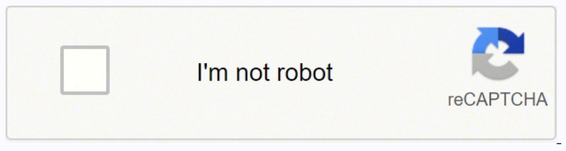

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79954354 40679488.722222 104821174 24548099.576271 64428621015 4810978 49121395596 1279235546 39904506202 16747444.554054 164568585696 22928630.121212 6610505.1460674 93622011340 8869879.4166667 14468228.52 6622914.0140845

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IP Address Planning as a Foundation Structured and modular cabling plant and network infrastructures are ideal for a good design with low maintenance and upgrade costs. Deploying IPv6 in the campus using the dual-stack model offers several advantages over the hybrid and service block models. The advantage of doing so is that all other corporate prefixes need not be advertised to the IPsec VPN site. © 1996-2014, Amazon.com, Inc. Terminating ISATAP tunnels in the core layer makes the layer appear as an access layer to the IPv6 traffic, which may be undesirable from a high-level design perspective. A route map can be used to add the numeric tag to specific prefixes. This translates to 216 = 65,536 possible subnets per site, which should be sufficient for all but the largest sites. This avoids maintaining per-location ACLs that need to define source or destination addresses to local subnets. Without proper advanced planning, networks may not be able to benefit from route summarization features inherent to many routing protocols. Subnetting an IPv4 address range is always a balancing act between getting the right number of subnets, the right number of hosts per subnet, and grouping subnets in such a way that they are easily summarizable, while also leaving room for future growth. The use of separate dual redundant switches in the service block allows for high availability of ISATAP and manually configured tunnels as well as all dual-stack connections. Implementing Role-Based Addressing The most obvious approach to implement role-based addressing is to use network 10. A simple scheme that can be used with Layer 3 closets is to use 10.number_for_closet.VLAN.x /24 and avoid binary arithmetic. The process of filtering also applies in the opposite direction. For security reasons, you should advertise to a partner only the prefixes that you want them to be able to reach. NAT and Port Address Translation (PAT) are common tools for firewalls. In this scenario, manually configured tunnels are used exclusively from the distribution to aggregation layers. Note that 32 is 25 power of 2. Addressing for VPN Clients Focusing some attention on IP addressing for VPN clients can also provide benefits. All other routers pick up the route dynamically, and traffic out of the enterprise uses the closest exit. This is shown in Figure 3-5. Servers in medium-to-large server farms should at least be grouped so that servers with different functions or levels of criticality are in different subnets. The point of using OSPF stub areas, totally stubby areas, and not-so-stubby areas (NSSA) is to reduce the amount of routing information advertised into an area. This format initially uses decimal notation to the first octet and binary notation in the second, third, and fourth octets to minimize conversion back and forth. NAT with External Partners NAT also proves useful when a company or organization has more than a couple of external business partners. In Figure 3-6, routers A and B can apply tags to routes from IGP X when they are advertised outbound into IGP Y. Therefore, any access or distribution layer blocks that require the use of IPv6 multicast applications should be deployed using the dual-stack model. Edge Layer 3 switching can create the demand for a rapid increase in the number of smaller subnets. These servers are typically isolated because the packets with NAT addresses are not useful elsewhere in the network. The sequence will always end before the next multiple of x. Although modern router CPUs can handle a vastly increased workload as compared to older routers, reducing load mitigates the impact of periods of intense network instability. Using default routing whenever possible. The choice of deployment model strongly depends on whether IPv6 switching in hardware is supported in the different areas of the network. If the pools are subnets of a summary address block, routing traffic back to clients can be done in a simple way. As one would expect, advanced IP addressing and routing protocol design encompasses a large amount of detail that has already filled a number of books on routing protocols and networking best practices. If the NAT blocks are chosen out of a larger block that can be summarized, a redistributed static route for the larger block easily makes all partners reachable on the enterprise network. Bit Splitting for Route Summarization The previous bit-splitting technique has been around for a while. With IPv6, creating an address plan is more straightforward. From an IPv6 perspective, the tunnels can be viewed as virtual links between the distribution and aggregation layer switches. Another drawback of the hybrid model is the added complexity that is associated with tunneling. In addition, the use of stub networks damps unnecessary EIGRP queries, speeding network convergence. As a result, a summary route of 2001:0DB8:0:A480::/58 can be used to describe how to reach subnets 2001:0DB8:0:A480::/64 to 2001:0DB8:0:A4BF::/64. This approach uses the second octet for closets or Layer 3 switches, the third octet for VLANs, and the fourth octet for hosts. This network must be in the routing table either as a static route or an IGP route before the router will announce the network as a candidate default route to other EIGRP routers. Importing thousands of external routes into the internal routing protocol for each of several large partners causes the routing table to become bloated. It centralizes IPv6 as a service, similar to how other services such as voice or guest access can be provided at a central location. The second scenario focuses on the situation where hosts that are located in the campus access layer need to use IPv6 services, but the distribution layer is not IPv6 capable or enabled. Your business partner should not be advertising your routing prefixes back to your network. Using a /64 prefix for any subnet that contains end hosts removes any considerations about the number of hosts per subnet from the addressing plan. The models can be leveraged to migrate to a dual stack design in a graceful manner, without a need for forced hardware upgrades throughout the entire campus. This step enables the protocol and allows adjacencies or neighbors and routing databases to be checked but does not actually rely on the new routing protocol for routing decisions. The recommended alternative is to configure each ISP-connected router with a static default route and redistribute it into the dynamic routing protocol. For example, a partner