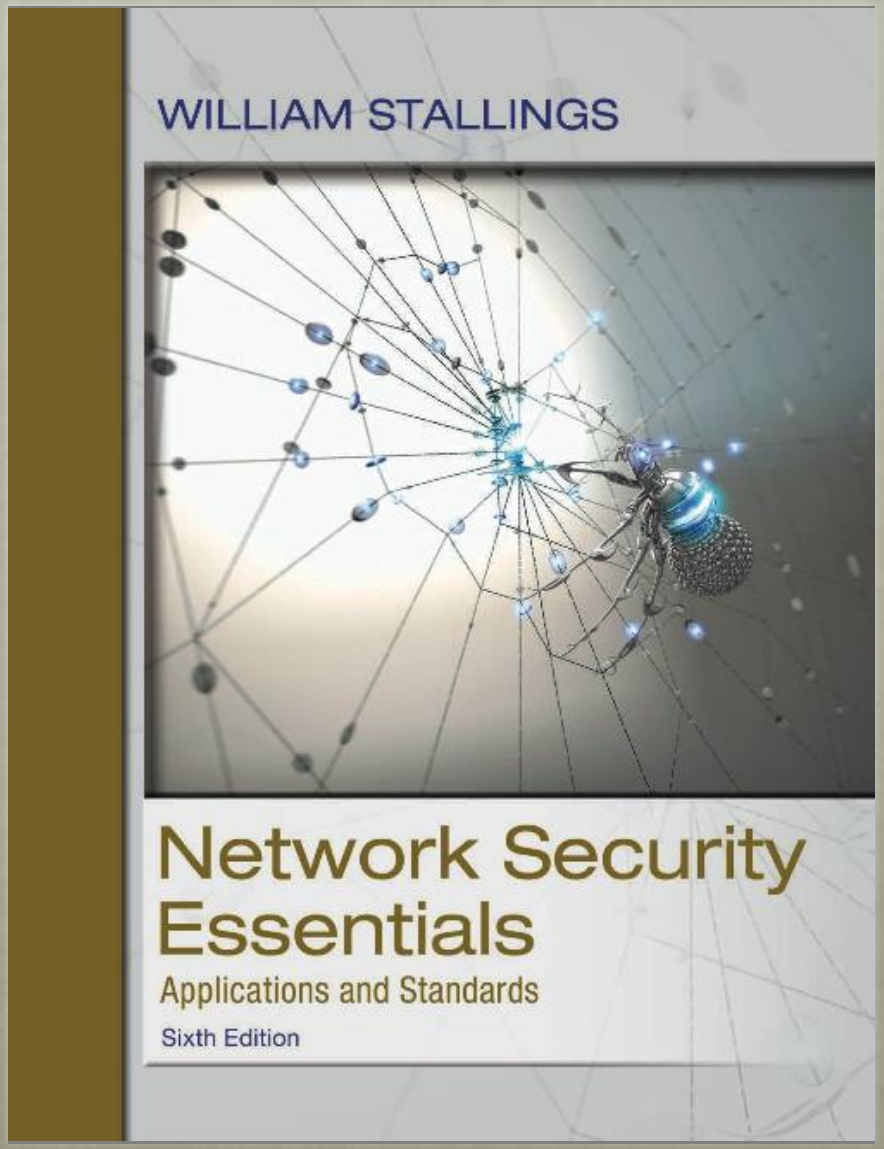
NETWORK SECURITY ESSENTIALS

Sixth Edition

by William Stallings



CHAPTER 11

Intruders

INTRUDERS

- 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

EXAMPLES OF INTRUSION

- Performing a remote root compromise of an e-mail server
- Defacing a Web server
- Guessing and cracking passwords
- Copying a database containing credit card numbers
- Viewing sensitive data, including payroll records and medical information, without authorization
- Running a packet sniffer on a workstation to capture usernames and passwords
- Using a permission error on an anonymous FTP server to distribute pirated software and music files
- Dialing into an unsecured modem and gaining internal network access
- Posing as an executive, calling the help desk, resetting the executive's e-mail password, and learning the new password
- Using an unattended, logged-in workstation without permission

HACKERS

- Traditionally, those who hack into computers do so for the thrill of it or for status
- Intrusion detection systems (IDSs) and intrusion prevention systems (IPSs) are designed to counter hacker threats
  - In addition to using such systems, organizations can consider restricting remote logons to specific IP addresses and/or use virtual private network technology
- CERTs
  - Computer emergency response teams
  - These cooperative ventures collect information about system vulnerabilities and disseminate it to systems managers
  - Hackers also routinely read CERT reports
  - It is important for system administrators to quickly insert all software patches to discovered vulnerabilities

CRIMINAL HACKERS

- Organized groups of hackers
- Usually have specific targets, or at least classes of targets in mind
- Once a site is penetrated, the attacker acts quickly, scooping up as much valuable information as possible and exiting
- IDSs and IPSs can be used for these types of attackers, but may be less effective because of the quick in-and-out nature of the attack

INSIDER ATTACKS

- Among the most difficult to detect and prevent
- Can be motivated by revenge or simply a feeling of entitlement
- Countermeasures:

Enforce least privilege, only allowing access to the resources employees need to do their job

Set logs to see what users access and what commands they are entering

Protect sensitive resources with strong authentication

Upon termination, delete employee's computer and network access

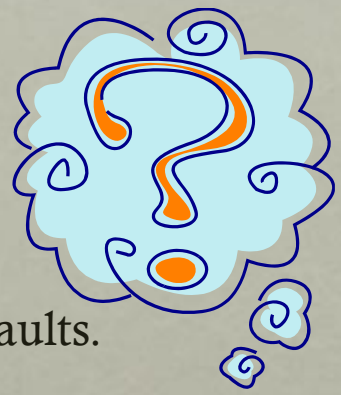
Upon termination, make a mirror image of employee's hard drive before reissuing it (used as evidence if your company information turns up at a competitor

INTRUSION TECHNIQUES

- Objective of the intruder is to gain access to a system or to increase the range of privileges accessible on a system
- Most initial attacks use system or software vulnerabilities that allow a user to execute code that opens a backdoor into the system
- Ways to protect a password file:

One-way functioning	Access control
• The system stores only the value of a function based on the user's password	• Access to the password file is limited to one or a very few accounts

PASSWORD GUESSING



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.

