



SECURITY

IPSec VPN Design

The definitive design and deployment guide for secure virtual private networks

Contents Introduction xvi Chapter 1 Introduction to VPNs Motivations for Deploying a VPN 3 VPN Technologies 5 Layer 2 VPNs Layer 3 VPNs 6 GRE Tunnels 6 MPLS VPNs IPSec VPNs 7 Remote Access VPNs 8 Summary 9 Chapter 2 **IPSec Overview** Encryption Terminology Symmetric Algorithms 12 Asymmetric Algorithms 13 Digital Signatures 14 IPSec Security Protocols IPSec Transport Mode 16 IPSec Tunnel Mode 17 Encapsulating Security Header (ESP) 18 Authentication Header (AH) Key Management and Security Associations 21 The Diffie-Hellman Key Exchange 21 Security Associations and IKE Operation IKE Phase 1 Operation 25 Main Mode 26 Aggressive Mode Authentication Methods 28 IKE Phase 2 Operation 30 Quick Mode 30 IPSec Packet Processing 32 Security Policy Database 32 Security Association Database (SADB) Cisco IOS IPSec Packet Processing 34 Summary 39 Chapter 3 Enhanced IPSec Features 41 IKE Keepalives 41

Dead Peer Detection 43 Idle Timeout 47

```
Reverse Route Injection 50
     RRI and HSRP 53
  Stateful Failover 56
     SADB Transfer 57
     SADB Synchronization 57
  IPSec and Fragmentation 65
     IPSec and PMTUD 66
     Look Ahead Fragmentation 69
  GRE and IPSec 70
  IPSec and NAT 76
     Effect of NAT on AH
                         76
     Effect of NAT on ESP
                         76
     Effect of NAT on IKE 77
     IPSec and NAT Solutions 77
       NAT Traversal (NAT-T) 77
       IPSec Pass-through 83
       IKE Passing Through PAT 83
       ESP Passing Through PAT
       Restricted ESP Through PAT Mode 84
 Summary 87
IPSec Authentication and Authorization Models
 Extended Authentication (XAUTH) and Mode Configuration (MODE-CFG) 89
 Mode-Configuration (MODECFG) 94
 Easy VPN (EzVPN) 95
     EzVPN Client Mode 96
     Network Extension Mode 99
 Digital Certificates for IPSec VPNs
                                103
     Digital Certificates 103
     Certificate Authority—Enrollment 104
     Certificate Revocation 105
 Summary 107
IPSec VPN Architectures 109
 IPSec VPN Connection Models 109
     IPSec Model 110
    The GRE Model 111
    The Remote Access Client Model
    IPSec Connection Model Summary 112
 Hub-and-Spoke Architecture
    Using the IPSec Model 115
```

Transit Spoke-to-Spoke Connectivity Using IPSec

Chapter 4

Chapter 5

Chapter 6

Internet Connectivity Scalability Using the IPSec Connection Model 127 GRE Model 128 Transit Site-to-Site Connectivity 140 Transit Site-to-Site Connectivity with Internet Access 141 Scalability of GRE Hub-and-Spoke Models Remote Access Client Connection Model 144 Easy VPN (EzVPN) Client Mode EzVPN Network Extension Mode Scalability of Client Connectivity Models Full-Mesh Architectures 156 Native IPSec Connectivity Model 156 GRE Model 165 Summary 170 Designing Fault-Tolerant IPSec VPNs 173 Link Fault Tolerance 173 Backbone Network Fault Tolerance 174 Access Link Fault Tolerance 175 Multiple IKE Identities 176 Multiple IKE Identities Associated with Dial Backup 182 Single IKE Identity 183 Single IKE Identity Using Multi-link PPP on the Access Links 188 Access Link Fault Tolerance Summary IPSec Peer Redundancy Simple Peer Redundancy Model 189 Virtual IPSec Peer Redundancy Using HSRP IPSec Stateful Failover 196 Peer Redundancy Using GRE 200 Virtual IPSec Peer Redundancy Using SLB 204 Server Load Balancing Concepts 205 IPSec Peer Redundancy Using SLB 205 Cisco VPN 3000 Clustering for Peer Redundancy 210 Peer Redundancy Summary 212 Intra-Chassis IPSec VPN Services Redundancy 212 Stateless IPSec Redundancy Stateful IPSec Redundancy 213 Summary 214

Chapter 7 Auto-Configuration Architectures for Site-to-Site IPSec VPNs 217 IPSec Tunnel Endpoint Discovery Principles of TED 218 Limitations with TED 220 TED Configuration and State 221 TED Fault Tolerance 225 Dynamic Multipoint VPN 227 Multipoint GRE Interfaces 229 Next Hop Resolution Protocol 232 Dynamic IPSec Proxy Instantiation 236 Establishing a Dynamic Multipoint VPN DMVPN Architectural Redundancy 248 DMVPN Model Summary 254 Summary 255 Chapter 8 IPSec and Application Interoperability 257 QoS-Enabled IPSec VPNs 258 Overview of IP OoS Mechanisms 258 IPSec Implications for Classification 259 QoS Applied to IPSec Transport Mode 260 QoS Applied to IPSec Tunnel Mode 261 IPSec Transport Mode - QoS Attribute Preservation of GRE Tunnels 261 Transitive QoS Applied to IPSec 264 Internal Preservation of QoS Attributes 264 IPSec Implications on QoS Policies 266 IPSec Implications of Packet Size Distribution on Queue Structures 266 IPSec Implications of Packet Size on Queue Bandwidth Assignments VoIP Application Requirements for IPSec VPN Networks 267 **Delay Implications** 267 Jitter Implications 269 Loss Implications 270 Mitigating Anti-replay Loss in Combined Voice/Data Flows 270 Mitigating Anti-replay Loss in Separate Voice/Data Flows 270 Engineering Best Practices for Voice and IPSec 271 IPSec VPN Architectural Considerations for VoIP Decoupled VoIP and Data Architectures 272 VoIP over IPSec Remote Access 274 VoIP over IPSec-Protected GRE Architectures VoIP Hub-and-Spoke Architecture 277 VoIP over DMVPN Architecture 278 VoIP Bearer Path Optimization with DMVPN 279 VoIP Bearer Path Synchronization with DMVPN 279 VoIP Traffic Engineering Summary

Chapter 9

```
Multicast over IPSec VPNs 280
     Multicast over IPSec-protected GRE 280
     Multicast on Full-Mesh Point-to-Point GRE/IPSec Tunnels 282
     DMVPN and Multicast 285
     Multicast Group Security 287
       Group Security Key Management 287
       Group Security Association 289
       Multicast Group Security Summary
     Multicast Encryption Summary 291
 Summary 291
Network-Based IPSec VPNs 293
 Fundamentals of Network-Based VPNs 293
 The Network-Based IPSec Solution: IOS Features 296
     The Virtual Routing and Forwarding Table 296
     Crypto Keyrings 297
     ISAKMP Profiles 297
 Operation of Network-Based IPSec VPNs 299
     A Single IP Address on the PE 300
     Front-Door and Inside VRF 300
     Configuration and Packet Flow 301
       Generic MPLS VPN Configuration on the PE 305
       Mapping an IPSec Tunnel from a Site into IVRF at the PE 306
       Mapping an IPSec Tunnel from a Telecommuter into an IVRF at the PE 315
     Termination of IPSec on a Unique IP Address Per VRF 321
 Network-Based VPN Deployment Scenarios 324
     IPSec to MPLS VPN over GRE 324
       DMVPN and VRF 327
     IPSec to L2 VPNs 330
     PE-PE Encryption 334
 Summary 339
```

Index 343