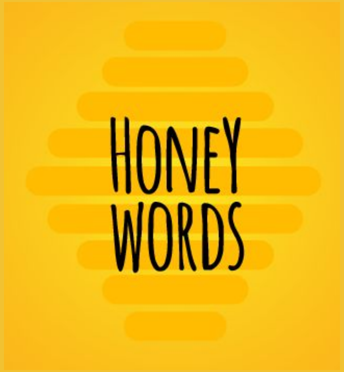
Honeywords:
Making Password-Cracking Detectable

Ari Juels
RSA Laboratories
Cambridge, MA, USA
ari.juels@rsa.com



Ronald L. Rivest
MIT CSAIL
Cambridge, MA, USA
rivest@mit.edu

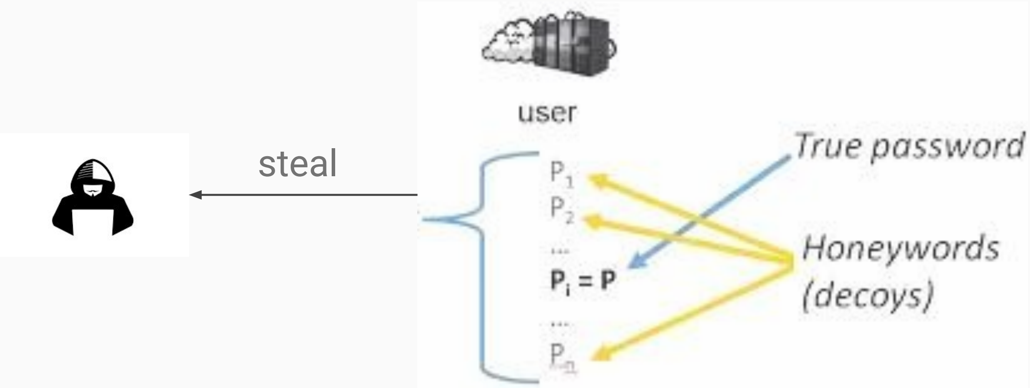
ΠΑΝΕΠΙΣΤΗΜΙΟ ΚΡΗΤΗΣ
UNIVERSITY OF CRETE

CS-558
INTERNET SYSTEMS AND TECHNOLOGIES
(SS 2021)

ABSTRACT

Honeywords

- Simple method
- Improving security of hashed passwords



steal

Password or Honeyword?

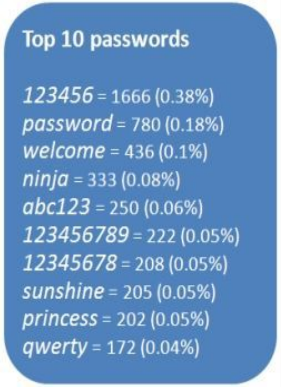
Use of honeyword →

INTRODUCTION

Passwords are weak

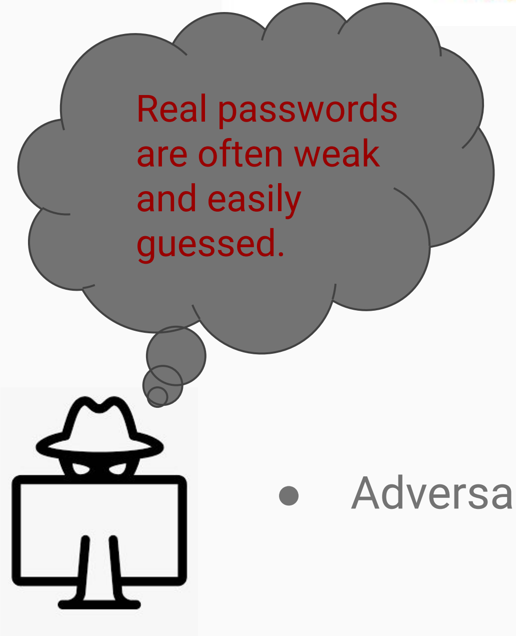
- Users frequently choose poor passwords

password
letmein
link
baseball
sunshine
job
mustang
123456
111111
1234
angel
iloveyou
welcome
123123
princess
trustno1
work
jesus
12345678
ashley
dragon
shadow
monkey
abc123
ninja
22222222
football
qwerty



Top 10 passwords

123456	= 1666 (0.38%)
password	= 780 (0.18%)
welcome	= 436 (0.1%)
ninja	= 333 (0.08%)
abc123	= 250 (0.06%)
123456789	= 222 (0.05%)
12345678	= 208 (0.05%)
sunshine	= 205 (0.05%)
princess	= 202 (0.05%)
qwerty	= 172 (0.04%)



Real passwords are often weak and easily guessed.

- Adversary applies brute-force attack

How about an example?

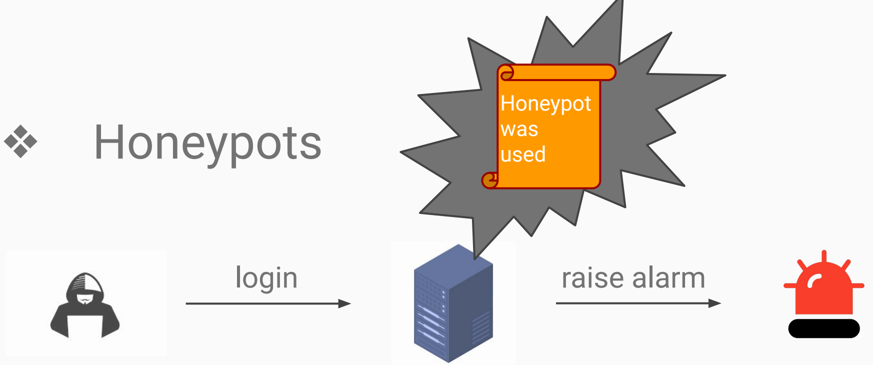
- **October 2013**
  - Adobe lost 130 million passwords
- **March 2013**
  - Evernote lost 50 million passwords
- **July 2012**
  - Yahoo lost 130 million passwords
- **June 2012**
  - Linkedin lost 130 million passwords

Can we tighten security?

