CS-C3130 Information security
Examination 2018-10-25
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No electronic equipment or reference material is allowed in the examination.

0. Please give the following information honestly. It will not affect the grading.

(a) How many of the 12 lectures did you attend?
(b) How many of the 12 lecture videos did you watch?

1. Access control

An access control matrix containing **S** subjects (e.g. users) and **O** objects (e.g. files) can be represented as either *access control lists* (one per object) or *capability lists* (one per subject), which in this case are stored locally on the file server. The size of the matrix is therefore **S × O**.

(a) When deleting a file, would it be more efficient (i.e. require fewer accesses to different data structures) if the permissions were represented as access control lists or capability lists? Explain in one sentence. (2p)

(b) When deleting a user, would it be more efficient (i.e. require fewer accesses to different data structures) if the permissions were represented as access control lists or capability lists? Explain in one sentence. (2p)

In some cases, role-based access control (RBAC) can be used to simply the access control system.

(c) Give a concrete real-world example of a system that uses RBAC and mention two roles in it. (2p)

2. User authentication

Our innovative *Potplants* service is gaining popularity and has one thousand users. Since the system is secure by design, it requires the users to memorize random 10-character passwords. The character set for the passwords is the following:

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ1234567890-+

The service stores the passwords in a database as hash values. The hash function is SHA-256, which is computed on the concatenation of the constant string "potty" and the password and then truncated to 16 bytes:

hash = leftmostbytes(SHA-256 ("potty" | password), 16)

The attacker has obtained the user and password database with an SQL injection attack and mounts a brute-force attack on the hashes. The attacker is using an array of expensive GPUs, which each can compute 1000 million (10^9) SHA-256 hashes per second. The price of a GPU day is approximately $1 including the hardware, electricity and other costs. Based on this information, how much does it cost to crack:

(a) the password of at least one user, without caring which user it is (2p)
(b) all the passwords? (2p)

Also:

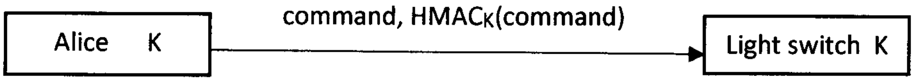
(c) Suggest at least two different improvements to the design so that the cost of password cracking is increased significantly. Sorry, but you cannot make the passwords any more complex, and all data on the server has to be stored in the database that is vulnerable to data leaks. (2p)

Since you do not have a pocket calculator, a rough estimate is ok. However, please write down the intermediate steps of the calculation. (1 day = 86 400 seconds)

Please turn the paper for the remaining problems.

3. Protocols

An IoT light switch is configured to receive commands via the Internet. It accepts the commands "ON" and "OFF". The legitimate user, Alice, shares a 128-bit random secret key (**K**) with the light switch. Whenever Alice sends a command to the light switch, she must also calculate and send a message authentication code (HMAC) based on the SHA-256 hash function. The inputs to the HMAC are the secret key **K** and the command. Upon receiving the message, the light switch verifies the HMAC using its own copy of the secret key **K**. If the HMAC is correct, the light switch executes the command.



Eve is the wireless network administrator and has access to all messages Alice sends to her light switch.

Assume there are no vulnerabilities in the light switch's software (i.e. no buffer overflows).

(a) On average, how many guesses would it take for Eve to guess the secret key? (2p)
(b) Even if Eve does not know the secret key, she may be able to control the light switch. Explain how. (2p)
(c) Suggest one way of improving the protocol to prevent the above attack. Mention also any possible security weaknesses in your solution. (2p)

4. Anonymity and differential privacy

University plans to share the dataset below with researchers. However, the university policy is to maintain 3-anonymity (i.e. *k*-anonymity with *k*=3) when releasing such data. The grade is the only sensitive information in the database. The researchers want to study factors that correlate with study success.

