Passwords | Time-memory trade-offs

INGI2347: COMPUTER SYSTEM SECURITY (Spring 2014)

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Lecture slides adapted from UCL INGI2347 by Gildas Avoine
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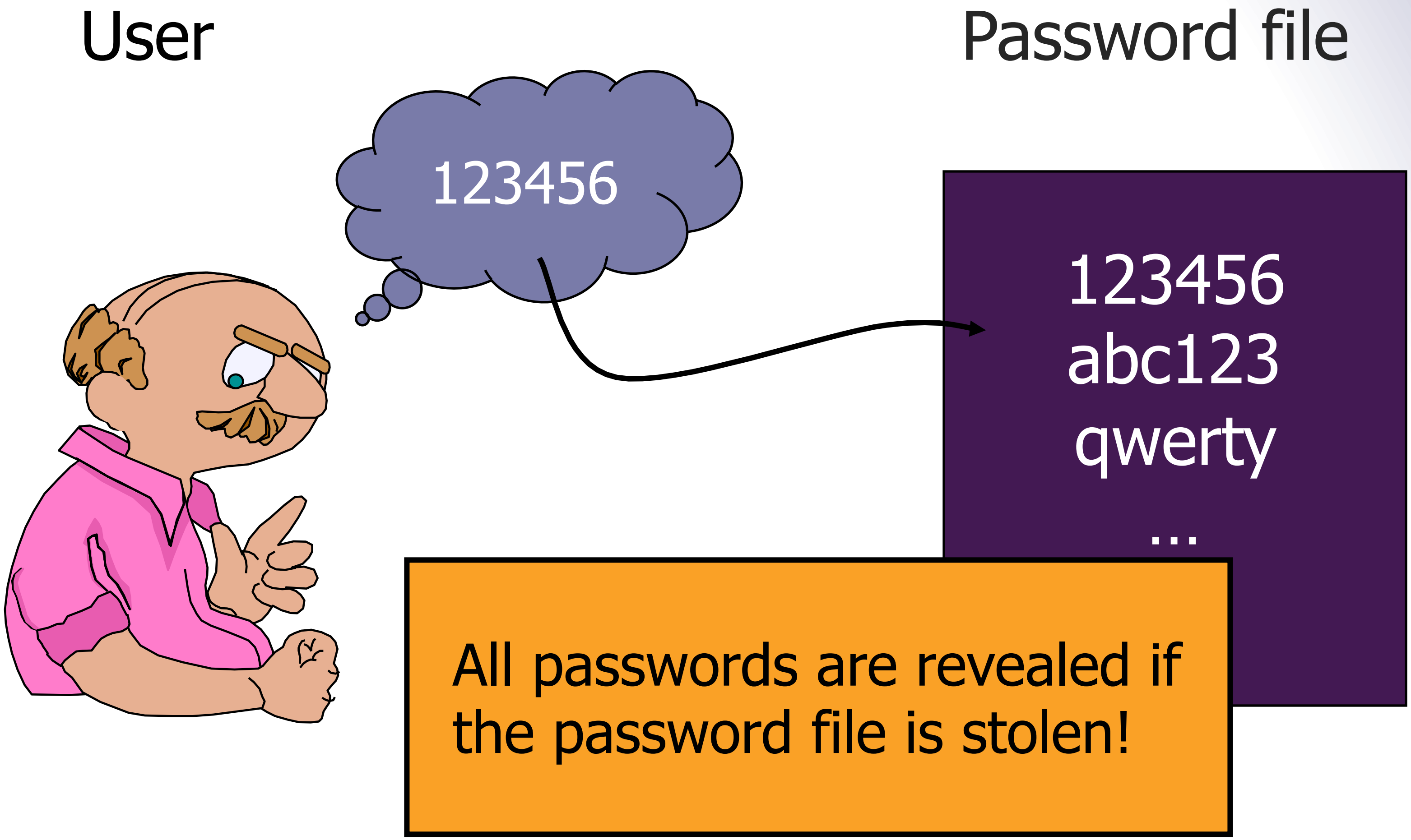
Plan for today

Lecture 11

- Passwords ← NEXT
  - Vulnerabilities
  - Online Attacks
  - Offline Attacks
  - Weak Passwords
  - Unix/Windows Cases
  - Strong Passwords and Good Practices
- Time-memory trade-offs

