

6.5 KEY TERMS, REVIEW QUESTIONS, AND PROBLEMS

Key Terms

Alert protocol Change Cipher Spec protocol Handshake protocol	HTTPS (HTTP over SSL) Master Secret Secure Shell (SSH)	Secure Socket Layer (SSL) Transport Layer Security (TLS)
---	--	---

Review Questions

- 6.1 What are the advantages of each of the three approaches shown in Figure 6.1?
- 6.2 What protocols comprise TLS?
- 6.3 What is the difference between a TLS connection and a TLS session?
- 6.4 List and briefly define the parameters that define a TLS session state.
- 6.5 List and briefly define the parameters that define a TLS session connection.
- 6.6 What services are provided by the TLS Record Protocol?
- 6.7 What steps are involved in the TLS Record Protocol transmission?
- 6.8 Give brief details about different levels of awareness of a connection in HTTPS.
- 6.9 Which protocol was replaced by SSH and why? Which version is currently in the process of being standardized?
- 6.10 List and briefly define the SSH protocols.

Problems

- 6.1 In SSL and TLS, why is there a separate Change Cipher Spec Protocol rather than including a `change_cipher_spec` message in the Handshake Protocol?
- 6.2 What purpose does the MAC serve during the change cipher spec TLS exchange?
- 6.3 Consider the following threats to Web security and describe how each is countered by a particular feature of TLS.
 - a. Brute-Force Cryptanalytic Attack: An exhaustive search of the key space for a conventional encryption algorithm.
 - b. Known Plaintext Dictionary Attack: Many messages will contain predictable plaintext, such as the HTTP GET command. An attacker constructs a dictionary containing every possible encryption of the known-plaintext message. When an encrypted message is intercepted, the attacker takes the portion containing the encrypted known plaintext and looks up the ciphertext in the dictionary. The ciphertext should match against an entry that was encrypted with the same secret key. If there are several matches, each of these can be tried against the full ciphertext to determine the right one. This attack is especially effective against small key sizes (e.g., 40-bit keys).
 - c. Replay Attack: Earlier TLS handshake messages are replayed.
 - d. Man-in-the-Middle Attack: An attacker interposes during key exchange, acting as the client to the server and as the server to the client.
 - e. Password Sniffing: Passwords in HTTP or other application traffic are eavesdropped.
 - f. IP Spoofing: Uses forged IP addresses to fool a host into accepting bogus data.

- g. IP Hijacking: An active, authenticated connection between two hosts is disrupted and the attacker takes the place of one of the hosts.
 - h. SYN Flooding: An attacker sends TCP SYN messages to request a connection but does not respond to the final message to establish the connection fully. The attacked TCP module typically leaves the “half-open connection” around for a few minutes. Repeated SYN messages can clog the TCP module.
- 6.4 Based on what you have learned in this chapter, is it possible in TLS for the receiver to reorder TLS record blocks that arrive out of order? If so, explain how it can be done. If not, why not?
- 6.5 For SSH packets, what is the advantage, if any, of not including the MAC in the scope of the packet encryption?

WIRELESS NETWORK SECURITY

7.1 Wireless Security

- Wireless Network Threats
- Wireless Security Measures

7.2 Mobile Device Security

- Security Threats
- Mobile Device Security Strategy

7.3 IEEE 802.11 Wireless LAN Overview

- The Wi-Fi Alliance
- IEEE 802 Protocol Architecture
- IEEE 802.11 Network Components and Architectural Model
- IEEE 802.11 Services

7.4 IEEE 802.11i Wireless LAN Security

- IEEE 802.11i Services
- IEEE 802.11i Phases of Operation
 - Discovery Phase
 - Authentication Phase
 - Key Management Phase
 - Protected Data Transfer Phase
- The IEEE 802.11i Pseudorandom Function

7.5 Key Terms, Review Questions, and Problems

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

- ◆ Present an overview of security threats and countermeasures for wireless networks.
- ◆ Understand the unique security threats posed by the use of mobile devices with enterprise networks.
- ◆ Describe the principal elements in a mobile device security strategy.
- ◆ Understand the essential elements of the IEEE 802.11 wireless LAN standard.
- ◆ Summarize the various components of the IEEE 802.11i wireless LAN security architecture.