- Make password hashing more complex and time-consuming
  - Improve password security
  - Slow down legitimate user’s authentication
  - Doesn’t make successful password cracking easier to detect

Fake user accounts

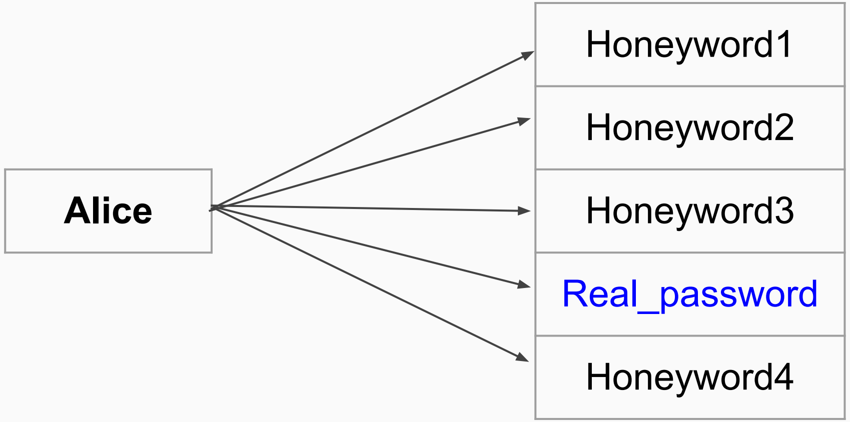
- Honeypots



- ➢ Help to password cracking detection ✓
- ➢ Adversary can distinguish fake accounts
  - ■ Usernames
  - ■ Account's activity

Paper's approach

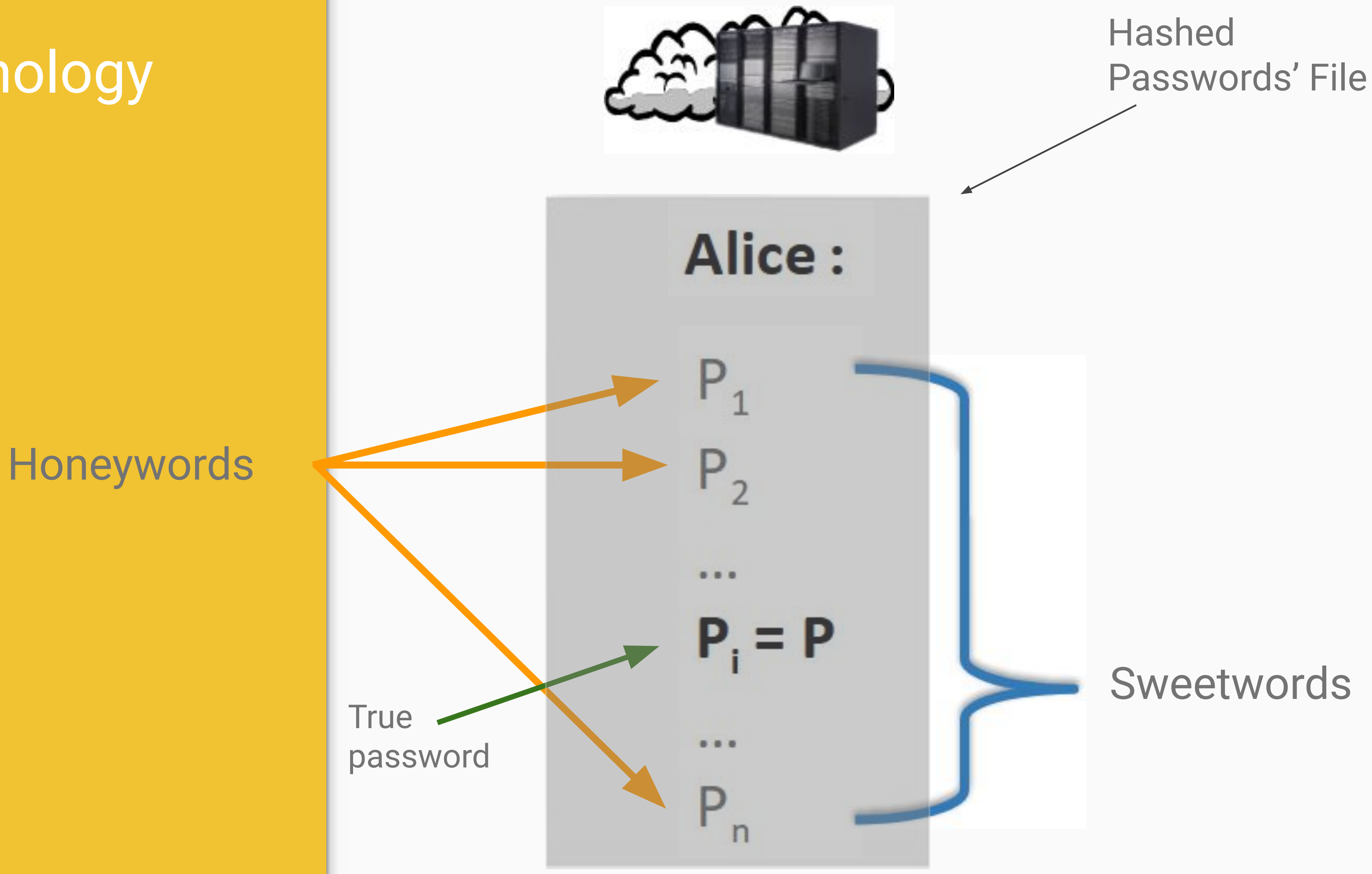
- Extending previous idea for all users
  - Multiple possible passwords per user
  - Set off an alarm if a honeyword is triggered



- ➢ Makes password cracking detection easier
- ➢ Effective and easy to implement
- ➢ Useful layer of defense

Terminology

Terminology



Hashed Passwords' File

Alice :

P_1

P_2

...

$P_i = P$

...

P_n

Honeywords

True password

Sweetwords

Attack scenarios

- Stolen files of passwords hashes
    - offline brute-force computation

- Easily guessable passwords
    - poorly or common passwords

- Visible passwords
- Same password for many systems

- Passwords stolen from users
    - phishing
- Password change compromised

➔ We focus on the first attack scenario

- ◆ Adversary has file of usernames and associated hashed passwords

Honeychecker

Honeychecker

What is it?

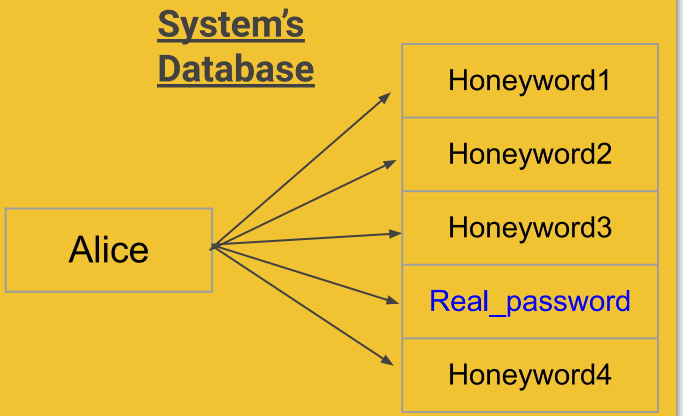
- An auxiliary secure server

- Communication is over dedicated lines and/or encrypted and authenticated

- Capable of taking an action

Honeychecker

Database



- Maintain a single database value for each user

Users-Real password pairs

Table C

Alice	**4**
Bob	3
Jax	1
Tommy	1

Honeychecker

API

Secure Channel

➔ Set(i,j): Sets c(i) to have value j → c(i) = j

Set(2,4) **User-password table**

Table c

Alice	4
Bob	3
Jax	1
Tommy	1

→

Alice	4
Bob	**4**
Jax	1
Tommy	1

➔ Check(i,j): Checks that c(i) = j.

