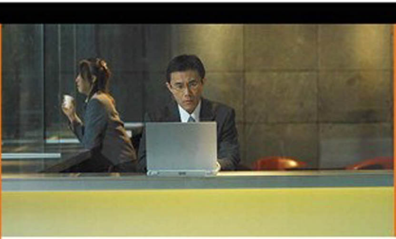
SECURITY



IPSec VPN Design

The definitive design and deployment guide for secure virtual private networks

Vijay Bollapragada, CCIE® No. 1606
Mohamed Khalid, CCIE No. 2435
Scott Wainner

ciscopress.com

IPSec VPN Design

Vijay Bollapragada
Mohamed Khalid
Scott Wainner

Cisco Press

800 East 96th Street
Indianapolis, IN 46240 USA

IPSec VPN Design

Vijay Bollapragada, Mohamed Khalid, Scott Wainner

Published by:
Cisco Press
800 East 96th Street
Indianapolis, IN 46240 USA

Printed in the United States of America 2 3 4 5 6 7 8 9 0

Second Printing March 2006

Library of Congress Cataloging-in-Publication Number: 2002106378

ISBN: 1-58705-111-7

Warning and Disclaimer

This book is designed to provide information about IPSec VPN design. Every effort has been made to make this book as complete and as accurate as possible, but no warranty or fitness is implied.

The information is provided on an “as is” basis. The authors, Cisco Press, and Cisco Systems, Inc. shall have neither liability nor responsibility to any person or entity with respect to any loss or damages arising from the information contained in this book or from the use of the discs or programs that may accompany it.

The opinions expressed in this book belong to the author and are not necessarily those of Cisco Systems, Inc.

Corporate and Government Sales

Cisco Press offers excellent discounts on this book when ordered in quantity for bulk purchases or special sales.

For more information, please contact U.S. Corporate and Government Sales, 1-800-382-3419, corpsales@pearsontechgroup.com.

For sales outside the U.S., please contact International Sales at international@pearsoned.com.

Trademark Acknowledgments

All terms mentioned in this book that are known to be trademarks or service marks have been appropriately capitalized. Cisco Press or Cisco Systems, Inc. cannot attest to the accuracy of this information. Use of a term in this book should not be regarded as affecting the validity of any trademark or service mark.

Feedback Information

At Cisco Press, our goal is to create in-depth technical books of the highest quality and value. Each book is crafted with care and precision, undergoing rigorous development that involves the unique expertise of members from the professional technical community.

Readers' feedback is a natural continuation of this process. If you have any comments regarding how we could improve the quality of this book, or otherwise alter it to better suit your needs, you can contact us through email at feedback@ciscopress.com. Please make sure to include the book title and ISBN in your message.

We greatly appreciate your assistance.

Publisher	John Wait
Editor-in-Chief	John Kane
Cisco Representative	Anthony Wolfenden
Cisco Press Program Manager	Jeff Brady
Executive Editor	Brett Bartow
Production Manager	Patrick Kanouse
Development Editor	Grant Munroe
Project Editor	Sheila Schroeder
Copy Editor	Michelle Grandin
Technical Editors	Anthony Kwan, Suresh Subbarao, Michael Sullenberger
Team Coordinator	Tammi Barnett
Cover Designer	Louisa Adair
Composition	Mark Shirar
Indexer	Tim Wright

CISCO SYSTEMS

Corporate Headquarters
Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA 95134-1706
USA
www.cisco.com
Tel: 408 526-4000
800 553-NETS (6387)
Fax: 408 526-4100

European Headquarters
Cisco Systems International BV
Haarlerbergpark
Haarlerbergweg 13-19
1101 CH Amsterdam
The Netherlands
www-europe.cisco.com
Tel: 31 0 20 357 1000
Fax: 31 0 20 357 1100

Americas Headquarters
Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA 95134-1706
USA
www.cisco.com
Tel: 408 526-7660
Fax: 408 527-0883

Asia Pacific Headquarters
Cisco Systems, Inc.
Capital Tower
168 Robinson Road
#22-01 to #29-01
Singapore 068912
www.cisco.com
Tel: +65 6317 7777
Fax: +65 6317 7799

Cisco Systems has more than 200 offices in the following countries and regions. Addresses, phone numbers, and fax numbers are listed on the **Cisco.com Web site at www.cisco.com/go/offices.**

Argentina • Australia • Austria • Belgium • Brazil • Bulgaria • Canada • Chile • China PRC • Colombia • Costa Rica • Croatia • Czech Republic
Denmark • Dubai, UAE • Finland • France • Germany • Greece • Hong Kong SAR • Hungary • India • Indonesia • Ireland • Israel • Italy
Japan • Korea • Luxembourg • Malaysia • Mexico • The Netherlands • New Zealand • Norway • Peru • Philippines • Poland • Portugal
Puerto Rico • Romania • Russia • Saudi Arabia • Scotland • Singapore • Slovakia • Slovenia • South Africa • Spain • Sweden
Switzerland • Taiwan • Thailand • Turkey • Ukraine • United Kingdom • United States • Venezuela • Vietnam • Zimbabwe

Printed in the USA

About the Authors

Vijay Bollapragada, CCIE No. 1606, is a director in the Network Systems Integration and Test Engineering group at Cisco Systems, where he works on the architecture, design, and validation of complex network solutions. An expert in router architecture and IP Routing, Vijay is a co-author of another Cisco Press publication titled *Inside Cisco IOS Software Architecture*. Vijay is also an adjunct professor in the Electrical Engineering department at Duke University.

Mohamed Khalid, CCIE No. 2435, is a technical leader working with IP VPN solutions at Cisco Systems. He works extensively with service providers across the globe and their associated Cisco account teams to determine technical and engineering requirements for various IP VPN architectures.

Scott Wainner is a Distinguished Systems Engineer in the U.S. Service Provider Sales Organization at Cisco Systems, where he focuses on VPN architecture and solution development. In this capacity, he works directly with customers in a consulting role by providing guidance on IP VPN architectures while interpreting customer requirements and driving internal development initiatives within Cisco Systems. Scott has more than 18 years of experience in the networking industry in various roles including network operations, network installation/provisioning, engineering, and product engineering. Most recently, he has focused his efforts on L2VPN and L3VPN service models using MPLS VPN, Pseudowire Emulation, and IPSec/SSL to provide VPN services to both enterprises and service providers. He holds a B.S. in Electrical Engineering from the United States Air Force Academy and a M.S. in Electronics and Computer Engineering from George Mason University in Fairfax, Virginia. Scott is currently an active member of the IEEE and the IETF.

