Lab 9: Future Crypto

1 Details

Aim: To provide a foundation in some of the up-and-coming methods in cryptography.

2 Light-weight crypto

L2.1 NIST has defined a number of possible contenders for light-weight crypto methods. By searching the Internet, can you find those that have been recommended:

Symmetric key: Public key: Hashing: Key exchange: MAC:

L2.2 In many operations within public key methods we use the exponential operation:

$g^x \pmod p$

If we compute the value of g^x and then perform a (mod p) it is a very costly operation in terms of CPU as the value of g^x will be large. A more efficient method is to use Montgomery reduction and is implemented in Python with pow(g,x,p).

```
import random
g=3
x= random.randint(2, 100)
n=997
res1 = g**x % n
res2= pow(g,x, n)
print res1
print res2
```

Run the program several times, and validate that it always produces the same values for res1 and res2.

Now add some code to determine the time taken to perform each of the two operations, and compare them:

Can you now put each of the methods into a loop, and perform each calculation 1,000 times?

Now measure the times taken. What do you observe?

Now increase the range for x (so that it is relatively large) and make n a large prime number. What do you observe from the performance?

L2.3 Normally light-weight crypto has to be fast and efficient. The XTEA method is one of the fastest around. Some standard open source code in Node.js is (use **npm install xtea**):

```
var xtea = require('xtea');

var plaintext = new Buffer('ABCDEFGH', 'utf8');
var key = new Buffer('0123456789ABCDEF0123456789ABCDEF', 'hex');
var ciphertext = xtea.encrypt( plaintext, key );

console.log('Cipher:\t'+ ciphertext.toString('hex') );
console.log('Decipher:\t'+ xtea.decrypt( ciphertext, key ).toString() );
```

A sample run is:

```
Cipher:52deb267335dd52a49837931c233cea8
Decipher:	ABCDEFGH
```

What is the block and key size of XTEA?

Can you add some code to measure the time taken for 1,000 encryptions?

Can you estimate the number for encryption keys that could be tried per second on your system?

If possible, run the code on another machine, and estimate the rate of encryption keys that can be used per second:

L2.4 RC4 is a stream cipher created by Ron Rivest and has a variable key length. Run the following Python code and test it:

```
def KSA(key):
    keylength = len(key)

    S = range(256)

    j = 0
    for i in range(256):
```

```
        j = (j + S[i] + key[i % keylength]) % 256
        S[i], S[j] = S[j], S[i]  # swap

    return S


def PRGA(S):
    i = 0
    j = 0
    while True:
        i = (i + 1) % 256
        j = (j + S[i]) % 256
        S[i], S[j] = S[j], S[i]  # swap

        K = S[(S[i] + S[j]) % 256]
        yield K

def RC4(key):
    S = KSA(key)
    return PRGA(S)

def asctohex(string_in):
          a=""
          for x in string_in:
                    a = a + ("0"+((hex(ord(x)))[2:]))[-2:]
          return(a)

def convert_key(s):
        return [ord(c) for c in s]

key="0102030405"

plaintext = 'Hello'

if (len(sys.argv)>1):
          plaintext=str(sys.argv[1])

if (len(sys.argv)>2):
          key=str(sys.argv[2])

key = key.decode('hex')
key = convert_key(key)

keystream = RC4(key)
print "Keystream: ",
for i in range (0,15):
          print hex(keystream.next()),
print
print "Cipher: ",
keystream = RC4(key)

for c in plaintext:
          sys.stdout.write("%02X" % (ord(c) ^ keystream.next()))
```

Now go to https://tools.ietf.org/html/rfc6229 and test a few key generation values and see if you get the same key stream.

Tests:

Key: 0102030405 **Key stream (first six bytes):**
Key: **Key stream (first six bytes):**
Key: **Key stream (first six bytes):**
Key: **Key stream (first six bytes):**

How does the Python code produce a key stream length which matches the input data stream:

Can you test the code by decrypting the cipher stream (note: you just use the same code, and do the same operation again)?

RC4 uses an s-Box. Can you find a way to print out the S-box values for a key of "0102030405"?

What are the main advantages of having a variable key size and having a stream cipher in light-weight cryptography?

