

**Figure 21.3** Example Firewall Configuration

1. The internal firewall adds more stringent filtering capability, compared to the external firewall, in order to protect enterprise servers and workstations from external attack.
2. The internal firewall provides two-way protection with respect to the DMZ. First, the internal firewall protects the remainder of the network from attacks launched from DMZ systems. Such attacks might originate from worms, root-kits, bots, or other malware lodged in a DMZ system. Second, an internal firewall can protect the DMZ systems from attack from the internal protected network.
3. Multiple internal firewalls can be used to protect portions of the internal network from each other. For example, firewalls can be configured so that internal servers are protected from internal workstations and vice versa. A common practice is to place the DMZ on a different network interface on the external firewall from that used to access the internal networks.

## 21.2 INTRUSION DETECTION SYSTEMS

It is useful to begin this section by defining the following terms:

- **Intrusion:** Violations of security policy, usually characterized as attempts to affect the confidentiality, integrity, or availability of a computer or network. These violations can come from attackers accessing systems from the Internet or from authorized users of the systems who attempt to overstep their legitimate authorization levels or who use their legitimate access to the system to conduct unauthorized activity.
- **Intrusion detection:** The process of collecting information about events occurring in a computer system or network and analyzing them for signs of intrusions.
- **Intrusion detection system:** Hardware or software products that gather and analyze information from various areas within a computer or a network for the purpose of finding, and providing real-time or near-real-time warning of, attempts to access system resources in an unauthorized manner.

Intrusion detection systems (IDSs) can be classified as follows:

- **Host-based IDS:** Monitors the characteristics of a single host and the events occurring within that host for suspicious activity. This vantage point allows host-based IDSs to determine exactly which processes and user accounts are involved in a particular attack on the OS. Furthermore, unlike network-based IDSs, host-based IDSs can more readily see the intended outcome of an attempted attack, because they can directly access and monitor the data files and system processes usually targeted by attacks.
- **Network-based IDS:** Monitors network traffic for particular network segments or devices and analyzes network, transport, and application protocols to identify suspicious activity.

An IDS comprises three logical components:

- **Sensors:** Sensors are responsible for collecting data. The input for a sensor may be any part of a system that could contain evidence of an intrusion. Types of input to a sensor include network packets, log files, and system call traces. Sensors collect and forward this information to the analyzer.
- **Analyzers:** Analyzers receive input from one or more sensors or from other analyzers. The analyzer is responsible for determining if an intrusion has occurred. The output of this component is an indication that an intrusion has occurred. The output may include evidence supporting the conclusion that an intrusion occurred. The analyzer may provide guidance about what actions to take as a result of the intrusion.
- **User interface:** The user interface to an IDS enables a user to view output from the system or control the behavior of the system. In some systems, the user interface may equate to a manager, director, or console component.

## Basic Principles

Authentication facilities, access control facilities, and firewalls all play a role in countering intrusions. Another 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 IDS can serve as a deterrent, thus acting to prevent intrusions.
3. Intrusion detection enables the collection of information about intrusion techniques that can be used to strengthen intrusion prevention measures.

## Approaches to Intrusion Detection

Intrusion detection assumes 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.

There are two general approaches to intrusion detection: misuse detection and anomaly detection (Figure 21.4).

**Misuse detection** is based on rules that specify system events, sequences of events, or observable properties of a system that are believed to be symptomatic of security incidents. Misuse detectors use various pattern-matching algorithms, operating on large databases of attack patterns, or *signatures*. An advantage of misuse detection is that it is accurate and generates few false alarms. A disadvantage is that it cannot detect novel or unknown attacks.

**Anomaly detection** searches for activity that is different from the normal behavior of system entities and system resources. An advantage of anomaly detection is that it is able to detect previously unknown attacks based on an audit of activity. A disadvantage is that there is a significant trade-off between false positives and false negatives. Figure 21.5 suggests, in abstract terms, the nature of the task confronting the designer of an anomaly detection system. Although the typical behavior of an intruder differs from the typical behavior of an authorized user, there is an overlap