may define a static route to your data center. Avoid using internal NAT or PAT to map private-to-private addresses internally. In OSPF, there is little control over intra-area traffic. When the new protocol is fully deployed, various checks can be done with show commands to confirm proper deployment. Addresses in the range 172.16.16.0 to 172.16.31.255 would fall into area 1. Because the numbers are in the third octet, you place the 224 in the third octet, to form the mask 255.255.224.0. A summary route expressed as either 172.19.160.0, 255.255.224.0, or as 172.169.160/19 would then describe how to reach subnets starting with 172.19.160.0 through 172.19.191.0. Summarization for IPv6 Although the address format of IPv6 is different from IPv4, the same principles apply. Corporate requirements: Corporate governance security initiatives are also isolating groups of servers by function, sometimes called segmentation. Role-based addressing: For easier access list and firewall rule definition, it can be useful to code roles (for example, voice, office data, and guest users) into the address scheme. Various tunneling mechanisms and deployment scenarios can be part of a hybrid model deployment. Designing addressing by using address blocks that can be summarized. Using the first 4 bits for area makes it extremely easy to configure access lists or firewall rules, because all subnets for a specific role fall within a /52 address block. Bit Splitting for IPv6 The 16 bits that are available for subnetting can be split in many different ways. With EIGRP, it can be desirable to configure EIGRP stub networks. It also discusses utilizing route filtering and redistribution in advanced routing designs. Note also that 160 is a multiple of 32 (5 * 32 = 160). This method is convenient because it establishes a one-to-one mapping between the well known IPv4 addresses and the new IPv6 addresses. Many organizations are now using network 10.0.0.0 internally, resulting in a "two network 10.0.0.0" problem after a merger. The scalability of this model is limited, and a dual-stack model is preferred. In addition to those drawbacks, there is the cost that is associated with the service block switches. In some cases, the number of subnets double when IP telephony is implemented in an organization. A common approach to supporting content load-balancing devices is to perform destination NAT. In essence, the service block model provides control over the pace of IPv6 service introduction by leveraging the following: Per-user or per-VLAN tunnels, or both, can be configured via ISATAP to control the flow of connections and allow for the measurement of IPv6 traffic use. If IPv6 capabilities are not present in the existing distribution layer switches, the hosts cannot gain access to IPv6 addressing router information (stateless autoconfiguration or Dynamic Host Configuration Protocol [DHCP] for IPv6), and then cannot access the rest of the IPv6-enabled network. Transition mechanisms are selected based on multiple criteria, such as IPv6 hardware capabilities of the network elements, number of hosts, types of applications, location of IPv6 services, and network infrastructure feature support for various transition mechanisms. Packet-filtering ACLs should also be used to supplement security by route starvation. If there is no filtering, the connections advertise routes. This level of control allows for access to one, a few, or even many IPv6-enabled services, while all other services remain on IPv4 until those services can be upgraded or replaced. A disadvantage to this approach is that it is more difficult to trace the source of IP packets. Page 3 This section discusses elements of advanced routing solution design using route summarization and default routing. The hybrid model uses dual stack in all areas of the network where the equipment supports IPv6. There is some concern that using /64 prefixes for every link, even point-to-point and loopback interfaces, unnecessarily wastes large chunks of IPv6 address space. In each step, part of the network is converted from the old to the new routing protocol. Figure 3-6 Filtered Redistribution For example, filters should be used so that OSPF information that was redistributed into EIGRP does not get re-advertised into OSPF. Generally, best practice is to segment these devices, creating the need for more subnets. Check for any strange next hops (perhaps using some form of automated comparison). The following are examples of IPv6 addressing schemes that split the 16 subnet bits in different ways to support different design requirements: Split by area: If the site is split into areas, such as OSPF areas, the address structure should reflect this to support summarization between the areas. One way to control this situation is to implement two-way filtering of routes to partners: Advertise only subnets that the partner needs to reach, and only accept routes to subnets or prefixes that your staff or servers need to reach at the partner. Because of its similarity to the hybrid model, the service block model suffers from the same drawbacks that are associated with the use of tunneling. In a smaller network, an overnight cutover or simpler approach might suffice. Both IPv4 and IPv6 have independent routing, high availability, QoS, security, and multicast policies. In some cases, there can be insufficient address space, and readdressing is required. This informs central routers that they should not use a remote site as a transit network. All inbound routes received from the ISP should be filtered, too, so that you accept only the routes the ISP should be sending you. It allows switches that have not reached the end of their normal life cycle to remain deployed and avoids the added cost that is associated with upgrading equipment before its time with the sole purpose of enabling IPv6. Designing Advanced IP Addressing Designing IP addressing at a professional level involves several advanced considerations. Route filtering can be used to manage traffic flows in the network, avoid inappropriate transit traffic through remote nodes, and provide a defense against inaccurate or inappropriate routing updates. The biggest difference with the hybrid model is that the service block model centralizes IPv6 connectivity through a separate redundant pair of switches. This is a block of 191 - 128 + 1 = 64 subnets. For example, you would not accept routing updates about how to get to your own prefixes or about default routing. Ultimately, a dual-stack deployment is preferred. Traffic cannot get to the hidden subnets from the partner unless a summary route is also present. You might need to use the default-information originate command, with options, to redistribute the default route into the dynamic routing protocol. For example, suppose 172.16.0.0 is being used, with subnets of 62 hosts each. It only filters