L1.5 Rabbit is a fast stream encryption method. The source code is here:

https://asecuritysite.com/encryption/rabbit2

and a sample run is here:

```
Message:              Hello
IV:                   0
Encryption password:  qwerty
Encryption key:       d8578edf8458ce06fbc5bb76a58c5ca4

======Rabbit encryption========
Encrypted:     184d78e6aa
Decrypted:     Hello
```

What is the key size and the size of the IV value:

The fastest code with be in C, can you download the version of the code from here, and get it to run:

http://www.ecrypt.eu.org/stream/e2-rabbit.html

From this can you test for a number of key streams that are given here:

https://asecuritysite.com/encryption/rabbit

For example:

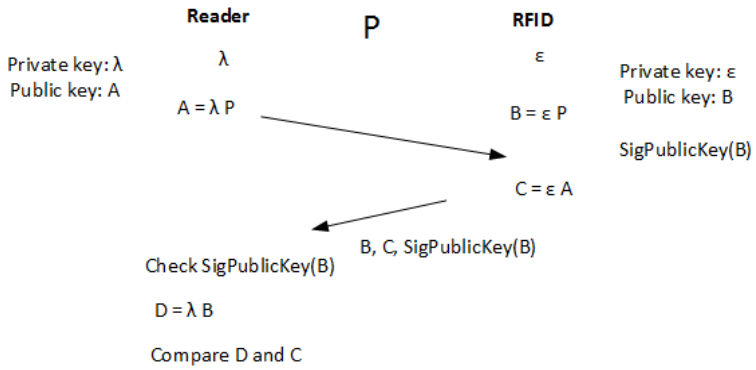
Test 1: Key setup and encryption/decryption/prng

key1 = [00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00]

out1 = [02 F7 4A 1C 26 45 6B F5 EC D6 A5 36 F0 54 57 B1
A7 8A C6 89 47 6C 69 7B 39 0C 9C C5 15 D8 E8 88
EF 9A 69 71 8B 82 49 A1 A7 3C 5A 6E 5B 90 45 95]

Test vector tests:

L1.6 The ELLI method can be used to identify an RFID tag.



Can you run the following code and determine that it works (C and D should be the same)? Can you also explain how it works?

```
from os import urandom
from eccsnacks.curve25519 import scalarmult, scalarmult_base
import binascii

lamb = urandom(32)
a = scalarmult_base(lamb)

eps = urandom(32)
b = scalarmult_base(eps)

c = scalarmult(eps, a)

d = scalarmult(lamb, b)

print "RFID private key: ",binascii.hexlify(eps)

print "Reader private key: ",binascii.hexlify(lamb)

print
print "A value: ",binascii.hexlify(a)
print "B value: ",binascii.hexlify(b)

print "C value: ",binascii.hexlify(c)
print "D value: ",binascii.hexlify(d)
```

3 Key exchange (Zero-knowledge)

WPA-2 suffers from an attack on the 4-way handshake. WPA-3 improves on this by getting rid of it and implementing a zero-knowledge key exchange method known as Dragonfly. Copy-and-paste the following code and prove that both sides will be able to share the same key:

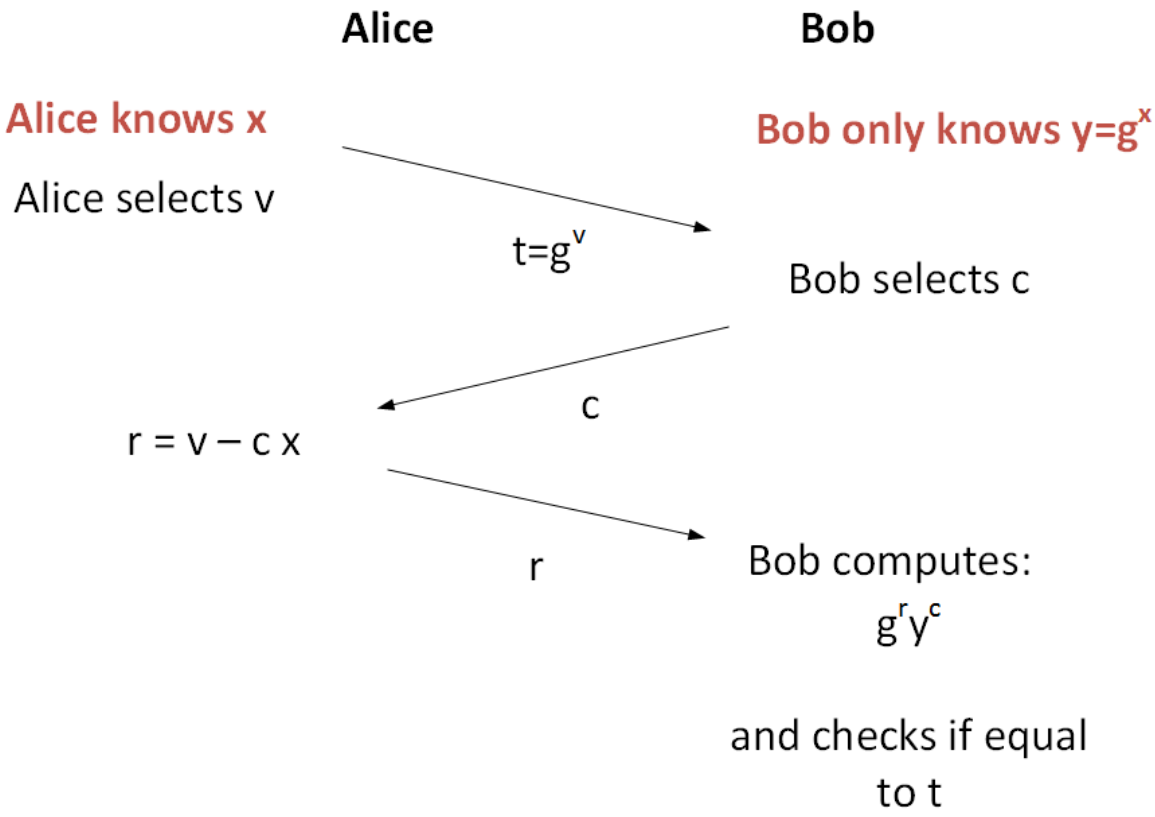
https://asecuritysite.com/encryption/dragonfly