Check(2,4)

Honeychecker

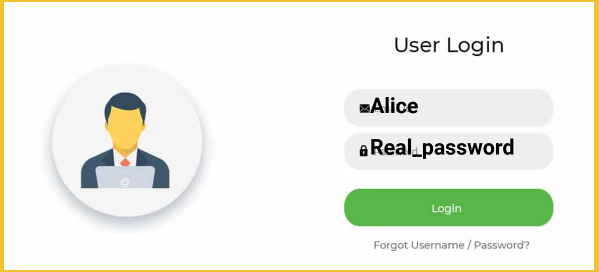
Design principles

- Extremely simple

- Minimal amount of secret state
- Little overhead in computation and communication
- The compromisation of the honeychecker at worst only reduces security to the level it was before honeywords and honeychecker was introduced, since it only stores random small integers.

Login

Login

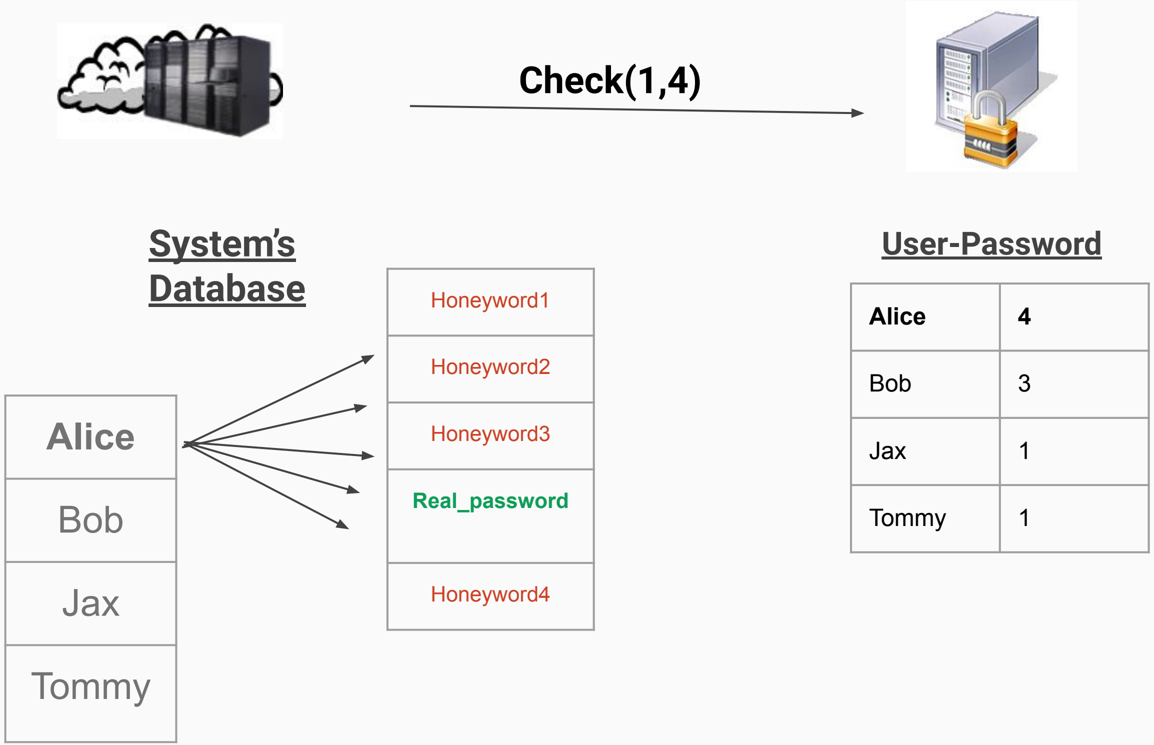


User Login

Alice

Real_password

Every time someone tries to login:



System's Database

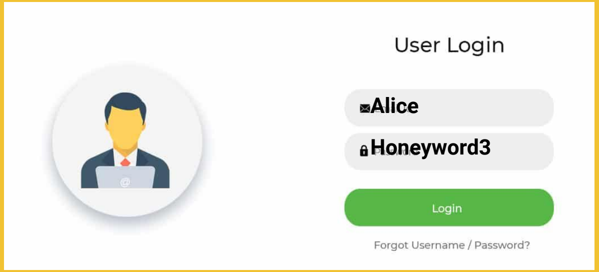
Alice
Bob
Jax
Tommy

Honeyword1
Honeyword2
Honeyword3
Real_password
Honeyword4

User-Password

Alice	**4**
Bob	3
Jax	1
Tommy	1

Login

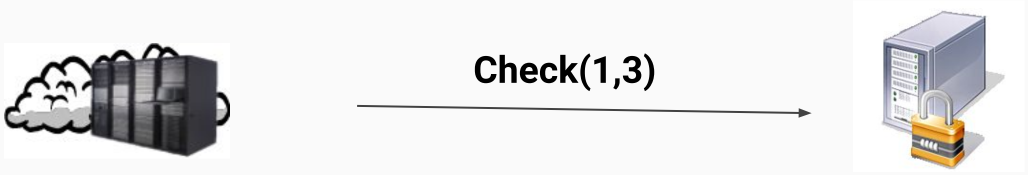


User Login

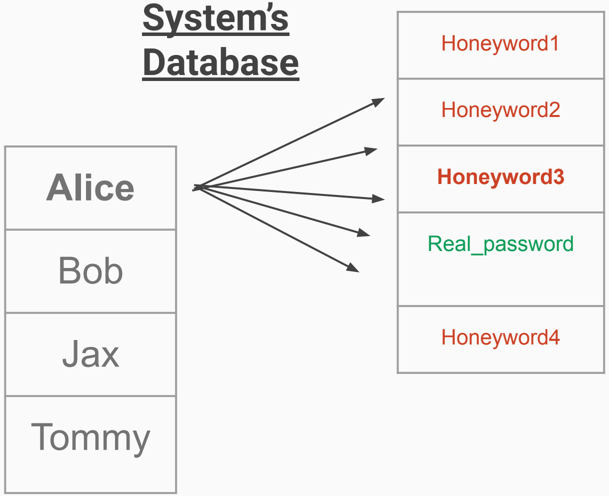
Alice

Honeyword3

Every time someone tries to login:



System's Database



Alice
Bob
Jax
Tommy

Honeyword1
Honeyword2
Honeyword3
Real_password
Honeyword4

User-Password

Alice	**4**
Bob	3
Jax	1
Tommy	1

★ Take an action (determined by policy)

Actions

- Notify administrator
- Let login proceed as usual
- Let login proceed on a honeypot system

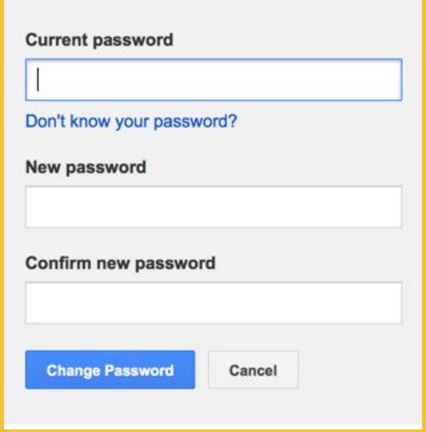
- Trace the source of the login
- Turn on additional logging of the user's activities

- Shut down user's account
- Shut down the whole system

If password is neither the real one nor one of the user's honeywords, login is denied!