INTRUSION DETECTION

- A system's second line of defense
- Is based on the assumption that the behavior of the intruder differs from that of a legitimate user in ways that can be quantified
- Considerations:
  - 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
  - An effective intrusion detection system can serve as a deterrent, so acting to prevent intrusions
  - Intrusion detection enables the collection of information about intrusion techniques that can be used to strengthen the intrusion prevention facility

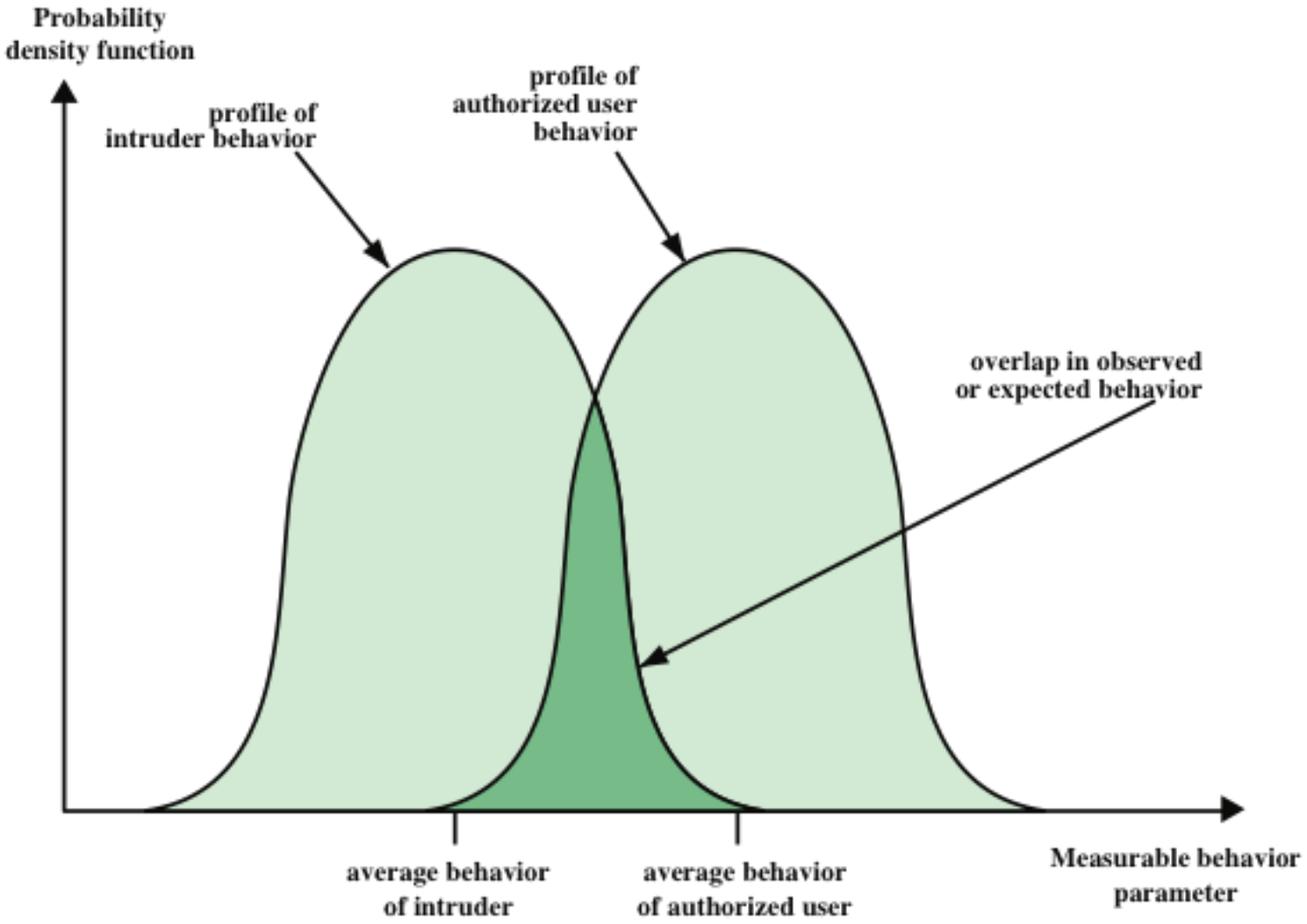


Figure 11.1 Profiles of Behavior of Intruders and Authorized Users

APPROACHES TO INTRUSION DETECTION

- Statistical anomaly detection
  - Involves the collection of data relating to the behavior of legitimate users over a period of time
  - Then statistical tests are applied to observed behavior to determine whether that behavior is not legitimate user behavior
  - Threshold detection
    - This approach involves defining thresholds, independent of user, for the frequency of occurrence of various events
  - Profile based
    - A profile of the activity of each user is developed and used to detect changes in the behavior of individual accounts
- Rule-based detection
  - Involves an attempt to define a set of rules or attack patterns that can be used to decide that a given behavior is that of an intruder
  - Often referred to as *signature detection*

AUDIT RECORDS

- Fundamental tool for intrusion detection

Native audit records

Virtually all multiuser operating systems include accounting software that collects information on user activity

The advantage of using this information is that no additional collection software is needed

The disadvantage is that the native audit records may not contain the needed information or may not contain it in a convenient form

Detection-specific audit records

A collection facility can be implemented that generates audit records containing only that information required by the intrusion detection system

One advantage of such an approach is that it could be made vendor independent and ported to a variety of systems

The disadvantage is the extra overhead involved in having two accounting packages running on a machine

STATISTICAL ANOMALY DETECTION

- Threshold detection
  - Involves counting the number of occurrences of a specific event type over an interval of time
  - If the count surpasses what is considered a reasonable number that one might expect to occur, then intrusion is assumed
  - By itself is a crude and ineffective detector of even moderately sophisticated attacks
- Profile-based
  - Focuses on characterizing the past behavior of individual users or related groups of users and then detecting significant deviations
  - A profile may consist of a set of parameters, so that deviation on just a single parameter may not be sufficient in itself to signal an alert

Table 11.1

Measures That May Be Used For Intrusion Detection

(This table can be found on page 371 in the textbook.)