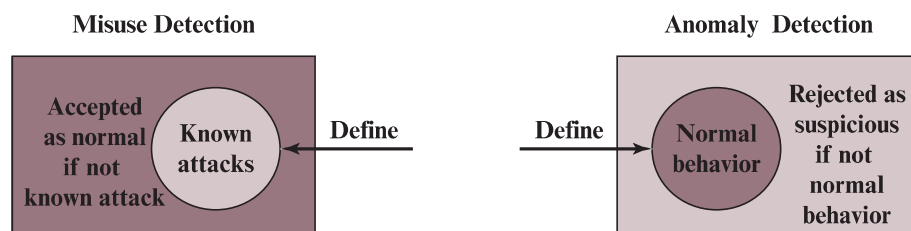
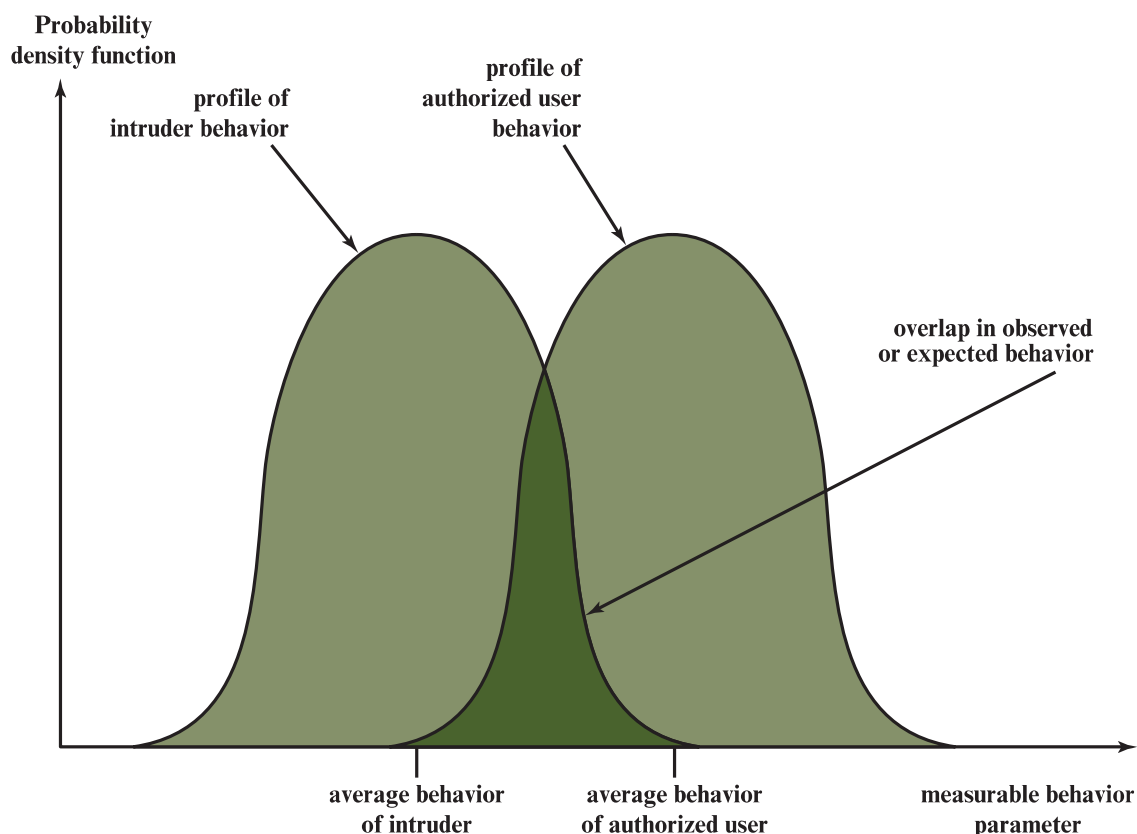


Figure 21.4 Approaches to Intrusion Detection



**Figure 21.5** Profiles of Behavior of Intruders and Authorized Users

**Table 21.2** Test Outcomes

Test Result	Condition A Occurs	Condition A Does Not Occur
Test says “A”	True positive	False positive
Test says “NOT A”	False negative	True negative

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 anomaly detection.

Table 21.2 clarifies the relationship between the terms false positive, true positive, false negative, and true negative.

### Host-Based Intrusion Detection Techniques

Host-based IDSs add a specialized layer of security software to vulnerable or sensitive systems; examples include database servers and administrative systems. The host-based IDS monitors activity on the system in a variety of ways to detect suspicious behavior. In some cases, an IDS can halt an attack before any damage

is done, but its primary purpose is to detect intrusions, log suspicious events, and send alerts.

The primary benefit of a host-based IDS is that it can detect both external and internal intrusions, something that is not possible either with network-based IDSs or firewalls.

Host-based IDSs use one or a combination of anomaly and misuse protection. For anomaly detection, two common strategies are:

- **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.

### Network-Based Intrusion Detection Systems

A network-based ID system (NIDS) monitors the traffic on its network segment as a data source. This is generally accomplished by placing the network interface card in promiscuous mode to capture all network traffic that crosses its network segment. Network traffic on other segments, and traffic on other means of communication (like phone lines), can't be monitored by a single NIDS.