Change Password

Change password



Current password

Don't know your password?

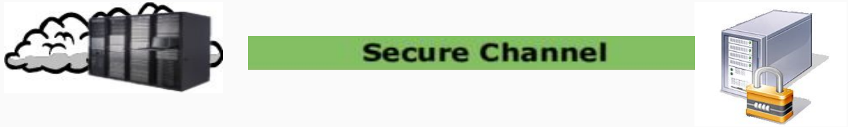
New password

Confirm new password

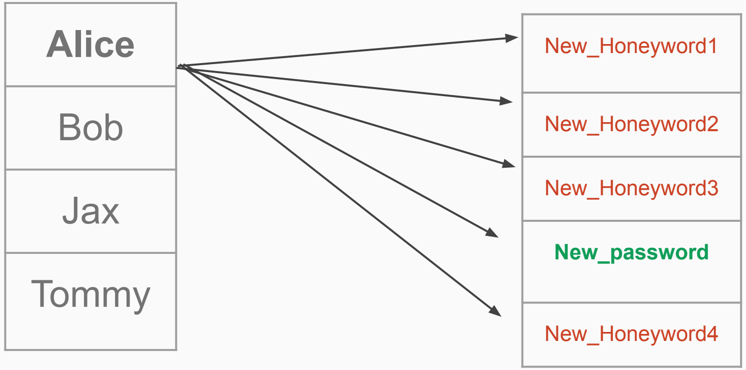
- Create a new list of sweetwords (honeywords + real password)

{ New_honeyword1, New_honeyword2, New_honeyword3,
New_password, New_honeyword4 }

- Securely notify the honeychecker of the new real password's index in sweetwords



- Update the user's entry in system's file



Alice
Bob
Jax
Tommy

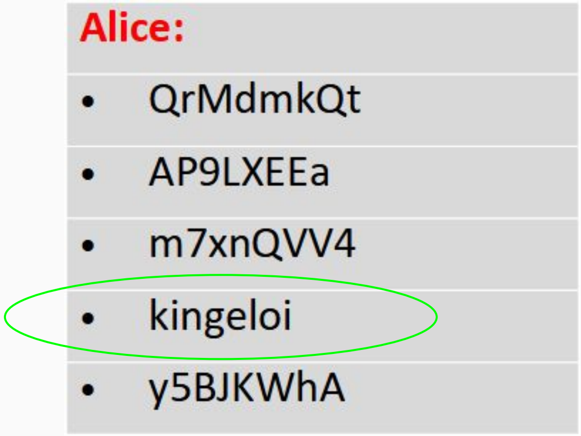
New_Honeyword1
New_Honeyword2
New_Honeyword3
New_password
New_Honeyword4

Honeyword Generation

Honeyword Generation

- User’s password must be indistinguishable from honeywords

Which is Alice’s real password?



Alice:

- QrMdmkQt
- AP9LXEEa
- m7xnQVV4
- [✓ kingeloi]
- y5BJKWhA

- How can we ensure that an adversary will not find the real password?

Approaches

Is there an impact on the user interface(UI)?

- Legacy-UI
  - Password-change UI is unchanged
  - User chooses his password

- Modified-UI
  - Password-change UI is changed for a better honeyword generation
  - User’s new password is modified

Legacy-UI

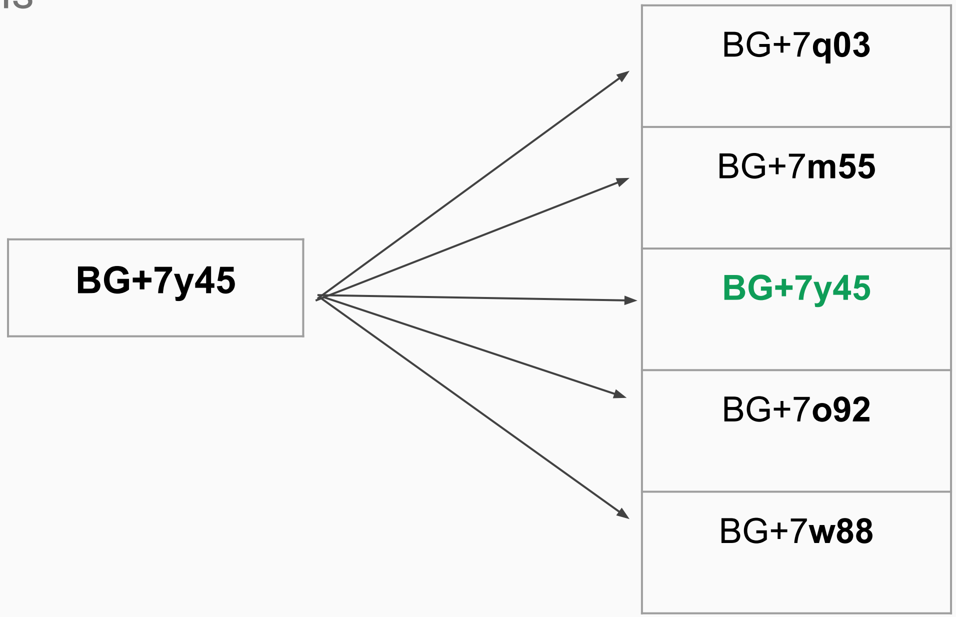
- Chaffing by tweaking
  - Chaffing-by-tail-tweaking
    - “Tweak” last t character positions
  - Chaffing-by-tweaking-digits
    - “Tweak” last t positions including integers
- Chaffing with a password model
  - Honeywords could be real passwords
    - Take from published list
  - Honeywords use password’s syntax

Chaffing-by-tail-tweaking

“Tweak” last t character positions

Let t = 3:

User-supplied password:



BG+7y45

BG+7**q03**

BG+7**m55**

BG+7y45

BG+7**o92**

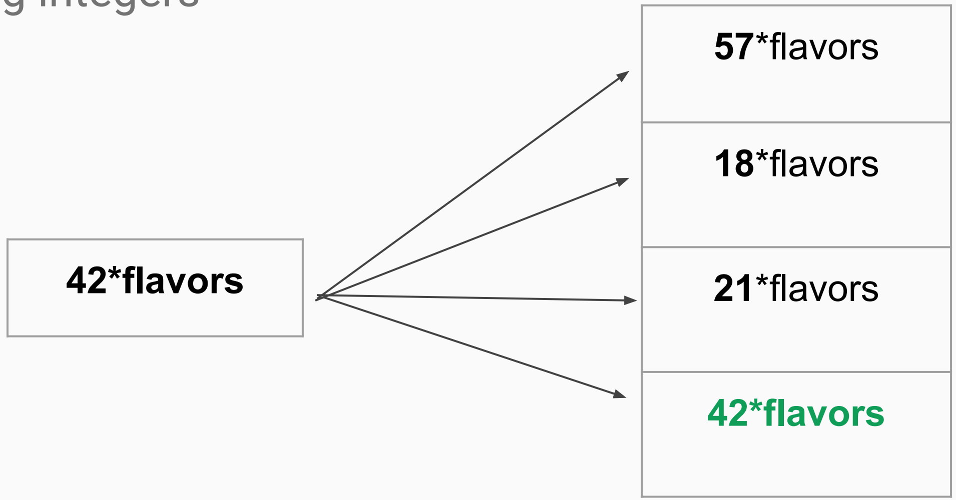
BG+7**w88**

Chaffing-by-tweaking-digits

“Tweak” last t positions including integers

Let t = 2:

User-supplied password:

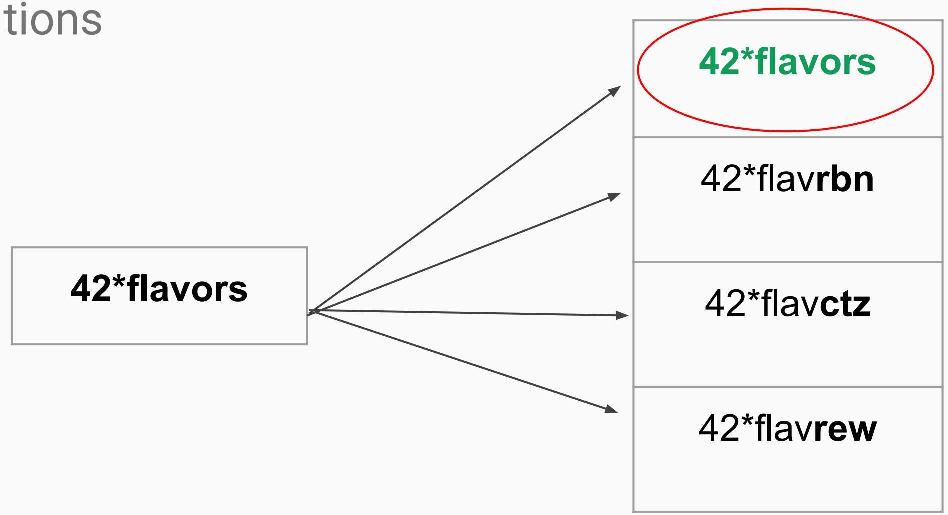


Chaffing-by-tail-tweaking

“Tweak” last t character positions

Let t = 3:

User-supplied password:



42*flavors

42*flavors

42*flav**rbn**

42*flav**ctz**

42*flav**rew**

Tough Nuts

- What is it?
  - ○ Very hard password that the adversary will not be able to crack

```
9,50PEe]KV.0?RIOtc&L-:IJ"b+Wol<*[!NWT/pb
```

➔ Give additional reason to:

- ◆ Pause before diving in
- ◆ Trying to log in with one of the cracked ones

Honeywords could be real passwords

Use a Published List

```
kebrton1            02123dia
a71ger              forlinux
1erapc               sbgo864959
aiwkme523            aj1aob12
9,50PEe]KV.0?RIOtc&L-:IJ"b+Wol<*[!NWT/pb
xyqi3tbato          a3915
#NDYRODD_!!         venlorhan
pizzhemix01         dfdhusZ2
sveniresly           ’Sb123
mobopy               WORFmgthness
```

“Tough Nut”

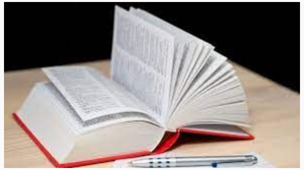
- ➢ List may also be available to the adversary

Honeywords use password’s syntax

User-supplied password

Mice3blind

W4 | D1 | W5



Bold3wings

Gold5rings

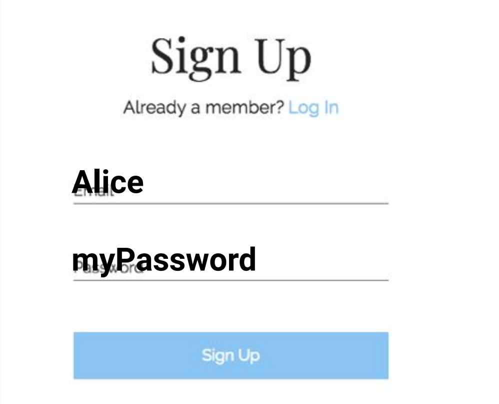
Hall2trick

Goal0leaks

Modified-UI

- Take-a-tail
    - Randomly chosen from the system
    - Required in the user-entered new password
- Passwords randomly chosen by the system

Take-a-tail

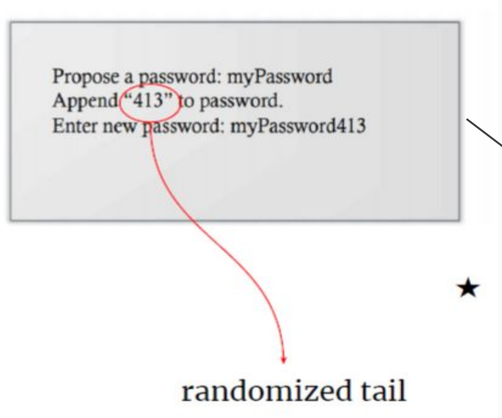


Sign Up

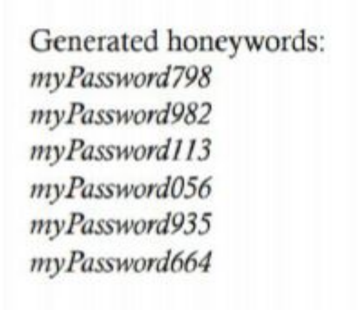
Already a member? Log In

Email: Alice

Password: myPassword



Propose a password: myPassword
Append "413" to password.
Enter new password: myPassword413



Generated honeywords:
myPassword798
myPassword982
myPassword113
myPassword056
myPassword935
myPassword664

VARIATIONS AND EXTENSIONS

‘Random pick’ honeyword generation

Generate a list of k distinct **random** sweetwords

Example k = 6:

4Tniners
sin(pi/2)
all41&14all
\{1,2,3\}
i8apickle
AB12:YZ90

Pick one element at **random** to be the new password (e.g. ’AB12:YZ90’);

The other are the honeywords

Sweetwords can be generated by :

- The user
- An algorithmic password generator

This method is completely **flat, no matter** how we generate the passwords

Which do you think is a better way of generating the sweetwords?