About the Technical Editors

Anthony Kwan is the director and executive project manager of infrastructure for HTA; CCNP, CCDP, MCSE, Master ASE, MCNE, CCIE(written). He has ten years of experience in the internetworking industry. He designed and built a number of secured enterprise datacenters with an upward budget of $120 million. He also directed a number of consulting firms in building a Network Infrastructure and Technology consulting practice. He is a frequent contributor to Cisco Press and other publications specializing in networking technology. He can be reached at atonio888@yahoo.com.

Suresh Subbarao has worked in the networking area for the last 10 years. He is currently a network engineer at Cisco Systems focusing on security services for Service Providers with a special emphasis on IPSec VPNs.

Michael Sullenberger received a bachelor of science degree in mathematics from Harvey Mudd College in 1981. He started working with computer networks at the Stanford Linear Accelerator Center (SLAC) in 1981 as a Fortran programmer and as a user of the BITnet network, an early world wide 9600 baud network. At SLAC Michael also managed DEC VMS computers and gained knowledge of the DECnet and LAT protocol. He was also part of the introduction of Ethernet and FDDI networks to SLAC. In 1988 Michael moved to the networking group, where he assisted in transforming a large bridged, primarily DECnet, network to a routed multi-protocol, primarily TCP/IP, network. In 1994, he left SLAC to work for a small company, TGV, that wrote TCP/IP stacks and applications for OpenVMS and Windows systems. At TGV he worked in technical support where he learned the details of TCP/IP from the IP layer through the Application layer. TGV was bought by Cisco in 1996, and Michael moved into the Routing Protocols group, where he enhanced his knowledge of TCP/IP by adding information on the link-layer and IP routing protocols. In 1998, Michael moved to the Escalation Team at Cisco, where he continues to expand his TCP/IP knowledge in areas such as NAT, HSRP, GRE and IPsec Encryption. In 2000, he started a project, as the principle architect, that became the Cisco Dynamic Multipoint VPN (DMVPN) solution for scaling IPsec VPN networks. In 2004, the DMVPN solution won the Cisco Pioneer Award. Michael continues to this day working on enhancing DMVPN as well as designing and troubleshooting DMVPN and IPsec networks. Also starting in 2000 Michael has been a speaker each year at the Cisco Networkers Conferences in the area of site-to-site IPsec and DMVPN networks.

Dedications

Vijay Bollapragada: To my best friend and wife, Leena, for her love and encouragement and for allowing me to take precious family time away to write this book. To my two lovely children, Amita and Abhishek, to my parents for instilling the right values in me, and all my wonderful friends.

Thanks to my coauthors, Mo and Scott, for bearing with me during the trials and tribulations of book writing and teaching me things along the way. And thanks to the awesome folks I work with at Cisco that constantly keep me challenged and remind me that there is something new to learn everyday.

Mohamed Khalid: First and foremost, I would like to acknowledge my parents—their dedication, sacrifice, and encouragement have been instrumental in all my achievements and success. Thanks to my wife Farhath, who gave me the time and constant encouragement to finish the book.

Thanks to Scott Wainner, Haseeb, and Sunil who provided valuable technical insights. Last but not least, I am deeply grateful to my friend and co-author, Vijay Bollapragada, who cajoled, encouraged, and assisted me in completing this book.

Scott Wainner: I would like to acknowledge my wife, Jill, for her love, patience, and encouragement. There are never enough hours in the day, so I thank her for caring for our family. I'd also like to thank my children—Craig, Brett, Natalie, and Caroline—for their patience and inspiration in exploring life's possibilities.

Special thanks go to my father and late mother—Tom and Zenith—for being an inspiration and guiding force in my life. To my colleagues, Vijay and Mo, you guys rock and it's been an honor working with you all these years. And finally, I'd like acknowledge my God for granting me the gifts to fulfill this dream.

Acknowledgments

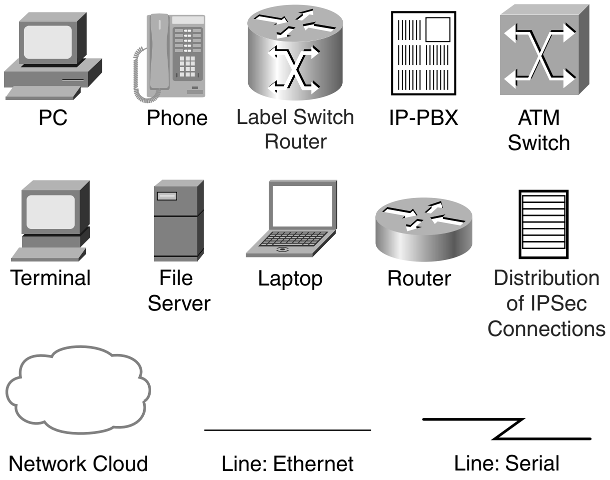
This book would have not been possible without the help of many people whose many comments and suggestions improved the end result. First, we would like to thank the technical reviewers for the book, which include Anthony Kwan, Mike Sullenberger, and Suresh Subbarao. Their knowledge of the subject, attention to detail, and suggestions were invaluable. We would like to thank Brett Bartow of Cisco Press for constantly keeping the pressure and pulling all of this together. Without his help, this project would have never seen the light of day. We would also like to thank Grant Munroe and Chris Cleveland from Cisco Press for their attention to detail and editorial comments that improved the quality of the book tremendously. We would also like to thank the IPSec development team at Cisco—they are the ones that write and perfect the code that makes all the features discussed in this book possible.

This page intentionally left blank

Contents at a Glance

Contents

Icons Used in This Book



Command Syntax Conventions

The conventions used to present command syntax in this book are the same conventions used in the IOS Command Reference. The Command Reference describes these conventions as follows:

- **Boldface** indicates commands and keywords that are entered literally as shown. In actual configuration examples and output (not general command syntax), boldface indicates commands that are manually input by the user (such as a **show** command).
- *Italics* indicate arguments for which you supply actual values.
- Vertical bars (|) separate alternative, mutually exclusive elements.
- Square brackets [ ] indicate optional elements.
- Braces { } indicate a required choice.
- Braces within brackets [{ }] indicate a required choice within an optional element.

Introduction

VPNs are becoming more important for both enterprises and service providers. IPSec specifically is one of the more popular technologies for deploying IP-based VPNs. There are many books in the market that go into technical details of IPSec protocols and cover product level configuration, but they do not address overall design issues for deploying IPSec VPNs.

The Goals of This Book

The objective of this book is to provide you with a good understanding of design and architectural issues of IPSec VPNs. This book will also give you guidance on enabling value-added services and integrating IPSec VPNs with other Layer 3 (MPLS VPN) technologies.

Who Should Read This Book

The primary audience for this book is network engineers involved in design, deployment, and troubleshooting of IPSec VPNs. The assumption in this book is that you have a good understanding of basic IP routing, although IPSec knowledge is not a prerequisite.