Naïve Idea



User

Password file

123456

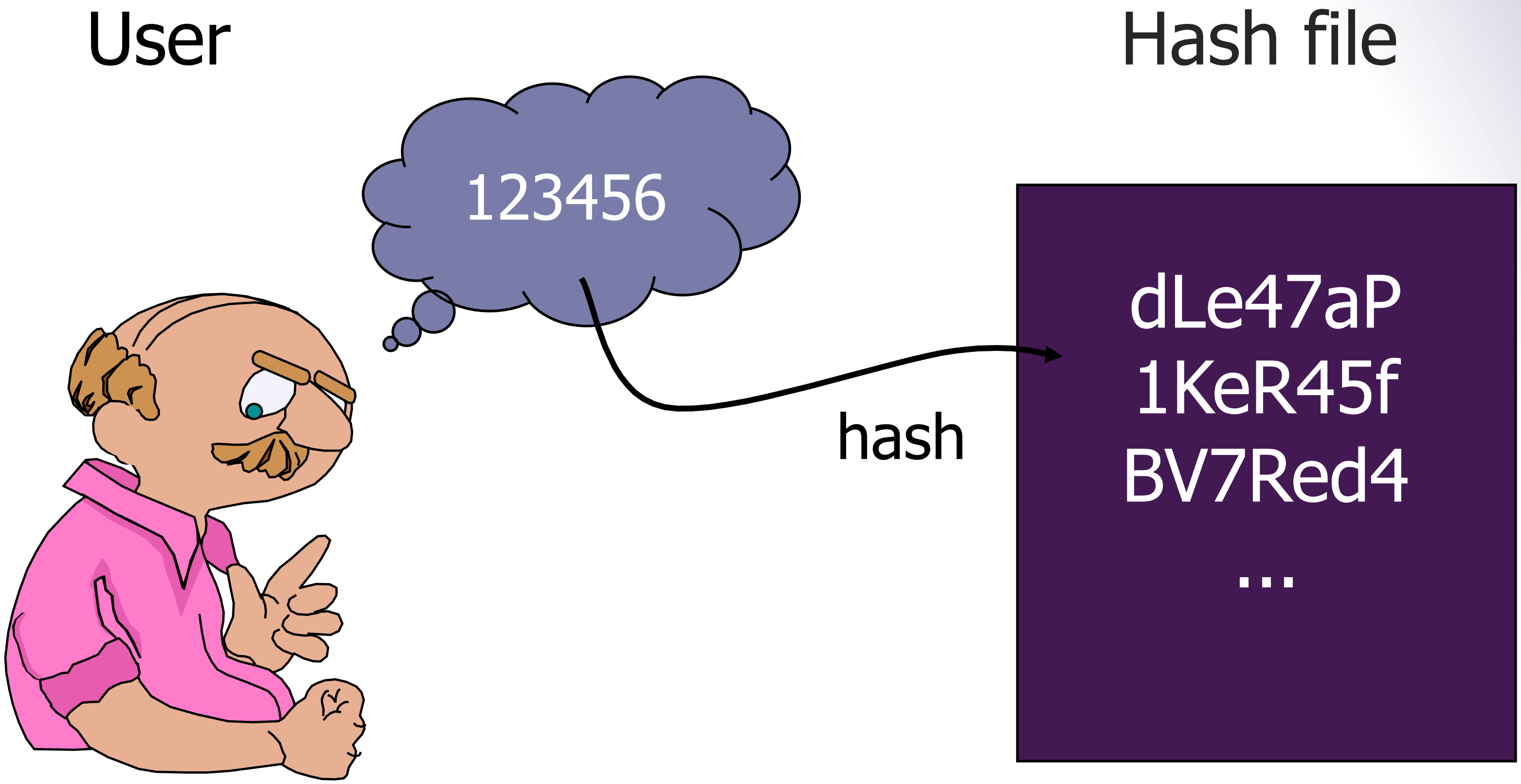
123456
abc123
qwerty
…

All passwords are revealed if the password file is stolen!

Password Storage

- Passwords must never stored as plaintext!
- Instead of passwords, store a hash
- The hash must be irreversible
- When logging in, the hashed password is compared with the stored hash

Implemented Idea



User

123456

hash

Hash file

dLe47aP
1KeR45f
BV7Red4
...

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Vulnerabilities

Some Vulnerabilities

- Written down passwords
- Shoulder surfing
- Social engineering
- Key logger, Rootkit
- Eavesdropping the network
- Multi-website passwords
- Audit trails
- Guessing the password (low entropy)

Written Down Passwords

According to a 2002 security survey:

- Probability of finding written passwords near a computer subjected to periodic password changes varied from 16% to 39%
- Probability varied from 4% to 9% when the administrator did not enforce periodic password changes

Shoulder Surfing

- Password keystroke observed
  - E.g. camera above an ATM
- Graduate students at the University of Maryland Baltimore County shown that:
  - Non-dictionary passwords are more vulnerable to shoulder surfing than passwords belonging to a dictionary
- Some keys are more easily observable

Social Engineering

- Abuse the users

Survey at AArhus University:

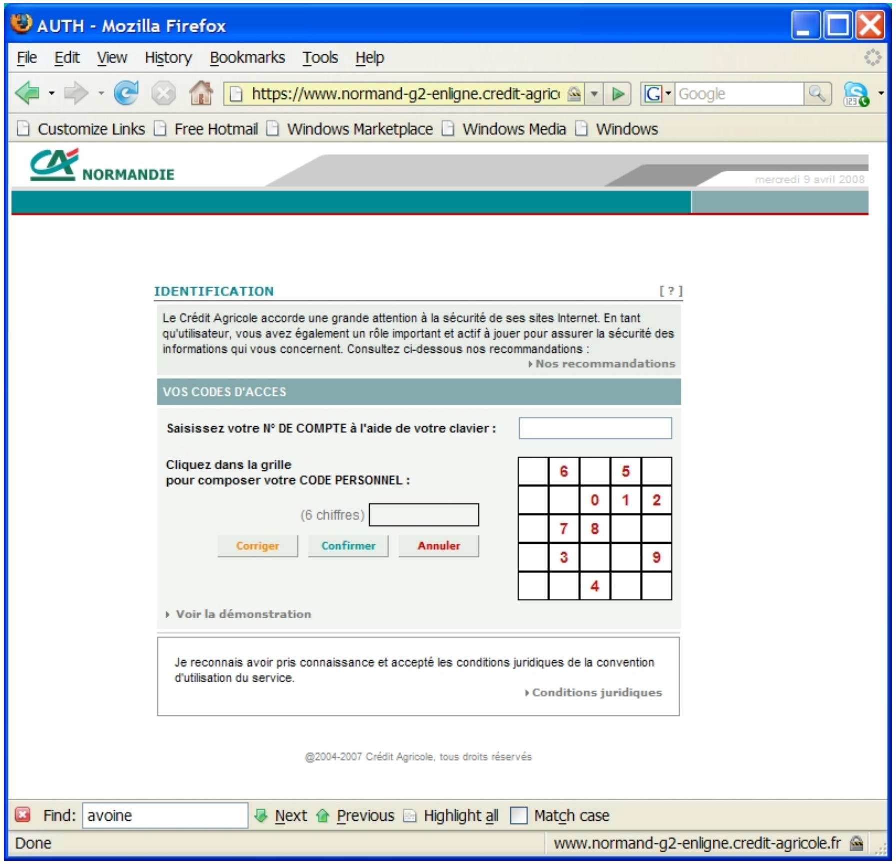
- 336 students were asked by mail to send back their passwords to validate the password database
- 138 revealed their passwords
- A few changed their passwords, but no one reported to the system administrator

Key Logger, Rootkit

- Software or Hardware
- Program that runs in the background, recording all the keystrokes.
- Device between the keyboard and the computer
  - It has a microcontroller and a non-volatile memory
  - Microcontroller interprets the keystrokes as they are typed and stores them in the memory
- Software example: ActualSpy

Key Logger, Rootkit

- Solution: On-screen keyboard, password typed in different order using the mouse



IDENTIFICATION [?]

