Chapter 6

Intruders

One of the two most publicized threats to security is the intruder (the other is viruses), generally referred to as a hacker or cracker. Inan important early study of intrusion, Anderson identified three classes of intruders:

Masquerader: An individual who is not authorized to use the computer and who penetrates a system's access controls to exploit a legitimate user's account
Misfeasor: A legitimate user who accesses data, programs, or resources for which such access is not authorized, or who is authorized for such access but misuses his or her privileges
Clandestine user: An individual who seizes supervisory control of the system and uses this control to evade auditing and access controls or to suppress audit collection

The masquerader is likely to be an outsider; the misfeasor generally is an insider; and the clandestine user can be either an outsider or an insider.Intruder attacks range from the benign to the serious. At the benign end of the scale, there are many people who simply wish to explore internets and see what is out there. At the serious end are individuals who are attempting to read privileged data, perform unauthorized modifications to data, or disrupt the system.
In 1990 there was a nationwide crackdown on illicit computer hackers, with arrests, criminal charges, one dramatic show trial, several guilty pleas, and confiscation of massive amounts of data and computer equipment. Many people believed that the problem had been brought under control.
In fact, the problem has not been brought under control. To cite one example, a group at Bell Labs has reported persistent and frequent attacks on its computer complex via the Internet over an extended period and from a variety of sources. At the time of these reports, the Bell group was experiencing the following:
Attempts to copy the password file (discussed later) at a rate exceeding once every other day
Suspicious remote procedure call (RPC) requests at a rate exceeding once per week
Attempts to connect to nonexistent "bait" machines at least every two weeks
Benign intruders might be tolerable, although they do consume resources and may slow performance for legitimate users. However, there is no way in advance to know whether an

intruder will be benign or malign. Consequently, even for systems with no particularly sensitive resources, there is a motivation to control this problem.

An example that dramatically illustrates the threat occurred at Texas A&M University. In August 1992, the computer center there was notified that one of its machines was being used to attack computers at another location via the Internet. By monitoring activity, the computer center personnel learned that there were several outside intruders involved, who were running password-cracking routines on various computers (the site consists of a total of 12,000 interconnected machines). The center disconnected affected machines, plugged known security holes, and resumed normal operation. A few days later, one of the local system managers detected that the intruder attack had resumed. It turned out that the attack was far more sophisticated than had been originally believed. Files were found containing hundreds of captured passwords, including some on major and supposedly secure servers. In addition, one local machine had been set up as a hacker bulletin board, which the hackers used to contact each other and to discuss techniques and progress.

An analysis of this attack revealed that there were actually two levels of hackers. The high level were sophisticated users with a thorough knowledge of the technology; the low level were the "foot soldiers" who merely used the supplied cracking programs with little understanding of how they worked. This teamwork combined the two most serious weapons in the intruder armory: sophisticated knowledge of how to intrude and a willingness to spend countless hours "turning doorknobs" to probe for weaknesses.

One of the results of the growing awareness of the intruder problem has been the establishment of a number of computer emergency response teams (CERTs). These cooperative ventures collect information about system vulnerabilities and disseminate it to systems managers. Unfortunately, hackers can also gain access to CERT reports. In the Texas A&M incident, later analysis showed that the hackers had developed programs to test the attacked machines for virtually every vulnerability that had been announced by CERT. If even one machine had failed to respond promptly to a CERT advisory, it was wide open to such attacks.

In addition to running password-cracking programs, the intruders attempted to modify login software to enable them to capture passwords of users logging on to systems. This made it possible for them to build up an impressive collection of compromised passwords, which was made available on the bulletin board set up on one of the victim's own machines.

In this section, we look at the techniques used for intrusion. Then we examine ways to detect intrusion. Finally, we look at password-based approaches to prevention.

Intrusion Techniques

The objective of the intruder is to gain access to a system or to increase the range of privileges accessible on a system. Generally, this requires the intruder to acquire information that should have been protected. In some cases, this information is in the form of a user password. With knowledge of some other user's password, an intruder can log in to a system and exercise all the privileges accorded to the legitimate user.