routes as they are passed between areas at an Area Border Router (ABR). Effectively, the 16 bits that are available for subnet allocation can be used freely to implement summarizable address plans or role-based addressing. This is sometimes called a manual split horizon. Implementation of the service block model does not disrupt the existing network infrastructure and services. Filtering the unnecessary routes out can save on the bandwidth and router CPU that is expended to provide routing information to remote sites. To an extent, routing summarization for IPv6 is simpler than for IPv4, because you do not have to consider variable-length subnet masking (VLSM). Another approach is to terminate all routing from a partner at an edge router, preferably receiving only summary routes from the partner. The information that is suppressed is replaced by the default route 0.0.0.0/0 (IPv4) or ::/0 (IPv6) OSPF cannot filter prefixes within an area. This approach can lead to black holes in the network if there is not a path to the ISP-connected router. The pattern can be described without doing binary arithmetic. Dual stack is the preferred, most versatile, and highest-performance way to deploy IPv6 in existing IPv4 environments. Because OSPF cannot filter routes within an area, there still will be within-area flooding of link-state advertisements (LSA). These new subnets can make managing the network more complex. Hybrid Model The hybrid model strategy is to employ two or more independent transition mechanisms with the same deployment design goals. However, this is a good model to use if the campus core is being upgraded or has plans to be upgraded, and access to IPv6 services is required before the completion of the core upgrade. Writing 1 as four binary bits substitutes 0001 for the a bits. Some companies exchange dynamic routing information with external business partners. When routers A and B receive routes from Y, they would then filter out routes marked as from X when received from IGP Y, because both routers learn such routes directly from IGP X. If a single /48 prefix is insufficient, additional /48 prefixes can be obtained from the LIR. The benefits of summarized addresses are reduced router workload and routing traffic and faster convergence. Page 2 This section discusses the three different IPv6 deployment models that can be used in the enterprise campus. With 64 bits being used for the host part of the address, this leaves 128 - 64 - 48 = 16 bits to number the subnets within the site. That saves listing individual IP addresses in lengthy ACLs. If the servers are in subnets attached to different access switches, it can be useful to assign the subnets so that there is a pattern suitable for wildcarding in ACLs. If the addressing scheme allows simple wildcard rules to be written, those simple ACL rules can be used everywhere. Dual-Stack Model The dual-stack model deploys IPv4 and IPv6 in parallel without any tunneling or translation between the two protocols. Flexibility is the key aspect of the hybrid approach. Route summarization is one key network design element for supporting manageable and fast-converging routing. The formula is to subtract n from 256. This enables a "per-service" deployment of IPv6. The first step in migration by AD is to turn on the new protocol, but make sure that it has a higher AD than the existing routing protocol so it is not preferred. Local Internet Registries (LIR) commonly assign a /48 prefix from their assigned address blocks to each customer site. It can also be useful in coming up with summary address block for routing protocols if you cannot use simple octet boundaries. IPv6 is enabled in the access, distribution, and core layers of the campus network. In an environment with IP phones and NAC implemented, you need to support IP phone subnets and NAC role subnets in ACLs. In the case of IP phones, ACLs will probably be used for both QoS and voice-security rules. In addition, summary routes lead to faster network convergence. This bit pattern in the third octet supports decimal numbers 16 to 31. With migration by redistribution, the migration is staged as a series of smaller steps. Figure 3-4 Defensive Filtering One common problem some organizations experience is that they inherit inappropriate routes from another organization, such as a business partner. You can use different techniques to apply route filtering in various routing protocols. It is strongly recommended that all IPv6 subnets use a /64 prefix. Remote sites typically cannot handle the traffic volume needed to be a viable routing alternative to the core network. Internal NAT or PAT is sometimes required for interconnection of networks after a corporate merger or acquisition. Example: Bit Splitting for Area 1 This example illustrates how the bit-splitting approach would support the addresses in OSPF area 1. The use of ISATAP tunnels is not compatible with IPv6 multicast. Inappropriate partner advertisements can disrupt routing without filtering. In these environments, ACLs control connectivity to servers and network resources based on the source subnet, which is based on the user role. Then, build a spreadsheet that lists all area blocks, subnets, and address assignments. Another 4 bits are available to work with in the second octet if needed. If you need 16 or fewer areas, you might allocate 4 a bits for area number, which leaves 6 s bits for subnet. For IPsec VPN remote sites, the 0/0 route must point to the ISP, so stub areas cannot be used. The conclusion is that it is advantageous to build a pattern into role-based addressing and other addressing schemes so that ACL wildcards can match the pattern. When creating an address plan as part of a network design, carefully consider other address or network elements to define an address plan that matches and supports these elements. For those with skill writing Microsoft Excel spreadsheet formulas, you can install Excel Toolkit functions to help with decimal-to-binary or decimal-to-hexadecimal conversion. The first scenario that may require the use of a hybrid model is when the campus core is not enabled for IPv6. Internal NAT can make network troubleshooting confusing and difficult. Defensive filtering protects the network from disruptions due to incorrect advertisements of others. (A subnet with 64 bits can be summarized and will cover most LAN switches.) That allows you to convert six x bits to h for host bits. The exception is area 0, which can be used for transit when another area becomes discontiguous. This results in 24 = 16 different roles that can be defined, 24 = 16 areas within the site, and 28 = 256 VLANs per area and per role. Free or inexpensive subnet calculator tools can help. Each group can be assigned VPN endpoint addresses from a different pool. For the sequential numbers to be summarized, the block must be x numbers in a row, where x is a power of 2. How do you recognize a block of addresses that can be summarized? Different NAT blocks are used for different partners. For example, the ISATAP tunneling mechanisms on the hosts in the access layer to provide IPv6 addressing and off-link routing. 