Le Crédit Agricole accorde une grande attention à la sécurité de ses sites Internet. En tant qu'utilisateur, vous avez également un rôle important et actif à jouer pour assurer la sécurité des informations qui vous concernent. Consultez ci-dessous nos recommandations :

Nos recommandations

VOS CODES D'ACCES

Saisissez votre N° DE COMPTE à l'aide de votre clavier :

Cliquez dans la grille
pour composer votre CODE PERSONNEL :

(6 chiffres)

Corriger Confirmer Annuler

	6		5	
		0	1	2
	7	8		
	3			9
		4		

Voir la démonstration

Je reconnais avoir pris connaissance et accepté les conditions juridiques de la convention d'utilisation du service.

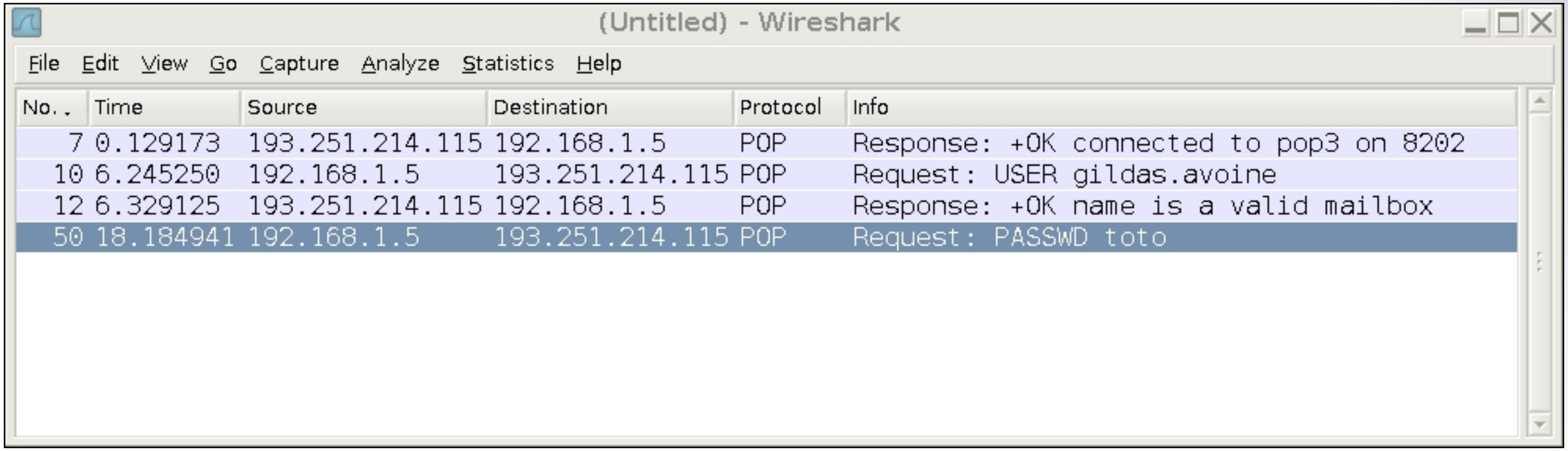
Conditions juridiques

@2004-2007 Crédit Agricole, tous droits réservés

Find: avoine ☐ Match case

Eavesdropping the network

- Passwords sent in the clear through the network: POP, FTP



```
No. .  Time       Source           Destination      Protocol  Info
   7  0.129173   193.251.214.115  192.168.1.5      POP       Response: +OK connected to pop3 on 8202
  10  6.245250   192.168.1.5      193.251.214.115  POP       Request: USER gildas.avoine
  12  6.329125   193.251.214.115  192.168.1.5      POP       Response: +OK name is a valid mailbox
  50  18.184941  192.168.1.5      193.251.214.115  POP       Request: PASSWD toto
```

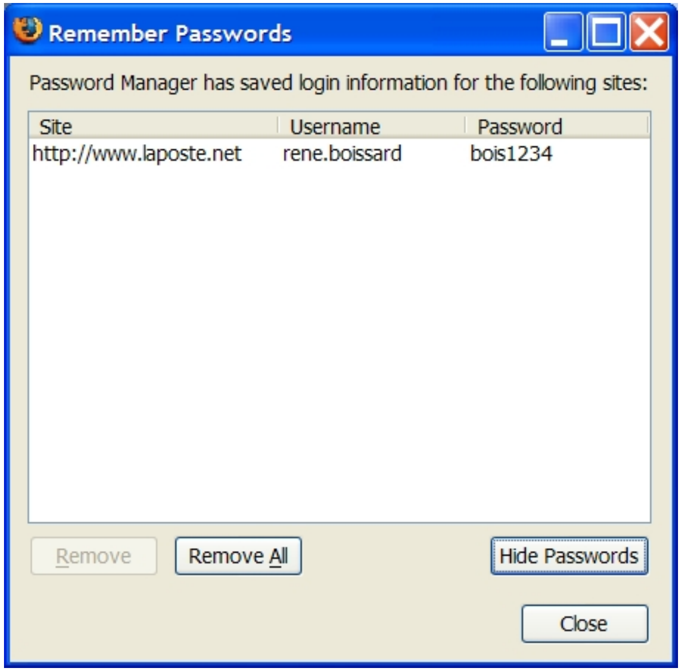
A POP session sniffed with Wireshark

Multi-Website Passwords

- Passwords should never be used for different purposes
  - Never use the same password for both Windows and Unix
  - Never use a password received by email for secure applications
- A common practice is to use different security level passwords
  - Good different passwords for Windows accounts, Unix accounts, main mailbox
  - A few weaker passwords (easier to remember) for less secure applications, like online registration with pseudo