(a) If the researchers receive only one column from the dataset in addition to the grade, which column could it be? Give the list of all such columns. (2p)
(b) The researchers prefer to receive as many columns from dataset as possible in addition to the grade. Which columns can be released? (2p)

Student	**Major**	**Minor**	**Gender**	**Age**	**Grade**
Gustav	CS	Math	male	22	5
Fatima	CS	Art	female	20	5
Yi	CS	Art	female	18	3
Ilona	CS	Math	female	44	2
Mikko	CS	Art	male	31	4
Ville	CS	Business	male	25	3
Mikael	EE	Business	male	20	4
Anna	EE	Business	female	21	5
Martti	EE	Business	male	24	4
Pedro	EE	Math	male	23	5
Noora	EE	Math	female	27	5
Mary	EE	Art	female	24	4
Average				**24.9**	**4.1**

(c) Alice took the exam one day later, and her data is missing from the dataset above. The administrator tells the researchers that the new dataset, in which Alice is included, cannot be released for privacy reasons, and anyway, the average increases only slightly. What privacy problem do you see here? (2p)

5. Network security

In Appendix 1, there is a pretty-printed certificate chain. Explain in detail how the web browser checks the certificate chain and how it is used to authenticate the web site in SSL or TLS. (6p)

Notes: You do not need to explain the details of the TLS handshake protocol. Also, note that "rsaEncryption" in this context means the RSA algorithm for any purpose, which may be encryption or signature.