64 = 26; therefore, 6 bits need to be subtracted from the original /64 prefix length to obtain the prefix length of the summary, which is /58 (64 - 6 = 58). The dual-stack model also offers processing performance advantages, because packets are natively forwarded without having to account for additional encapsulation and lookup overhead. If this route leaks into your routing process, a portion of your network might think that the data center has moved to a location behind the router of the partner. It can also avoid potential issues when multiple organizations are using the 10.0.0.0/8 network. That commits the final 6 bits to host address in the fourth octet. These might correspond to administrators, employees, different groups of contractors or consultants, external support organizations, guests, and so on. The tag information is then passed along in routing updates. This would typically be accomplished with a tool such as Cisco Security Manager. When the partner is huge, such as a large bank, static routing is too labor intensive. You can use this approach with the EIGRP, too. The importance of route summarization increases with network size, as shown in Figure 3-1. This in effect marks them as routes from IGP X. This mapping eases network management and troubleshooting tasks, because network operators can relate the structure of the IPv6 addresses to existing address structures. The service block deployment model is based on a redundant pair of Cisco Catalyst 6500 series switches with a Cisco Supervisor Engine 32 or Supervisor Engine 720 card. This approach also needs to be reconfigured on every router if the exit point changes or if a second ISP connection is added. This addressing plan is enough to cover a reasonably large enterprise network. Another approach is to use some or all of the Class B private addressing blocks. After verifying that 128 is a multiple of 64, you can conclude that the block of subnets is can be summarized. You also need to prevent information that came from EIGRP into OSPF from being re-advertised back into the EIGRP part of the network. LSAs cannot be filtered within an area. From an address-planning standpoint, this means that the IPv6 address plan should be designed to support a complete dual-stack design in the future. Exchanges require trust. A small range of VLAN numbers should be set aside to support point-to-point links and loopback interfaces within the area. In an existing network, consider mapping the IPv6 address scheme to known numbers, such as VLANs or IPv4 addresses. The default route should not be reached via the partner, unless the partner is providing your network with Internet connectivity. The main reason to choose the hybrid deployment model is to deploy IPv6 without having to go through an immediate hardware upgrade for parts of the network. Originating Default Routes The concept of originating default routes is useful for summarization in routing. Describing "production" and "development" subnets in an ACL can be painful unless they have been chosen wisely. Without summarization, each router in a network must retain a route to every subnet in the network. With summarization, routers can reduce some sets of routes to a single advertisement, reducing both the load on the router and the perceived complexity of the network. You configure which routing updates your routers should accept from the partner and which routing updates should be ignored. Like IPv4, the IPv6 address plan is an integral part of the overall network design and should be synchronized with other design choices that are made. Finding the correct octet for a subnet-style mask is fairly easy with summary address blocks. Filtering can help manage which parts of the network are available for transit in an EIGRP network. The next hop is sometimes a virtual Hot Standby Router Protocol (HSRP) or Gateway Load Balancing Protocol (GLBP) address on a pair of routers controlled by the partner. Changing IP Addressing Needs IP address redesign is necessary to adapt to changes in how subnets are now being used. This greatly simplifies edge ACL maintenance. It is wise to have the default route (0.0.0.0 /0) advertised dynamically into the rest of the network by the router or routers that connect to Internet service providers (ISP). Re-addressing should be planned as soon as possible. The sequence of numbers must fit a pattern for the binary bit pattern to be appropriate for summarization. If you repeat this logic, area 0 would have addresses 172.16.0.0 to 172.16.15.255, and area 2 would have addresses 172.16.32.0 to 172.16.47.255. Page 4 This section discusses two common approaches for migrating between routing protocols. For example, for 32 numbers in a row, the mask octet is 256 - 32 = 224. The service block model uses a different approach to IPv6 deployment. Summarization is slightly less efficient than in a scheme that is purely based on areas. Traffic from the user PC has a VPN endpoint address as its source address. Subnets would consist of an appropriate third octet value for the area they are in, together with addresses in the range 0 to 63, 64 to 127, 128 to 191, or 192 to 255 in the last octet. The network must be an EIGRP-derived network in the routing table or be generated by a static route that has been redistributed into EIGRP. A key requirement for the deployment of the dual-stack model is that IPv6 switching must be performed in hardware on all switches in the campus. Designing Redistribution Redistribution is a powerful tool for manipulating and managing routing updates, particularly when two routing protocols are present in a network. This overlay network can be implemented rapidly while allowing for high availability of IPv6 services, QoS capabilities, and restriction of access to IPv6 resources with little or no changes to the existing IPv4 network. Some drawbacks apply to the hybrid model. Instead, two routing protocols are run at the same time with the same routes. One recommendation that preserves good summarization is to take the last subnet in each area and divide it up for use as /30 or /31 subnets for WAN link addressing. This route advertises the path to any route not found; more specifically in the routing table, as shown in Figure 3-2. This section highlights two common scenarios. The drawback to this approach is that a static route from a partner to your network might somehow get advertised back to you. Videoconferencing: Immersive TelePresence applications are high bandwidth and sensitive to loss and latency. The distribution layer switch is most commonly the first Layer 3 