Typically, a system must maintain a file that associates a password with each authorized user. If such a file is stored with no protection, then it is an easy matter to gain access to it and learn passwords. The password file can be protected in one of two ways:

One-way function: The system stores only the value of a function based on the user's password. When the user presents a password, the system transforms that password and compares it with the stored value. In practice, the system usually performs a one-way transformation (not reversible) in which the password is used to generate a key for the one-way function and in which a fixed-length output is produced.

Access control: Access to the password file is limited to one or a very few accounts.

If one or both of these countermeasures are in place, some effort is needed for a potential intruder to learn passwords. On the basis of a survey of the literature and interviews with a number of password crackers, reports the following techniques for learning passwords:

1. Try default passwords used with standard accounts that are shipped with the system. Many administrators do not bother to change these defaults.

2. Exhaustively try all short passwords (those of one to three characters).

3. Try words in the system's online dictionary or a list of likely passwords. Examples of the latter are readily available on hacker bulletin boards.

4. Collect information about users, such as their full names, the names of their spouse and children, pictures in their office, and books in their office that are related to hobbies.

5. Try users' phone numbers, Social Security numbers, and room numbers.

6. Try all legitimate license plate numbers for this state.

7. Use a Trojan horse to bypass restrictions on access.

8. Tap the line between a remote user and the host system. The first six methods are various ways of guessing a password. If an intruder has to verify the guess by attempting to log in, it is a tedious and easily countered means of attack. For example, a system can simply reject any login after three password attempts, thus requiring the intruder to reconnect to the host to try again. Under these circumstances, it is not practical to try more than a handful of passwords. However, the intruder is unlikely to try such crude methods. For example, if an

intruder can gain access with a low level of privileges to an encrypted password file, then the strategy would be to capture that file and then use the encryption mechanism of that particular system at leisure until a valid password that provided greater privileges was discovered.
Guessing attacks are feasible, and indeed highly effective, when a large number of guesses can be attempted automatically and each guess verified, without the guessing process being detectable. Later in this chapter, we have much to say about thwarting guessing attacks.
The seventh method of attack listed earlier, the Trojan horse, can be particularly difficult to counter. An example of a program that bypasses access controls was cited in .A low-privilege user produced a game program and invited the system operator to useit in his or her spare time. The program did indeed play a game, but in the background it also contained code to copy the password file,which was unencrypted but access protected, into the user's file. Because the game was running under the operator's high-privilege mode, it was able to gain access to the password file.
The eighth attack listed, line tapping, is a matter of physical security. It can be countered with link encryption techniques, discussed in Other intrusion techniques do not require learning a password. Intruders can get access to a system by exploiting attacks such as bufferoverflows on a program that runs with certain privileges. Privilege escalation can be done this way as well. We turn now to a discussion of the two principal countermeasures: detection and prevention. Detection is concerned with learning of an attack, either before or after its success. Prevention is a challenging security goal and an uphill battle at all times. The difficulty stems from the fact that the defender must attempt to thwart all possible attacks, whereas the attacker is free to try to find the weakest link in the defense chain and attack at that point.

Intrusion Detection

Inevitably, the best intrusion prevention system will fail. A system's second line of defense is intrusion detection, and this has been the focus of much research in recent years. This interest is motivated by a number of considerations, including the following:
1. If an intrusion is detected quickly enough, the intruder can be identified and ejected from the system before any damage is done or any data are compromised. Even if the detection is not sufficiently timely to preempt the intruder, the sooner that the intrusion is detected, the less the amount of damage and the more quickly that recovery can be achieved.