Audit Trails

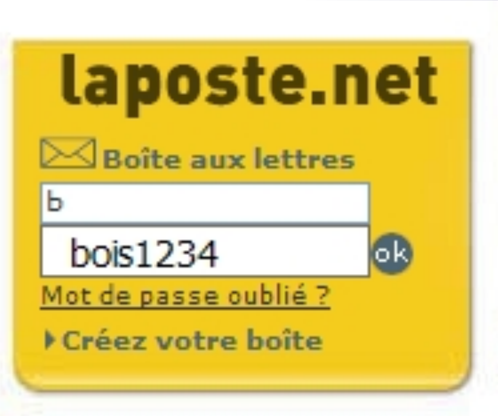
- Audit Trails can reveal the user name of the users
  - Password managers (be careful on public computers)
  - People enter passwords in the field of user name
  - Passwords in emails



Remember Passwords

Password Manager has saved login information for the following sites:

Site	Username	Password
http://www.laposte.net	rene.boissard	bois1234



laposte.net

Boîte aux lettres

b

bois1234

Guessing some Password(s)

- Targeted attack on one account
- Attempt to penetrate any account on a system

Guessing a (the) Password(s)

- Online Attack
  - The system is used as an oracle (black box)
  - Slow
- Offline Attack
  - The attacker steals the hash file
  - The attacker recovers the passwords offline
  - The algorithm must be known
- Target
  - A given account
  - Any account on the system

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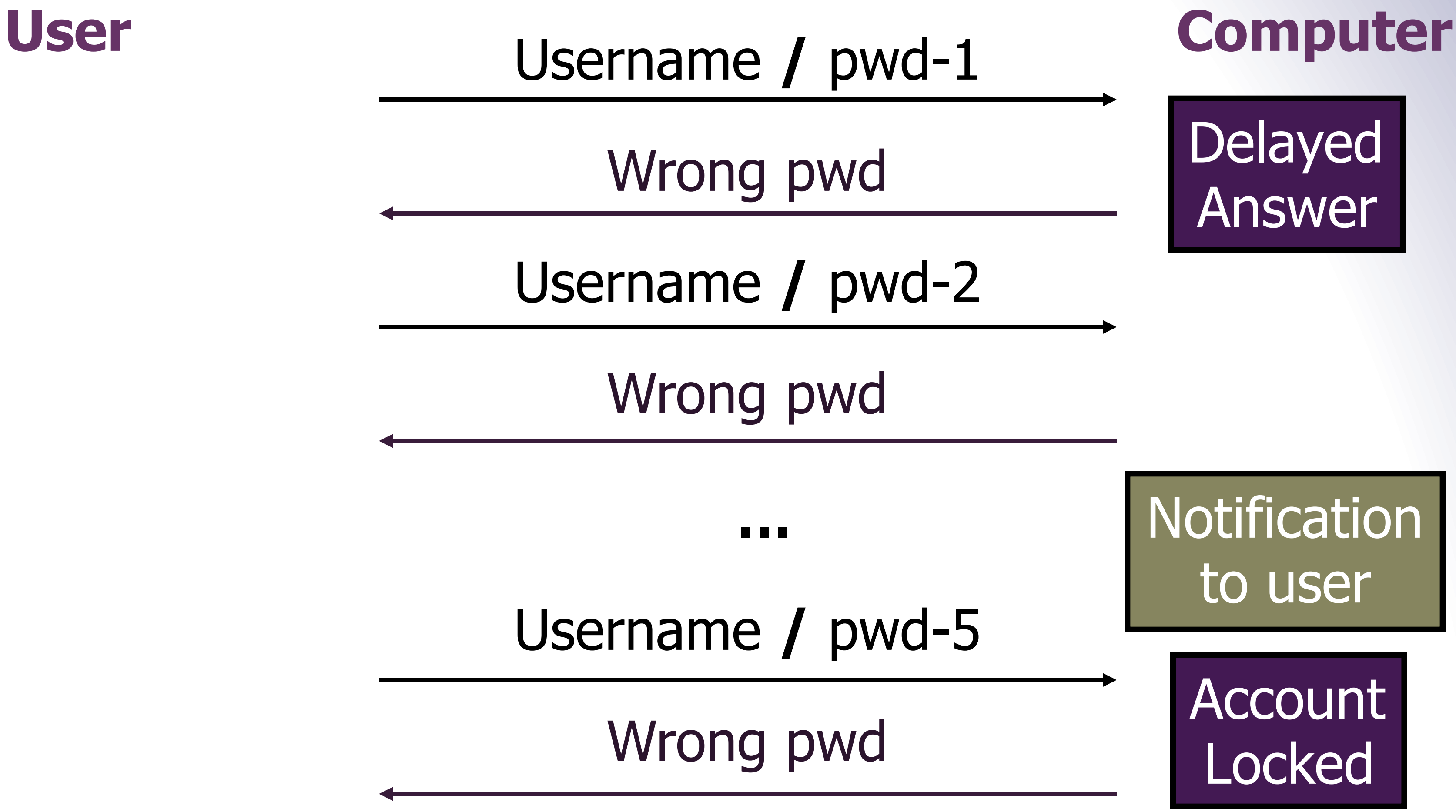
Online Attacks

Countermeasures



User

Computer

Username / pwd-1

Wrong pwd

Delayed Answer

Username / pwd-2

Wrong pwd

…

Notification to user

Username / pwd-5

Wrong pwd

Account Locked

Locking Account

Denial of service attacks:

- To lock a user, try to login into his account with random passwords

Customer service costs:

- Users whose accounts are locked call a customer service center

Computing Cost for the User

- Each login attempt must be accompanied by h(username,pwd,r) such that 20 least significant bits are 0
- Negligible overhead for a single request
- Attacks are slowed
- Implementation Issues:
  - Clients must use a special software
  - Legitimate user with a slow machine

Captcha

- Legitimate logins are done by humans while attacks are done by computers
- Captcha: Completely Automated Public Turing Test to tell Computers and Humans Apart
- Login attempts must be accompanied by a computation that is easy for humans and hard for programs

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Offline Attacks

Offline Cracking

- Hash algorithm must be known
- Attacker must obtain a copy of passwords' hashes
- Since she cannot inverse hashes, she must guess the passwords (dictionary) or perform an exhaustive search
- She generates the hashes of those words
- She finally compares the generated hashes with the stolen hashes until finding a match

Dictionary Attacks

- Many people use dictionary words as passwords
  - Average dictionary contains only 150,000 to 200,000 words
  - People’s names, common pet names, and ordinary words
- Hence files containing hashed passwords are susceptible to pre-compiled dictionary attack
  - A file of hashes of all possible dictionary words is generated
- A PC can generate 200,000 to 10,000,000 password hashes per second depending on the type of hash

Heuristic Attack

- Combine dictionary and brute force
- Some rules are applied to the dictionary words according to the most used practices
  - Convert to lowercase, uppercase
  - Capitalize
  - Reverse: “Fred” -> “derF”
  - Duplicate: “Fred” -> “FredFred”
  - Reflect: “Fred” -> “FredderF”
  - Rotate the word left: “jsmith” -> “smithj”
  - Rotate the word right: “smithj” -> “jsmith”
  - Append or prefix character X to the word
  - Prefix the word with character X

Offline Attack Procedure

Progressive cracking:

- Trivial and short passwords
- Dictionary + Heuristics
- Brute force

Cracking Tools:

- Unix/Windows cracking: John the ripper, L0phtCrack
- Windows password cracking: Cain, Ophcrack

Weak Passwords

Weak Passwords

- Based on common dictionary words
- Based on common names
- Based on user/account identifier
- Short (under 7 characters)
- Based on keyboard patterns (e.g., “qwerty”)
- Composed of single symbol type (e.g., characters)
- …

Weak Passwords: Length

Length	Percent
1-4	0.82%
5	1.1%
6	15%
7	23%
8	25%
9	17%
10	13%
11	2.7%
12	0.93%
13-32	0.93%

Source: www.schneier.com

Weak Passwords: Content

numbers only	1.3%
letters only	9.6%
alphanumeric	81%
non-alphanumeric	8.3%

Source: www.schneier.com

Weak Passwords

- Top-used passwords are (in order):

password1, abc123, myspace1, password, blink182, qwerty1, fuckyou, 123abc, baseball1, football1, 123456, soccer, monkey1, liverpool1, princess1, jordan23, slipknot1, superman1, iloveyou1, monkey.

Source: www.schneier.com

- “We used to quip that ‘password’ is the most common password. Now it’s ‘password1’. Who said users haven't learned anything about security?” (Schneier, 2006)
- Passwords are much better today than 15 years ago

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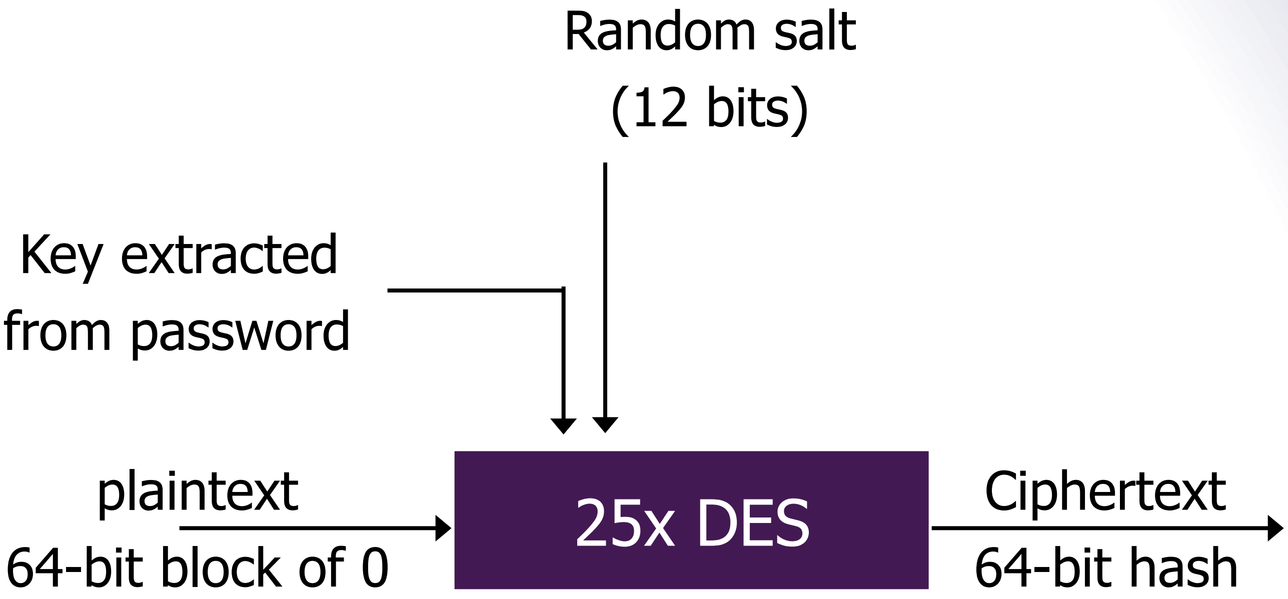
Unix/Windows Cases