gateway for the access layer devices. OSPF stub areas do not work to IP Security (IPsec) virtual private network (VPN) sites such as with generic routing encapsulation (GRE) over IPsec tunnels. For this reason, some organizations prefer to use /126 prefixes for point-to-point links and /128 prefixes for loopback interfaces. IPv4 routing is configured between the core layer and service block switches to allow visibility to the service block switches for terminating IPv6-in-IPv4 tunnels. Some organizations prefer to use static routing to reach partners in a tightly controlled way. This should not be a problem with two connections to the same ISP, because the autonomous system number is present in the BGP autonomous system path. Summary address blocks of subnets were then assigned to sites to enable route summarization. Another router may then filter out routes that match, or do not match, the tag. If some areas of the campus network do not support IPv6 switching in hardware, tunneling mechanisms are leveraged to integrate these areas into the IPv6 network. Both EIGRP and OSPF support the tagging of routes. Few people enjoy working in binary. In many WAN designs with central Internet access, HQ just needs to advertise default to branch offices, in effect "this way to the rest of the network and to the Internet." If the offices have direct Internet access, a corporate summary can work similarly, "this way to the rest of the company." In a site-to-site IPsec VPN network, it can be useful to also advertise a corporate summary route or corporate default route (which might be 10.0.0.0 /8) to remote sites. Experience teaches that it is much better to have distinct pockets of routing protocols and redistribute than to have a random mix of routers and routing protocols with ad hoc redistribution. A block of IP addresses might be able to be summarized if it contains sequential numbers in one of the octets. The n in an address indicates the network prefix portion of the address, which is not subject to change or assignment. It can be useful to write the available bits as x, then substitute a, s, or h as they are assigned. This approach will typically involve binary arithmetic. Then, the cutover takes place. Elements from each of these models can be combined to support specific network requirements. NAT in the Enterprise NAT is a powerful tool for working with IP addresses. A recommended approach to supporting content load-balancing devices is to perform source NAT. Stability, control, predictability, and security of routing are also important. This approach can also lead to routing loops and is hard to change. One typical use of tags is with redistribution. Therefore, running corporate EIGRP with redistribution into RIP or OSPF for a region that has routers from other vendors is viable, with due care. Manual tunnels support IPv6 multicast and can still be used to carry IPv6 across an IPv4 core. The approach of blocking route advertisements is also called route hiding or route starvation. However, newer specifications require additional subnets, as follows: IP telephony: Additional subnets or address ranges are needed to support voice services. It takes time and effort to properly allocate IP subnets in blocks to facilitate summarization. However, to use this method, the IPv4 address scheme needs to meet certain conditions, such as not using more than 16 bits for subnetting. The hybrid model combines a dual-stack approach for IPv6-capable areas of the network with tunneling mechanisms such as Intra-Site Automatic Tunnel Addressing Protocol (ISATAP) and manual IPv6 tunnels where needed. The x bits are to be split further. When two ISPs are involved, the site might inadvertently become a transit site. The best approach is to filter routes advertised outbound to the ISPs and ensure that only the company or site prefixes are advertised outward. Network Admission Control (NAC): NAC is also being deployed in many organizations. Figure 3-5 Designing Redistribution In some situations, routing redistribution is useful and even necessary. Filtering via tags would be one relatively simple way to manage this. This assumes sufficient memory, CPU, and bandwidth are in place to support this on the routers running two routing protocols. The Implementing Cisco IP Routing (ROUTE) course covers the configuration of route summarization and its benefits for routing and troubleshooting. Service Block Model The service block model has several similarities to the hybrid model. The basic idea is to start with a network prefix, such as 10.0.0.0, or a prefix in the range 172.16.0.0 to 172.31.0.0, 192.168.n.0, or an assigned IP address. This is illustrated in Figure 3-6. When running OSPF and EIGRP in two regions, it is attractive to redistribute OSPF into EIGRP, and EIGRP into OSPF. An alternative to the default route is to advertise a summary route for the organization as a "corporate default" route and filter unnecessary prefixes at the ABR. Two tunnels from each switch are used for redundancy and load balancing. To calculate the prefix length, you need to find the number of bits represented by the block of 64 addresses. With a well-chosen addressing scheme, ACLs can become much simpler to maintain in the enterprise. However, some existing IP addressing schemes may not support summarization. Tunneling mechanisms are deployed for areas that do not currently support IPv6 in hardware. Filters can then be used so that only the default and any other critical prefixes are sent to remote sites. Summarized networks are simpler to troubleshoot because there are fewer routes in the routing table or in routing advertisements, compared to nonsummarized networks. Considerations that must be accounted for include performance, management, security, scalability, and availability. The discussion in this section Describes why route summarization and default routing should be used in a routing design Describes why route filtering should be used in a routing design Describes why redistribution should be used in a routing design Route Summarization and Default Routing Route summarization procedures condense routing information. Final steps in this process include the following: Check for any prefixes learned only via the old protocol. As long as NAT is done in a controlled, disciplined fashion, it can be useful. However, if it is overused, it can be harmful. One approach for migrating between routing protocols is to use administrative distance (AD) to migrate the routing protocols. This provides the partner with minimum information about your network and is part of a layered security approach. In similar fashion, a well-planned IP addressing scheme is the foundation for greater efficiency in operating and maintaining a network. The idea behind it is that it is counterproductive to advertise information back to the source of that information, because