Why?

Typo-safety

Rare for the user to set of an alarm by accident

password == ‘gt79’ and honeywords == [‘gt76’, “gt77’, “gt78’, ...]

tail-tweaking requires the password tail to be **quite different** from the honeywords’ tails!

Honeywords’ tails should be quite different from each other as well.

Typo-safety (example)

Example of using an error-detection code to detect typos

Use an error-detection code to detect typos! How? (example t=3)

Pick a small prime greater than 10: q = 13

tail_2 = 913

3*(9) + 2*(1) + 1*(3) =
= 27 + 2 + 4 = **33**

tail_1 = 413

3*(4) + 2*(1) + 1*(3) =
= 12 + 2 + 3 = **17**

|17 - 33| = 16 The difference between these 2 should be a multiple of q. Here it is not, so… (#sorrynotsorry)

This property:

- is **easy** to arrange between sweetwords
- allows detection of any **single digit substitution** (e.g. 413 and 913)
- allows detection of **transposition of two adjacent digits** (e.g. 413 and 431)

Proof :
err(tail_1) - err(tail_2) = 3*x + 2*y + 1*z - 3*k - 2*y - 1*z = 3*x - 3*k = 3*(x-k) which will never be a prime, no matter the index
err(tail_1) - err(tail_2) = 3*x + 2*y + 1*z - 3*y - 2*x - 1*z = 3x - 2x + 2y - 3y = x - y which will always be < 10, where x, y are single digits

Managing old passwords

Many systems keep old passwords of users stored (usually the last 10)

Prohibiting a user from **reusing** her old passwords

Why do the authors **disagree** with this method?

- Hashes of old passwords should not be stored cause **hashes can be inverted** on weak passwords
- A user has probably changed her passwords just because it was weak, but she may be **using on other systems**

HER ACCOUNT ON OTHER SYSTEMS IS AT RISK !

Managing old passwords: authors’ suggestions

Record previously used password across the full user population

- A newly created password should **not conflict** with any of the passwords in the list (of previously used passwords)
- This list could be stored as a Bloom filter (not the hashed passwords themselves) for more efficiency

However..., if it required to store the old passwords

- In a protected module **separated** from the main system (**distributed security**), or …
- Store them in the main system for legacy compatibility but,
  - encrypted
  - keys for encryption/decryption stored in the honeychecker

Storage optimization

Reduce storage of honeyword generation methods

Password = '32flavors' then T(password) =

00flavors
01flavors
02flavors
…
99flavors

- Save a **random** on the computer system (e.g. H(45flavors))
- Save the index of the real password to the honeychecker (e.g. C(i) = 33, index of '32flavors')

Example: Adversary or user submits a guess 'g' to the system for logging in (e.g. 67flavors)

- **Produce T(g)** (e.g. T(g) will be equal to T(password))
- if H(45flavors) in T(g) then find the **index** of g in T(g)
- if index == 45 'ALARM'
  else if index == 33 'allow login'
  else 'deny login'

Hybrid generation methods

Combine the **benefits** of different honeyword generation methods

chaffing-by-tweaking-digits with **chaffing-with-a-password-model**

Password provide by user ‘abacad513’

chaffing-with-a-password-model

abacad513 => $W_5 \mid D_3D$

produce

abacad513	snurfle672	zinja750

chaffing-by-tweaking-digits

abacad513	snurfle672	zinja750
abacad941	snurfle806	zinja802
abacad004	snurfle772	zinja116
abacad752	snurfle091	zinja649

POLICY CHOICES

Password Eligibility

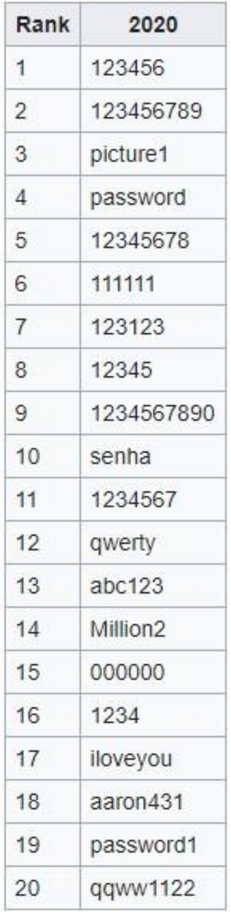
Some words may be **ineligible as passwords.**

Which passwords should **not** be used!

1. Password syntax
   a. **minimum length** (**‘Hi’** can’t be a password)
   b. **minimum number of digits** (e.g. ’myname41’ - for honeywords to be produced ’myname42’, ...)
   c. **minimum number of special characters**
2. Dictionary words (‘giraffe’, ’floWer’, etc.)
3. Most common passwords

#funfacts
The 20 most common passwords made up more than 10% of the surveyed passwords

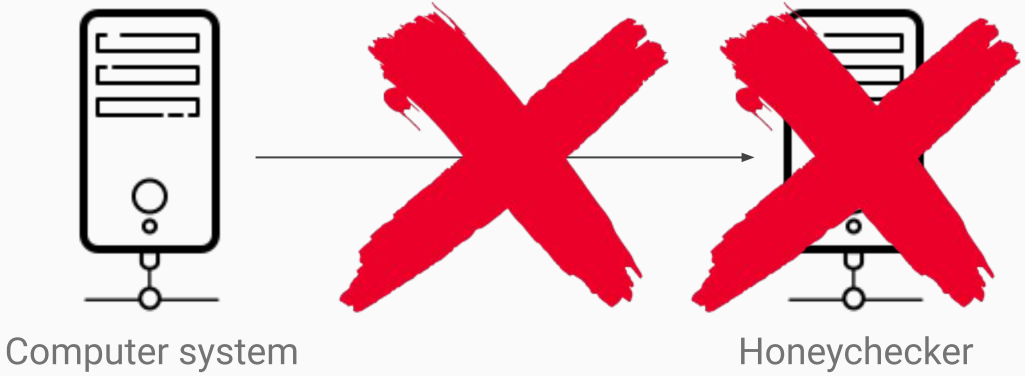
The most common password "123456", makes up **4**%



Rank	2020
1	123456
2	123456789
3	picture1
4	password
5	12345678
6	111111
7	123123
8	12345
9	1234567890
10	senha
11	1234567
12	qwerty
13	abc123
14	Million2
15	000000
16	1234
17	iloveyou
18	aaron431
19	password1
20	qqww1122

Top 20 most common passwords according to NordPass

Failover



Logins should **proceed** even if the honeychecker has failed

Buffer messages on the computer system for later delivery to the honeychecker

Per-user and Per-sweetword Policies

Policies that vary **per-user**

Per-user policies

- **Honeypot accounts:** known only to the honeychecker
- **Selective alarms**: raise an alarm for sensitive accounts (administrator accounts)

Per-sweetword policies

- Hits on honeywords with **small edit distance** to the password should invoke a **less severe** reaction
  - To prevent user-typos
- Examples of such actions:
  - “Raise silent alarm,”
  - “Allow login,”
  - “Allow for single login only,” etc...

