SIGPwny

FA2023 Week 07 • 2023-10-12

Crypto I

Anakin and Sagnik

Announcements

- Lockpicking Support Group!
  - Come practice lockpicking
  - Mondays 8-9 PM

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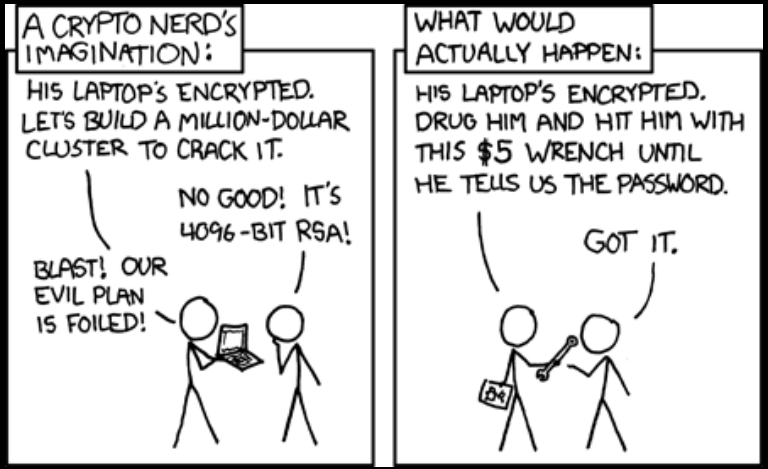


Outline

Basics

XOR

Diffie-Hellman

Scoreboard

Place	User		Score
1	ronanboyarski	+1.5k points	28035
2	NullPoExc		24515
3	caasher	+4k points	21290
4	CBCicada	+9k points (up 1 place)	18015
5	mgcsstywth	+.1k points	17125
6	EhWhoAmI		8645
7	aaronthewinner	+.4k points	7655
8	ilegosmaster		6660
9	drizzle	+.1k points	6225
10	SHAD0WV1RUS		5970

Get Involved Callout

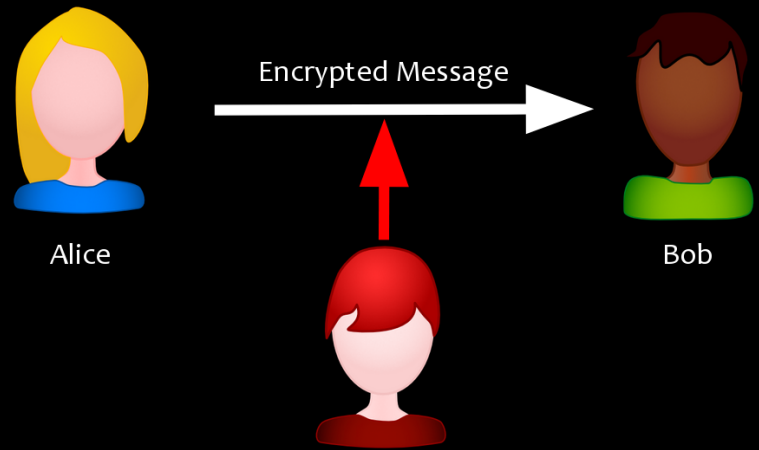
Looking for people to:

- run meetings
- plan events
- create challenges
- get more involved in the club :0
- Let us know if interested!

Section 1

Basics

What is Crypto Anyways?



Why Do We Care?

Crypto in Ye Olden Days

- Relied on simple patterns
- Hard / annoying to break by hand, **easy to break by computer**
- Examples:
  - Caesar Cipher (rot k)
    - $a \to c,\ b \to d,\ \ldots,\ y \to a,\ z \to b$ (rot 2)
  - Substitution
    - Create a table mapping each letter to another
    - Generalization of Caesar Cipher
  - Many More
    - **All insecure!!**

Data Representation

- TL;DR: computers store things in binary (0s and 1s), and we have different ways of representing this
- Look at the challenge source if given and mimic what they do
- Tip: In Python, always work with bytes / bytestrings, never with normal strings (Python 3.8+)

Conversion Cheatsheet

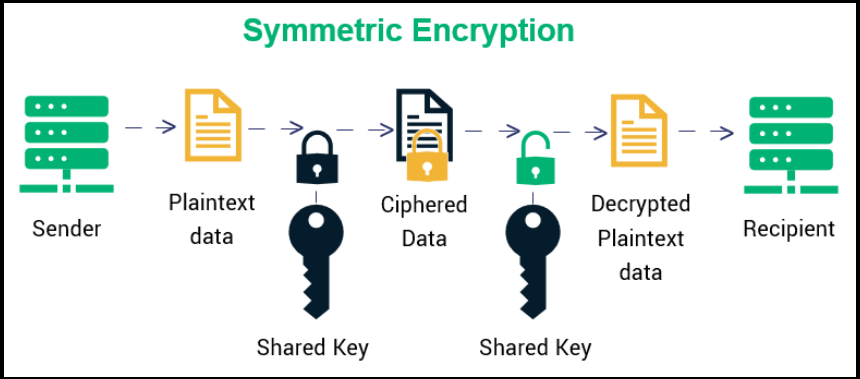
This is hard to read, download the slides!!

