# CSCI 331:
# Introduction to Computer Security

## Lecture 7: Password Cracking, part 2

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Williams

## Topics

Address Sanitizer

Paper discussion (Oechslin)

Precomputed Hash Chains

## Your to-dos

1. Project part 1 **due Sunday 10/3**.
2. Reading response (Davis), **due Wed 10/4**.
3. Lab 3 **due Sunday 10/10**.

## Address Sanitizer

Keyed encryption functions

Precomputed Hash Chains

## Precomputed Hash Chains

Motivation: dictionaries are **too big** to distribute

Recall:


**About 29 terabytes!**

Want: something smaller

Paper discussion (Oechslin)

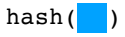
## Interesting fact about salts: usually stored in plaintext!

When you change your password, the */bin/passwd* program selects a salt based on the time of day. The salt is converted into a two-character string and is stored in the */etc/passwd* file along with the encrypted "password." In this manner, when you type your password at login time, the same salt is used again. Unix stores the salt as the first two characters of the encrypted password.

— Practical UNIX and Internet Security, 3rd Edition by Simson Garfinkel, Gene Spafford, Alan Schwartz

## Ordinary dictionary


## Ordinary dictionary



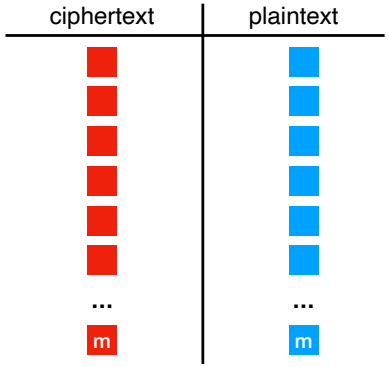


## Ordinary dictionary


# Ordinary dictionary

**m** = # of possible passwords

So storing a table takes roughly O(**m**) space.




plaintext ciphertext

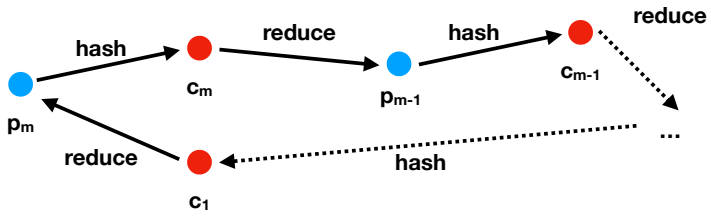
# We can enumerate all plaintexts*

plaintexts

ciphertexts

Suppose f($p_i$) = $c_i$

Suppose $r(c_i)$ = $p_{i-1}$ if $i$>1 otherwise $p_m$




*in principle, assuming no collisions

# Hash chain

a

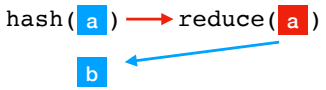
plaintext ciphertext

# Hash chain

hash( a ) → b

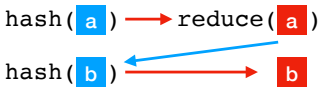
plaintext ciphertext

# Hash chain



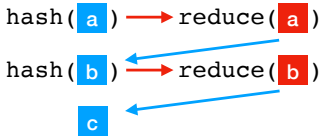

plaintext ciphertext

# Hash chain



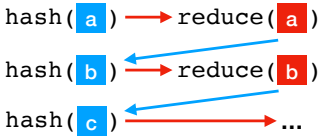

plaintext ciphertext

# Hash chain




plaintext ciphertext

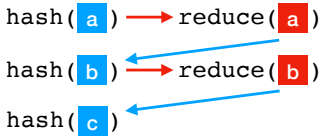
# Hash chain




plaintext ciphertext

# Hash chain of length 2

Chain length: # of calls to `reduce()`




plaintext ciphertext

# Hash chain of length 2

Discard everything but **start** and **end** points and store them in a table

| start | end |
|---|---|
| a | c |

plaintext ciphertext

# Hash chain of length 2

But store the **end** as the **`key`** and **start** as the **`data`**.

(e.g., using the `hsearch(3)` implementation we explored in lab)

| end | start |
|---|---|
| c | a |

plaintext ciphertext

# Hash chain of length 2

Each chain contains roughly **k** plaintexts

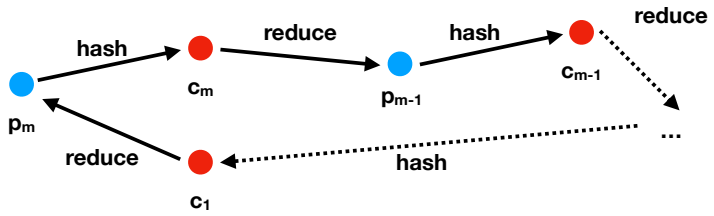
So storing a table now takes roughly O(**m/k**) space.

| end | start |
|---|---|
| c | a |
| f | d |
| i | g |
| l | j |
| o | m |
| ... | ... |
| | |