Measure	Model	Type of Intrusion Detected
Login and Session Activity		
Login frequency by day and time	Mean and standard deviation	Intruders may be likely to log in during off-hours.
Frequency of login at different locations	Mean and standard deviation	Intruders may log in from a location that a particular user rarely or never uses.
Time since last login	Operational	Break-in on a "dead" account.
Elapsed time per session	Mean and standard deviation	Significant deviations might indicate masquerader.
Quantity of output to location	Mean and standard deviation	Excessive amounts of data transmitted to remote locations could signify leakage of sensitive data.
Session resource utilization	Mean and standard deviation	Unusual processor or I/O levels could signal an intruder.
Password failures at login	Operational	Attempted break-in by password guessing.
Failures to login from specified terminals	Operational	Attempted break-in.
Command or Program Execution Activity		
Execution frequency	Mean and standard deviation	May detect intruders, who are likely to use different commands, or a successful penetration by a legitimate user, who has gained access to privileged commands.
Program resource utilization	Mean and standard deviation	An abnormal value might suggest injection of a virus or Trojan horse, which performs side-effects that increase I/O or processor utilization.
Execution denials	Operational model	May detect penetration attempt by individual user who seeks higher privileges.
File access activity		
Read, write, create, delete frequency	Mean and standard deviation	Abnormalities for read and write access for individual users may signify masquerading or browsing.
Records read, written	Mean and standard deviation	Abnormality could signify an attempt to obtain sensitive data by inference and aggregation.
Failure count for read, write, create, delete	Operational	May detect users who persistently attempt to access

RULE-BASED INTRUSION DETECTION

- Techniques detect intrusion by observing events in the system and applying a set of rules that lead to a decision regarding whether a given pattern of activity is or is not suspicious

- **Rule-based anomaly detection**
  - Is similar in terms of its approach and strengths to statistical anomaly detection
  - Historical audit records are analyzed to identify usage patterns and to automatically generate rules that describe those patterns
  - Current behavior is then observed, and each transaction is matched against the set of rules to determine if it conforms to any historically observed pattern of behavior
  - In order for this approach to be effective, a rather large database of rules will be needed

RULE-BASED INTRUSION DETECTION

- **Rule-based penetration identification**
  - Typically, the rules used in these systems are specific to the machine and operating system
  - The most fruitful approach to developing such rules is to analyze attack tools and scripts collected on the Internet
  - These rules can be supplemented with rules generated by knowledgeable security personnel
- USTAT
  - A model independent of specific audit records
  - Deals in general actions rather than the detailed specific actions recorded by the UNIX auditing mechanism
  - Implemented on a SunOS system that provides audit records on 239 events

Table 11.2
USTAT Actions versus SunOS Event Types

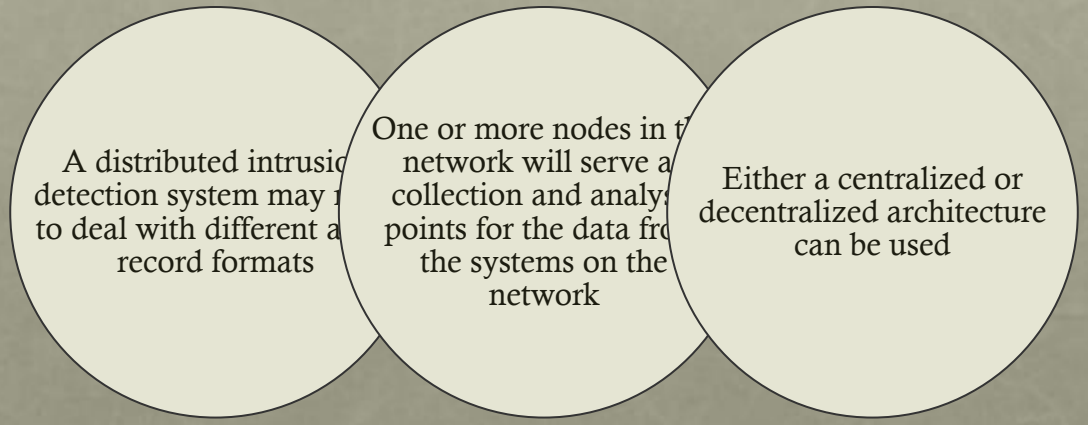
USTAT Action	SunOS Event Type
Read	open_r, open_rc, open_rtc, open_rwc, open_rwtc, open_rt, open_rw, open_rwt
Write	truncate, ftruncate, creat, open_rtc, open_rwc, open_rwtc, open_rt, open_rw, open_rwt, open_w, open_wt, open_wc, open_wct
Create	mkdir, creat, open_rc, open_rtc, open_rwc, open_rwtc, open_wc, open_wtc, mknod
Delete	rmdir, unlink
Execute	exec, execve
Exit	exit
Modify_Owner	chown, fchown
Modify_Perm	chmod, fchmod
Rename	rename
Hardlink	link

BASE-RATE FALLACY

- To be of practical use, an intrusion detection system should detect a substantial percentage of intrusions while keeping the false alarm rate at an acceptable level
  - If only a modest percentage of actual intrusions are detected, the system provides a false sense of security
  - If the system frequently triggers an alert when there is no intrusion, then either system managers will begin to ignore the alarms or much time will be wasted analyzing the false alarms
- Because of the nature of the probabilities involved, it is very difficult to meet the standard of high rate of detections with a low rate of false alarms
  - If the actual numbers of intrusions is low compared to the number of legitimate uses of a system, then the false alarm rate will be high unless the test is extremely discriminating
- See Appendix J for a brief background on the mathematics of this problem

DISTRIBUTED INTRUSION DETECTION

- Traditional systems focused on single-system stand-alone facilities
  - The typical organization, however, needs to defend a distributed collection of hosts supported by a LAN or internetwork
  - A more effective defense can be achieved by coordination and cooperation among intrusion detection systems across the network
- Major design issues:



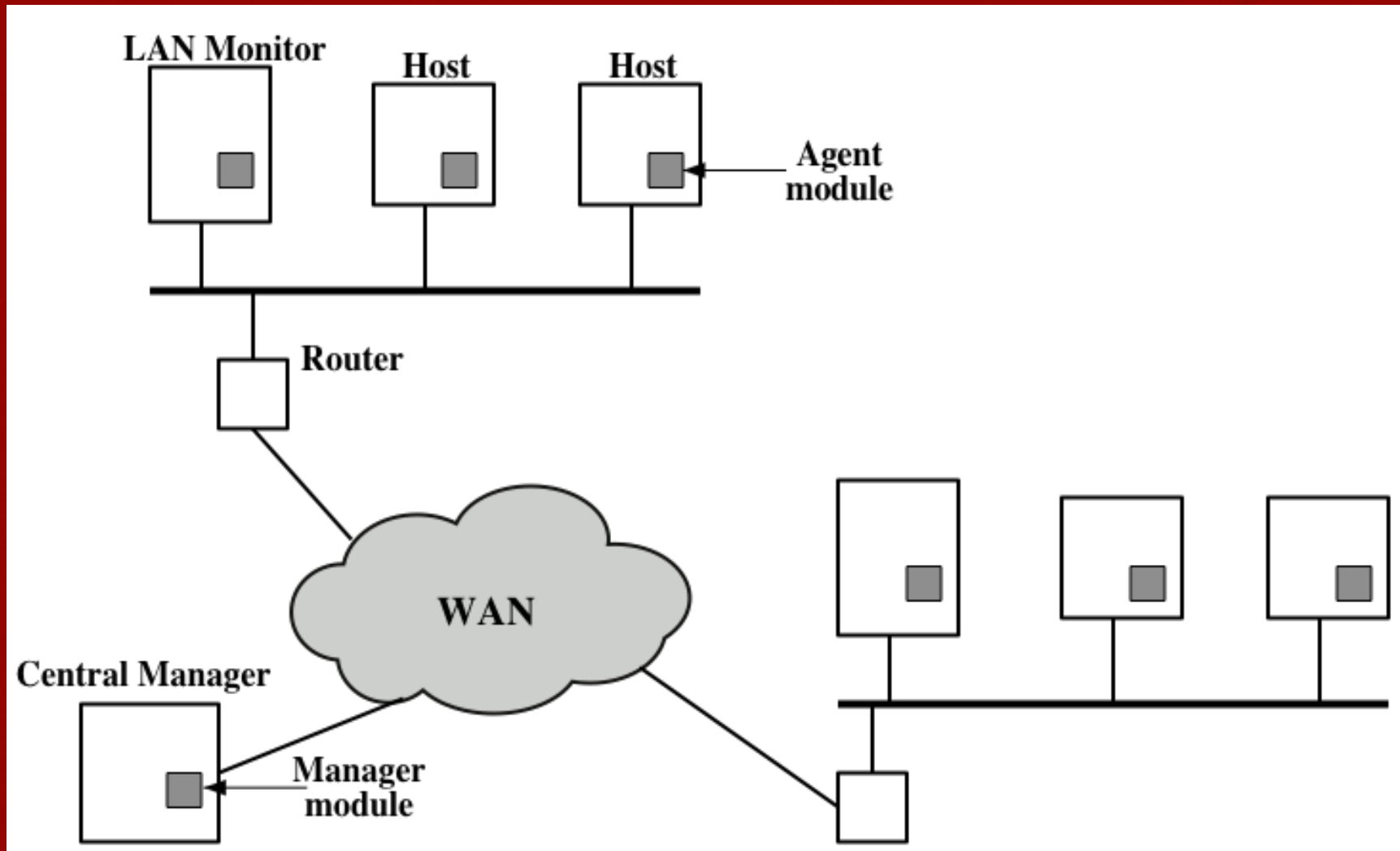


Figure 11.2 Architecture for Distributed Intrusion Detection

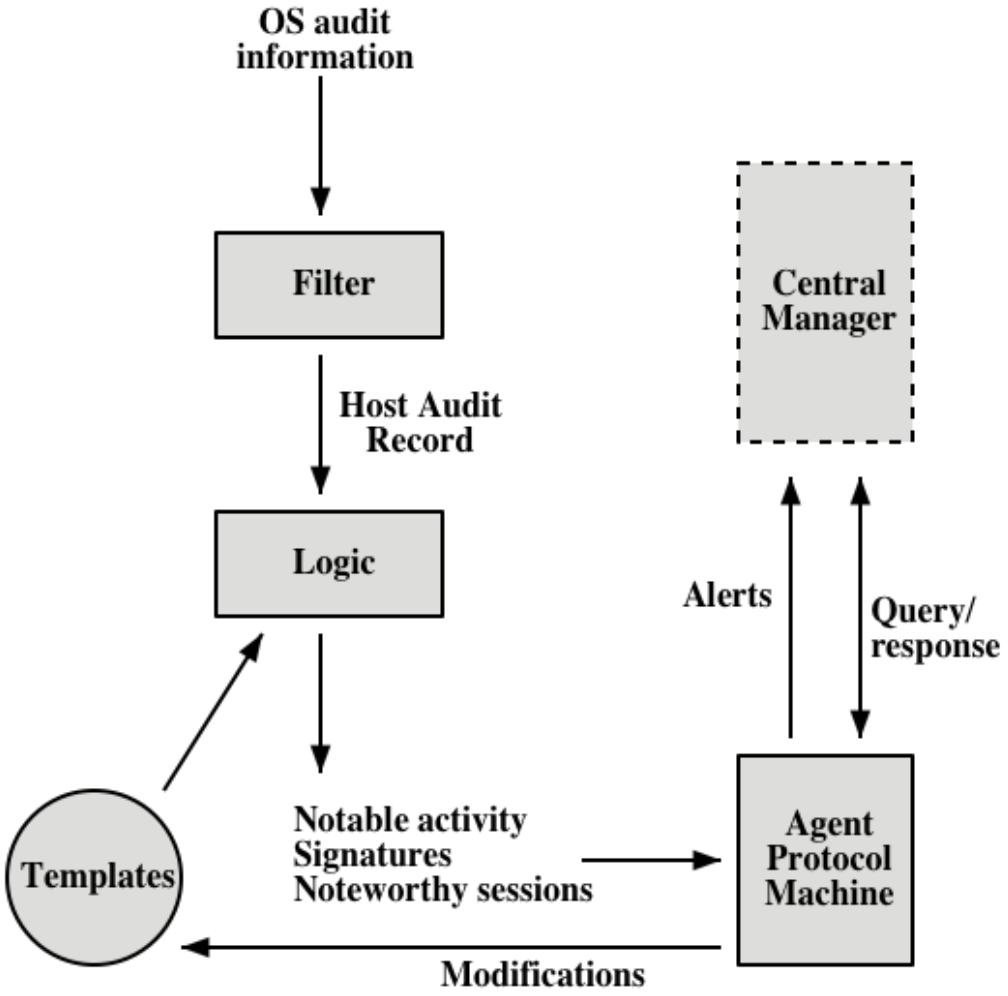


Figure 11.3 Agent Architecture

HONEYPOTS

- Decoy systems that are designed to lure a potential attacker away from critical systems