How This Book Is Organized

The book is divided into three general parts. Part I covers the general architecture of IPSec, including its protocols and Cisco IOS IPSec implementation details. Part II, beginning with Chapter 5, examines the IPSec VPN design principles covering hub-and-spoke, full-mesh, and fault-tolerant designs. Part II also covers dynamic configuration models used to simplify IPSec VPNs designs, and presents a case study. Part III, beginning with Chapter 8, covers design issues in adding services to an IPSec VPN such as voice, multicast, and integrating IPSec VPNs with MPLs VPNs. The book is organized as follows:

- **Part I, "Introduction and Concepts"**
  - **Chapter 1, "Introduction to VPNs"**—Provides an introduction to VPN concepts and covers a brief introduction to various VPN technologies.
  - **Chapter 2, "IPSec Overview"**—Gives an overview of IPSec protocols and describes differences between transport mode and tunnel mode. Cisco IOS IPSec packet processing is also explained in this chapter.
  - **Chapter 3, "Enhanced IPSec Features"**—Introduces advanced IPSec features that improve IPSec VPN scalability and fault tolerance, such as dead peer detection and control plane keepalives. This chapter also explains the challenges of IPSec interoperating with Network Address Translation (NAT) and Path Maximum Transmission Unit detection (PMTUD) and how to overcome these challenges.

  - **Chapter 4, "IPSec Authentication and Authorization Models"**—Explores IPSec features that are primarily called upon for the remote access users such as Extended Authentication (XAUTH) and Mode-configuration (MODE-CFG). It also explains the Cisco EzVPN connection model and digital certificate concepts.

- **Part II, "Design and Deployment"**
  - **Chapter 5, "IPSec VPN Architectures"**—Covers various IPSec connections models such as native IPSec, GRE, and remote access. Deployment architectures for each of the connection models are explored with pros and cons for each architecture.
  - **Chapter 6, "Designing Fault-Tolerant IPSec VPNs"**—Discusses how to introduce fault tolerance into VPN architectures and describes the caveats with the various fault-tolerance methods.
  - **Chapter 7, "Auto-Configuration Architectures for Site-to-Site IPSec VPNs"**—Covers mechanisms to alleviate the configuration complexity of a large-scale IPSec VPN; Tunnel Endpoint Discovery (TED) and Dynamic Multipoint VPNs (DMVPN) are the two mechanisms discussed in depth.

- **Part III, "Service Enhancements"**
  - **Chapter 8, "IPSec and Application Interoperability"**— Examines the issues with IPSec VPNs in the context of the running applications such as voice and multicast over the VPN.
  - **Chapter 9, "Network-Based IPSec VPNs"**—Concludes by introducing the concept of network-based VPNs.

CHAPTER 4

IPSec Authentication and Authorization Models

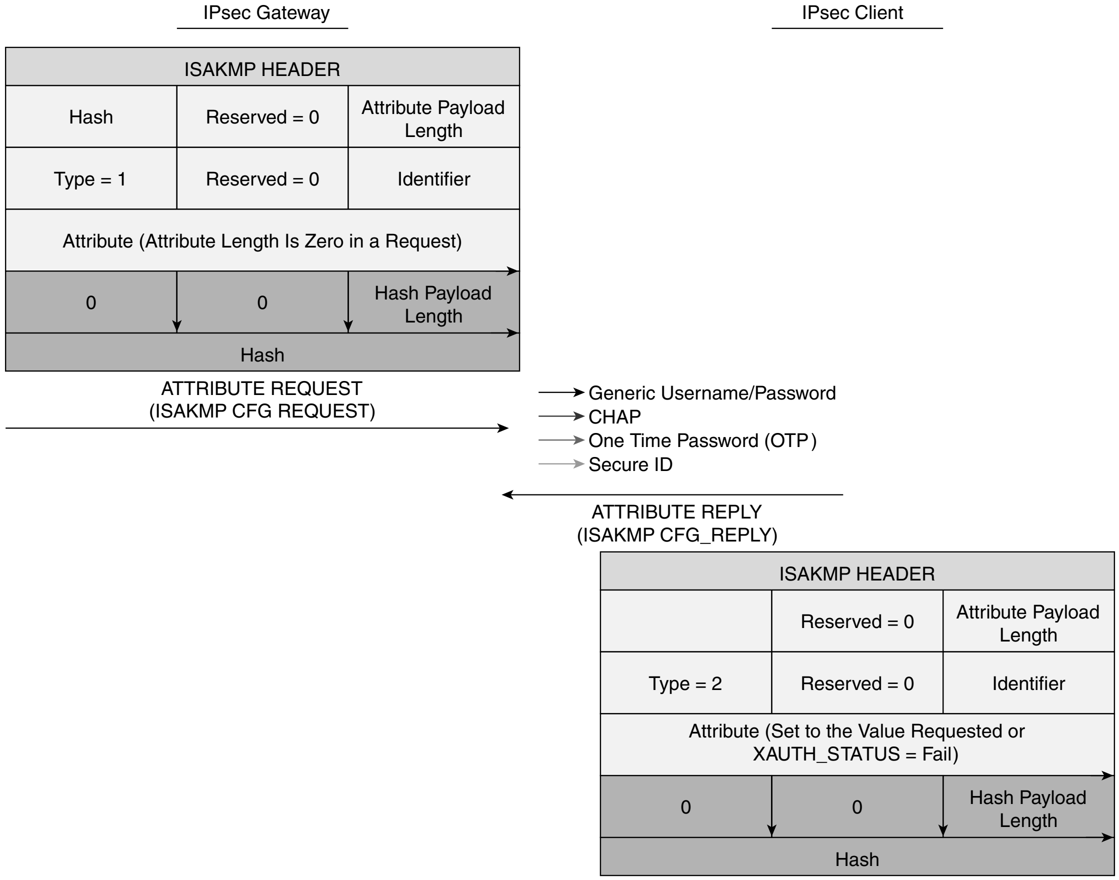
Telecommuting is increasingly becoming a part of everyday life, and IPSec connectivity is arguably the most popular connection method that telecommuters use to connect to a VPN across the public Internet. Given that telecommuters can be anywhere in the Internet, the successful completion of authorization and authentication is critical for granting access to the VPN. This chapter explores authentication and authorization models for the IPSec telecommuter.

Extended Authentication (XAUTH) and Mode Configuration (MODE-CFG)

Authentication schemes such as Remote Authentication Dial-In User Service (RADIUS) and SecureID are commonly used for providing secure remote access. It is highly desirable to leverage these authentication mechanisms for IPSec remote access. But Internet Key Exchange (IKE) protocol, which you learned about in Chapter 2, "IPSec Overview," does not provide a method to leverage these unidirectional authentication schemes. Extended Authentication, commonly referred to as XAUTH, was developed to leverage these legacy authentication schemes with IKE.