This chapter begins with a general overview of wireless security issues. We then focus on the relatively new area of mobile device security, examining threats and countermeasures for mobile devices used in the enterprise. Then, we look at the IEEE 802.11i standard for wireless LAN security. This standard is part of IEEE 802.11, also referred to as Wi-Fi. We begin the discussion with an overview of IEEE 802.11, and then we look in some detail at IEEE 802.11i.

7.1 WIRELESS SECURITY

Wireless networks, and the wireless devices that use them, introduce a host of security problems over and above those found in wired networks. Some of the key factors contributing to the higher security risk of wireless networks compared to wired networks include the following [MA10]:

- **Channel:** Wireless networking typically involves broadcast communications, which is far more susceptible to eavesdropping and jamming than wired networks. Wireless networks are also more vulnerable to active attacks that exploit vulnerabilities in communications protocols.
- **Mobility:** Wireless devices are, in principal and usually in practice, far more portable and mobile than wired devices. This mobility results in a number of risks, described subsequently.
- **Resources:** Some wireless devices, such as smartphones and tablets, have sophisticated operating systems but limited memory and processing resources with which to counter threats, including denial of service and malware.
- **Accessibility:** Some wireless devices, such as sensors and robots, may be left unattended in remote and/or hostile locations. This greatly increases their vulnerability to physical attacks.

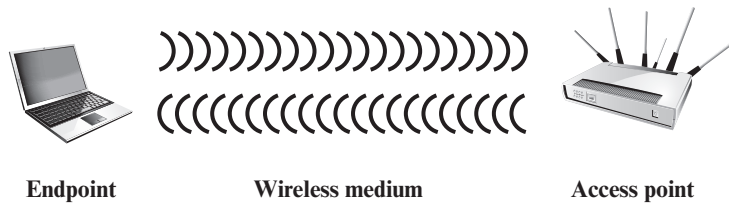


Figure 7.1 Wireless Networking Components

In simple terms, the wireless environment consists of three components that provide point of attack (Figure 7.1). The wireless client can be a cell phone, a Wi-Fi-enabled laptop or tablet, a wireless sensor, a Bluetooth device, and so on. The wireless access point provides a connection to the network or service. Examples of access points are cell towers, Wi-Fi hotspots, and wireless access points to wired local or wide area networks. The transmission medium, which carries the radio waves for data transfer, is also a source of vulnerability.

Wireless Network Threats

[CHOI08] lists the following security threats to wireless networks:

- **Accidental association:** Company wireless LANs or wireless access points to wired LANs in close proximity (e.g., in the same or neighboring buildings) may create overlapping transmission ranges. A user intending to connect to one LAN may unintentionally lock on to a wireless access point from a neighboring network. Although the security breach is accidental, it nevertheless exposes resources of one LAN to the accidental user.
- **Malicious association:** In this situation, a wireless device is configured to appear to be a legitimate access point, enabling the operator to steal passwords from legitimate users and then penetrate a wired network through a legitimate wireless access point.
- **Ad hoc networks:** These are peer-to-peer networks between wireless computers with no access point between them. Such networks can pose a security threat due to a lack of a central point of control.
- **Nontraditional networks:** Nontraditional networks and links, such as personal network Bluetooth devices, barcode readers, and handheld PDAs, pose a security risk in terms of both eavesdropping and spoofing.
- **Identity theft (MAC spoofing):** This occurs when an attacker is able to eavesdrop on network traffic and identify the MAC address of a computer with network privileges.
- **Man-in-the middle attacks:** This type of attack is described in Chapter 3 in the context of the Diffie–Hellman key exchange protocol. In a broader sense, this attack involves persuading a user and an access point to believe that they are talking to each other when in fact the communication is going through an intermediate attacking device. Wireless networks are particularly vulnerable to such attacks.

