Index

Numerics

3DES (triple data encryption standard), 21

A–B

aggressive mode negotiation, 89-90 AH (Authentication Headers), 6, 57-58 alternatives to IPsec VPN HA, stateful, 257-260 stateless, 242 HSRP, 244-245 RRI, 245 applying crypto maps in SOHO environments, 432-446 asymmetric cryptography, 392 asymmetric key encryption, 36-39, 46 impact on CPU processing, 404 asymmetric routing as cause of broken VPN tunnels, 220 authentication, 44 of public key certificates, 402 authentication errors (IKE), troubleshooting, 146-165 authentication services (IKE) preshared keys, 83-85 RSA encryption, 85 RSA signatures, 86-87 X.509 certificates, 86-87

BGP (Border Gateway Protocol), crypto path availability, 219 business drivers for VPNs, 29–30 remote access VPNs, 30 site-to-site VPNs, 30–31

С

CA hierarchy configuration, case study, 412-414 CAs (Certificate Authorities), 393, 397 enrollment process, 395 RA interoperability, configuring, 410-412 case studies, PKI CA hierarchy, 412-414 configuring CA/RA interoperability, 410-412 cryptographic endpoint integration, 407-409 CBC (cipher block chaining), 55 CBWFO (class-based weighted fair queuing), impact of IPsec on, 181-182 CE (customer edge) routers, 18-20 characteristics of effective VPNs, 6-7 cipher text, 6 ciphers, 36 **Cisco IPSec VPN 3000 series** concentrators, 225 **Cisco Security Wheel, 31** Cisco VPN 3000 series concentrators, clustering, 227-230 clustered spoke VPN design, 130 clustered VPN concentrator designs, 137-138 commands, redistribute static, 245, 269 comparing In-Path and Out-of-Path encryption, 361, 368-369 compulsory tunnels, 13 concentrator clustering, 225-230 configuring CA hierarchy, case study, 412-414 CA/RA interoperability, case study, 410-412 crypto maps, 66-68 dynamic crypto maps, 425-430

geographic HA DMVPNs, 287-294 IPsec+GRE, 279-280, 283-287 RRI with multiple IPsec peers, 267-278 ISAKMP, 94-95 RAVPN HA DNS-based load balancing, 343-345 using multiple IPsec peers, 345, 348-355 with HSRP, 327-333 with VCA, 333–342 with VRRP, 315-326 site-to-site VPNs, 108-110 TED, 432 control messages, 16 creating message digests, 42-44 transforms, 63-66 **CRLs, 396** scalability, 404 crypto ACLs, 169 mismatches, troubleshooting, 169-170 crypto engines, 50 crypto maps, 236 configuring, 66-68 multiple peering statements, tunnel termination HA, 213 crypto path availability, 215-218 cryptographic endpoints, 397 cryptographic key derivation (SSL VPNs), 23 - 24CSM (Content Switch Module), external load balancing, 231-232

D

data authentication, 44 data confidentiality, 6 in VPDN deployments, 10 data integrity, 7, 42-44 decryption, 6 deployment models hub-and-spoke VPNs, 128-130 clustered spoke design, 130 redundant clustered spoke design, 131 IPsec+GRE, 121-122 sample configurations, 123-125 tunnel establishment, verifying, 126-127 RAVPNs, 132 clients, 132 clustered VPN concentrator designs, 137-138 standalone VPN concentrator designs, 133-136 site-to-site VPNs, 107 configuring, 108-110 over routed domain, 117-120 verifying configuration, 111-117 DES (data encryption standard), 21 Diffie, Whitfield, 392 **Diffie-Hellman** key exchange, 51 secret key generation, 79-80, 82-83 DiffServ, impact of IPsec on, 181–182 digital signatures, generating, 44-46 distribute lists, 199 DMVPNs (Dynamic Multipoint VPNs), 27, 130 geographic HA, configuring, 287-294 DNS server load balancing, 225-227 in RAVPNs with geographic HA, 343-345 454 DPD (Dead Peer Detection)

DPD (Dead Peer Detection), 92-94 peer availability, 217 dual-DMZ tunnel termination, 372-373, 377 dynamic crypto maps, 418 and RRI, 420 applying in SOHO environments, 432-446 configuring, 425-430 impact on ISAKMP/IKE, 418-419 impact on VPN behavior, 418-424 routing considerations, 419-420 security considerations, 421 key administration and scalability, 421-424 unrestricted peering and traffic flows, 424 TED, 430-432 verifying, 425-430