XAUTH provides an additional level of authentication by allowing the IPSec gateway to request extended authentication from remote users, thus forcing remote users to respond with their credentials before being allowed access to the VPN. It should be noted that XAUTH functions by first forming an IKE phase 1 SA using conventional IKE, and then by extending the IKE exchange to include additional user authentication exchanges. Figure 4-1 shows an XAUTH exchange using a generic username and password authentication scheme.

Figure 4-1 *Extended Authentication (XAUTH) Exchange*



As shown in Figure 4-1, XAUTH uses a Request/Reply mechanism to provide the extended authentication. The XAUTH process is terminated, either when the gateway starts a SET/ACK exchange, which includes an XAUTH_STATUS attribute, or when the remote device sends a XAUTH_STATUS attribute in a REPLY message.

The XAUTH protocol defines four message types that are exchanged between the remote user and the IPSec gateway. These messages carry various attributes for the extended authentication process to work. The four XAUTH message types are:

- ISAKMP_CFG_REQUEST
- ISAKMP_CFG_REPLY
- ISAKMP_CFG_SET
- ISAKMP_CFG_ACK

A description of the XAUTH message types follows:

- **ISAKMP_CFG_REQUEST**—This message is sent from the IPSec gateway to the IPSec client requesting extended authentication of the client.
- **ISAKMP_CFG_REPLY**—This message must contain the filled-in authentication attributes that were requested by the gateway or, if the proper authentication attributes cannot be retrieved, this message must contain the XAUTH_STATUS attribute with a value of FAIL.
- **ISAKMP_CFG_SET**—This message is sent from the gateway and is used only to state the success or failure of the authentication.
- **ISAKMP_CFG_ACK**—This message is sent from the IPSec client, acknowledging receipt of the authentication result.

The XAUTH message types defined above carry various attributes. A brief description of the attributes is shown in Table 4-1.

Table 4-1 *XAUTH Attributes*

Attribute	Description
XAUTH_TYPE	This attribute describes the type of extended authentication method requested. Four authentication methods are defined in the protocol: Generic, RADIUS_CHAP, One Time password (OTP), and Secure ID. This is an optional attribute for the ISAKMP_CFG_REQUEST and ISAKMP_CFG_REPLY messages. The XAUTH_TYPE in a REPLY must be identical to the XAUTH_TYPE in the REQUEST. However, an XAUTH transaction may have multiple REQUEST/REPLY pairs with different XAUTH_TYPE values in each pair.
XAUTH_USER_NAME	The username may be any unique identifier of the user, such as a login name, an email address, or a X.500 Distinguished Name.
XAUTH_USER_PASSWORD	The user's password.
XAUTH_PASSCODE	A token card's passcode.

continues

Table 4-1 *XAUTH Attributes (Continued)*

Attribute	Description
XAUTH_MESSAGE	A textual message from the gateway to the IPSec client. The message may contain a textual challenge or instruction.
XAUTH_CHALLENGE	A challenge string sent from the gateway to the IPSec client to be included in its calculation of a password. This attribute should be sent only in an ISAKMP_CFG_REQUEST message. Typically, the XAUTH_TYPE attribute dictates how the receiving device should handle the challenge. For example, RADIUS-CHAP uses the challenge to hide the password.
XAUTH_STATUS	A variable that is used to denote authentication success (OK=1) or failure (FAIL=0). This attribute *must* be sent in the ISAKMP_CFG_SET message, in which case it may be set to either OK or FAIL, and *may* be sent in a REPLY message by a remote peer, in which case it *must* be set to FAIL.

When a remote access user connects to an IPSec gateway and XAUTH is required by the gateway, configuration on the gateway initiates the XAUTH messages before IKE phase 2 negotiation begins. If the remote access client does not have support for the authentication method requested by the gateway, the client would send back a REPLY with the XAUTH_STATUS attribute set to FAIL, thus failing the authentication.

Example 4-1 shows the configuration of XAUTH using the RADIUS/AAA authentication method.

Example 4-1 *Cisco IOS XAUTH Configuration on the IPSec Gateway*

```
vpn-gw1-east#
!
hostname vpn-gw1-east
!
username ezvpn password 0 east
username ezvpn1@vpngroup password 0 ezvpn1east
username ezvpn2@vpngroup password 0 ezvpn2east
aaa new-model
!
aaa authentication login vpn local
aaa authorization network vpn local
aaa session-id common
ip subnet-zero
!
crypto isakmp policy 1
 encr 3des
 authentication pre-share
 group 2
crypto isakmp keepalive 10 10
```

Example 4-1 *Cisco IOS XAUTH Configuration on the IPSec Gateway (Continued)*

```
!
crypto ipsec transform-set vpn esp-3des esp-sha-hmac
!
crypto dynamic-map dynamic 1
 set transform-set vpn
 reverse-route remote-peer 9.1.1.33
!
!
crypto map vpn client authentication list vpn
crypto map vpn isakmp authorization list vpn
crypto map vpn client configuration address respond
crypto map vpn 3 ipsec-isakmp dynamic dynamic
```

The addition of the following command on the crypto map enables XAUTH and triggers the XAUTH transaction after IKE phase 1 and before IKE phase 2:

```
crypto map map-name client authentication list list-name
```

As you learned in Chapter 2, "IPSec Overview," a very common deployment scenario for IPSec telecommuters is the use of IKE pre-shared key authentication with Aggressive Mode. The primary motivation for this scenario is that the IP address of an IPSec remote access user connecting to an IPSec gateway over the public Internet is typically not known in advance to the gateway. In most deployments using pre-shared keys, a single shared group key is used for all users of the VPN. What this means is that without employing some form of additional user authentication, there is no way to verify that the person connecting with that VPN client is indeed a valid user.

Imagine, for example, a situation where a laptop with a VPN client is stolen—because the VPN client is already configured with a valid group key, anyone with the laptop can connect to the VPN without any problems, as no further authentication is required! Extended Authentication (XAUTH) is widely employed to address this serious security gap. XAUTH forces users to identify themselves with a user id and a password *after* the group pre-shared key has been verified.

XAUTH is also referred to as "two factor authentication." The password could be a "one-time password" (for example, from a SecureID card) adding further security to such a deployment. Although the usage of XAUTH is very common and desired for the telecommuter scenario using pre-shared keys and Aggressive Mode, it can also be used with Main Mode and other authentication methods such as digital certificates. It is important to note that although XAUTH is deployed very commonly, it has not been established as a standard by the IPSec working group in the IETF, which means that it may present interoperability issues among different vendor implementations.