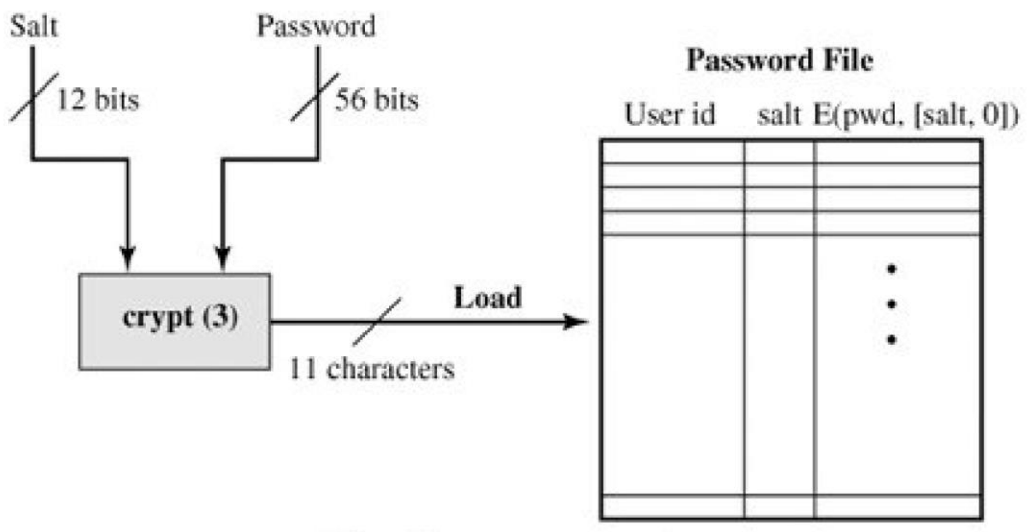
2. An effective intrusion detection system can serve as a deterrent, so acting to prevent intrusions.
3. Intrusion detection enables the collection of information about intrusion techniques that can be used to strengthen the intrusion prevention facility.
Intrusion detection is based on the assumption that the behavior of the intruder differs from that of a legitimate user in ways that can be quantified. Of course, we cannot expect that there will be a crisp, exact distinction between an attack by an intruder and the normal use of resources by an authorized user. Rather, we must expect that there will be some overlap.
Figure 18.1 suggests, in very abstract terms, the nature of the task confronting the designer of an intrusion detection system. Although the typical behavior of an intruder differs from the typical behavior of an authorized user, there is an overlap in these behaviors. Thus, a loose interpretation of intruder behavior, which will catch more intruders, will also lead to a number of "false positives," or authorized users identified as intruders. On the other hand, an attempt to limit false positives by a tight interpretation of intruder behavior will lead to an increase in false negatives, or intruders not identified as intruders. Thus, there is an element of compromise and art in the practice of intrusion detection.

Password Management
Password Protection
The front line of defense against intruders is the password system. Virtually all multiuser systems require that a user provide not only a name or identifier (ID) but also a password. The password serves to authenticate the ID of the individual logging on to the system. In turn, the ID provides security in the following ways:
The ID determines whether the user is authorized to gain access to a system. In some systems, only those who already have an ID filed on the system are allowed to gain access.
The ID determines the privileges accorded to the user. A few users may have supervisory or "superuser" status that enables them to read files and perform functions that are especially protected by the operating system. Some systems have guest or anonymous accounts, and users of these accounts have more limited privileges than others.
The ID is used in what is referred to as discretionary access control. For example, by listing the IDs of the other users, a user may grant permission to them to read files owned by that user.

