CSCI 331: Introduction to Computer Security

Lecture 10: Anatomy of a bug

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Announcements

- TA applications open tomorrow; due by Oct 29.
- TA feedback survey Oct 17.
- Next lab: meet in lobby of Jesup. Do not be late! We will leave promptly at the start of lab.

Topics

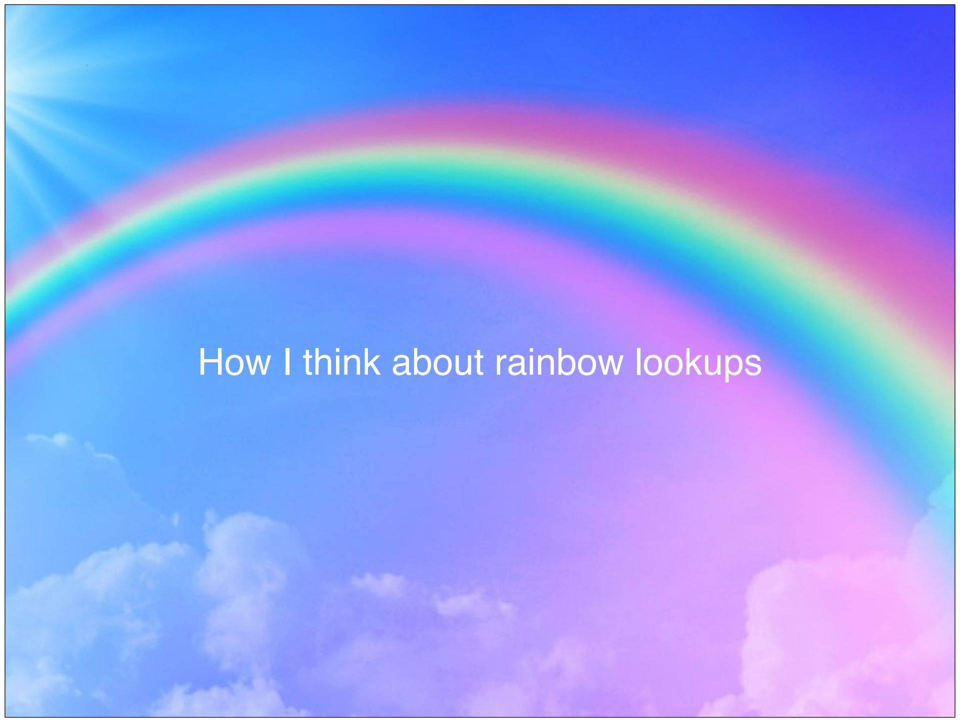
Rainbow Table Generation

Rainbow Table Lookup

A Sample Exploit

Your to-dos

1. Start studying for midterm.
2. Lab 3 part 2, **due Sunday 10/17**.
3. Project part 2, out soon.



How I think about rainbow lookups

Class activity:

generating rainbow chains

of length 3

Hash function lookup table:

plaintext	Hash of plaintext
♥♥♥♥	4A7D1ED414474E4033AC29CCB8653D9B
♥♥♥★	25BBDCD06C32D477F7FA1C3E4A91B032
♥♥★♥	FC1198178C3594BFDDA3CA2996EB65CB
♥♥★★	AE2BAC2E4B4DA805D01B2952D7E35BA4
♥★♥♥	DB2F40F24260BC41DB48D82D5E7ABF1D
♥★♥★	814F06AB7F40B2CFF77F2C7BDFFD3415
♥★★♥	2A66ACBC1C39026B5D70457BB71B142B
♥★★★	7D7C45B9A935CF9D845FC75679A41559
★♥♥♥	A9B7BA70783B617E9998DC4DD82EB3C5
★♥♥★	B8C37E33DEFDE51CF91E1E03E51657DA
★♥★♥	1E48C4420B7073BC11916C6C1DE226BB
★♥★★	7F975A56C761DB6506ECA0B37CE6EC87
★★♥♥	1E6E0A04D20F50967C64DAC2D639A577
★★♥★	C6BFF625BDB0393992C9D4DB0C6BBE45
★★★♥	2CBCA44843A864533EC05B321AE1F9D1
★★★★	B59C67BF196A4758191E42F76670CEBA

```
func reducer(c,i):

Convert the ith hexadecimal
digit of c into a plaintext
using the following table:
```

hex	plaintext
0	♥♥♥♥
1	♥♥♥★
2	♥♥★♥
3	♥♥★★
4	♥★♥♥
5	♥★♥★
6	♥★★♥
7	♥★★★
8	★♥♥♥
9	★♥♥★
A	★♥★♥
B	★♥★★
C	★★♥♥
D	★★♥★
E	★★★♥
F	★★★★

Find the first three rainbow chains of length 3.