- **Denial of service (DoS):** This type of attack is discussed in detail in Chapter 10. In the context of a wireless network, a DoS attack occurs when an attacker continually bombards a wireless access point or some other accessible wireless port with various protocol messages designed to consume system resources. The wireless environment lends itself to this type of attack, because it is so easy for the attacker to direct multiple wireless messages at the target.
- **Network injection:** A network injection attack targets wireless access points that are exposed to nonfiltered network traffic, such as routing protocol messages or network management messages. An example of such an attack is one in which bogus reconfiguration commands are used to affect routers and switches to degrade network performance.

Wireless Security Measures

Following [CHOI08], we can group wireless security measures into those dealing with wireless transmissions, wireless access points, and wireless networks (consisting of wireless routers and endpoints).

SECURING WIRELESS TRANSMISSIONS The principal threats to wireless transmission are eavesdropping, altering or inserting messages, and disruption. To deal with eavesdropping, two types of countermeasures are appropriate:

- **Signal-hiding techniques:** Organizations can take a number of measures to make it more difficult for an attacker to locate their wireless access points, including turning off service set identifier (SSID) broadcasting by wireless access points; assigning cryptic names to SSIDs; reducing signal strength to the lowest level that still provides requisite coverage; and locating wireless access points in the interior of the building, away from windows and exterior walls. Greater security can be achieved by the use of directional antennas and of signal-shielding techniques.
- **Encryption:** Encryption of all wireless transmission is effective against eavesdropping to the extent that the encryption keys are secured.

The use of encryption and authentication protocols is the standard method of countering attempts to alter or insert transmissions.

The methods discussed in Chapter 10 for dealing with DoS apply to wireless transmissions. Organizations can also reduce the risk of unintentional DoS attacks. Site surveys can detect the existence of other devices using the same frequency range, to help determine where to locate wireless access points. Signal strengths can be adjusted and shielding used in an attempt to isolate a wireless environment from competing nearby transmissions.

SECURING WIRELESS ACCESS POINTS The main threat involving wireless access points is unauthorized access to the network. The principal approach for preventing such access is the IEEE 802.1X standard for port-based network access control. The standard provides an authentication mechanism for devices wishing to attach to a LAN or wireless network. The use of 802.1X can prevent rogue access points and other unauthorized devices from becoming insecure backdoors.

Section 5.3 provides an introduction to 802.1X.

SECURING WIRELESS NETWORKS [CHOI08] recommends the following techniques for wireless network security:

1. Use encryption. Wireless routers are typically equipped with built-in encryption mechanisms for router-to-router traffic.
2. Use antivirus and antispyware software, and a firewall. These facilities should be enabled on all wireless network endpoints.
3. Turn off identifier broadcasting. Wireless routers are typically configured to broadcast an identifying signal so that any device within range can learn of the router's existence. If a network is configured so that authorized devices know the identity of routers, this capability can be disabled, so as to thwart attackers.
4. Change the identifier on your router from the default. Again, this measure thwarts attackers who will attempt to gain access to a wireless network using default router identifiers.
5. Change your router's pre-set password for administration. This is another prudent step.
6. Allow only specific computers to access your wireless network. A router can be configured to only communicate with approved MAC addresses. Of course, MAC addresses can be spoofed, so this is just one element of a security strategy.

7.2 MOBILE DEVICE SECURITY

Prior to the widespread use of smartphones, the dominant paradigm for computer and network security in organizations was as follows. Corporate IT was tightly controlled. User devices were typically limited to Windows PCs. Business applications were controlled by IT and either run locally on endpoints or on physical servers in data centers. Network security was based upon clearly defined perimeters that separated trusted internal networks from the untrusted Internet. Today, there have been massive changes in each of these assumptions. An organization's networks must accommodate the following:

- **Growing use of new devices:** Organizations are experiencing significant growth in employee use of mobile devices. In many cases, employees are allowed to use a combination of endpoint devices as part of their day-to-day activities.
- **Cloud-based applications:** Applications no longer run solely on physical servers in corporate data centers. Quite the opposite, applications can run anywhere—on traditional physical servers, on mobile virtual servers, or in the cloud. Additionally, end users can now take advantage of a wide variety of cloud-based applications and IT services for personal and professional use. Facebook can be used for an employee's personal profiles or as a component of a corporate marketing campaign. Employees depend upon Skype to speak with friends abroad or for legitimate business video conferencing. Dropbox and Box can be used to distribute documents between corporate and personal devices for mobility and user productivity.

