Care and Feeding of Passwords

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The Menu

- Risks of Using Passwords

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- How to Steal ATM PINs

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- Storing Passwords

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- Eliminating Passwords

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A password is an *authenticator*

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- it could be guessed if it is easily guessable

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- the password could be stored encrypted but the encryption might be breakable (or there might be other problems with the encryption)

ATM PIN Fraud

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First, the fraudsters attached a small device to the side of the ATM and observed the electromagnetic signals emanating from it when the card was swiped through the card reader. This was enough to create a copy of the card. Still, they needed the PIN in order to impersonate the customer.

How would you do it?

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- Stand close behind the person when they're entering their PIN and observe the PIN directly.
- A slight variation: mount a small camera so that it can view the PIN entry terminal.
- Wait for an elderly person to actually ask you to enter their PIN for them (it happens).

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  In order to find out which of the $4! = 24$ permutations is the correct one, try two at a time, wait a month (why?), try another two etc. until you find the right one. (Failed attempts are logged, but the customer will be unaware of them.)

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- The above can also be (and has been) tried with infrared cameras observing residual warmth on the keys. That will also give you the correct permutation.

Giving the Password Away

Giving the password away, either voluntarily or involuntarily, or having it stolen when it’s written down somewhere is really outside the scope of this lecture.

The only defense against that is to *educate* your users and having a good *security policy* in place that is *consistently enforced*.

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- A password is an authenticator.
- It is a shared secret.
- Therefore, *both* parties (the authenticating service and the authenticated person) must make sure to keep the password safe.
- Educate your users to choose good passwords and keep them safe.

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- Choose good, unguessable passwords
- Protect them during entry
- Store them in encrypted form (but do it right)

Password Storage: Turning Echo Off (1)

"Local Echo" is the name for the process of printing the character that you have just typed to the screen. For obvious reasons, local echo should be disabled when entering passwords.

Under Unix (Linux), using bash or in a boune-shell script:

```
stty -echo       # Turn echo off
stty echo        # Turn echo back on
read -s somevar # Read variable "somevar" without echo
```

Password Storage: Turning Echo Off (2)

Under Linux, in C, using *ioctl*(2):

```
#include <sys/ioctl.h>
#include <sys/types.h>

void echo_off(int fd) {
  struct sgttyb tdata;

  if (ioctl (fd, TIOCGETP, &tdata) == -1)
    error ("can't get terminal parameters");

  tdata.sg_flags &= ~ECHO; /* Use |= ECHO to turn echo back on. */
  /* tdata.sg_flags |= CBREAK; */

  if (ioctl (fd, TIOCSETP, &tdata) == -1)
    error ("can't set terminal parameters");
}
```

Password Storage: Turning Echo Off (3)

Under Linux, in C, using *tcgetattr*(3):

```c
#include <termios.h>
#include <unistd.h>

void echo_off(int fd) {
  struct termios ios;

  if (tcgetattr(fd, &ios) == -1)
    error ("can't get terminal parameters");

  ios.c_lflag &= ~ECHO;

  if (tcsetattr(fd, &ios) == -1)
    error ("can't set terminal parameters");
}
```

Password Storage: Cleartext

Storing passwords in clear text is *never* advised.

Passwords should be stored encrypted, but don’t do this:

```c
#include <string.h>

typedef unsigned char key_t[8];

extern key_t lookup_master_key(void);
extern char *decrypt(char *ciphertext, key_t key);

bool check_password(const char *given_password,
                    const char *encrypted_password) {
  key_t master_key = look_up_master_key();
  char *plaintext_password = decrypt(encrypted_password, master_key);

  return strcmp(plaintext_password, given_password) == 0;
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This needs the master key in plaintext stored somewhere

Storing Encrypted Passwords (1)

Don't use the password as the *data* to en/decrypt, use it as the *key* to encrypt a known plaintext block:

```
#include <string.h>

typedef unsigned char key_t[8];

extern key_t make_key(const char* key_material);
extern char *encrypt(char *plaintext, key_t key);

static const char *block = "AAAAAAAA";

bool check_password(const char *given_password,
                    const char *encrypted_password) {
  key_t key = make_key(given_password);
  char *encrypted_given_password = encrypt(block, key);

  return strcmp(encrypted_given_password, encrypted_password) == 0;
}
```

Storing Encrypted Passwords (2)

The following encryption algorithm appears in Microsoft SQL Server:

1. Convert the password to UTF-16, an encoding of Unicode. Because of some peculiarities of UTF-16 and Unicode, the effect is the same as as putting each ASCII character right-justified into a 16-bit field. The must significant 8 bits will be zero.

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Now, since there is no *secret* involved, this is at most an *encoding*, but not an *encryption*. It is totally reversible without knowing any secrets.

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Passwords: Some Simple Theory

Let Σ be an alphabet. For example, Σ could be the set of printable seven-bit ASCII characters, or the set of lower-case alphabetic ASCII characters. Let the maximum length of a password be n.

7-bit ASCII subsection	Range	$\|\Sigma\|$
All printable	32 (' ') to 126 ('~')	95
Letters and digits	48 ('0') to 57 ('9'); 65 ('A') to 90 ('Z'); 97 ('a') to 122 ('z');	62
Letters	65 ('A') to 90 ('Z'); 97 ('a') to 122 ('z');	52
Lowercase letters	97 ('a') to 122 ('z');	26

Number of Passwords

There are $|\Sigma|^k$ possible strings of length k made out of characters of Σ ($0 \le k \le n$).

There are $\sum_{k=0}^{n} |\Sigma|^k = \left(|\Sigma|^{n+1} - 1\right) / \left(|\Sigma| - 1\right)$ possible passwords of length at most n. Unix used to have $n = 8$:

ASCII subsection	Number of Passwords	Fraction
All printable	6704780954517121	1.0
Letters and digits	221919451578091	0.033
Letters	54507958502661	0.00813
Lowercase letters	217180147159	0.0000324
Lowercase words(*)	96099	0.0000000000143

(*) Number of words in a word list made from Webster's that are eight characters or less. Webster's has 311141 words total.

Attacking the Encrypted Scheme

We are somehow in posession of a file containing user names and encrypted passwords. The cryptographic algorithm (that we know) is so strong that we cannot break the encryption. How can we still try to get the plaintext passwords?

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If no special precautions are taken, we can do this *offline* and thus precompute a dictionary of encrypted passwords (Dictionary Attack).

Storage Estimate for Dictionary Attack

Assume that both the plaintext password and the corresponding encrypted password each need eight bytes to store. With 6704780954517121 plain/ciphertext pairs, that would be 107276495272273936 bytes, or about 2^{53} bytes (about 8000 Terabytes).

This would be just about feasible for a really large organization or government today.

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2339	(71.0%)	were easily guessable passwords

Password Quality (2)

Additionally, 492 passwords appeared in various dictionaries and word lists. All in all, **2831 or 86% of all passwords fell into these classes!** (There was overlap between the word lists and the exhaustive tests)

How bad is that?

Cost of Dictionary Attack (1)

There are

95	single ASCII characters
9025	strings of two ASCII characters
100000	English words
857375	strings of three ASCII characters
14776336	strings of four alphanumerics
23762752	were five letters, all upper-case or all lower-case
308915776	were six letters, all lower-case
348421359	Total

A *conservative* estimate is that you can do 1,000,000 crypto operations per second on a current machine. Compared with the time to write that to a disk, the time to encrypt is negligible.

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Defense Against Precomputation: Salting

Store, together with each password, a small integer (up to a few thousand) in the clear. This integer is called the *salt*. For Unix, the salt is a 12-bit value.

In order to check a password, the salt is used to perturb the encryption algorithm (for example, by prepending the salt to the given password prior to encryption). $\Longrightarrow$ the same password with two different salts will encrypt to different strings.

Same passwords no longer appear related in the password file and a precomputed dictionary attack is made more difficult. For Unix, a dictionary would have to be 2^{12} or 4096 times as large.

Unix crypt() (1)

The Unix password file contains seven fields:

```
neuhaus:abf/31kl&1@fe:7006:100:Stephan Neuhaus:/home/neuhaus:/bin/bash
```

The second field is the password field. The password contains the salt in the first two characters, and the encrypted password in the following characters.

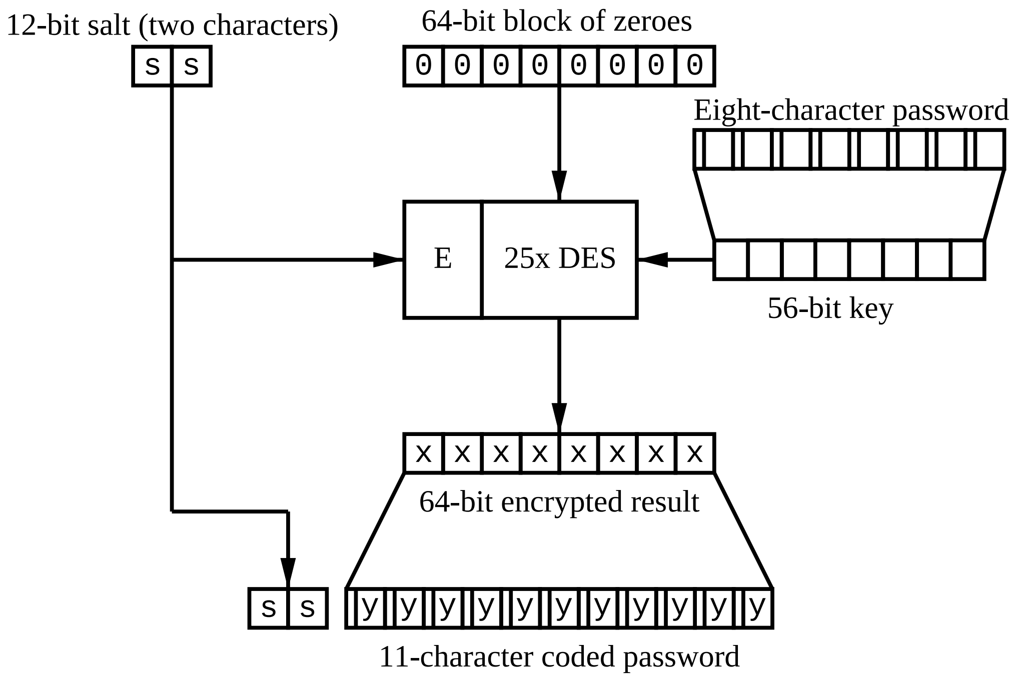
The eight seven-bit characters of the password are used to form a 56-bit DES key.

The salt is used to change the E table in DES that expands a 32-bit intermediate result to 48 bits

The DES is called 25 times on a 64-bit block of zeroes.

The result is expanded into 11 7-bit ASCII characters and prepended with the salt.

Unix crypt() Function (2)



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Still can't make good passwords from bad ones!

State of the Passwords in 1989/1993

David C. Feldmeier, Philip R. Karn, *Unix Password Security - Ten Years Later*, Proceedings of CRYPTO ’89, pp. 44–63.

Walter Belgers, *Unix Password Security*, Technical Report, Technische Universiteit Eindhoven, December 1993.

Very fast *crypt*(3) functions tuned especially for cracking many passwords

Cracked 11% of all accounts (10.7% of accounts with shell) in about 25 hours of wall clock (not CPU) time using 11 Sun ELCs (25 MHz Sparc processors, 16–24 MB main memory).

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- New password algorithm allows longer salt

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$\Longrightarrow$ Passwords are probably not more difficult to crack now than they were in 1993.

How to Choose Good Passwords? (1)

Generate passwords by machine (and live with the fact that they'll be written down)

Attempt to crack a password when it's set and dismiss those that can be cracked (there are libraries that plug into the password program that do precisely this). A good password should be at least seven characters, have uppercase and lowercase letters and some punctuation.

How to Choose Good Passwords? (2)

Here are some bad passwords for a user ‘neuhaus’. They should be rejected by a password entry program.

Bad password	Reason
neuhaus	Same as user name
neuhaus!	Derived from user name
NeUhAuS	Also derived from user name
suahuen	Also derived from user name
tree	In word list
eert	Derived from word in word list
qwerty	Simple keyboard pattern
Bessie	Name of user’s cat(*)

(*) I don’t know how the password program could know this, but it should reject the password anyway!

How to Choose Good Passwords? (3)

Here are some more bad passwords.

Bad password	Reason
`fuck`	In wordlist
`Frodo`	Well-known password
`Joshua`	Also a well-known password(*)
`agnitfom`	Also a well-known password(*)
`redrum`	Also a well-known password(*)

(*) Name the source and win a prize!

How to Choose Good Passwords? (3)

Take a sentence that you can easily remember. Use the first letter of each word, preserving case, and including punctuation. For example, “My name is Ozymandias, king of kings!” becomes “MniO,kok!”.

Take care that you don’t misremember the sentence as, e.g., “I am Ozymandias. . . ” I have lost several passwords and passphrases this way!

