using for this part of the assignment
    - Password: Optional but **recommended** password to secure your key

4. Import Charizard's public key from http://courses.cs.washington.edu/courses/cse484/17au/homework/charizard_pub.asc by pasting the contents into Mailvelope (Options -> Import Keys)

5. You are now set up! Go to your email page, hit Compose and you should see 📝 . Click on it to start composing an encrypted email, click 'encrypt' when you are done.

6. In the encrypted email compose dialog, make sure you encrypt to Charizard. If you want to be able to read your own email, make sure to also encrypt it to yourself.



Compose Email

chari

Charizard (My seismic toss is no match for RSA 2048) <**chari**zard.thehacker@gmail.com> - 40834551B...

7. **Using the email account that you associated with your key above** (you'll get an error back if your email account and key don't match), send an email to the TA in this format:

   To: charizard.thehacker@gmail.com
   Subject: [CSE 484] Encrypted email
   Content: Whatever secret message you'd like to send us :)
   Attachment: <your public key> (Select your key from 'Display Keys' on the Mailvelope site, and export the public key **only.** Download <yourkey>_pub.asc and attach it.)

Once you are OK with the contents, hit encrypt, select the correct key for the recipient and transfer the encrypted contents.

Note: In order for the TA to send you an encrypted email, you will need to attach **your** public key with your email. If you forget, you'll get an error.

If you don't want to use your main email account, you can use this with a throw away email address inside a virtual machine.

Once the TA receives this email, a secret reply will be sent back to you. Submit the content of this email to your writeup.

Though we have an automated bot to respond to your emails, *please email the TA at least 48 hours before the deadline* in case we have to fall back to a manual process.

Deliverables

1. The email address you used
2. Secret value provided by the TA
3. Answers to short answer questions
   a. Does this process (PGP encryption) involve the use of symmetric or asymmetric

encryption or both?

b. We recommended a browser extension for ease of use, but what are the security risks of enabling this browser extension? (Hint: what permissions did the extension ask for during install?)