Unix Passwords

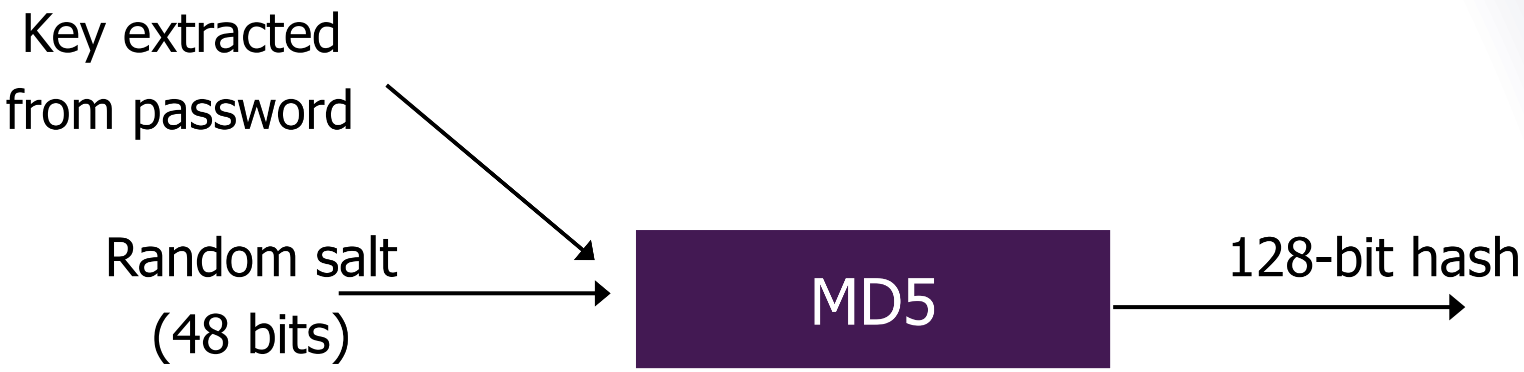
The hash function can be based on:

- DES
- MD5 (Linux, BSD, Sun)
- Blowfish (OpenBSD)
- SHA256
- SHA512

Unix Passwords (DES)



Unix Passwords (MD5)



Key extracted from password

Random salt (48 bits)

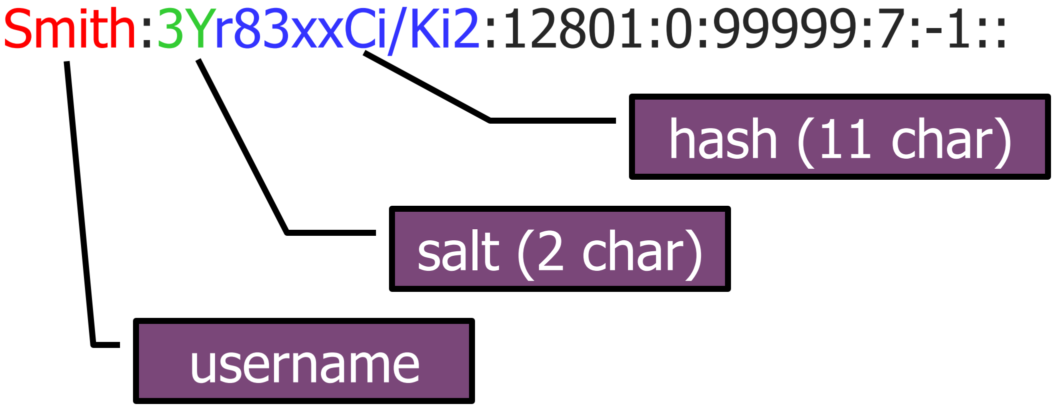
MD5

128-bit hash

Storage Under Unix

- Old method:
  - Name and hashes of passwords in the file /etc/passwd with free read access
- Safer method:
  - The hashes are found in a separate file, /etc/shadow that can be read only by the administrator
  - Why is it safer since the function is one-way?
- Two ways to gain access to the password file:
  - Reboot the machine with a USB key or a CD
  - Obtain administrator privileges using an exploit

/etc/shadow (DES, MD5)

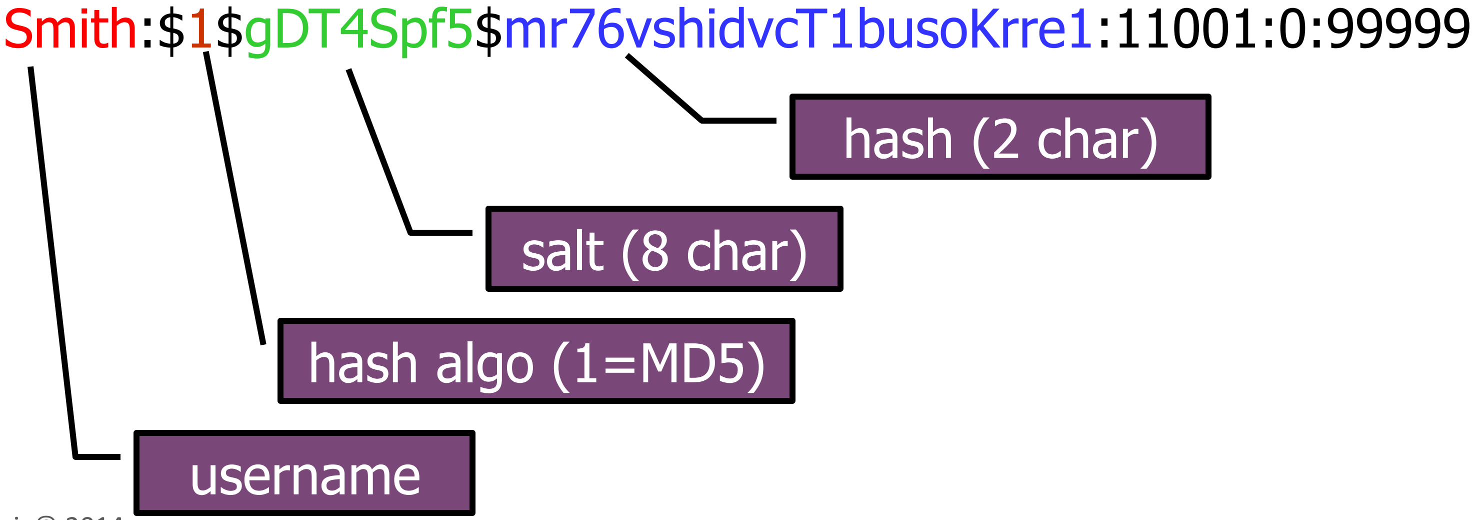


Smith:3Yr83xxCi/Ki2:12801:0:99999:7:-1::