“One Ring to rule them, one Ring to find them” ⇒ “1R2rt,1R2ft”; “If this be error and upon me proved, I never writ and no man ever loved” ⇒ “Itbeaump,Inwanmel.”; “Call me Ishmael. Some years ago - never mind how long precisely - having little or no money in my purse,” ⇒ “CmI. Sya-nmhlp-hlonmimp,” (Name the sources and win prizes).

How to Choose Good Passwords? (4)

For a variation, take the last letter or the second letter of each word. For example, “My name is Ozymandias, king of kings!” becomes “yess,gfs!”.

Or: “One Ring to rule them, one Ring to find them” ⇒ “niouh,nioih”; “If this be error and upon me proved, I never writ and no man ever loved” ⇒ “Iibonome,Ieinnaee.”; “Call me Ishmael. Some years ago - never mind how long precisely - having little or no money in my purse,” ⇒ “CeI.oyg-nihop-alrnoiyp,”

Don’t choose *any* of these examples any more!

Thease passwords can still be brute-forced (see exercises).

More Bad News: Replay Attacks

Passwords are often used to authenticate yourself over some network.

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Defense: Use One-time passwords (later in this lecture) and/or encrypt passwords (e.g., ssh, later lecture), or eliminate passwords altogether (below).

Eliminate Passwords Altogether

A password is of the type *you are what you know*.

If others know the shared secret, they can impersonate you. There is no way around that.

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- liability: what if the retina-scan laser makes some people blind?
- acceptance: “Please deposit urine sample here”

Cryptographic Tokens (1)

The RSA SecurID token contains a secret cryptographic key and a clock that changes the display every minute.

The corresponding server software also contains the key.

The key and the time-of-day together make a unique code with a lifetime of 60 seconds.

When you authenticate, you enter your user ID and the code on your SecurID token. The server also generates a token from the time-of-day and its copy of the key. If they match, you're in.

Cryptographic Tokens (1)

This can be combined with a PIN pad.

Therefore the user is identified by a combination of what they have (the token) and what they know (the PIN)

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With additional PIN, stealing only the device is useless

Problems

What happens when the clock inside the token and the clock inside the server don't agree?

Recommended solution:

- Keep server clocks in check using the Network Time Protocol (NTP)
- Periodically re-synchronize the tokens on the server

What if the token goes out of sync on a Friday evening?

Summary (1)

The problem with passwords is typical of security design problems:

How to ensure Confidentiality, Integrity, and Authenticity?

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- Passwords are Doomed
- Eliminating Passwords

References

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