ATTACKS

General password guessing

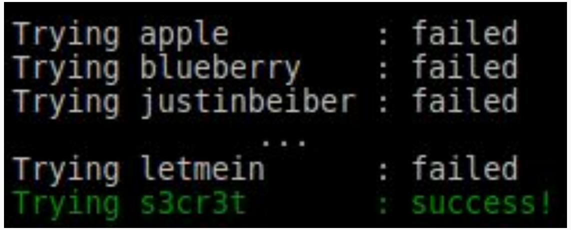
Do **not use common** passwords

Take-a-tail method can reduce the probability of guessing the password by a factor of 1000

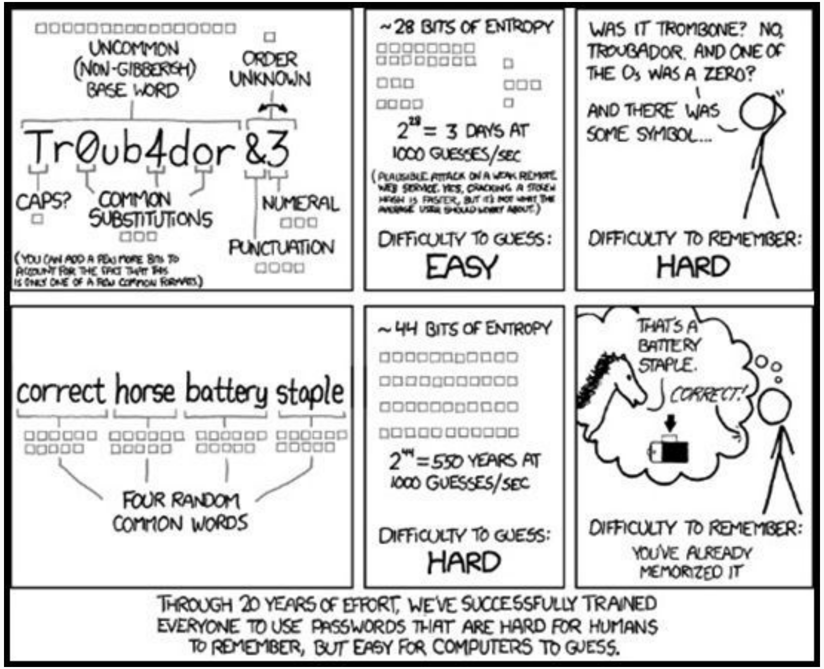
Example:
password = applethief

take-a-tail with t = 3
password = applethief355

- hard to remember
- can be brute forced in ms if you find ‘applethief’ in a dictionary



```
Trying apple        : failed
Trying blueberry    : failed
Trying justinbeiber : failed
              ...
Trying letmein      : failed
Trying s3cr3t       : success!
```

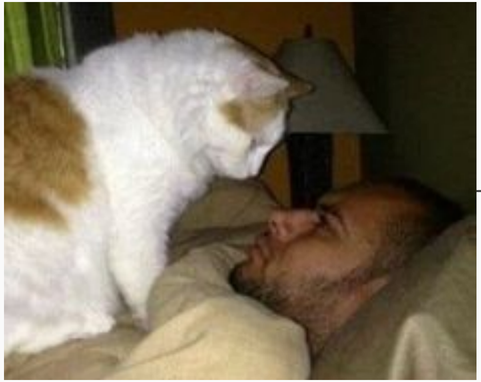


UNCOMMON (NON-GIBBERISH) BASE WORD
ORDER UNKNOWN
Tr0ub4dor &3
CAPS?
COMMON SUBSTITUTIONS
NUMERAL
PUNCTUATION
(YOU CAN ADD A FEW MORE BITS TO ACCOUNT FOR THE FACT THAT THIS IS ONLY ONE OF A FEW COMMON FORMATS.)
~28 BITS OF ENTROPY
2^28 = 3 DAYS AT 1000 GUESSES/SEC
(PLAUSIBLE ATTACK ON A WEAK REMOTE WEB SERVICE. YES, CRACKING A STOLEN HASH IS FASTER, BUT IT'S NOT WHAT THE AVERAGE USER SHOULD WORRY ABOUT.)
DIFFICULTY TO GUESS: EASY
WAS IT TROMBONE? NO, TROUBADOR. AND ONE OF THE Os WAS A ZERO?
AND THERE WAS SOME SYMBOL...
DIFFICULTY TO REMEMBER: HARD
correct horse battery staple
FOUR RANDOM COMMON WORDS
~44 BITS OF ENTROPY
2^44 = 550 YEARS AT 1000 GUESSES/SEC
DIFFICULTY TO GUESS: HARD
THAT'S A BATTERY STAPLE.
CORRECT!
DIFFICULTY TO REMEMBER: YOU'VE ALREADY MEMORIZED IT
THROUGH 20 YEARS OF EFFORT, WE'VE SUCCESSFULLY TRAINED EVERYONE TO USE PASSWORDS THAT ARE HARD FOR HUMANS TO REMEMBER, BUT EASY FOR COMPUTERS TO GUESS.

Targeted password guessing

Personal information **help** an adversary distinguish the password from the honeywords