hash (11 char)

salt (2 char)

username



Smith:$1$gDT4Spf5$mr76vshidvcT1busoKrre1:11001:0:99999

hash (2 char)

salt (8 char)

hash algo (1=MD5)

username

Practice Yourself

DES:

- openssl passwd –crypt –salt pH <PASSWORD>

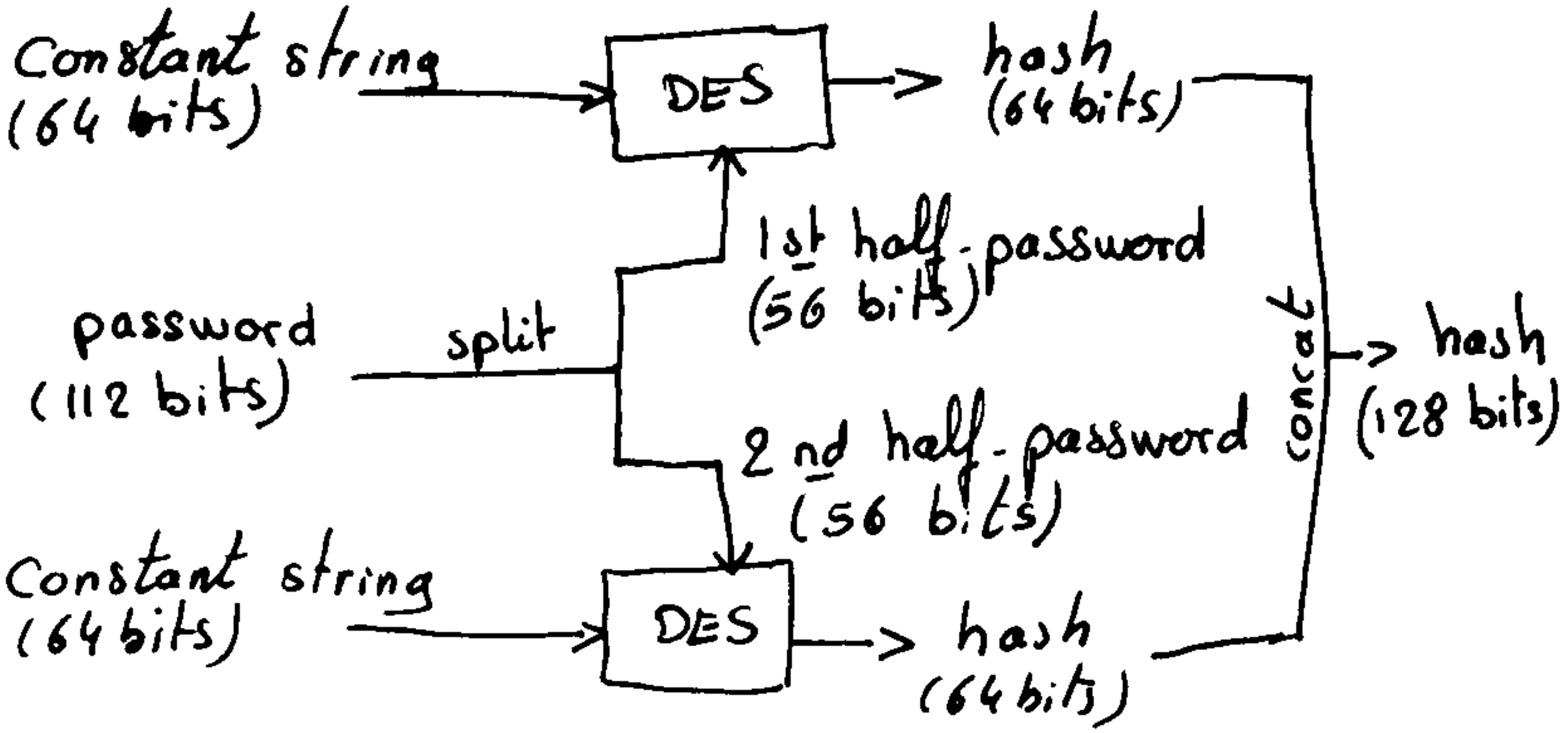
MD5:

- openssl passwd -1 –salt gDT4Spf5 <PASSWORD>

Win 9x Passwords (LM Hash)

- Win98/ME uses the Lan Manager Hash (LM hash)
- The password is cut in two blocks of 7 characters after completion to 14 characters with empty char
- Lowercase letters are converted to uppercase
- A separate hash is generated for each 7-char block
- The 7 bytes block are used as DES keys to encrypt an 8-byte constant string:
  - 0x4B, 0x47, 0x53, 0x21, 0x40, 0x23, 0x24, 0x25
- The LM hash does not use any salt
- http://lasecwww.epfl.ch/~oechslin/projects/ophcrack

Win 9x Passwords (LM Hash)


Constant string (64 bits)
DES
hash (64 bits)
password (112 bits)
split
1st half-password (56 bits)
2nd half-password (56 bits)
concat
hash (128 bits)
Constant string (64 bits)
DES
hash (64 bits)

Win NT/2000/XP/Vista/Seven (NT LM Hash)