Has no production value

- These systems are filled with fabricated information designed to appear valuable but that a legitimate user of the system wouldn't access
- Thus, any attempt to communicate with the system is most likely a probe, scan, or attack

Designed to:

- Divert an attacker from accessing critical systems
- Collect information about the attacker's activity
- Encourage the attacker to stay on the system long enough for administrators to respond

- Because any attack against the honeypot is made to seem successful, administrators have time to mobilize and log and track the attacker without ever exposing productive systems

- Recent research has focused on building entire honeypot networks that emulate an enterprise, possible with actual or simulated traffic and data

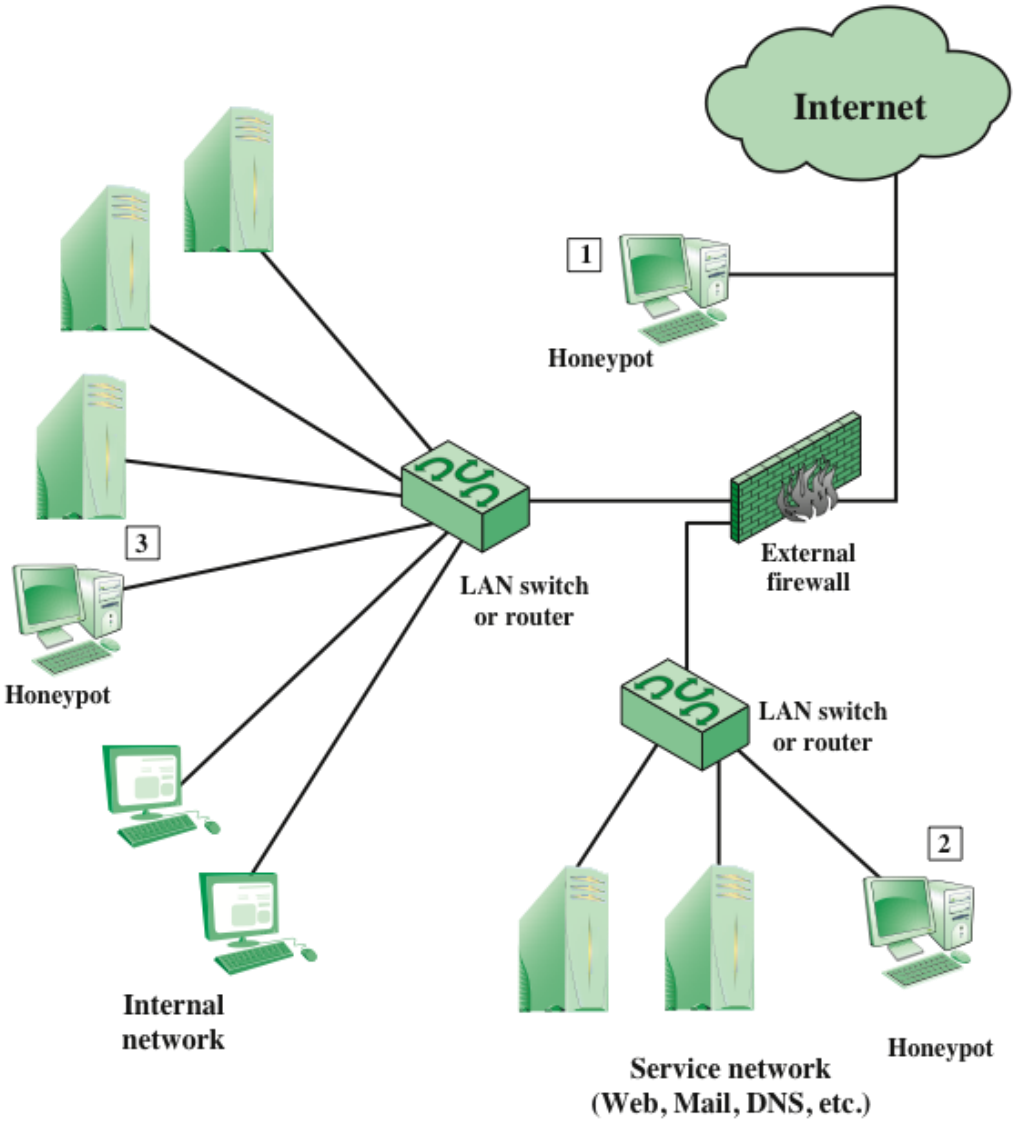


Figure 11.4 Example of Honeypot Deployment

INTRUSION DETECTION EXCHANGE FORMAT

- To facilitate the development of distributed intrusion detection systems that can function across a wide range of platforms and environments, standards are needed to support interoperability
- IETF Intrusion Detection Working Group
  - Purpose of the group is to define data formats and exchange procedures for sharing information of interest to intrusion detection with response systems and to management systems that may need to interact with them
  - Have issued the following RFCs:
    - Intrusion Detection Message Exchange Requirements (RFC 4766)
    - The Intrusion Detection Message Exchange Format (RFC 4765)
    - The Intrusion Detection Exchange Protocol (RFC 4767)