E-F-G

eliminating single points of failure for site-to-site VPNs, 209 enabling TED, 432 encryption, 6 asymmetric, 36-39 In-Path versus Out-of-Path, 361, 368-369 Out-of-Path, 370 symmetric, 21, 39-41 enrollment process, 395 for RSA signatures, 398, 402 for X.509 certficates, 398, 402 ESP (Encapsulating Standard Protocol), 6 confidentiality services, 55-56 data integrity and authentication services, 56-57 extensions for IKE mode config, 96-98 xauth, 98-99 external load balancers, 230-232

failover

stateful HA failover process, 261–263 stateless HA failover process, 246–257 firewalled VPN environments ICMP unreachables, troubleshooting, 174 troubleshooting, 171-174 tunnel termination, 370-378 floating static routes, 238 flow-based QoS, impact of IPsec on, 180-181 format of L2F packets, 10 forwarding public key certificates, 403 fragmentation on Cisco IOS VPN endpoints, 189-193 PMTUD, 184-188 preventing with IPsec Prefragmentation, 193-196 with manual MTU adjustment, 196 Virtual Fragmentation Reassembly, 174 generating Diffie-Hellman secret keys, 79-83 digital signatures, 44-46 geographic HA, 267 DMVPNs, 287-294

IPsec+GRE, 279–280, 283–287 RRI with multiple IPsec peers, 267–277 goals of VPN implementation, 6–7 GRE-offload, 306, 379–383. See also IPsec+GRE model with cleartext firewall paths, 385 with dynamic crypto maps, 383–384 with high-speed tunnel termination, 385 with IKE x-Auth, 384–385

Η

HA (High Availability) geographic HA, 267 DMVPNs, 287–294 IPsec+GRe, 279–287 RRI with multiple IPsec peers, 267–277 in RAVPNs, 314 concentrator redundancy with multiple peers, 345, 348–355 DNS-based load balancing, 343–345 HSRP, 327–333

VCA, 333-342 VRRP, 315, 320, 323-326 load-balanced designs concentrator clustering, 227-230 DNS server load balancing, 225-227 external load balancers, 230-232 load sharing with peer statements, 222-224 routing, 224 peer availability, 216 on-demand DPD, 217 SSO, 259 stateful HA alternatives to, 257-260 failover process, 261–263 stateless HA alternatives to, 242-245 failover process, 246-257 tunnel termination redundancy, 210 on HSRP/VRRP virtual interfaces, 211 using RP-based IPsec HA, 214-215 with multiple peer statements, 212-214 handshake process (SSL VPNs), 22-24 hardware-based VPN clients, 133 hashes, 42 Hellman, Martin, 392 HMAC (hashed message authentication codes), 24, 42 home gateways, 10 HSRP (Hot Standby Routing Protocol), 244 RAVPN concentrator HA, 327-333 timers, tuning, 255 HSRP/VRRP virtual interfaces, tunnel termination point HA, 211 hub-and-spoke IPsec model, 128-130 clustered spoke design, 130-131 site-to-site VPNs, 26

ICMP messages rate-limiting, 187 unreachables, troubleshooting in firewalled VPN environments, 174 identifying IPsec transform set mismatches, 168

IKE, 78 authentication errors, troubleshooting, 146-165 authentication services pre-shared keys, 83-85 RSA encryption, 85 RSA signatures, 86-87 X.509 certificates, 86-87 Diffie-Hellman secret key generation, 79-83 keepalives, removing stale SAs from SADB, 217 key mismatches, troubleshooting, 150-151 mode config extension, 96-98 Phase I negotiation aggressive mode negotiation, 89–90 main mode negotiation, 88-89 Phase II negotiation DPD, 92 IKE keepalives, 92–94 PFS, 91-92 quick mode negotiation, 90 SA negotiation and maintenance, 79 SA proposal mismatches, troubleshooting, 142-146 x-auth, 421 xauth extension, 98-99 impact of vendor interoperability on path availability, 301-305 In-Path encryption, 368-369 integrity, 7 IntServ, impact of IPsec on, 183 invalid SPI recovery, 308-309 IPComp, 58-59 **IPPCP** (IP Payload Compression Protocol), 58-59 **IPsec Prefragmentation**, 193–196 IPsec+GRE model, 121-122, 190 geographic HA, configuring, 279-280, 283-287 sample configurations, 123-125 tunnel establishment, verifying, 126-127 ISAKMP, 78 configuring, 94-95 ITU-T X.509v3-compliant certificates, 396 IV (Initialization Vector), 57