Appendix 1

```
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            0c:e7:e0:e5:17:d8:46:fe:8f:e5:60:fc:1b:f0:30:39
    Signature Algorithm: sha1WithRSAEncryption
        Issuer: C=US, O=DigiCert Inc, OU=www.digicert.com, CN=DigiCert Assured ID Root CA
        Validity
            Not Before: Nov 10 00:00:00 2006 GMT
            Not After : Nov 10 00:00:00 2031 GMT
        Subject: C=US, O=DigiCert Inc, OU=www.digicert.com, CN=DigiCert Assured ID Root CA
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (2048 bit)
                Modulus:
                    00:ad:0e:15:ce:e4:43:80:5c:b1:87:f3:b7:60:f9:
                    71:12:a5:ae:dc:26:94:88:aa:f4:ce:f5:20:39:28:
                    58:60:0c:f8:80:da:a9:15:95:32:61:3c:b5:b1:28:
                    84:8a:8a:dc:9f:0a:0c:83:17:7a:8f:90:ac:8a:e7:
                    79:53:5c:31:84:2a:f6:0f:98:32:36:76:cc:de:dd:
                    3c:a8:a2:ef:6a:fb:21:f2:52:61:df:9f:20:d7:1f:
                    e2:b1:d9:fe:18:64:d2:12:5b:5f:f9:58:18:35:bc:
                    47:cd:a1:36:f9:6b:7f:d4:b0:38:3e:c1:1b:c3:8c:
                    33:d9:d8:2f:18:fe:28:0f:b3:a7:83:d6:c3:6e:44:
                    c0:61:35:96:16:fe:59:9c:8b:76:6d:d7:f1:a2:4b:
                    0d:2b:ff:0b:72:da:9e:60:d0:8e:90:35:c6:78:55:
                    87:20:a1:cf:e5:6d:0a:c8:49:7c:31:98:33:6c:22:
                    e9:87:d0:32:5a:a2:ba:13:82:11:ed:39:17:9d:99:
                    3a:72:a1:e6:fa:a4:d9:d5:17:31:75:ae:85:7d:22:
                    ae:3f:01:46:86:f6:28:79:c8:b1:da:e4:57:17:c4:
                    7e:1c:0e:b0:b4:92:a6:56:b3:bd:b2:97:ed:aa:a7:
                    f0:b7:c5:a8:3f:95:16:d0:ff:a1:96:eb:08:5f:18:
                    77:4f
                Exponent: 65537 (0x10001)
        X509v3 extensions:
            X509v3 Key Usage: critical
                Digital Signature, Certificate Sign, CRL Sign
            X509v3 Basic Constraints: critical
                CA:TRUE
            X509v3 Subject Key Identifier:
                45:EB:A2:AF:F4:92:CB:82:31:2D:51:8B:A7:A7:21:9D:F3:6D:C8:0F
            X509v3 Authority Key Identifier:
                keyid:45:EB:A2:AF:F4:92:CB:82:31:2D:51:8B:A7:A7:21:9D:F3:6D:C8:0F
    Signature Algorithm: sha1WithRSAEncryption
         a2:0e:bc:df:e2:ed:f0:e3:72:73:7a:64:94:bf:f7:72:66:d8:
         32:e4:42:75:62:ae:87:eb:f2:d5:d9:de:56:b3:9f:cc:ce:14:
         28:b9:0d:97:60:5c:12:4c:58:e4:d3:3d:83:49:45:58:97:35:
         69:1a:a8:47:ea:56:c6:79:ab:12:d8:67:81:84:df:7f:09:3c:
         94:e6:b8:26:2c:20:bd:3d:b3:28:89:f7:5f:ff:22:e2:97:84:
         1f:e9:65:ef:87:e0:df:c1:67:49:b3:5d:eb:b2:09:2a:eb:26:
         ed:78:be:7d:3f:2b:f3:b7:26:35:6d:5f:89:01:b6:49:5b:9f:
         01:05:9b:ab:3d:25:c1:cc:b6:7f:c2:f1:6f:86:c6:fa:64:68:
         eb:81:2d:94:eb:42:b7:fa:8c:1e:dd:62:f1:be:50:67:b7:6c:
         bd:f3:f1:1f:6b:0c:36:07:16:7f:37:7c:a9:5b:6d:7a:f1:12:
         46:60:83:d7:27:04:be:4b:ce:97:be:c3:67:2a:68:11:df:80:
         e7:0c:33:66:bf:13:0d:14:6e:f3:7f:1f:63:10:1e:fa:8d:1b:
         25:6d:6c:8f:a5:b7:61:01:b1:d2:a3:26:a1:10:71:9d:ad:e2:
         c3:f9:c3:99:51:b7:2b:07:08:ce:2e:e6:50:b2:a7:fa:0a:45:
         2f:a2:f0:f2

Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            08:70:bc:c5:af:3f:db:95:9a:91:cb:6a:ee:ef:e4:65
    Signature Algorithm: sha256WithRSAEncryption
        Issuer: C=US, O=DigiCert Inc, OU=www.digicert.com, CN=DigiCert Assured ID Root CA
        Validity
            Not Before: Nov 18 12:00:00 2014 GMT
            Not After : Nov 18 12:00:00 2024 GMT
        Subject: C=NL, ST=Noord-Holland, L=Amsterdam, O=TERENA, CN=TERENA SSL CA 3