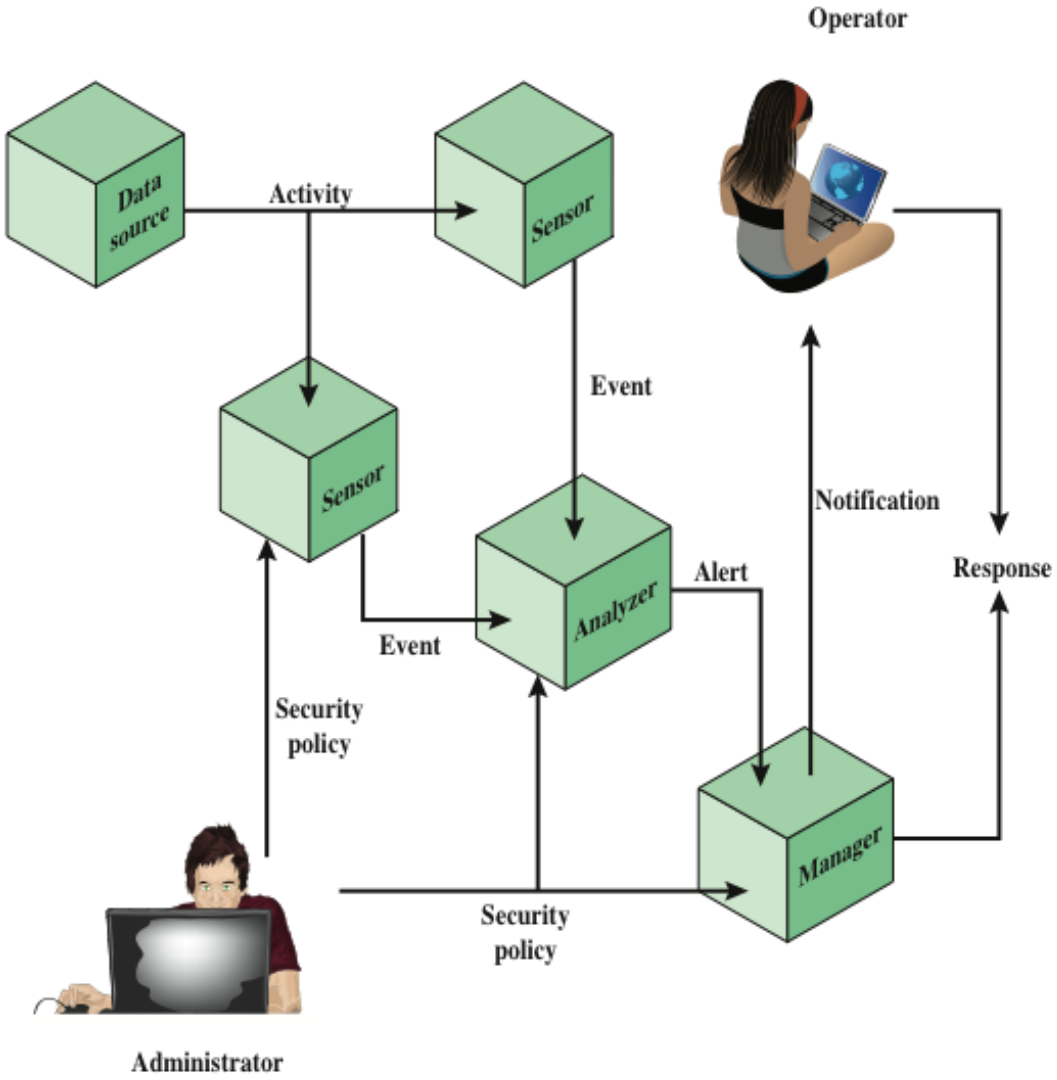


Figure 11.5 Model For Intrusion Detection Message Exchange

PASSWORD MANAGEMENT

- Front line of defense against intruders
- Virtually all multiuser systems require that a user provide not only a name or identifier (ID) but also a password
  - Password serves to authenticate the ID of the individual logging on to the system
  - The ID provides security by:
    - Determining whether the user is authorized to gain access to a system
    - Determining the privileges accorded to the user
    - Used in discretionary access control

ATTACK STRATEGIES AND COUNTERMEASURES

Workstation hijacking

- The attacker waits until a logged-in workstation is unattended
- The standard countermeasure is automatically logging the workstation out after a period of inactivity

Exploiting user mistakes

- Attackers are frequently successful in obtaining passwords by using social engineering tactics that trick the user or an account manager into revealing a password; a user may intentionally share a password to enable a colleague to share files; users tend to write passwords down because it is difficult to remember them
- Countermeasures include user training, intrusion detection, and simpler passwords combined with another authentication mechanism

Offline dictionary attack

- Determined hackers can frequently bypass access controls and gain access to the system's password file
- Countermeasures include controls to prevent unauthorized access to the password file, intrusion detection measures to identify a compromise, and rapid reissuance of passwords should the password file be compromised

Specific account attack

- The attacker targets a specific account and submits password guesses until the correct password is discovered
- The standard countermeasure is an account lockout mechanism, which locks out access to the account after a number of failed login attempts

ATTACK STRATEGIES AND COUNTERMEASURES

Electronic monitoring

- If a password is communicated across a network to log on to a remote system, it is vulnerable to eavesdropping
- Simple encryption will not fix this problem, because the encrypted password is, in effect, the password and can be observed and reused by an adversary

Password guessing against single user

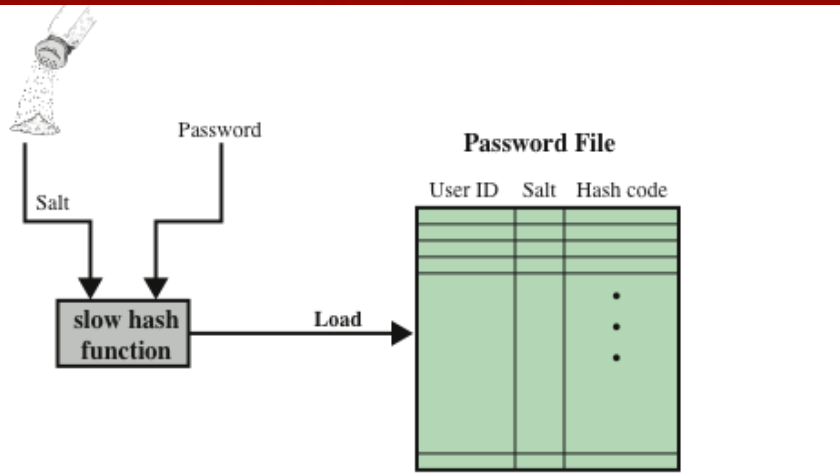
- The attacker attempts to gain knowledge about the account holder and system password policies and uses that knowledge to guess the password
- Countermeasures include training in and enforcement of password policies that make passwords difficult to guess