Mode-Configuration (MODECFG)

In remote access scenarios, it is highly desirable to be able to push configuration information such as the private IP address, a DNS server's IP address, and so forth, to the client. The IPSec Mode-configuration (MODECFG) allows this functionality. Configuration for MODECFG using Cisco IOS is shown in Example 4-2.

Example 4-2 *Cisco IOS MODECFG Configuration on the IPSec Gateway*

```
vpn-gw1-east#
!
hostname vpn-gw1-east
!
username ezvpn password 0 east
username ezvpn1@vpngroup password 0 ezvpn1east
username ezvpn2@vpngroup password 0 ezvpn2east
aaa new-model
!
aaa authentication login vpn local
aaa authorization network vpn local
aaa session-id common
ip subnet-zero
!
crypto isakmp policy 1
 encr 3des
 authentication pre-share
 group 2
crypto isakmp keepalive 10 10
!
crypto isakmp client configuration group vpngroup
 key ciscoezvpn
 dns 10.1.1.10
 wins 10.1.1.11
 pool vpnpool
 include-local-lan
 backup-gateway 9.1.1.36
!
crypto ipsec transform-set vpn esp-3des esp-sha-hmac
!
crypto dynamic-map dynamic 1
 set transform-set vpn
 reverse-route remote-peer 9.1.1.33
!
!
crypto map vpn client authentication list vpn
crypto map vpn isakmp authorization list vpn
crypto map vpn client configuration address respond
crypto map vpn 3 ipsec-isakmp dynamic dynamic
```

Some of the key attributes that can be pushed to a remote user using MODECFG follow:

- **INTERNAL_IP4_ADDRESS**, **INTERNAL_IP6_ADDRESS**—Specifies an address within the internal network. The requested address is valid until the expiration of the ISAKMP SA that was used to secure the request. The address may also expire when the IPSec phase 2 SA expires, if the request is associated with a phase 2 negotiation.
- **INTERNAL_IP4_NETMASK**, **INTERNAL_IP6_NETMASK**—The internal network's netmask.
- **INTERNAL_IP4_DNS**, **INTERNAL_IP6_DNS**—Specifies an address of a DNS server or multiple DNS servers within the network. The responder may respond with zero, one, or more DNS server attributes.
- **INTERNAL_IP4_NBNS**, **INTERNAL_IP6_NBNS**—Specifies an address of a NetBios Name Server (NBNS) within the network. Multiple NBNSs may be requested. The responder may respond with zero, one, or more NBNS attributes.

Like XAUTH, MODECFG is not a standard of the IPSec working group in the IETF. Although Cisco defined this protocol and most client implementations work with the Cisco implementation, given that this not a standard, there are no guarantees for interoperability.

Easy VPN (EzVPN)

As you saw in Chapter 2, “IPSec Overview,” for an IPSec tunnel to be established between two peers, there is a significant amount of configuration required on both peers. This includes IPSec policies, Diffie-Hellman parameters, encryption algorithms, and so on. In a large corporate environment with hundreds of sites, managing the IPSec configuration can get quite tedious. The Cisco Easy VPN feature, also known as EzVPN, eases IPSec configuration by allowing an almost no-touch configuration of the IPSec client.

EzVPN uses the Unity client protocol, which allows most IPSec VPN parameters to be defined at an IPSec gateway, which is also the EzVPN server. When an EzVPN client initiates an IPSec tunnel connection, the EzVPN server pushes the IPSec policies and other attributes required to form the IPSec tunnel to the EzVPN client and creates the corresponding IPSec tunnel connection. The tunnel on the EzVPN client can be initiated automatically or manually, or it could be traffic triggered, depending on the configuration or type of EzVPN client used. Minimal configuration is required at the EzVPN client. EzVPN provides the following general functions in order to simplify the configuration process:

- **Negotiating tunnel parameters**—This is done with encryption algorithms, SA lifetimes, and so on.
- **User authentication**—This entails validating user credentials by way of XAUTH.
- **Automatic configuration**—Performed by pushing attributes such as IP address, DNS, WINs, and so on, using MODECFG.

NOTE The term EzVPN client is used for both Cisco Unity VPN clients, called EzVPN software clients, and the Unity client protocol running on smaller Cisco routers like the 800, 1700, and 2600 series, commonly referred to as EzVPN hardware clients.

The Cisco Easy VPN feature supports two modes of operation:

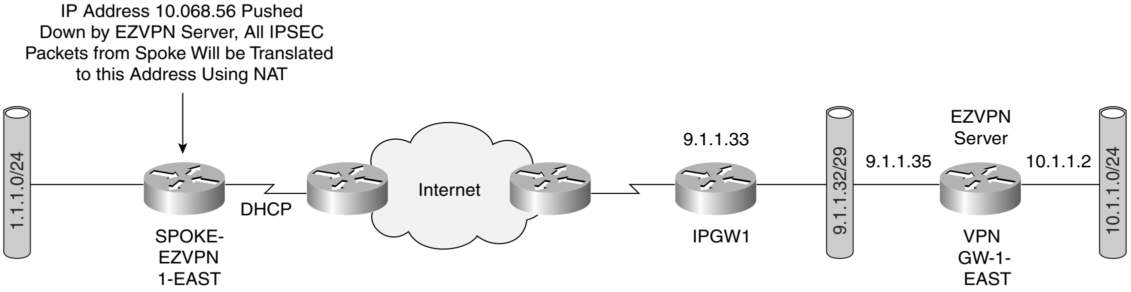
- Client Mode
- Network Extension Mode

You will examine each of these modes in detail in the following sections.

EzVPN Client Mode

Figure 4-2 shows an IPSec Unity client configured for Client Mode in order to establish an IPSec VPN tunnel to the gateway.

Figure 4-2 *EzVPN IPSec Client Mode Connection*


IP Address 10.068.56 Pushed Down by EZVPN Server, All IPSEC Packets from Spoke Will be Translated to this Address Using NAT
1.1.1.0/24
SPOKE-EZVPN 1-EAST
DHCP
Internet
9.1.1.33
IPGW1
9.1.1.32/29
9.1.1.35
EZVPN Server
VPN GW-1-EAST
10.1.1.2
10.1.1.0/24

EzVPN Client Mode is also known as Network/Port Address Translation (NAT/PAT) Mode. In this mode, all traffic from the client side uses a single IP address for all hosts on the private network. In Figure 4-2, all traffic from the hosts on the FastEthernet interface on the EzVPN client is translated by NAT to a source IP address of 10.0.68.5, which is assigned by the EzVPN server as an attribute using MODECFG. The client keeps track of the mappings so that it can be forwarded to the correct host on the private network.