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (2048 bit)
                Modulus:
                    00:c5:76:0f:0f:d9:43:29:3b:6c:6d:d1:47:ad:de:
                    10:bf:23:c2:78:a8:4a:77:35:f1:23:5b:e0:4c:1e:
                    41:e7:c2:31:00:bd:88:37:45:75:dd:b9:02:10:80:
                    1e:8f:ed:64:23:04:45:a7:a0:39:3b:81:4d:cf:63:
                    3f:c2:49:ff:22:9e:88:b0:d2:96:b9:5c:8a:74:1f:
                    92:2a:2a:f2:12:c8:b7:68:54:b5:58:41:81:40:68:
                    06:1a:4f:85:29:fb:b5:4d:3c:0f:4f:3f:40:96:1b:
                    ce:a8:cc:5e:35:ff:64:98:f5:75:dd:74:54:05:a0:
                    36:11:04:12:24:55:63:ef:94:77:2e:77:f1:15:76:
                    ee:d3:a4:59:45:21:9f:a8:be:d1:27:ed:0a:e8:ab:
                    38:ca:3f:87:d1:da:f1:8f:b9:0b:1f:44:e7:e0:ad:
                    f3:95:c2:16:4d:ec:84:a3:3a:92:d4:cf:c6:7d:e6:
                    bd:cb:1a:40:4f:b3:54:b1:f3:8f:6f:0d:1e:e3:be:
                    49:a3:56:e4:07:bc:8d:a7:ce:1d:b0:5b:57:56:d1:
                    c4:1c:fc:98:65:d1:cd:46:2f:91:94:bf:45:85:49:
                    f8:6d:52:87:1c:02:56:01:27:16:ab:72:2e:f4:71:
                    e4:61:b5:20:a0:fa:26:69:6a:0a:f1:ab:9f:6d:b7:
                    cf:25
                Exponent: 65537 (0x10001)
        X509v3 extensions:
            X509v3 Basic Constraints: critical
                CA:TRUE, pathlen:0
            X509v3 Key Usage: critical
                Digital Signature, Certificate Sign, CRL Sign
            Authority Information Access:
                OCSP - URI:http://ocsp.digicert.com
                CA Issuers - URI:http://cacerts.digicert.com/DigiCertAssuredIDRootCA.crt
            X509v3 CRL Distribution Points:
                Full Name:
                  URI:http://crl3.digicert.com/DigiCertAssuredIDRootCA.crl
                Full Name:
                  URI:http://crl4.digicert.com/DigiCertAssuredIDRootCA.crl
            X509v3 Certificate Policies:
                Policy: X509v3 Any Policy
                  CPS: https://www.digicert.com/CPS
            X509v3 Subject Key Identifier:
                67:FD:88:20:14:27:98:C7:09:D2:25:19:BB:E9:51:11:63:75:50:62
            X509v3 Authority Key Identifier:
                keyid:45:EB:A2:AF:F4:92:CB:82:31:2D:51:8B:A7:A7:21:9D:F3:6D:C8:0F
    Signature Algorithm: sha256WithRSAEncryption
         a9:28:35:7a:c4:7b:d6:da:27:1e:ac:98:cf:27:36:4f:11:32:
         74:74:e6:40:dd:1d:cd:f2:68:77:35:af:b3:8c:5d:c6:04:bf:
         15:f4:23:67:8b:b9:6f:97:04:eb:46:9d:c2:cd:c9:d1:a4:ae:
         81:2e:c9:ba:b1:e8:80:d0:1c:c9:39:c1:56:76:59:6c:9c:7d:
         e3:a9:f0:d3:d1:34:d8:3c:49:59:8b:1a:98:ce:bf:c6:f2:d8:
         30:35:ff:e9:6f:5d:a0:af:3a:ee:66:53:ae:aa:8c:69:c8:be:
         9a:a7:a0:7b:d8:82:4b:33:13:c8:07:f3:77:d7:f3:64:cd:9e:
         63:f9:42:27:53:ae:10:33:89:72:37:15:f1:be:f7:1e:35:a2:
         ce:c3:2d:f2:d7:b2:e6:0b:c7:69:c0:e5:1f:5f:7c:69:9b:7e:
         ce:26:1a:33:44:c3:ba:77:05:3b:ba:5d:3f:41:89:fa:16:3b:
         ee:04:6e:5b:ac:56:4b:ef:8c:70:f2:4a:7b:57:bd:19:6e:8b:
         36:07:54:26:2d:86:09:94:1f:5f:37:ab:f0:23:3f:8f:2c:5f:
         96:9e:47:71:a8:44:de:a9:b9:85:2f:b5:34:60:a5:5f:09:a0:
         9a:43:1d:d4:bf:2d:44:d6:8d:da:fd:75:cb:5f:16:a0:0e:61:
         c2:70:3d:36

Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            02:72:71:c2:fe:ca:5c:4e:3b:1c:cc:a8:67:97:c4:1e
    Signature Algorithm: sha256WithRSAEncryption
        Issuer: C=NL, ST=Noord-Holland, L=Amsterdam, O=TERENA, CN=TERENA SSL CA 3
        Validity
            Not Before: Jan 15 00:00:00 2016 GMT
            Not After : Jan 23 12:00:00 2019 GMT