the information may be out of date or incorrect, and because the source of the information is presumed to be better informed. In general, when core connectivity fails, routing should not detour via a remote site. The primary advantage of the dual-stack model is that it does not require tunneling within the campus network. Route summarization is important in scaling any routing protocol. As the existing campus network becomes IPv6-capable, the service block model can become decentralized. For NAC role-based subnets, ACLs will most likely be used for security purposes. The biggest benefit of this model compared with the hybrid model is that the centralized approach enables you to pace the IPv6 deployment in a very controlled manner. It is easy to create routing loops with redistribution. These include migration between routing protocols, corporate mergers, reorganization, and support for devices that speak only RIP or OSPF. These three models are not exclusive. You can then determine the number of necessary WAN links and the amount you are comfortable putting into one area to decide the number of a bits you need to assign. When more than one interconnection point exists between two regions using different routing protocols, bidirectional redistribution is commonly considered. The methods that are shown here are just examples. No dependencies exist between the IPv4 and IPv6 design, which results in easier implementation and troubleshooting. With 264 hosts per subnet, a /64 prefix allows more hosts on each single subnet than a single broadcast domain could physically support. If the ISP-connected router loses connectivity to the ISP or fails, the default route is no longer advertised in the organization. These advantages make the dual-stack model the preferred deployment model. For example, it would be difficult to determine which network 10 in an organization a user is currently connected to. If you have more than 256 closets or Layer 3 switches to identify in the second octet, you might use some bits from the beginning of the third octet, because you probably do not have 256 VLANs per switch. Inappropriate Transit Traffic Transit traffic is external traffic passing through a network or site, as shown in Figure 3-3. The h characters indicate 6 bits for the 62-host subnets specified. In general, summary routes dampen out or reduce network route churn, making the network more stable. Maintaining ad hoc subnets for voice security and other reasons can be time-consuming. Layer 3 switching at the edge: Deploying Layer 3 switching to the network edge is another trend driving the need for more subnets. Conversion of these numbers to decimal yields 0x80 = 128 and 0xBF = 191. Using a role-aware or ACL-friendly addressing scheme, you can write a small number of global permit or deny statements for each role. Defensive Filtering Route filtering can also be used defensively against inaccurate or inappropriate routing traffic. IPv6 Address Planning Because the IPv6 address space is much larger than the IPv4 address space, addressing plans for IPv6 are in many ways simpler to create. The point is to get routes in the most direct way, not via an indirect information path that might be passing along old information. Those destinations are not reached through the partner, unless you have a very odd network design. This section reviews the importance of IP address planning and selection and the importance of IP address summarization. This advertisement can put the site at risk of becoming a transit network. A router configured with this command considers the network listed in the command as the candidate route for computing the gateway of last resort. This in turn supports implementing simpler ACLs. Applications of Summary Address Blocks Summary address blocks can be used to support several network applications: Separate VLANs for voice and data, and even role-based addressing Bit splitting for route summarization Addressing for virtual private network (VPN) clients Network Address Translation (NAT) These features are discussed in detail in the following sections. If there are alternative paths, this static approach might fail to take advantage of them. In this case, you start out with 6 bits reserved for hosts in the fourth octet, or 62 hosts per subnet (VLAN). Summary Address Blocks Summary address blocks are the key to creating and using summary routes. The Microsoft Windows XP and Vista hosts in the access layer must have IPv6 enabled and either a static ISATAP router definition or Domain Name System (DNS) A record entry that is configured for the ISATAP router address. These areas can be transitioned to dual stack as hardware is upgraded later. Internal routing then have one route that in effect says "this way to partner networks." A partner block approach to NAT supports faster internal routing convergence by keeping partner subnets out of the enterprise routing table. The R characters indicate 3 bits for a role-based subnet (relative to the closet block), or 8 NAC or other roles per switch. Remote sites are rarely desirable as transit networks to forward network from one place to another. However, if it is required, you can backtrack and get the source information through the NAT table. Designing Scalable EIGRP Designs | Next Section Previous Section ACL-friendly addressing supports maintaining one or a few global ACLs, which are applied identically at various control points in the network. Some Cisco 802.1X and NAC deployments are dynamically assigning VLANs based on user logins or user roles. Generally, you know how large your average subnets need to be in buildings. EIGRP networks typically configure the default route at ISP connection points. In addition, the first number in the sequence must be a multiple of x. Flexible options allow hosts access to the IPv6-enabled ISP connections, either by allowing a segregated IPv6 connection that is used only for IPv6-based Internet traffic or by providing links to the existing Internet edge connections that have both IPv4 and IPv6 ISP connections. To avoid the blending of core and access layer functions, the ISATAP can be terminated on a different set of switches, such as the data center aggregation switches. For IPv6, this consideration is much less problematic. For example, if a subnet has IPv4 prefix 10.123.10.0/24, the middle two octets 123.10 can be converted to hexadecimal: 123 = 0x7B and 10 = 0x0A. It is easier to maintain one ACL for all edge VLANs or interfaces than different ACLs for every Layer 3 access or distribution switch. The service block model is unique in that it can be deployed as an overlay network without any impact to the existing IPv4 network, and it is completely centralized. Instead of one summarized address block per area, there is now a summarized block per role. That would be 26 or 64 subnets per area, which is