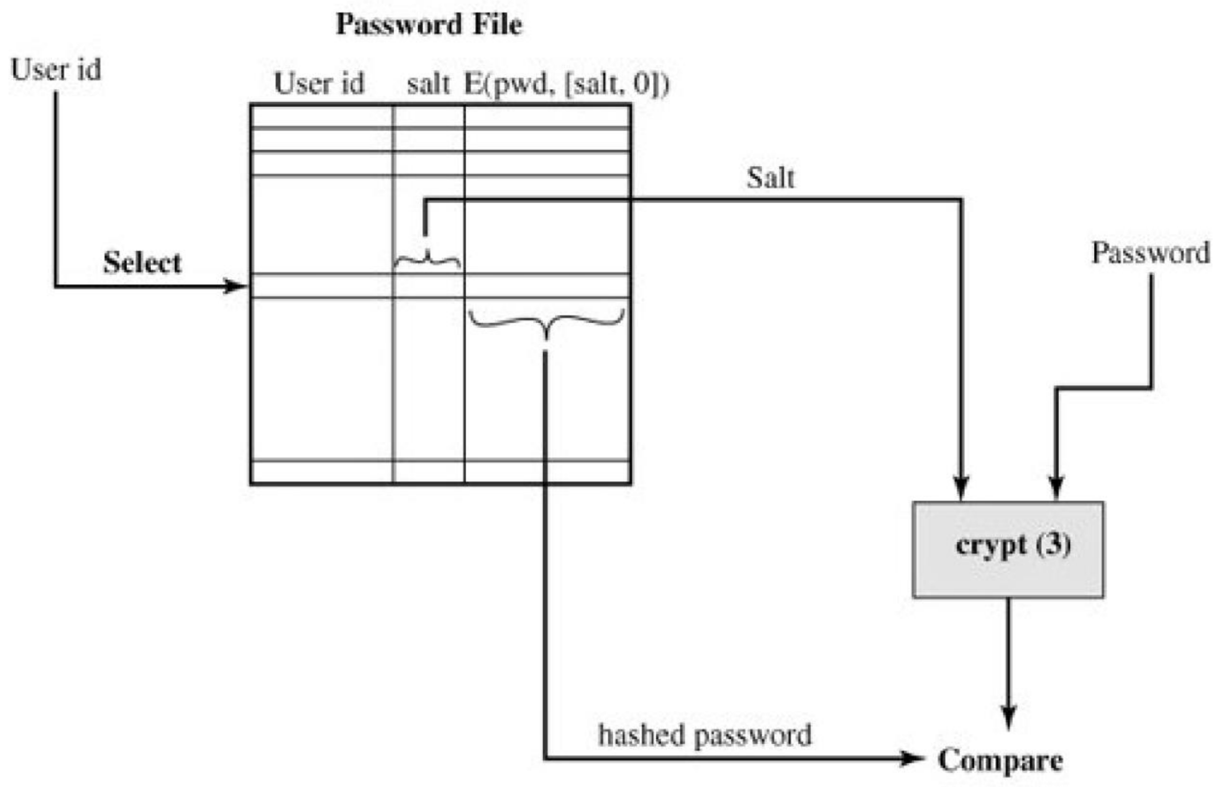
The Vulnerability of Passwords

To understand the nature of the threat to password-based systems, let us consider a scheme that is widely used on UNIX, in which passwords are never stored in the clear. Rather, the following procedure is employed (Figure 18.4a). Each user selects a password of up to eight printable characters in length. This is converted into a 56-bit value (using 7-bit ASCII) that serves as the key input to an encryption routine. The encryption routine, known as crypt(3), is based on DES. The DES algorithm is modified using a 12-bit " salt" value. Typically,this value is related to the time at which the password is assigned to the user. The modified DES algorithm is exercised with a data input consisting of a 64-bit block of zeros. The output of the algorithm then serves as input for a second encryption. This process is repeated for a total of 25 encryptions. The resulting 64-bit output is then translated into an 11-character sequence. The hashed password is thenstored, together with a plaintext copy of the salt, in the password file for the corresponding user ID. This method has been shown to besecure against a variety of cryptanalytic attacks

Figure 18.4. UNIX Password Scheme



(a) Loading a new password



(b) Verifying a password

The salt serves three purposes:

It prevents duplicate passwords from being visible in the password file. Even if two users choose the same password, those passwords will be assigned at different times. Hence, the "extended" passwords of the two users will differ.

It effectively increases the length of the password without requiring the user to remember two additional characters. Hence, the number of possible passwords is increased by a factor of 4096, increasing the difficulty of guessing a password.
It prevents the use of a hardware implementation of DES, which would ease the difficulty of a brute-force guessing attack.

When a user attempts to log on to a UNIX system, the user provides an ID and a password. The operating system uses the ID to index into the password file and retrieve the plaintext salt and the encrypted password. The salt and user-supplied password are used as input to the encryption routine. If the result matches the stored value, the password is accepted.
The encryption routine is designed to discourage guessing attacks. Software implementations of DES are slow compared to hardware versions, and the use of 25 iterations multiplies the time required by 25. However, since the original design of this algorithm, two changes have occurred. First, newer implementations of the algorithm itself have resulted in speedups. For example, the Internet worm able to do online password guessing of a few hundred passwords in a reasonably short time by using a more efficient encryption algorithm than the standard one stored on the UNIX systems that it attacked. Second, hardware performance continues to increase, so that any software algorithm executes more quickly.