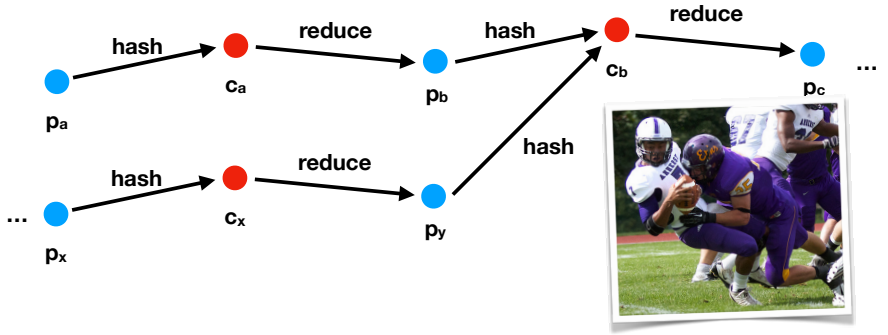
plaintext ciphertext

# Thought experiment: drawbacks

- Saving just the first password **buys us nothing**. On average, we have to compute **O(m/2)** hash-reductions to find a password.
- It is **probably not possible** to find a reducer that lets you explore the entire password space.
- **Hash functions collide!**



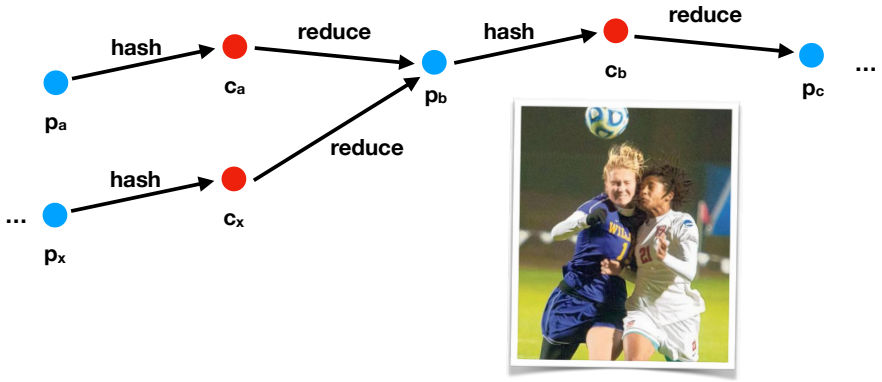

# Collisions from hash functions




After the **collision**, the chain "**loops**."

Collisions prevent us from enumerating the **entire space**!

# Collisions from reducers



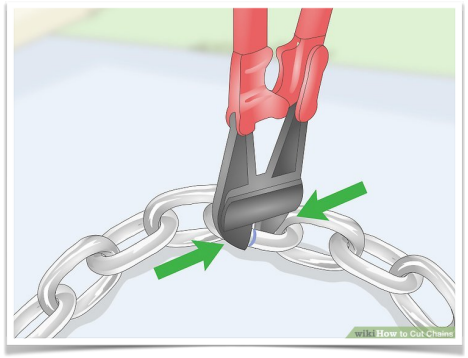



**Reducers** can produce collisions too!

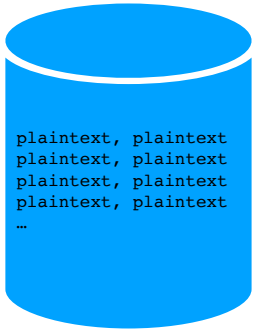
This is what we mean by an **imperfect reducer**.

# Hash chain of length k

We are going to chop up our long chain into **smaller chains** of length **k**.



# Precomputed hash chain




Ahead of time:

```
while i < NUM_PT:
    // gen ith possible plaintext
    p = genPassword(i)
    start = p
    for j from 0 to k-1:
      // create ciphertext
      c = hash(p)
      // reduce
      p = reduce(c)
    // save chain in table
    table[p] = start
    i++
```

# Suppose you are given $c_4$

| end, start |
|---|
| $p_{m-3}$ , $p_m$ |
| … |
| $p_3$ , $p_5$ |
| $p_1$ , $p_3$ |

$c_4$ —reduce→ $p_3$

Is $p_3$ an **end point**? **yes**

**Hash** and **reduce** from **start point**.

password! original ciphertext

$p_5$ —hash→ $c_5$ —reduce→ $p_4$ —hash→ $c_4$

# Hash chain lookup pseudocode

chain table

ciphertext

chain length

```
def lookup(c, db, len):
  // look for endpoint
  p = reduce(c)
  i = 0
  while p not end in db && i < len:
    c2 = hash(p)
    p = reduce(c2)
    i++
  if p not end: FAIL
  // we found chain; lookup start pt
  s = db[p]
  c2 = hash(s)
  // decrypt
  i = 0
  while c2 != c && i < len:
    s = reduce(c2)
    c2 = hash(s)
    i++
  if i == len: FAIL
  return s
```

| end,start |
|---|
| ♥♥★♥, ♥♥♥♥ |
| ♥★★★, ♥♥♥★ |
| ★♥★★, ★★♥★ |
| ★★★★, ♥★♥★ |

chain table

Stores **plaintexts**!

# Class Activity

Decrypt the hash

**7F975A56C761DB6506ECA0B37CE6EC87**

Answer:

★♥★★

## Question

Can a precomputed hash chain **decrypt all hashes**?

## Recap & Next Class

### Today we learned:

PCHC algorithm

### Next class:

Rainbow algorithm