The configuration of the EzVPN hardware client is shown in Example 4-3.

Example 4-3 *EzVPN Client Mode Configuration*

```
spoke-ezvpn1-east#
!
hostname spoke-ezvpn1-east
!
```

Example 4-3 *EzVPN Client Mode Configuration (Continued)*

```
crypto ipsec client ezvpn vpn
 connect auto
 group vpngroup key ciscoezvpn
 local-address Ethernet0
 mode client
 peer 9.1.1.35
 username ezvpn1@vpngroup password  ezvpn1east
!
!
interface Ethernet0
 ip address dhcp
 load-interval 30
 half-duplex
 crypto ipsec client ezvpn vpn outside
!
interface FastEthernet0
 ip address 1.1.1.1 255.255.255.0
 load-interval 30
 speed 100
 full-duplex
 no keepalive
 crypto ipsec client ezvpn vpn inside
!
ip route 0.0.0.0 0.0.0.0 Ethernet0
!
end
```

Notice that in the EzVPN client configuration, none of the IPSec policies, encryption algorithms, and so forth are configured. Example 4-4 shows how to monitor an EzVPN client configuration.

Example 4-4 *Verification of EzVPN Client Mode Configuration*

```
spoke-ezvpn1-east#show crypto isakmp sa
dst             src             state          conn-id slot
9.1.1.35        9.1.1.146       QM_IDLE              4    0
spoke-ezvpn1-east#show crypto ipsec client ezvpn
Easy VPN Remote Phase: 2
Tunnel name : vpn
Inside interface list: FastEthernet0,
Outside interface: Ethernet0
Current State: IPSEC_ACTIVE
Last Event: SOCKET_UP
Address: 10.0.68.56
Mask: 255.255.255.255
DNS Primary: 10.1.1.10
NBMS/WINS Primary: 10.1.1.11
```

The configuration of the EzVPN server is shown in Example 4-5.

Example 4-5 *EzVPN Server-side Configuration*

```
vpn-gw1-east#
!
hostname vpn-gw1-east
!
username ezvpn password 0 east
username ezvpn1@vpngroup password 0 ezvpn1east
username ezvpn2@vpngroup password 0 ezvpn2east
aaa new-model
!
aaa authentication login vpn local
aaa authorization network vpn local
aaa session-id common
ip subnet-zero
!
crypto isakmp policy 1
 encr 3des
 authentication pre-share
 group 2
crypto isakmp keepalive 10 10
!
crypto isakmp client configuration group vpngroup
 key ciscoezvpn
 dns 10.1.1.10
 wins 10.1.1.11
 pool vpnpool
 include-local-lan
 backup-gateway 9.1.1.36
!
!
crypto ipsec transform-set vpn esp-3des esp-sha-hmac
!
crypto dynamic-map dynamic 1
 set transform-set vpn
 reverse-route remote-peer 9.1.1.33
!
!
crypto map vpn client authentication list vpn
crypto map vpn isakmp authorization list vpn
crypto map vpn client configuration address respond
crypto map vpn 3 ipsec-isakmp dynamic dynamic
!
!
interface Loopback0
 ip address 9.2.1.100 255.255.255.255
!
interface FastEthernet0/0
 ip address 9.1.1.35 255.255.255.248
 duplex full
 crypto map vpn
!
```

Example 4-5 *EzVPN Server-side Configuration (Continued)*

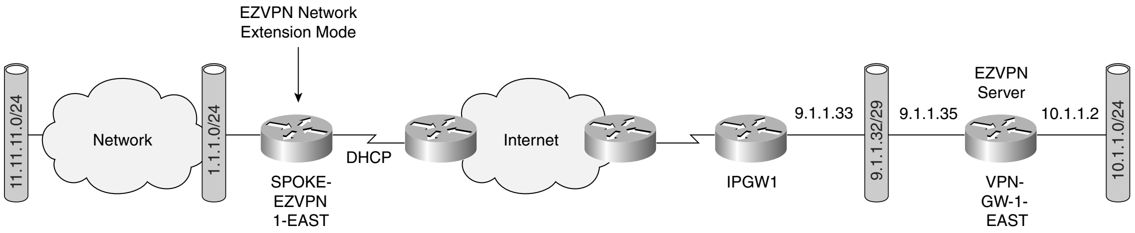
```
interface FastEthernet2/0
 ip address 100.1.1.147 255.255.255.0
 duplex full
!
interface FastEthernet4/0
 ip address 10.1.1.1 255.255.255.0
 duplex full
!
router ospf 1
 log-adjacency-changes
 redistribute static subnets
 network 10.1.1.0 0.0.0.255 area 0
!
ip local pool vpnpool 10.0.68.1 10.0.68.100
ip classless
ip route 0.0.0.0 0.0.0.0 9.1.1.33
!
radius-server host 100.1.1.4 auth-port 1645 acct-port 1646
radius-server key cisco
end
```

The IOS command **crypto isakmp client configuration group vpngroup** defines the attributes for the VPN group that was assigned to the EzVPN client.

Network Extension Mode

Figure 4-3 shows an EzVPN client in Network Extension Mode. This mode allows the EzVPN client to present a full, routable network to the tunneled network.

Figure 4-3 *EzVPN IPSec Network Extension Mode Connection*



IPSec encapsulates all traffic from the EzVPN client's private network, which is marked as 'inside' to networks behind the IPSec gateway. Therefore, devices behind the gateway have direct access to devices on the EzVPN client's private network via the tunnel and vice versa without the need for NAT or PAT. As there is no reason for NAT or PAT, the EzVPN server does not push down an IP address for tunneled traffic, but all other attributes like ACLs, DNS, and

WINS, can be pushed down. Example 4-6 shows the configuration of Network Extension Mode on the EzVPN client shown in Figure 4-3.

Example 4-6 *EzVPN Client Configuration for Network Extension Mode*

```
spoke-ezvpn1-east#
!
hostname spoke-ezvpn1-east
!
crypto ipsec client ezvpn vpn
 connect auto
 group vpngroup key ciscoezvpn
 local-address Ethernet0
 mode network-extension
 acl 100
 peer 9.1.1.35
 username ezvpn1@vpngroup password  ezvpn1east
!
interface Ethernet0
 ip address dhcp
 load-interval 30
 half-duplex
 crypto ipsec client ezvpn vpn outside
!
interface FastEthernet0
 ip address 1.1.1.1 255.255.255.0
 load-interval 30
 speed 100
 full-duplex
 no keepalive
 crypto ipsec client ezvpn vpn inside
!
access-list 100 permit 11.1.1.0 0.0.0.255 any
ip route 0.0.0.0 0.0.0.0 dhcp
```

Note the ACL 100 under the mode network-extension in the configuration. The ACL 100 permits networks behind the "inside" network (11.1.1.0/24) and allows traffic to and from these subnets to be encrypted. Without the access list, only traffic to and from the "inside" subnet (1.1.1.0/24) is encrypted.