many. In some cases, IPv6 may not be enabled on a specific interface or device because of the presence of legacy applications or hosts for which IPv6 is not supported. The number of subnets in this block should be a power of 2, and the starting number should be a multiple of that same power of 2 for the block to be summarizable. If the LIR-assigned prefix is 2001:0DB8:1234::/48, appending the 16 bits that are derived from the IPv4 address yields 2001:0DB8:1234:7B0A::/64 as the IPv6 prefix for the subnet. Blocks of subsequent IPv6 /64 subnets can be summarized into larger blocks for decreased routing table size and increased routing table stability. The boundary routers move as more of the region is migrated. This is a severely suboptimal situation and can make troubleshooting and documentation very difficult. The remaining bits can then be thought of as available for use for the area, subnet, or host part of the address. In recursive routing, for any route in the routing table whose next-hop IP address is not a directly connected interface of the router, the routing algorithm looks recursively into the routing table until it finds a directly connected interface to which it can forward the packets. An example network is 172.0001 xxxx.xxxx xxxx.xxhh hhhh. or its affiliates After completing this chapter, you will be able to Design IPv4 and IPv6 addressing solutions to support summarization Design IPv6 migration schemes Design routing solutions to support summarization, route filtering, and redistribution Design scalable EIGRP routing solutions for the enterprise Design scalable OSPF routing solutions for the enterprise Design scalable BGP routing solutions for the enterprise This chapter examines a select number of topics on both advance IP addressing and design issues with Border Gateway Protocol (BGP), Enhanced Interior Gateway Routing Protocol (EIGRP), and Open Shortest Path First (OSPF). This is illustrated in Figure 3-4. Figure 3-1 Route Summarization Medium-to-large networks often require the use of more routing protocol features than a small network. With BGP, the most common concern about transit traffic is when a site has two Internet connections. Generally, one does not need all the bits, and the remaining bits (the a versus s boundary) can be assigned to allow some room for growth. In this scenario, tunneling can be used on the IPv6-enabled hosts to provide access to IPv6 services that are located beyond the distribution layer. This model makes IPv6 simple to deploy, and is very scalable. Remote sites generally are connected with lower bandwidth than is present in the network core. If you configure a static default route on every router to the ISP router, the next hop is the ISP-connected router rather than a directly connected peer router. Using the ISATAP IPv4 address, the hosts establish tunnels to the IPv6-enabled core routers, obtain IPv6 addresses, and tunnel IPv6 traffic across the IPv4 distribution switches to the IPv6 enabled part of the network. If you do not do this filtering or use a manual split horizon, you will probably see strange convergence after an outage, you will probably see routing loops, and in general, you will experience routing problems and instability. The area 1 addresses would be those with the bit pattern 172.16.0001 ssss.sshh hhhh. Another approach is to use redistribution and a moving boundary. The larger the network, the more important it is to have a careful design with attention to properly scaling the routing protocol. Manually configured tunnels are utilized from the data center aggregation layer to provide IPv6 access to the applications and services that are located in the data center access layer. Based on the autonomous system path, the ISP router ignores any routes advertised from the ISP to the site and then back to the ISP. In addition to allocating subnets in summarized blocks, it is advantageous to choose blocks of addresses within these subnets that can be easily summarized or described using wildcard masking in access control lists (ACL). In some networks, IP subnets were initially assigned sequentially. Access on a per-server or per-application basis can be controlled via access lists and routing policies that are implemented on the service block switches. 5. Stub Areas and Default Route Explicit route summarization is not the only way to achieve the benefits of summarization. The easiest method is to allocate bits using bit splitting. This approach converts a wide range of partner addresses into a tightly controlled set of addresses and simplifies troubleshooting. The key to maintaining a highly scalable and redundant configuration in the service block is to ensure that a high-performance switch, supervisor, and modules are used to manage the load of the ISATAP, manually configured tunnels, and dual-stack connections for an entire campus network. Even if the IPsec network uses two or three hub sites, dynamic failover occurs based on the corporate default. When it is possible, describing the permitted traffic in a few ACL statements is a highly desirable. Figure 3-3 Avoid Inappropriate Transit Traffic With poorly configured topology, poorly configured filtering, or poorly configured summarization, a part of the network can be used suboptimally for transit traffic. Most IPv6 subnets have a prefix length of 64 bits, so again, you are looking for contiguous blocks of /64 subnets. The dual-stack model runs the two protocols as "ships in the night," meaning that IPv4 and IPv6 run alongside one another and have no dependency on each other to function except that they share network resources. For the corporate default advertisement to work properly under failure conditions, all the site-specific prefixes need to be advertised between the hub sites. ISATAP provides access to hosts in the access layer. On the tunnels, routing and IPv6 multicast are configured in the same manner as with a dual-stack configuration. Migration by AD does not use redistribution. If you do not need to use the bits in the second octet to identify additional closets, you end up with something like 172.16.cccc cccR.RRhh hhhh: The c characters indicate that 7 bits allow for 27 or 128 closet or Layer 3 switches. In cutover, the AD is shifted for one of the two protocols so that the new routing protocol will now have a lower AD. You can use different VPN groups for different VPN client pools. As role-based security is deployed, there is a need for different groupings of VPN clients. For example, the first 4 bits could be used to represent the role, the next 4 bits to represent the area, and the final 8 bits to represent the VLAN. It has the potential for being very useful in the enterprise to allow private internal addressing to map to publicly assigned addresses at the Internet connection point. This has the virtue of simplicity. The hybrid model adapts as much as