Exploiting multiple password use

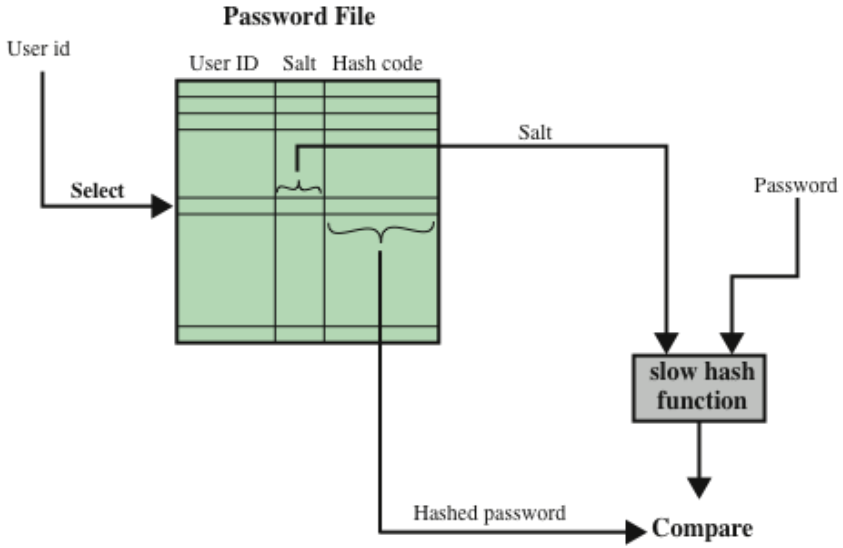
- Attacks can become much more effective or damaging if different network devices share the same or a similar password for a given user
- Countermeasures include a policy that forbids the same or similar password on particular network devices

Popular password attack

- Attack is to use a popular password and try it against a wide range of user IDs
- Countermeasures include policies to inhibit the selection by users of common passwords and scanning the IP addresses of authentication requests and client cookies for submission patterns



(a) Loading a new password



(b) Verifying a password

Figure 11.6 UNIX Password Scheme

UNIX IMPLEMENTATIONS

- Crypt(3)
  - Was designed to discourage guessing attacks
  - This particular implementation is now considered inadequate
  - Despite its known weaknesses, this UNIX scheme is still often required for compatibility with existing account management software or in multivendor environments
- MD5 secure hash algorithm
  - The recommended hash function for many UNIX systems, including Linux, Solaris, and FreeBSD
  - Far slower than crypt(3)
- Bcrypt
  - Developed for OpenBSD
  - Probably the most secure version of the UNIX hash/salt scheme
  - Uses a hash function based on the Blowfish symmetric block cipher
  - Slow to execute
  - Includes a cost variable

Table 11.3

Passwords Cracked from a Sample Set of 13,797 Accounts [KLEI90]

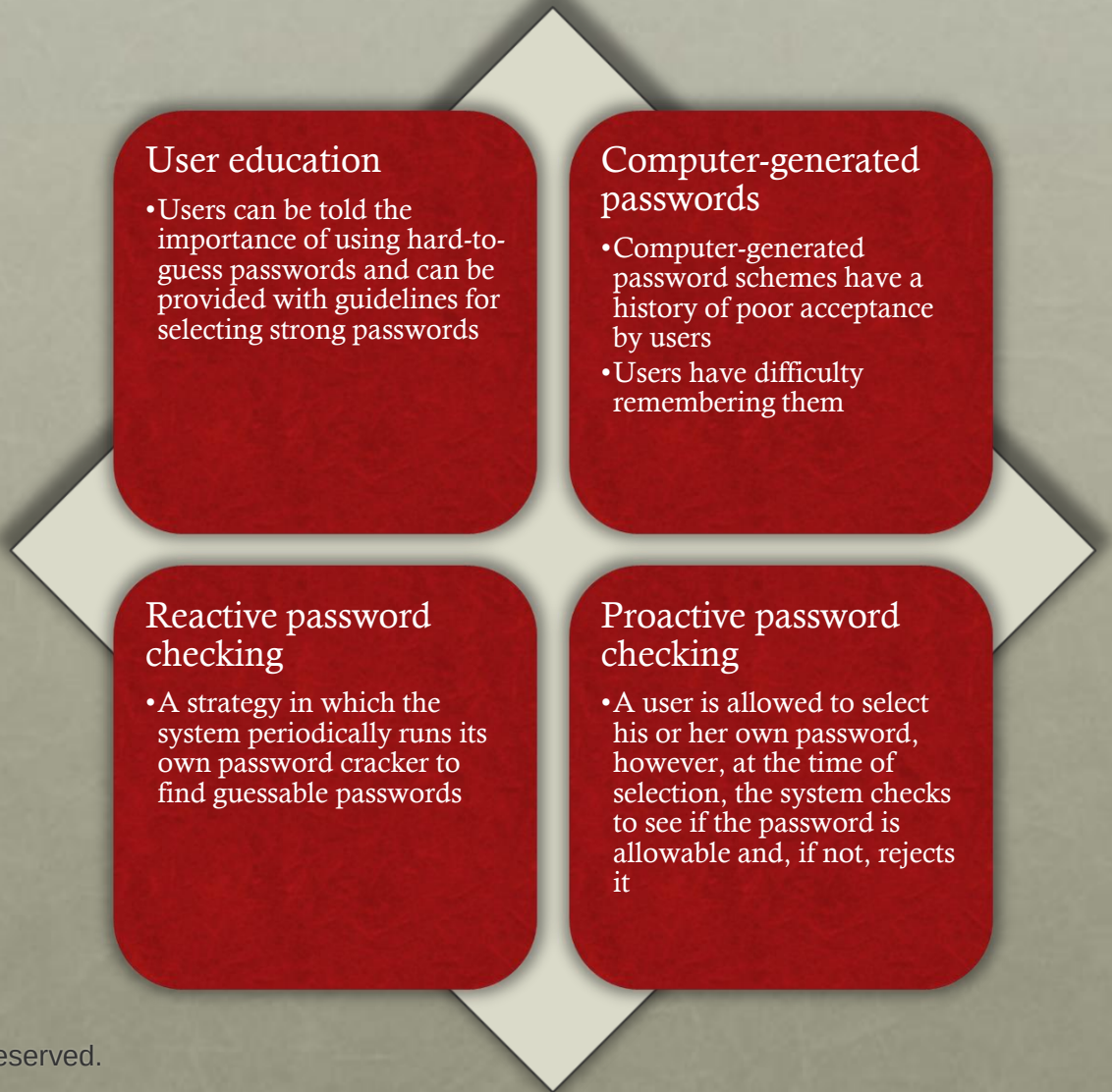
(This table can be found on page 386 in the textbook.)