NOTE The EzVPN server configuration is the same for both Client Extension Mode and Network Extension Mode. The client configuration determines which mode is being used.

Redundancy is always an integral part of any IPSec design and, in the case of EzVPN dead peer detection along with backup peer list, makes such a design possible. Example 4-7 shows the client configuration with multiple EzVPN server peer addresses manually configured on the client. An alternate mechanism to provide EzVPN server redundancy is to push the backup server's address list down to the client as an attribute. Dead peer detection is on by default on the EzVPN clients.

Example 4-7 *EzVPN Server Redundancy*

```
spoke-ezvpn1-east#
!
hostname spoke-ezvpn1-east
!
crypto ipsec client ezvpn vpn
 connect auto
 group vpngroup key ciscoezvpn
 local-address Ethernet0
 mode network-extension
 peer 9.1.1.35
 peer 9.1.1.45
 username ezvpn1@vpngroup password  ezvpn1east
```

EzVPN can be combined with XAUTH and MODECFG to provide extended authentication and thereby push all MODECFG attributes to the client. The attributes to be pushed can be defined locally on the EzVPN server or defined on a AAA server and defined either on a per-group or per-user basis. Example 4-8 shows the policies configured on a AAA server on a group basis.

Example 4-8 *Per-Group–based Policy Configuration on a AAA Server*

```
vpngroup Password = "cisco", Service-Type = Outbound
 cisco-avpair = "ipsec:tunnel-type=ESP"
 cisco-avpair = "ipsec:key-exchange=ike"
 cisco-avpair = "ipsec:tunnel-password=ciscoezvpn"
 cisco-avpair = "ipsec:addr-pool=vpnpool"
 cisco-avpair = "ipsec:default-domain=cisco"
 cisco-avpair = "ipsec:inacl=101"
 cisco-avpair = "ipsec:access-restrict=fastethernet 0/0"
 cisco-avpair = "ipsec:group-lock=1"
cisco-avpair = "ipsec:backup-server=9.1.1.35"

 cisco-avpair = "ipsec:dns-servers=10.1.1.10"
 cisco-avpair = "ipsec:firewall=1"
 cisco-avpair = "ipsec:include-local-lan=1"
 cisco-avpair = "ipsec:save-password=1"
 cisco-avpair = "ipsec:wins-servers=10.1.1.11"
 cisco-avpair = "ipsec:max-users = 100"
 cisco-avpair = "ipsec:max-logins = 2"
```

NOTE When AAA is used for pushing the attributes, AAA between EzVPN server and the AAA server requires a hard-coded password of **cisco**. Therefore, notice the use of the string **cisco** as the vpngroup password. This is a requirement of the Cisco AAA implementation.

Example 4-9 shows the configuration of the policy attributes locally on the EzVPN server on a per-group basis.

Example 4-9 *Per-Group EzVPN Policy Attributes Configured Locally on an EzVPN Server*

```
crypto isakmp client configuration group vpngroup
 key ciscoezvpn
 dns 10.1.1.10
 wins 10.1.1.11
 domain cisco.com
 pool vpnpool
 group-lock
 save-password
 include-local-lan
 pfs
 backup-gateway 9.1.1.36
 max-users 100
 max-logins 2
 access-restrict fastEthernet 0/0
```

You've already seen described some attributes such as IP address, WINS, DNS, and backup server in the previous section. For a complete list of attributes and their description, refer to Cisco IOS EzVPN documentation. A couple of very useful attributes for telecommuter scenarios are max-logins and include-local-lan. The max-logins attribute allows the administrator to restrict the number of simultaneous IPSec connections from the same user to the gateway. The include-local-lan attribute is very useful in scenarios in which the telecommuter's LAN has resources, such as printers, attached to the LAN and access to these resources is required when the VPN tunnel is up.

The attributes may also be applied on a per-user basis. A user attribute overrides a group attribute value. These attributes are retrieved at the time user authentication occurs using XAUTH, and are then combined with group attributes and applied during Mode-Configuration. User-based attributes are available only if RADIUS is used as the database. Example 4-10 shows the RADIUS attributes that must be configured on a per-user basis.

Example 4-10 *User-Based Policy Control Using AAA*

```
ezvpn1@vpngroup Password = "ezvpn1east"
framed-Ip-Address=10.0.68.1
ipsec:user-save-password=1
ipsec:user-include-local-lan=1
ipsec:user-vpn-group=cisco
```

Note that EzVPN using the Cisco Unity protocol is not an IETF standard. The Cisco proprietary Unity protocol is supported by Cisco IOS devices, VPN 3000, and PIX devices for interoperability across Cisco devices.

Digital Certificates for IPSec VPNs

You have learned from Chapter 2, "IPSec Overview," that pre-shared keys and digital certificates are two primary authentication methods in IKE that can be used in the context of IPSec VPN deployments. You also saw that pre-shared keys with IKE Main Mode cannot be used for remote access scenarios in which the responder does not know the source IP address of the initiator in advance. Although Aggressive Mode can alleviate this issue, given that Aggressive Mode does not offer any form of ID protection, such a solution may not be acceptable. You also saw XAUTH provide an additional level of authentication for Aggressive Mode with pre-shared keys. Another solution for such a scenario is the use of digital certificates instead of pre-shared keys.

In addition to solving the authentication issue for remote access users, digital certificate–based authentication is also becoming increasingly popular for large IPSec VPN site-to-site deployments because it is more scalable than pre-shared keys. Without digital signatures, users must either manually exchange public keys or secrets between each pair of devices that use IPSec to protect communications. This is cumbersome because when a new device is added to the network, users are required to make configuration changes on every other device it securely communicates with. By using digital certificates, users simply enroll each new device with a Certificate Authority, and none of the other devices need modification. When the new device attempts an IPSec connection, IKE automatically exchanges certificates with the peer and the devices authenticate each other, thus making a large-scale IPSec VPN deployment very scalable using digital certificates. An entire book can be written on digital certificates and PKI. You will be introduced to some of the components of PKI in the remainder of this chapter.

Digital Certificates

Digital certificates provide a means to digitally authenticate devices and individual users. These certificates act kind of like an online passport—they are tamper proof and cannot be forged. An individual that wishes to send encrypted data obtains a digital certificate from a *Certificate Authority (CA)*. The CA issues an encrypted digital certificate containing the applicant's public key and a variety of other identification information. The CA makes its own public key readily available. The recipient of the encrypted message uses the CA's public key to decode the digital certificate attached to the message, verifies it as issued by the CA, and then obtains the sender's public key and identification information held within the certificate. With this information, the recipient can send an encrypted reply. Public key infrastructure (PKI) is the enabler for managing digital certificates for IPSec VPN deployment. The most widely used format for digital certificates is X.509, which is supported by Cisco IOS.