- **De-perimeterization:** Given new device proliferation, application mobility, and cloud-based consumer and corporate services, the notion of a static network perimeter is all but gone. Now there are a multitude of network perimeters around devices, applications, users, and data. These perimeters have also become quite dynamic as they must adapt to various environmental conditions such as user role, device type, server virtualization mobility, network location, and time-of-day.
- **External business requirements:** The enterprise must also provide guests, third-party contractors, and business partners network access using various devices from a multitude of locations.

The central element in all of these changes is the mobile computing device. Mobile devices have become an essential element for organizations as part of the overall network infrastructure. Mobile devices such as smartphones, tablets, and memory sticks provide increased convenience for individuals as well as the potential for increased productivity in the workplace. Because of their widespread use and unique characteristics, security for mobile devices is a pressing and complex issue. In essence, an organization needs to implement a security policy through a combination of security features built into the mobile devices and additional security controls provided by network components that regulate the use of the mobile devices.

Security Threats

Mobile devices need additional, specialized protection measures beyond those implemented for other client devices, such as desktop and laptop devices that are used only within the organization's facilities and on the organization's networks. SP 800-14 (*Guidelines for Managing and Securing Mobile Devices in the Enterprise*, July 2012) lists seven major security concerns for mobile devices. We examine each of these in turn.

LACK OF PHYSICAL SECURITY CONTROLS Mobile devices are typically under the complete control of the user, and are used and kept in a variety of locations outside the organization's control, including off premises. Even if a device is required to remain on premises, the user may move the device within the organization between secure and nonsecured locations. Thus, theft and tampering are realistic threats.

The security policy for mobile devices must be based on the assumption that any mobile device may be stolen or at least accessed by a malicious party. The threat is twofold: A malicious party may attempt to recover sensitive data from the device itself, or may use the device to gain access to the organization's resources.

USE OF UNTRUSTED MOBILE DEVICES In addition to company-issued and company-controlled mobile devices, virtually all employees will have personal smartphones and/or tablets. The organization must assume that these devices are not trustworthy. That is, the devices may not employ encryption and either the user or a third party may have installed a bypass to the built-in restrictions on security, operating system use, and so on.

USE OF UNTRUSTED NETWORKS If a mobile device is used on premises, it can connect to organization resources over the organization's own in-house wireless networks. However, for off-premises use, the user will typically access organizational resources via Wi-Fi or cellular access to the Internet and from the Internet to the organization. Thus, traffic that includes an off-premises segment is potentially susceptible to eavesdropping or man-in-the-middle types of attacks. Thus, the security policy must be based on the assumption that the networks between the mobile device and the organization are not trustworthy.

USE OF APPLICATIONS CREATED BY UNKNOWN PARTIES By design, it is easy to find and install third-party applications on mobile devices. This poses the obvious risk of installing malicious software. An organization has several options for dealing with this threat, as described subsequently.

INTERACTION WITH OTHER SYSTEMS A common feature found on smartphones and tablets is the ability to automatically synchronize data, apps, contacts, photos, and so on with other computing devices and with cloud-based storage. Unless an organization has control of all the devices involved in synchronization, there is considerable risk of the organization's data being stored in an unsecured location, plus the risk of the introduction of malware.

USE OF UNTRUSTED CONTENT Mobile devices may access and use content that other computing devices do not encounter. An example is the Quick Response (QR) code, which is a two-dimensional barcode. QR codes are designed to be captured by a mobile device camera and used by the mobile device. The QR code translates to a URL, so that a malicious QR code could direct the mobile device to malicious Web sites.