Guess above user's password from the list

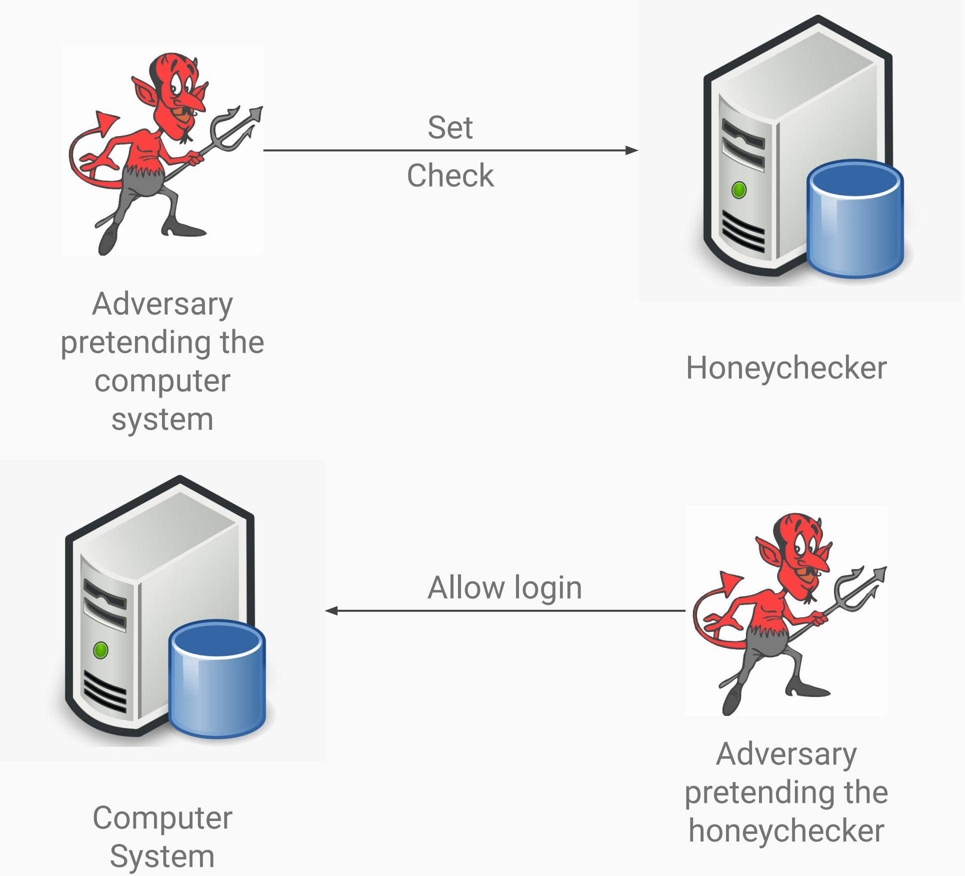


- lovemycat45
- lovemydog24
- hatemyhamster87
- ilikebeers64
- stanley49

How can an adversary find personal information about the user?

Attacking the honeychecker

An adversary may decide to **attack** the **honeychecker** or its **communications**



Set

Check

Adversary pretending the computer system

Honeychecker

Allow login

Computer System

Adversary pretending the honeychecker

Requests to the and replies from the honeychecker should always be **authenticated**!

Likelihood attack

Maximize the chance of picking a password from a sweetword list

Having stolen file F calculate the probability of each sweetword being a honeyword or a password

The probability that sweetword x is a password:

$$R(x) = U(x) / G(x)$$

U(x) user picked
G(x) algorithm generated

Example: ‘NewtonSaid:F=ma’
obvious structure to a human
not very obvious to an automatic generator

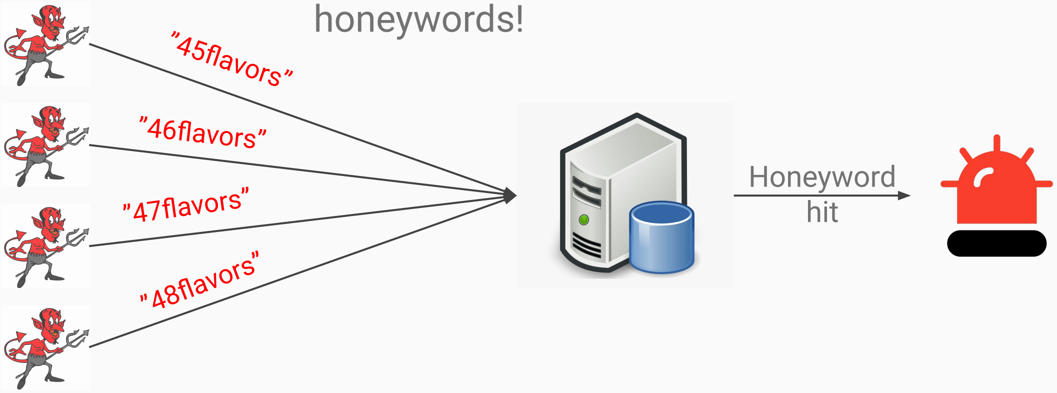
Denial-of-service

Denial-of-service attacks caused by **chaffing-by tweaking**

Methods such as chaffing-by-tweaking e.g.
45flavors
46flavors
47flavors
etc.

Give the **opportunity** to an adversary that knows a user's password to perform a **DoS attack**!

Easy to guess honeywords!



Adversary can **guess** passwords **simulating** a DoS attack

Global password reset!

Inadequately sensitive
Overly sensitive

Multiple systems

Attack **multiple** systems against users that **use** the **same** password

Intersection attack

Organisations A file F	Organisations B file F
cat93	cat93
cat54	cat74
cat22	cat28
cat42	cat62

Their intersection == 'cat93'
That's user's password!

Suggestion: take-a-tail

cat93	cat15
cat54	cat74
cat22	cat28
cat42	cat62

Same head but **different tail**!

Sweetword-submission attack

Even if the adversary only has organisations A file F

cat93
cat54
cat22
cat42

submit → Organisations B

No honeywords hit →

RELATED WORK

RELATED WORK

Password strength

- basic8 -> 1 billion guesses 40.3% cracked
- MD5 -> 3 billion guesses/sec on GPUs
- The majority of passwords has around **20 bits of entropy** against optimal attacker
  - 1 million guesses on average are enough
  - based on 70 million Yahoo! users
- **Bonneau and Preibusch** advice on :
  - password management
  - account lockout policies
  - update and recovery

Password strengthening

- **take-a-tail** -> password strengthening
- **System generates** random characters until user obtains a memorable password
- e.g. **user's suggestion** = 'ilovecats'
- **system-generated** passwords:
  - 'ilovecats523'
  - 'ilovecats847'
  - 'ilovecats196'

pick one!

Related Work

Password storage and verification

- **Splitting** password related secrets
    - distributed cryptography
- Preferable to honeywords
    - **require** big system and client **changes**
- **Honeywords** are a **stepping stone** to such approaches

Decoys

- Use of decoy resources is an old practice to detect security breaches!
- honeypots
- ”Honeytokens” bogus credentials e.g.
    - fake credit card numbers
- Fabricated/decoy files

Conclusion

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- Someone who has stolen a password file can **brute-force** to search for **passwords**
- By using **honeywords** adversary does not have the confidence that he can login without being **detected**.
- Despite their benefits over common methods honeywords **aren't a wholly satisfactory approach** to user authentications.
- **Simple**-to-deploy and a powerful new line of defense

References

https://en.wikipedia.org/wiki/Bloom_filter

https://en.wikipedia.org/wiki/List_of_the_most_common_passwords

https://www.ece.unb.ca/tervo/ece4253/isbn.shtml

ΠΑΝΕΠΙΣΤΗΜΙΟ ΚΡΗΤΗΣ
UNIVERSITY OF CRETE

Andreas Theofanous csd3768@csd.uoc.gr
Emmanouil Sylligardos csd3849@csd.uoc.gr

Contact

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