Certificate Authority—Enrollment

The Certificate Authority is the entity that issues the digital certificate. Enrollment is the process of obtaining a new certificate from a certificate authority. The IOS command **crypto ca trustpoint** is used to declare the specific CA that the router should use for enrollment.

As PKI is deployed on larger networks, enrollment becomes a big problem if it requires manual enrollment. The Cisco auto-enroll feature will be useful for this situation. With this feature, an IOS router can be configured to periodically contact the CA and request a new certificate. Auto enrollment may be configured to generate new encryption keys or to continue to use existing keys. Routers can initially auto-enroll with CA and when the certificate lifetime expires, the router re-enrolls automatically. Example 4-11 shows the configuration snippet for enrolling a Cisco router to a CA as well as the auto-enrollment command.

Example 4-11 *Cisco IOS Configuration for Enrolling with CA*

```
crypto ca trustpoint Public_CA
 enrollment url http://100.1.1.5:80
subject-name OU=Engineering., O=ABC

 auto-enroll 95 regenerate
 password cisco
 rsakeypair public-ca
```

Auto enrollment makes sure that the router re-enrolls with the CA after the certificate lifetime expires. However, while re-enrollment is occurring, new incoming IKE connections cannot be established because the existing certificate and key pairs are deleted immediately after the new key is generated, and the new key does not have a certificate to match it until the enrollment is complete. A simple workaround is to have the router re-enroll to the CA *before* the certificate lifetime expires, using the IOS command **auto enroll <*percent*> regenerate**.”

It's possible that a router may be required to enroll with multiple certificate servers. Each CA server has an independent policy and may have different requirements as to general versus special purpose certificates or key length. Also, although it does not substantially affect the security of the system, VPN providers would like to use different key pairs for each VPN. Using the same key pair gives the impression of lower security, which is detrimental to end-user satisfaction. Example 4-12 shows an example of enrollment to multiple CAs using multiple key pairs.

Example 4-12 *Enrollment with Multiple CAs Using Multiple Key Pairs*

```
vpn-gw1-east#show running-config
!
crypto ca trustpoint Public_CA
 enrollment url http://100.1.1.5:80
 revocation-check crl
 rsakeypair public-ca
 match certificate engg
!
crypto ca trustpoint IOS_CA
```

Example 4-12 *Enrollment with Multiple CAs Using Multiple Key Pairs (Continued)*

```
 enrollment url http://100.1.1.179:80
 revocation-check none
 rsakeypair ios-ca
!

vpn-gw1-east#show cry ca trustpoints
Trustpoint Public_CA:
    Subject Name:
    cn=Certificate Manager
    ou=nsite-rtp
    o=cisco-rtp
    l=rtp
    st=nc
    c=US
          Serial Number: 01
    Certificate configured.
    CEP URL: http://100.1.1.5

Trustpoint IOS_CA:
    Subject Name:
    cn=Certmanager O\=cisco OU\=nsite
          Serial Number: 01
    Certificate configured.
    CEP URL: http://100.1.1.179
```

Certificate Revocation

Situations may arise in which the certificate issued by a CA may need to be revoked before the lifetime of the certificate expires. One such situation would be if the certificate itself is known to have been compromised. Yet another more common situation in the context of IPSec VPNs is when temporary access to a VPN is desired. For example, assume that a user that belongs to Company A may want temporary access to Company B's VPN, and is granted a certificate for access. The access would need to be revoked after a short time in order to maintain integrity of the network.

Another precaution maintained prevents users whose certificate has been revoked from being granted access to a VPN. To achieve this, a list of certificates that have been revoked, known as a Certificate Revocation List (CRL), is sent periodically from the CA to the IPSec gateway. When an incoming IKE session is initiated for a user whose certificate is revoked, the CRL will be checked to see if the certificate is valid; if the certificate is revoked, IKE will fail and access to the VPN will be denied. Example 4-13 shows Cisco IOS configuration to check for a revoked certificate in the CRL.

Example 4-13 *Cisco IOS Configuration for Checking Certificate Status Using CRL*

```
crypto ca trustpoint Public_CA
 enrollment url http://100.1.1.5:80
 revocation-check crl
 rsakeypair public-ca
 match certificate eng
```

Once the CRL is obtained by the VPN endpoint from the CA, it will maintain it until the Certificate Revocation timer expires or if the endpoint reloads.

An alternate mechanism for checking the validity of a certificate is the use of the Online Certificate Status Protocol (OCSP). Unlike CRLs, which provide only periodic certificate status checks, OCSP can provide timely information regarding the status of a certificate. Example 4-14 shows the configuration to enable OCSP to check certificate status.

Example 4-14 *Cisco IOS Configuration for Checking Certificate Status Using OCSP*

```
crypto ca trustpoint Public_CA
 enrollment url http://100.1.1.5:80
 revocation-check ocsp
 rsakeypair public-ca
 match certificate eng
```

If the deployment needs more granular control over the permission to connect users (even those with valid certificates), certificate-based ACLs may be used. For example, there may be situations in which you wish to allow only a subset of users with a valid certificate to connect to the VPN. The configuration in Example 4-15 allows only users whose certificates contain “Engineering” in the subject name.

Example 4-15 *Cisco IOS Configuration for Certificate-Based ACLs*

```
crypto ca certificate map eng 10
 subject-name co Engineering

crypto ca trustpoint Public_CA
match certificate eng
 enrollment url http://100.1.1.5:80
 auto-enroll 95 regenerate
 password cisco
 rsakeypair public-ca
```

Digital certificates as an authentication method for large-scale IPSec VPNs is becoming increasingly popular for both remote access and site-to-site deployments. You learned in this section that the use of digital certificates requires some form of PKI infrastructure such as a CA server. Network administrators should be aware that managing the PKI infrastructure and digital certificates can be much more complicated than username-based password management. The benefits to be gained by the additional work by network administration should be carefully considered before using digital certificates.

Summary

This chapter covered IPSec features and mechanisms that are primarily targeted at the authentication of remote access users. You learned about XAUTH, which provides extended authentication for IPSec telecommuters by using authentication schemes such as RADIUS. MODECFG uses a push model to push attributes to the IPSec client. You also saw how EzVPN greatly simplifies configuration for IPSec clients and allows central configuration of the IPSec policies. You explored the use of digital certificates and PKI, which are becoming increasingly popular for scalable IPSec deployments for both remote access and site-to-site VPNs.

This page intentionally left blank

INDEX