        Subject: C=FI, ST=Uusimaa, L=Espoo, O=Aalto University Foundation, OU=Department of Computer Science,
CN=www.cs.hut.fi
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
                Public-Key: (2048 bit)
                Modulus:
                    00:ce:7a:5c:cd:45:da:fb:51:db:8f:13:fb:ea:39:
                    cd:3f:db:e6:18:45:8d:75:12:b6:3b:8a:be:df:4f:
                    5c:c0:42:2c:1a:7a:d4:ca:d5:35:ff:e3:f3:a5:7f:
                    a9:71:df:2e:95:c8:3e:cb:9e:b9:e1:22:b8:70:7c:
                    7f:f4:9c:67:61:da:a6:01:56:8a:f4:e5:97:01:9f:
                    dc:dc:4a:2b:36:f7:91:0e:fe:a9:e3:91:c3:cf:0b:
                    22:94:bf:55:ea:de:d4:cb:8c:7f:c4:5f:4e:3c:e7:
                    16:30:d6:5a:c3:fe:ab:71:39:a0:d9:2b:f7:6e:54:
                    7a:8c:c3:e6:c5:59:37:3d:51:40:66:36:38:2b:4d:
                    7d:a6:c2:5f:f8:e7:a1:d9:07:1f:c6:2e:01:ba:b3:
                    a8:52:a5:8e:b8:da:48:3a:2d:e7:3a:d4:ee:e7:d5:
                    fe:d6:06:f5:9e:50:bd:d3:99:2a:65:7e:09:74:0f:
                    40:d7:87:e3:bc:0f:39:90:69:7f:8c:1a:af:1e:8b:
                    88:e9:4f:99:29:f4:4b:14:36:f3:ee:46:32:91:ca:
                    37:ea:21:37:ef:13:f2:99:42:ad:f3:93:2c:97:1f:
                    26:84:7c:73:00:27:ad:cf:fe:bb:10:6e:e9:b3:29:
                    c4:dd:f4:f1:56:21:95:e1:2f:96:8a:76:bf:89:6e:
                    52:3b
                Exponent: 65537 (0x10001)
        X509v3 extensions:
            X509v3 Authority Key Identifier:
                keyid:67:FD:88:20:14:27:98:C7:09:D2:25:19:BB:E9:51:11:63:75:50:62
            X509v3 Subject Key Identifier:
                DD:21:81:30:50:E5:D6:D2:E7:1F:8C:BB:C5:0C:31:C7:60:50:C4:91
            X509v3 Subject Alternative Name:
                DNS:www.cs.hut.fi, DNS:www.cse.tkk.fi
            X509v3 Key Usage: critical
                Digital Signature, Key Encipherment
            X509v3 Extended Key Usage:
                TLS Web Server Authentication, TLS Web Client Authentication
            X509v3 CRL Distribution Points:
                Full Name:
                  URI:http://crl3.digicert.com/TERENASSLCA3.crl
                Full Name:
                  URI:http://crl4.digicert.com/TERENASSLCA3.crl
            X509v3 Certificate Policies:
                Policy: 2.16.840.1.114412.1.1
                  CPS: https://www.digicert.com/CPS
                Policy: 2.23.140.1.2.2
            Authority Information Access:
                OCSP - URI:http://ocsp.digicert.com
                CA Issuers - URI:http://cacerts.digicert.com/TERENASSLCA3.crt
            X509v3 Basic Constraints: critical
                CA:FALSE
    Signature Algorithm: sha256WithRSAEncryption
         88:25:ff:0c:a6:6d:55:01:b3:fc:64:35:16:c5:56:c4:e1:bb:
         0e:94:83:85:07:7a:6e:96:2e:50:6a:8a:b9:8c:00:a9:c8:f9:
         ba:cc:6e:ec:da:ab:0a:e3:77:c0:d8:f6:91:d2:b2:8e:7a:5b:
         4c:1c:e5:82:d1:49:a0:95:e3:c8:d4:d8:ce:62:59:43:b3:db:
         d6:e6:c9:ad:e3:63:d2:24:d7:d6:49:a8:20:92:df:01:79:03:
         d2:54:93:98:06:e0:cd:13:79:29:ea:a6:9c:63:83:37:06:3f:
         36:71:ed:a4:62:54:ec:b4:61:40:41:f1:66:3f:32:3c:f0:33:
         98:4b:84:43:d0:0c:ec:08:71:51:8e:32:66:64:4f:cf:41:d7:
         e0:ac:53:fe:b5:cd:f2:5a:43:19:69:b7:f4:7a:c8:b2:fb:57:
         54:1b:ab:04:ce:18:e6:54:1c:52:d0:a6:7a:ad:db:43:ac:82:
         ad:37:71:d3:be:4e:97:26:0e:9a:8e:3f:c6:0e:52:bc:fa:b7:
         f7:91:01:d9:cf:36:e5:72:58:29:6f:fb:29:6b:78:87:98:49:
         85:42:3a:ea:57:09:2a:92:52:2a:c2:18:11:1a:ef:62:29:65:
         de:5a:47:7b:49:41:d0:ee:c5:a6:73:0a:9f:f2:14:ed:95:1b:
         b0:b6:7f:8b
```