First three rainbow chains

$$\begin{tikzcd}
\text{♥♥♥♥} \arrow[r, "h"] & \text{4A7D} \arrow[r, "r_0"] & \text{♥★♥♥} \arrow[r, "h"] & \text{DB2F} \arrow[r, "r_1"] & \text{★♥★★} \arrow[r, "h"] & \text{7F97} \arrow[r, "r_2"] & \text{★♥♥★} \\
\text{♥♥♥★} \arrow[r, "h"] & \text{25BB} \arrow[r, "r_0"] & \text{♥♥★♥} \arrow[r, "h"] & \text{FC11} \arrow[r, "r_1"] & \text{★★♥♥} \arrow[r, "h"] & \text{1E6E} \arrow[r, "r_2"] & \text{♥★★♥} \\
\text{♥♥★♥} \arrow[r, "h"] & \text{FC11} \arrow[r, "r_0"] & \text{★★★★} \arrow[r, "h"] & \text{B59C} \arrow[r, "r_1"] & \text{♥★♥★} \arrow[r, "h"] & \text{814F} \arrow[r, "r_2"] & \text{♥★♥♥}
\end{tikzcd}$$

end	start
★♥♥★	♥♥♥♥
♥★★♥	♥♥♥★
♥★♥♥	♥♥★♥

Rainbow table (for first 3 chains)

end	start
★♥♥★	♥♥♥♥
♥★★♥	♥♥♥★
♥★♥♥	♥♥★♥

Decrypt `FC11`.

Hypothesis: `FC11` is the third link in the chain.

`FC11` $\xrightarrow{r_2}$ ♥♥♥★ Is ♥♥♥★ an **end**? **No.**

Hypothesis: `FC11` is the second link in the chain.

`FC11` $\xrightarrow{r_1}$ ★★♥♥ $\xrightarrow{h}$ `1E6E` $\xrightarrow{r_2}$ ♥★★♥ Is ♥★★♥ an **end**? **Yes.**

Decrypt from **start** ♥♥♥★: **plaintext**

♥♥♥★ $\xrightarrow{h}$ `25BB` $\xrightarrow{r_0}$ ♥♥★♥ $\xrightarrow{h}$ `FC11`

Countermeasures Against Cracking Attacks

- Password salts.
- Uniformly-distributed passwords.
- Two-factor authentication.
- Last-known IP address.
- Make hashing expensive.

Key Stretching

Key stretching is a technique used to make password decryption attacks **computationally expensive**. Unlike an ordinary user, an attacker must invoke a hash function many times. Key stretching **amplifies the cost of a hash function** using a **stretch factor s**.

$f^s(p) = c^s$ is an iterated hash function, where

$$f^1(p) = f(p) = c^1$$
$$f^2(p) = f(f(p)) = c^2$$
$$f^3(p) = f(f(f(p))) = c^3$$
$$\dots$$
$$f^n(p) = c^n$$

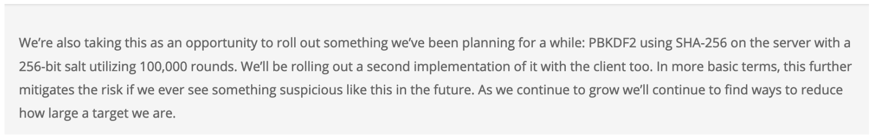
Key Stretching

There are many publicly-available key stretching implementations. Two commonly-used implementations:

- bcrypt (default hash function in OpenBSD)
- PBKDF2 (part of the RSA encryption standard)

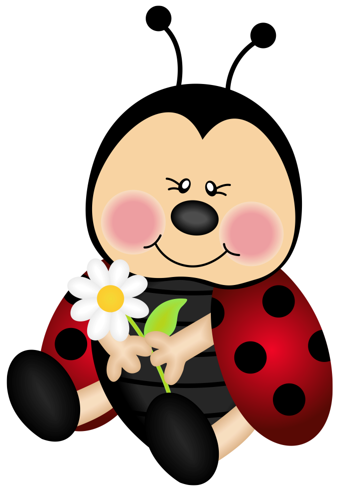
Both are interesting in that the stretch factor can be tied to available computational power.

LastPass



We're also taking this as an opportunity to roll out something we've been planning for a while: PBKDF2 using SHA-256 on the server with a 256-bit salt utilizing 100,000 rounds. We'll be rolling out a second implementation of it with the client too. In more basic terms, this further mitigates the risk if we ever see something suspicious like this in the future. As we continue to grow we'll continue to find ways to reduce how large a target we are.

Bugs



Anatomy of a bug

We can use the GCC assembler to figure out what's going on.

Note that I use a large number of GCC flags here. Don't let them scare you. These flags essentially reduce the program to its simplest form in assembly.

- -S : output assembly
- -c : compile as library (no C startup routines)
- -fno-dwarf2-cfi-asm : no control flow integrity
- -fno-asynchronous-unwind-tables : no exception support
- -fno-exceptions : exception support
- -z execstack : allow executable stacks
- -fno-stack-protector : disable stack canaries

Recap & Next Class

Today we learned:

Rainbow table generation

Rainbow table lookup

Sample buffer overflow exploit

Next class:

How to craft an exploit