By searching on the Internet, can you find an example of the WPA-2 hack on the 4-way handshake? What is the method used? Does it apply to all implementations of WPA-2?

What is the current state of the roll-out of WPA-3? Can you find any existing wireless routers that currently support it?

4 Zero-knowledge proof (ZKP)

L1.7 With ZKP, Alice can prove that he still knows something to Bob, without revealing her secret. At the basis of many methods is the Fiat-Shamir method:



Ref: https://asecuritysite.com/encryption/fiat

The following code implements some basic code for Fiat-Shamir, can you prove that for a number of values of x, that Alice will always be able to prove that she knows x.

x: Proved: Y/N
x: Proved: Y/N
x: Proved: Y/N
x: Proved: Y/N

The value of n is a prime number. Now increase the value of n, and determine the effect that this has on the time taken to compute the proof:

```
import sys
import random

n=97

g= 5

x = random.randint(1,5)
v = random.randint(n//2,n)
c = random.randint(1,5)

y= pow(g,x, n)

t = pow(g,v,n)

r = (v - c * x)

print r
if (r<0): r=-r

Result = ( pow(g,r,n)) * (pow(y,c,n))  % n


print 'x=',x
print 'c=',c
print 'v=',v
print 'P=',n
print 'G=',g
print '======'
print 't=',t
print 'r=',Result
if (t==Result):
          print 'Alice has proven she knows x'
else:
          print 'Alice has not proven she knows x'
```

L1.8 We can now expand this method by creating a password, and then making this the secret. Copy and run the code here:

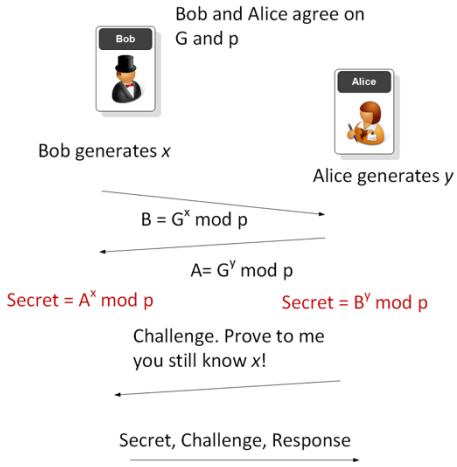
https://asecuritysite.com/encryption/fiat2

Now test the code with different passwords. Does it work?

How does the password get converting into a form which can be used in the Fiat-Shamir method?

L1.9 The Diffie-Hellman method can be used to perform a zero-knowledge proof implementation. Copy the code from the following link and verify that it works:

https://asecuritysite.com/encryption/diffiez



5 Hashing

There are a number of light-weight hashing methods that are proposed. Using the following links, can you get the methods to work and produce the correct outputs:

- Spongent. https://asecuritysite.com/encryption/spongent
- Quark. https://asecuritysite.com/encryption/quark
- Lesamnta-LW https://asecuritysite.com/encryption/lw