456 keepalives (IKE)

K_I

keepalives (IKE), 92-94 key management need for, 77 PKI, 391-393 CAs. 397 CRLs, 396 cryptographic endpoints, 397 public key certificates, 394–395 registration authorities, 395-396 L2F (Layer 2 Forwarding), home gateways, 10 L2TP (Laver 2 Tunneling Protocol) control messages, 16 payload packets, 16 tunnel negotiation process, 17 LAC (L2TP Access Concentrator), 16 lack of RP support, effect on IPS HA design, 302-304 Layer 2 Forwarding Protocol, 10 packet format, 10 tunnel establishment process, 11 - 12life cycle of public key certificates, 397 RSA signatures, 397, 401 X.509 certificates, 398, 401 limitations of vendor HA interoperability inability to specify multiple peers, 297-300 lack of peer availability mechanisms, 300-301 LLO (low-latency queuing), impact of IPsec on. 181-182 LNS (L2TP Network Server), 16 load balanced designs concentrator clustering, 227-230 DNS server load balancing, 225-227 configuring in RAVPNs with geographic HA, 343-345 external load balancers, 230-232 load sharing with peer statements, 222-224 routing, 224 load sharing with peer statements, 222-224 local IPsec HA, 235 Lookahead Fragmentation, 194 LZS (Lempel Ziv Stac), 58-59

M-N-O

main mode negotiation, 88-89 manual keying, 68-77 manual MTU adjustment, preventing fragmentation, 196 MD5 (Message Digest 5), 43 message digests, creating and verifying, 42-44 messages (ICMP), rate-limiting, 187 mismatched crypto ACLs, troubleshooting, 169-170 mismatched IKE SA proposals, troubleshooting, 142-146, 165-168 mismatched transform sets, identifying, 168 mode config extension (IKE), 96-98 MODP (prime modulus), 51 MP-BGP (Multiprotocol Border Gateway Protocol), 18 MPLS VPNs, 18-20 VRFs, 19 MPPE (Microsoft Point-to-Point Encryption), 13 MTUs (maximum transmission units), manual adjustment, 196 NAS (Network Access Server), 10 NAT (Network Address Translation) SPI-based, troubleshooting, 179-180 troubleshooting, 174-178 NAT Detect, 179 NAT-on-a-stick. IPsec VPN tunnel termination, 362-368 NAT-T, troubleshooting, 178–179 NHRP (next hop routing protocol), 27 nonces, 85 obtaining public key certificates, 403 **OCSP** (Online Certificate Status Protocol), 405 "on-a-stick" designs, 386 NAT-on-a-stick, 362-368 router-on-a-stick, 359-362

on-demand DPD, 217

OSI reference model, 9

Out-of-Path encryption, 368-370

Ρ

P (provider) routers, 18 packets, L2F, 10 path availability, 218, 284 and vendor HA availability, 301-305 path symmetry, managing, 219 pavload packets, 16 PE (provider edge) routers, 18 peer availability, 215-216, 297 on-demand DPD, 217 peer mismatches (IKE), troubleshooting, 150-151 periodic DPD, 218 PFS (perfect forward secrecy), 69, 91–92 PKI (Public Key Infrastructure), 391–393 CAs, 397 case studies CA hierarchy, 412–414 configuring CA/RA interoperability, 410-412 cryptographic endpoint integration, 407-409 CRLs, 396 cryptographic endpoints, 397 enrollment process, 163 public key certificates, 394-395 registration authorities, 395-396 PMTUD (Path MTU Discovery), 184-188 **PPTP** (Point-to-Point Tunneling Protocol), 12 compulsory tunnels, 13 data structure, 14 tunnel negotiation process, 14 voluntary tunnels, 13 preshared keys, 83-85 preventing fragmentation with IPsec Prefragmentation, 193-196 with manual MTU adjustment, 196 proxies, 169 PSKs (preshared keys), troubleshooting mismatched peer addresses, 149-150 public key certificates, 394-395 authentication, 402 forwarding, 403 life cycle of, 397 obtaining, 403 registration process, 402