Type of Password	Search Size	Number of Matches	Percentage of Passwords Matched	Cost/Benefit Ratio[a]
User/account name	130	368	2.7%	2.830
Character sequences	866	22	0.2%	0.025
Numbers	427	9	0.1%	0.021
Chinese	392	56	0.4%	0.143
Place names	628	82	0.6%	0.131
Common names	2239	548	4.0%	0.245
Female names	4280	161	1.2%	0.038
Male names	2866	140	1.0%	0.049
Uncommon names	4955	130	0.9%	0.026
Myths & legends	1246	66	0.5%	0.053
Shakespearean	473	11	0.1%	0.023
Sports terms	238	32	0.2%	0.134
Science fiction	691	59	0.4%	0.085
Movies and actors	99	12	0.1%	0.121
Cartoons	92	9	0.1%	0.098
Famous people	290	55	0.4%	0.190
Phrases and patterns	933	253	1.8%	0.271
Surnames	33	9	0.1%	0.273
Biology	58	1	0.0%	0.017
System dictionary	19683	1027	7.4%	0.052
Machine names	9018	132	1.0%	0.015
Mnemonics	14	2	0.0%	0.143
King James bible	7525	83	0.6%	0.011
Miscellaneous words	3212	54	0.4%	0.017
Yiddish words	56	0	0.0%	0.000
Asteroids	2407	19	0.1%	0.007
TOTAL	62727	3340	24.2%	0.053

*** Computed as the number of matches divided by the search size. The more words that needed to be tested for a match, the lower the cost/benefit ratio.**

PASSWORD SELECTION STRATEGIES

- The goal is to eliminate guessable passwords while allowing the user to select a password that is memorable
- Four basic techniques are in use:



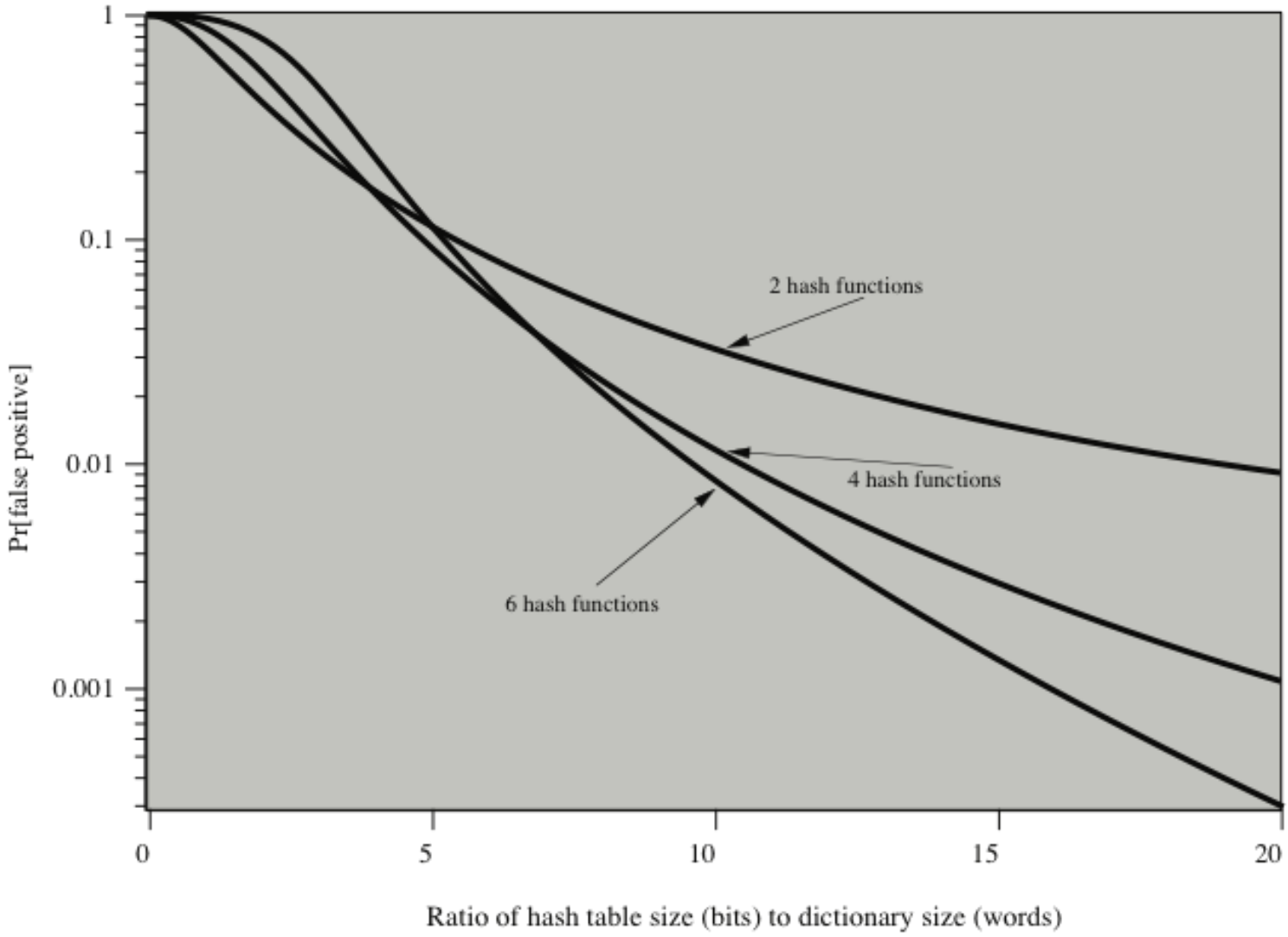


Figure 11.7 Performance of Bloom Filter

SUMMARY

- Intruders
  - Behavior patterns
  - Intrusion techniques
- Intrusion detection
  - Audit records
  - Statistical anomaly detection
  - Rule-based intrusion detection
  - The base-rate fallacy
  - Distributed intrusion detection
  - Honeypots
  - Intrusion detection exchange format
- Password management
  - The vulnerability of passwords
  - The use of hashed passwords
  - User password choices
  - Password selection strategies
  - Bloom filter