Format	Description	From Bytes	To Bytes
base64	uses printable letters to encode more complex binary	base64.b64encode	base64.b64decode
hex	uses symbols 0-9, A-F	bytearray.hex(), binascii.hexlify()	bytes.fromhex(), binascii.unhexlify()
integer	normal integers	Crypto.Util.number.bytes_to_long (PyCryptoDome), int.from_bytes	Crypto.Util.number.long_to_bytes (PyCryptoDome), int.to_bytes

Section 2

XOR

Symmetric Encryption



XOR

A	B	$A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

XOR

- XOR has some really nice properties that make it perfect for symmetric encryption
- Say M is some message as a bitstring, K is some key
- Then let $C = M \oplus K$ be a ciphertext
- Properties:
  - **Order doesn't matter:** $M \oplus K = K \oplus M$
  - **Group as needed:** $M \oplus (K \oplus K) = (M \oplus K) \oplus K$
  - **0 is the identity:** $M \oplus 0 = M$
  - **Self Inverse:** $K \oplus K = 0$
- All of this means $C \oplus K = M \oplus K \oplus K = M \oplus 0 = M$

Overview of Easy Some Attacks

- For certain reasons, in general XOR is really really hard to break
  - Without more information, you need to try 2^{λ} guesses to break a bitstring of length λ
- Usually you need to know some information about the plaintext
  - Known plaintext + ciphertext pair
  - Properties like language (common letters / words)
- You may need to know some information about the key
  - Really short keys are able to be brute forced
  - Flag Formats: sigpwny{

Section 3

Diffie-Hellman

Modular Arithmetic

- Numbers can get really big really fast
- We use **modular arithmetic** to deal with this
- Modular arithmetic is **arithmetic with remainders after division**
  - Keep taking remainders as you do arithmetic
- If we do computation **mod** n that means we will take remainders after division by n

Remainders

- Assume we have some number n. We are going to do some computation **mod** n
- For now, say $n = 101$

$$
\begin{aligned}
131 + 140 * (102)^{2000} &\equiv 131 + 39 * (102)^{2000} && (\text{mod } 101) \\
&\equiv 30 + 39 * (102)^{2000} && (\text{mod } 101) \\
&\equiv 30 + 39 * (1)^{2000} && (\text{mod } 101) \\
&\equiv 30 + 39 && (\text{mod } 101) \\
&\equiv 69 && (\text{mod } 101)
\end{aligned}
$$

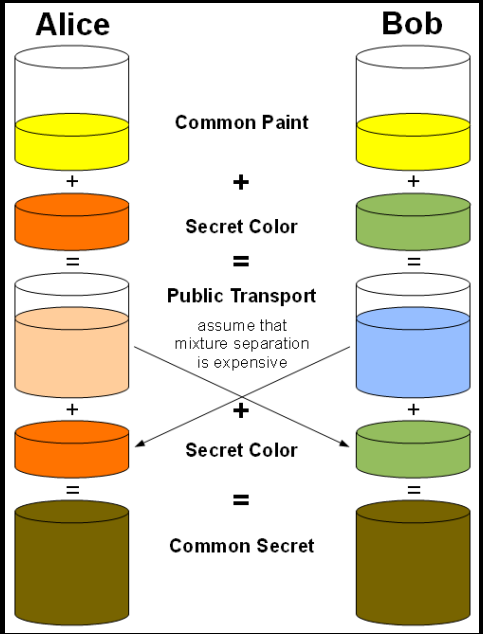
Discrete Log

- If $a^b \equiv X \pmod{p}$, $b =$ the **discrete log of** X **with base** a
- Given some random X and a, finding b is really hard to compute for large primes p
- This **Discrete Log Problem (DLP)** is the basis for many modern cryptography standards

Trapdoors

- Think of the DLP as a trapdoor
  - Easy to enter, hard to exit
- If $2^n \equiv 79 \pmod{97}$, what is n?
- $n = 15$
- Imagine this with larger primes. Multiplication is easy, logs are hard

Diffie-Hellman takes advantage of this!


Alice
Bob
Common Paint
+
+
+
Secret Color
=
=
=
Public Transport
assume that
mixture separation
is expensive
+
+
+
Secret Color
=
=
=
Common Secret

Painting with Numbers

- Let g be a public number we call a generator and p be some public prime
- Alice generates secret a and computes $A \equiv g^a \pmod{p}$
- Bob generates secret b and computes $B \equiv g^b \pmod{p}$
- Alice sends Bob A and Bob sends Alice B
- Alice computes $B^a \pmod{p}$
- Bob computes $A^b \pmod{p}$

Alice and Bob now have the same key!

$$A^b \equiv (g^a)^b \equiv g^{ab} \equiv (g^b)^a \equiv B^a \pmod{p}$$

Overview of Some Attacks

Remember, discrete log in general is **hard**

- Small Primes are easy to bruteforce
  - You have a computer, use it!
- "Oracle" attacks: access to a special machine that leaks information
  - Write out what do and don't know as equations
  - Do not be afraid of pen and paper
- Primes are generated in specific ways
  - "Smooth Primes" p where $p - 1$ has many factors
  - Pohlig-Hellman, Pollard's Rho
  - More on this next week with advanced factoring!

Misc Chals

- Alot of Crypto people like cute little math / puzzles, many challenges are just "reverse the math"
  - Solve some polynomial equations
  - Linear algebra
  - Undo Randomness
    - Is it really random? Does the randomness really have an effect on anything?
- Strategy: Just try things, look for patterns, more like math-y reverse engineering. Don't be afraid to just start.

Tools!

- Python + SageMath is your friend
- PyCryptodome is an extremely useful Python crypto library
- PwnTools will allow you to automate parts of your attacks
- Google + StackOverflow (“how to crack DH with ...”)
- Installation is annoying, use the CryptoHack Docker

Practice @ CryptoHack

Next Meetings

2023-10-15 – This Sunday

- Crypto II
- More Diffie-Hellman + RSA

2023-10-19 – Next Thursday

- PWN I with Sam

2022-10-22 – Next Sunday

- Pwn II with Kevin

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Thanks for listening!