RSA signatures, life cycle of, 397, 401 signing, 403 X.509 certificates, life cycle of, 398, 401 **public key cryptography, 392 public key encryption, 45–46** Diffie-Hellman key exchange, 51 RSA, 48–50 RSA signatures, 50

Q-R

QoS (quality of service), impact of IPsec on DiffServ, 181-182 flow-based, 180-181 IntServ, 183 quick mode negotiation, 90 RAs (registration authorities), 395-396 CA interoperability, configuring, 410-412 rate-limiting ICMP messages, 187 **RAVPNs** (remote-access VPNs) deployment model, 132 clients, 132 clustered VPN concentrator designs, 137-138 standalone VPN concentrator designs, 133-136 HA, 314 DNS-based load balancing, 343-345 geographic HA, DNS-based load balancing, 345, 348-355 HSRP, 327-333 VCA, 333–342 VRRP, 315, 320, 323-326 reconvergence of routing protocols, impact on IPsec reconvergence, 238–240 recursive routing effect on IPsec VPNs, 197-200 symptoms of, 197–198 redistribute static command, 245, 269 redistribution distribute lists, 199 of VPN routes, 253 redundant clustered spoke VPN design, 131 registration authorities, 395–396 CA interoperability, configuring, 410-412

```
registration process for public key
  certificates, 402
remote-access VPNs
    business drivers, 30
    SSL, 28
removing stale SAs from SADB, 217
round-robin approach to DNS resolution, 227
route descriptors, 20
router-on-a-stick, IPsec VPN tunnel
  termination, 359-362
routing, 224
RP-based IPsec HA, 214-215
RRI (Reverse Route Injection), 245
    and dynamic crypto maps, 420
    impact on vendor interoperability,
       304-305
RSA encryption, 48-50, 85
    IKE authentication errors, troubleshooting,
       151-158
    signatures, 23, 50, 86-87, 396
         enrollment process, 398, 402
         IKE authentication errors,
            troubleshooting, 158–165
         life cycle of, 397, 401
RSVP (Resource Reservation Protocol),
  impact of IPsec on, 183
```

S

sample IPsec+GRE model configurations, 123-125 SAs (security associations) IPsec tunnel security parameters, 59, 62-63 need for, 77 proposal mismatches, troubleshooting, 165-168 security parameters, manual keying, 68-77 transport mode, 52 tunnel mode, 54 scalability of CRLs, 404 **SCEP** (Simple Certificate Enrollment Protocol), 402 SCTP (Stream Control Transmission Protocol), 260 security wheel, 32 sender non-repudiation, 7 serialization delay, 196 session authentication (SSL VPNs), 24 SHA (Secure Hash Algorithm), 43

shared secret keys, 39 signing public key certificates, 403 single points of failure for site-to-site VPNs, 208-209 site-to-site IPsec VPNs, 25, 107 business drivers, 30-31 configuration, verifying, 111-117 configuring, 108-110 hub-and-spoke networks, 26 over routed domains, 117, 120 single points of failure, eliminating, 208-209 site-to-site IPsec+GRE model. See **IPsec+GRE model** software-based VPN clients, 132 SOHO deployments, applying dynamic crypto maps case study, 432-446 SPI (security parameter index), 56 SPI-based NAT, troubleshooting, 179-180 SSL VPNs, 21 cryptographic key derivation, 23-24 handshake process, 22-24 HMAC, 24 **RAVPN** architectures, 28 session authentication, 24 transport layer security, 25 tunnel establishment process, 22 SSO (stateful switchover), 259 stale SAs impact on IPsec reconvergence, 240 removing from SADB, 217 standalone VPN concentrator designs, 133-137 stateful IPSec HA, 212 alternatives to, 257-260 failover process, 261-263 stateless IPsec HA, 212 alternatives to, 242 HSRP, 244-245 RRI, 245 failover process, 246-257 goals of, 243-244 static crypto maps, 417-418 symmetric encryption, 21, 39-41 shared secret keys, Diffie-Hellman secret key generation, 79-83 symptoms of recursive routing, 197–198