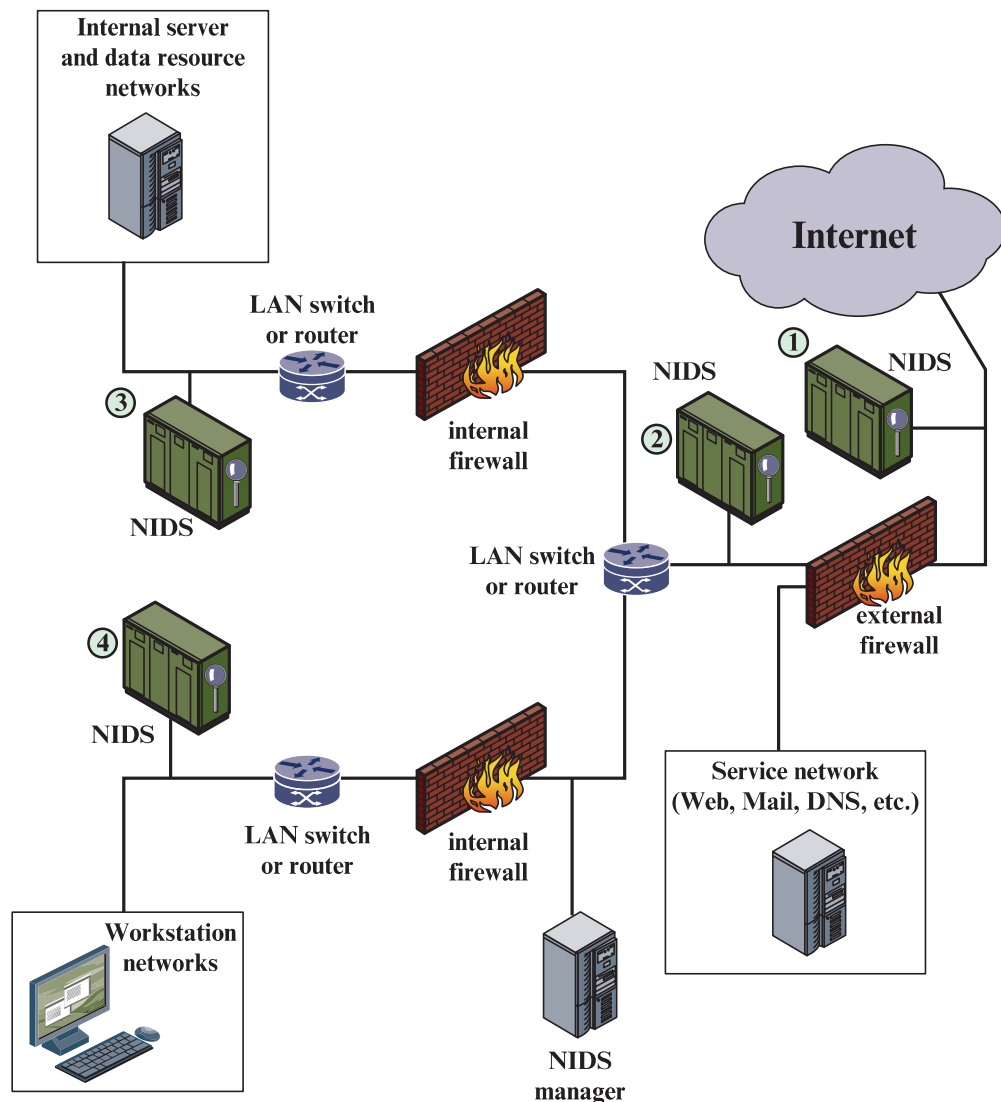
**NIDS FUNCTION** Network-based ID involves looking at the packets on the network as they pass by some sensor. Packets are considered to be of interest if they match a signature. Three primary types of signatures are string signatures, port signatures, and header condition signatures.

String signatures look for a text string that indicates a possible attack. An example string signature for UNIX might be "cat "+ +" >/.rhosts", which if successful, might cause a UNIX system to become extremely vulnerable to network attack. To refine the string signature to reduce the number of false positives, it may be necessary to use a compound string signature. A compound string signature for a common Web server attack might be "cgi-bin" AND "aglimpse" AND "IFS".

Port signatures simply watch for connection attempts to well known, frequently attacked ports. Examples of these ports include telnet (TCP port 23), FTP (TCP port 21/20), SUNRPC (TCP/UDP port 111), and IMAP (TCP port 143). If any of these ports aren't used by the site, then incoming packets to these ports are suspicious.

Header signatures watch for dangerous or illogical combinations in packet headers. The most famous example is WinNuke, where a packet is destined for a NetBIOS port and the Urgent pointer, or Out Of Band pointer is set. This resulted in the "blue screen of death" for Windows systems. Another well-known header signature is a TCP packet with both the SYN and FIN flags set, signifying that the requestor wishes to start and stop a connection at the same time.

**NIDS PLACEMENT** An NIDS sensor can only see the packets that happen to be carried on the network segment to which it is attached. Accordingly, a NIDS deployment is typically set up as a number of sensors distributed on key network points to passively gather traffic data and feed information on potential threats to a central



**Figure 21.6** Example of NIDS Sensor Deployment

NIDS manager. Figure 21.6 gives examples of NIDS sensor placement. There are four types of locations for the sensors:

1. Outside the main enterprise firewall. Useful for establishing the level of threat for a given enterprise network. Those responsible for winning management support for security efforts can find this placement valuable.
2. In the network DMZ (inside the main firewall but outside internal firewalls). This location can monitor for penetration attempts that target Web and other services generally open to outsiders.
3. Behind internal firewalls, positioned to monitor major backbone networks, such as those that support internal servers and database resources.
4. Behind internal firewalls, positioned to monitor LANs that support user workstations and servers specific to a single department. Locations 3 and 4 in Figure 21.6 can monitor for more specific attacks at network segments, as well as attacks originating from inside the organization.