Thus, there are two threats to the UNIX password scheme. First, a user can gain access on a machine using a guest account or by some other means and then run a password guessing program, called a password cracker, on that machine. The attacker should be able to check hundreds and perhaps thousands of possible passwords with little resource consumption. In addition, if an opponent is able to obtain a copy of the password file, then a cracker program can be run on another machine at leisure. This enables the opponent to run through many thousands of possible passwords in a reasonable period.
As an example, a password cracker was reported on the Internet in August 1993 [MADS93]. Using a Thinking Machines Corporation parallel computer, a performance of 1560 encryptions per second per vector unit was achieved. With four vector units per processing node (a standard configuration), this works out to 800,000 encryptions per second on a 128-node machine (which is a modest size) and 6.4 million encryptions per second on a 1024-node machine.
Even these stupendous guessing rates do not yet make it feasible for an attacker to use a dumb brute-force technique of trying all possible combinations of characters to discover a

password. Instead, password crackers rely on the fact that some people choose easily guessable passwords.

Some users, when permitted to choose their own password, pick one that is absurdly short. The results of one study at Purdue University are shown in Table 18.3. The study observed password change choices on 54 machines, representing approximately 7000 user accounts.

Almost 3% of the passwords were three characters or fewer in length. An attacker could begin the attack by exhaustively testing all possible passwords of length 3 or fewer. A simple remedy is for the system to reject any password choice of fewer than, say, six characters or even to require that all passwords be exactly eight characters in length. Most users would not complain about such a restriction.

Password Selection Strategies

The lesson from the two experiments just described (Tables 18.3 and 18.4) is that, left to their own devices, many users choose a password that is too short or too easy to guess. At the other extreme, if users are assigned passwords consisting of eight randomly selected printable characters, password cracking is effectively impossible. But it would be almost as impossible for most users to remember their passwords. Fortunately, even if we limit the password universe to strings of characters that are reasonably memorable, the size of the universe is still too large to permit practical cracking. Our goal, then, is to eliminate guessable passwords while allowing the user to select a password that is memorable. Four basic techniques are in use:

User education

Computer-generated passwords

Reactive password checking

Proactive password checking

This **user education** strategy is unlikely to succeed at most installations, particularly where there is a large user population or a lot of turnover. Many users will simply ignore the guidelines. Others may not be good judges of what is a strong password. For example, many users (mistakenly) believe that reversing a word or capitalizing the last letter makes a password unguessable.

Computer-generated passwords also have problems. If the passwords are quite random in nature, users will not be able to remember them. Even if the password is pronounceable, the user may have difficulty remembering it and so be tempted to write it down. In general, computer-generated password schemes have a history of poor acceptance by users. FIPS PUB 181 defines one of the best-designed automated password generators. The standard includes not only a description of the approach but also a complete listing of the C source code of the algorithm. The algorithm generates words by forming pronounceable syllables and concatenating them to form a word. Arandom number generator produces a random stream of characters used to construct the syllables and words.

A **reactive password checking** strategy is one in which the system periodically runs its own password cracker to find guessable passwords. The system cancels any passwords that are guessed and notifies the user. This tactic has a number of drawbacks. First, it is resource intensive if the job is done right. Because a determined opponent who is able to steal a password file can devote full CPU time to the task for hours or even days, an effective reactive password checker is at a distinct disadvantage. Furthermore, any existing passwords remain vulnerable until the reactive password checker finds them.

The most promising approach to improved password security is a **proactive password checker**. In this scheme, a user is allowed to select his or her own password. However, at the time of selection, the system checks to see if the password is allowable and, if not, rejects it. Such checkers are based on the philosophy that, with sufficient guidance from the system, users can select memorable passwords from a fairly large password space that are not likely to be guessed in a dictionary attack.