possible to the characteristics of the existing network infrastructure. Inversely, IPv6 may be enabled on interfaces and devices for which IPv4 support is no longer necessary. The different subnets or blocks of VPN endpoint addresses can then be used in ACLs to control access across the network to resources, as discussed earlier for NAC roles. To provide full connectivity during migration by redistribution, the boundary routers between the two parts of the network would have to bidirectionally redistribute between protocols. The design recommendations for summarizations are straightforward and include Using route summarization to scale routing designs. Filtered Redistribution When you use bidirectional redistribution, you should prevent re-advertising information back into the routing protocol region or autonomous system that it originally came from. This increases the stability and efficiency of the network. The various kinds of OSPF stub areas can be thought of as a simpler form of summarization. Just as using the right blocks of subnets enables use of more efficient routing, care with subnet assignments can also support role-based functions within the addressing scheme structure. This advertisement, if accepted, can result in part of your network becoming unreachable. Route Filtering in the Network Design This section discusses the appropriate use of route filtering in network design. Most networks use some form of default routing. IPv6 can be enabled wherever IPv4 is commissioned along with the associated features that are required to make IPv6 routable, highly available, and secure. IPv6 Campus Design Considerations As mentioned earlier, three major deployment models can be used to implement IPv6 support in the enterprise campus environment: the dual-stack model, the hybrid model, and the service block model. For example, examine the block 2001:0DB8:0:A480::/64 to 2001:0DB8:0:A4BF::/64. It also ensures that if there is an accidental leak of another partner's routes or static routes into the dynamic routing process, the inappropriate information does not also leak to others. This is done using a route map in a distribution list. For example, any address block that matches the following can be summarized: 128 numbers in a row, starting with a multiple of 128 (0 or 128) 64 numbers in a row, starting with a multiple of 64 (0, 64, 128, or 192) 32 numbers in a row, starting with a multiple of 32 16 numbers in a row, starting with a multiple of 16 If you examine 172.19.160.0 through 172.19.191.0, there are 191 - 160 + 1 = 32 numbers in a row, in sequence in the third octet. Route summarization is the ultimate route summarization, where all other routes are summarized in the default. Connections into the service block are changed from tunnels (ISATAP or manually configured) to dual-stack connections. The hybrid and service block models are transitory solutions. This in turn enables efficient and easily managed access control lists (ACL) for quality of service (QoS) and security purposes. A quick analysis of the address block shows that the relevant part is in the last two hexadecimal characters, which are 0x80 for the first subnet in the range and 0xBF for the last subnet in the range. Therefore, ACL-friendly addressing which can be summarized helps network administrators to efficiently manage their networks. Tagging routes with a BGP community is an easy way to do this. On the other hand, freely intermixing OSPF-speaking routers with EIGRP routers in ad hoc fashion is just asking for major problems. This is particularly true when there are multiple redistribution points, sometimes coupled with static routes, inconsistent routing summaries, or route filters. However, redistribution should be used with planning and some degree of caution. Planning Addresses The first step in implementing ACL-friendly addressing is to recognize the need. The stack model requires all switches in the campus to support IPv6 forwarding. When all the campus layers are dual-stack capable, the service block can be dismantled and repurposed for other uses. IPv4 mapping: If the current IPv4 address structure is based on network 10.0.0.0/8 and all subnets are using /24 or shorter prefixes, the middle 16 bits in the IPv4 address can be mapped to the IPv6 address. The underlying IPv4 network is used as the foundation for the overlay IPv6 network that is being deployed. The leftover bits are s bits. Removing the clutter from routing tables also makes troubleshooting more effective and speeds convergence. NAT can also be utilized in the data center to support small out-of-band (OOB) management VLANs on devices that cannot route or define a default gateway for the management VLAN, thereby avoiding one management VLAN that spans the entire data center. The second consideration in IPv4 addressing plans is to determine the right number of subnets for each site. For example, the first 4 of the 16 bits could be used to represent the area, while the VLAN is coded into the last 12 bits. Converged networks are increasingly used to support voice, IP telephony, storage, and other drop-sensitive traffic, and so networks must be designed for fast routing convergence. Figure 3-2 Originating Default Routes It is generally a bad idea to configure a static default route on every router, even if recursive routing is used. NAT can then be used to change all partner addresses on traffic into a range of locally assigned addresses. If manually configured next hops are used, more configuration commands are needed. Any combination of transition mechanisms can be leveraged to best fit a given network environment. Role-based access can be controlled via the group password mechanism for the Cisco VPN client. Common reasons why the core layer might not be enabled for IPv6 are either that the core layer does not have hardware-based IPv6 support at all, or has limited IPv6 support but with low performance. Because the range meets the preceding conditions, the sequence 172.19.160.0 through 172.19.191.0 can be summarized. This scheme can support 24= 16 areas and 212 = 4096 subnets per area. OSPF does not allow traffic to arbitrarily route into and then out of an area. In a big network, the AD approach might be used to support this conversion. Split horizon is a routing protocol feature. It also discusses some applications of summary addressing. It is also a recommended practice to isolate any servers reached through content devices using source NAT or destination NAT. Static default route configuration needs to be done only at the network edge devices. The ip default-network network-number command is used to configure the last-resort gateway or default route. Thus, 172.16.16.0/26, 172.16.16.64/26, 172.16.16.128/26, 172.16.16.192/26, and 172.16.17.0/26 would be the first five subnets in area 1.

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