- Win NT/2000/XP/Vista/Seven uses the NT Lan Manager Hash (aka NT hash)
- The password is no longer cut in two blocks
- Passwords can be longer than 14 characters (but compatibility issues arise beyond 14 characters)
- Lowercase letters are not converted to uppercase
- The hash function is MD4
- The NT hash still does not use any salt

Storage

- Under W2k, XP, 2003, NTLM and LM hash of all users are stored in the Security Account Manager file or in the Active Directory (ntds.dit)
- The file is encrypted, but by default the key can be extracted from the machine
- If the machine is running we need administrator privileges plus a special exploit (pwdump) to extract the hashes
- If we can boot another OS, we can steal and decrypt the hashes

Cracking Times – Benchmarks John (2011)

- Traditional DES: 1134K c/s
- FreeBSD MD5: 4400 c/s
- OpenBSD Blowfish: 269 c/s
- LM DES: 6547K c/s
- NT MD4: 8260K c/s

LM Hash

- All (LM Hash) alphanum passwords cracked within a few seconds (success 99.9%)
- (Alphanum + 15 special char) LM Hash passwords cracked in a few minutes (success about 96%)
- Storage: CD or DVD (fit the RAM)
- See http://ophcrack.sourceforge.net/

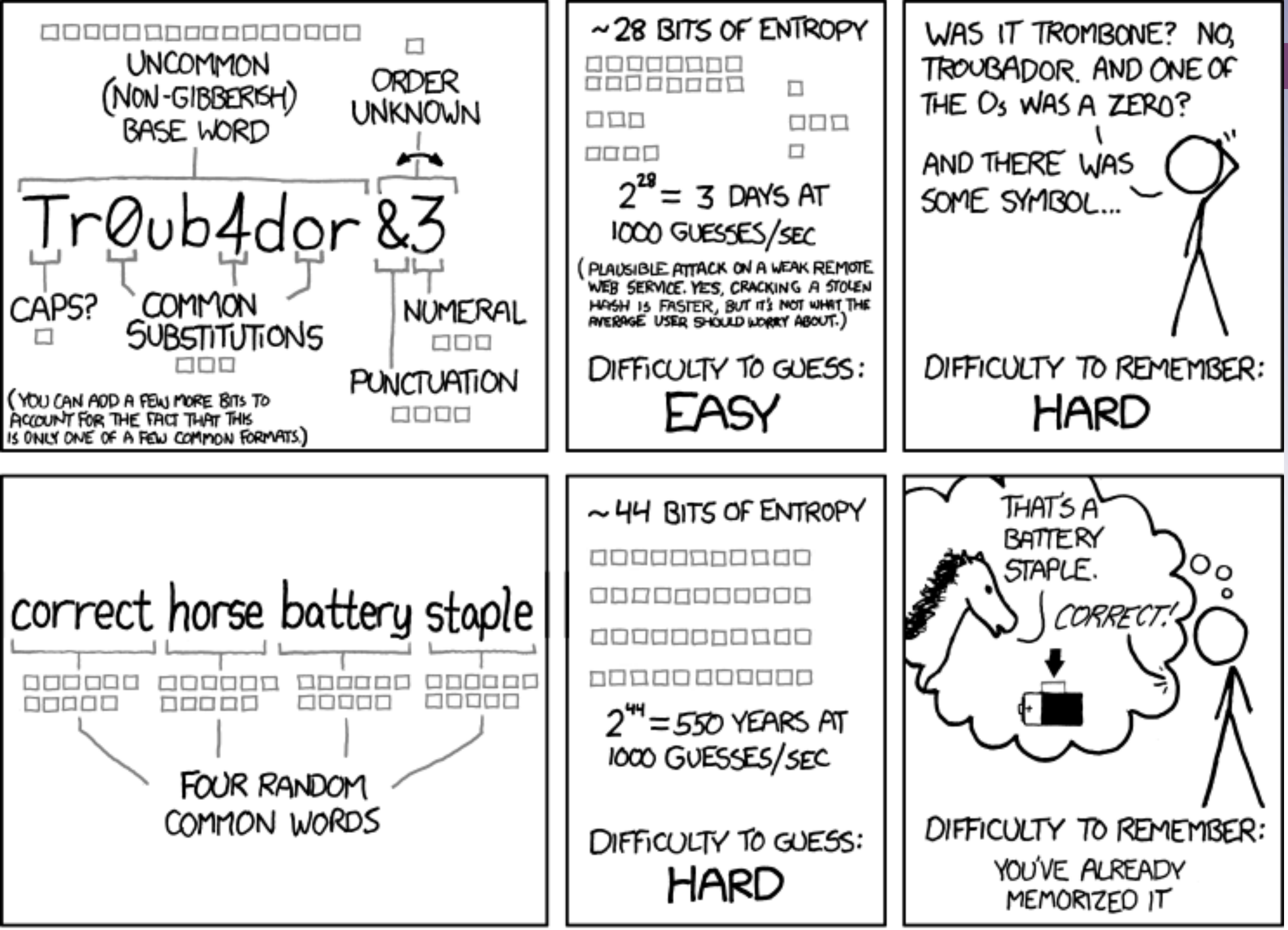
+ Strong passwords and good practices

Strong Passwords

- Contain at least *one of each* of the following
  - Digit (0…9)
  - Letter (a…Z)
  - Punctuation symbol (e.g., !)
  - Control character (e.g., ^s, Ctrl-s)
  - Special character in the first 7 characters
- Based on a verse (e.g., passphrase)
- Easily remembered but difficult for others to guess

Some good practices

- Never recycle passwords
- Never record a password anywhere
  - Exceptions include encrypted password “vaults”
- Use a different password for each system/context
- Change password regularly (?)
- Change your password immediately if you suspect it has been “stolen”, or after using a public computer
- Passwords should be protected in a manner that is consistent with the damage that could be caused by their compromise


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.

xkcd