USE OF LOCATION SERVICES The GPS capability on mobile devices can be used to maintain a knowledge of the physical location of the device. While this feature might be useful to an organization as part of a presence service, it creates security risks. An attacker can use the location information to determine where the device and user are located, which may be of use to the attacker.

Mobile Device Security Strategy

With the threats listed in the preceding discussion in mind, we outline the principal elements of a mobile device security strategy. They fall into three categories: device security, client/server traffic security, and barrier security (Figure 7.2).

DEVICE SECURITY A number of organizations will supply mobile devices for employee use and preconfigure those devices to conform to the enterprise security policy. However, many organizations will find it convenient or even necessary to adopt a bring-your-own-device (BYOD) policy that allows the personal mobile devices of employees to have access to corporate resources. IT managers should be able to inspect each device before allowing network access. IT will want to establish configuration guidelines for operating systems and applications. For example, "rooted" or "jail-broken" devices are not permitted on the network, and mobile

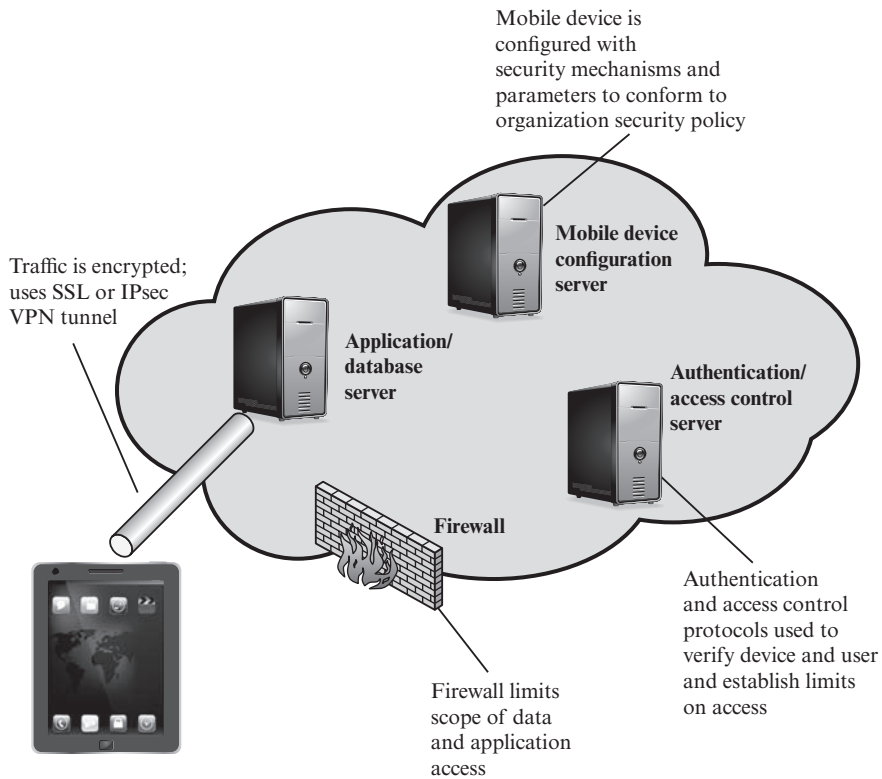


Figure 7.2 Mobile Device Security Elements

devices cannot store corporate contacts on local storage. Whether a device is owned by the organization or BYOD, the organization should configure the device with security controls, including the following:

- Enable auto-lock, which causes the device to lock if it has not been used for a given amount of time, requiring the user to re-enter a four-digit PIN or a password to re-activate the device.
- Enable password or PIN protection. The PIN or password is needed to unlock the device. In addition, it can be configured so that e-mail and other data on the device are encrypted using the PIN or password and can only be retrieved with the PIN or password.
- Avoid using auto-complete features that remember user names or passwords.
- Enable remote wipe.
- Ensure that SSL protection is enabled, if available.
- Make sure that software, including operating systems and applications, is up to date.
- Install antivirus software as it becomes available.