TED (Tunnel Endpoint Discovery), 430-432 timers (HSRP), tuning, 255 topologies. See VPN topologies transform sets, identifying mismatches, 168 transforms AH, 57-58 creating, 63-66 ESP confidentiality services, 55-56 data integrity and authentication services, 56-57 IPComp, 58-59 LZS, 58-59 transport layer VPNs, SSL VPNs, 21 cryptographic key derivation, 23-24 handshake process, 22-24 HMAC. 24 session authentication, 24 transport layer security, 25 tunnel establishment process, 22 transport mode, 52, 55 troubleshooting IKE authentication errors, 146-165 peer mismatches, 150-151 SA proposal mismatches, 142–146, 165-168 mismatched crypto ACLs, 169-170 NAT issues in IPsec VPN designs, 174-178 SPI-based NAT, 179-180 NAT-T issues in IPsec VPN designs, 178 - 179VPNs in firewalled environments, 171-174 TTI (Trusted Transitive Introduction), 434 tunnel mode, 54-55 tunnel termination. See also tunnels dual-DMZ firewall design, 372-373, 377 firewalled, 370-378 GRE-offload, 379-383 with cleartext firewall paths, 385 with dynamic crypto maps, 383-384 with high-speed tunnel termination, 385 with IKE x-Auth. 384–385 "on a stick" termination NAT-on-a-stick, 362-368 router-on-a-stick, 359-362

termination redundancy, 210 on HSRP/VRRP virtual interfaces, 211 using RP-based IPsec HA, 214-215 with multiple peer statements, 212-214 tunnels L2F establishment process, 11-12 load-balanced designs concentrator clustering, 227-230 DNS, 225-227 external load balancers, 230-232 load sharing with peer statements, 222-224 routing, 224 negotiation process, 17 PPTP compulsory, 13 tunnel negotiation process, 14 voluntary, 13 SA security parameters, 59, 62-63

V

"validity period" field (ITU-T X.509v3compliant certificates), 396 VCA (Virtual Cluster Agent) protocol, 228 RAVPN concentrator HA, 333-342 vendor HA interoperability design considerations, 306 interoperability with stateful IPsec HA, 309-311 invalid security parameter index recovery, 308-309 Phase1/2 SA lifetime expiry, 307 SADB management, 307-308 impact on path availability, 301-305 limitations of inability to specify multiple peers, 297-300 lack of peer availability mechanisms, 300-301 verifying dynamic crypto maps, 425-430 IPsec+GRE model, tunnel establishment, 126-127 message digests, 42-44 site-to-site VPN configuration, 111-117 TED, 432 Virtual Fragmentation Reassembly, 174 voluntary tunnels, 13

VPDNs (virtual private dialup networks)

460

VPDNs (virtual private dialup networks), 10 L2TP, 16 control messages, 16 payload packets, 16 tunnel negotiation process, 17 Layer 2 Forwarding Protocol, 10 packet format, 10 tunnel establishment process, 11-12 **PPTP**, 12 compulsory tunnels, 13 data structure, 14 tunnel negotiation process, 14 voluntary tunnels, 13 VPN clients, 28 **VPN concentrators, 28** VPN routes, redistribution, 253 **VPN** topologies hub-and-spoke, 128-130 clustered spoke design, 130 redundant clustered spoke design, 131 IPsec+GRE model, 121-122 sample configurations, 123-125 tunnel establishment, verifying, 126-127 RAVPNs, 132 clients, 132 clustered VPN concentrator designs, 137-138 standalone VPN concentrator designs, 133-136 site-to-site, 107 configuring, 108-110 over routed domain, 117, 120 verifying configuration, 111-117

VPN tunnel termination dual-DMZ firewall design, 372-373, 377 firewalled, 370-378 GRE-offload, 379-383 with cleartext firewall paths, 385 with dynamic crypto maps, 383-384 with high-speed tunnel termination, 385 with IKE x-Auth, 384-385 "on a stick" termination NAT-on-a-stick, 362-368 router-on-a-stick, 359-362 termination redundancy, 210 on HSRP/VRRP virtual interfaces, 211 using RP-based IPsec HA, 214-215 with multiple peer statements, 212-214 VPN3000 Clustering, 227–230 **VRFs (VPN Routing and Forwarding** Instances), 19 VRRP, RAVPN concentrator HA, 315, 320, 323-326

W-X-Y-Z

wildcard preshared keys, 83

X.509 certificates, 86–87 enrollment process, 398, 402 life cycle of, 398, 401 x-auth, 421 xauth extension (IKE), 98–99