SAFE: A Security Blueprint for Enterprise Networks

Authors

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Abstract

The principle goal of Cisco's secure blueprint for enterprise networks (SAFE) is to provide best practice information to interested parties on designing and implementing secure networks. SAFE serves as a guide to network designers considering the security requirements of their network. SAFE takes a defense-in-depth approach to network security design. This type of design focuses on the expected threats and their methods of mitigation, rather than on "Put the firewall here, put the intrusion detection system there." This strategy results in a layered approach to security where the failure of one security system is not likely to lead to the compromise of network resources. SAFE is based on Cisco products and those of its partners.

This document begins with an overview of the architecture, then details the specific modules that make up the actual network design. The first three sections of each module describe the traffic flows, key devices, and expected threats with basic mitigation diagrams. Detailed technical analysis of the design follows, along with more detailed threat mitigation techniques and migration strategies. Appendix A details the validation lab for SAFE and includes configuration snapshots. Appendix B is a primer on network security. Readers who are unfamiliar with basic network security concepts are encouraged to read this section before the rest of the document. Appendix C contains glossary definitions of the technical terms used in this document and a legend for the included figures.

This document focuses heavily on threats encountered in enterprise environments. Network designers who understand these threats can better decide where and how to deploy mitigation technologies. Without a full understanding of the threats involved in network security, deployments tend to be incorrectly configured, are too focused on security devices, or lack threat response options. By taking the threat-mitigation approach, this document should provide network designers with information for making sound network security choices.

Audience

Though this document is technical in nature, it can be read at different levels of detail, depending on the reader. A network manager, for example, can read the introductory sections in each area to obtain a good overview of network security design strategies and considerations. A network engineer or designer can read this document in its entirety and gain design information and threat analysis details, which are supported by configuration snapshots for the devices involved.

Caveats

This document presumes that you already have a security policy in place. Cisco Systems does not recommend deploying security technologies without an associated policy. This document directly addresses the needs of large enterprise customers. Readers interested in security best-practices for smaller networks should read “SAFE: Extending the Security Blueprint to Small, Midsize, and Remote-User Networks” at the following URL: http://www.cisco.com/warp/public/cc/so/cuso/epso/sqfr/safes_wp.htm.

Following the guidelines in this document does not guarantee a secure environment, or that you will prevent all intrusions. True absolute security can only be achieved by disconnecting a system from the network, encasing it in concrete, and putting it in the bottom floor of Fort Knox. Your data will be very safe, though inaccessible. However, you can achieve reasonable security by establishing a good security policy, following the guidelines in this document, staying up to date on the latest developments in the hacker and security communities, and maintaining and monitoring all systems with sound system administration practices. This includes awareness of application security issues that are not comprehensively addressed in this paper.

Though virtual private networks (VPNs) are included in this architecture, they are not described in great detail. Information such as scaling details, resilience strategies, and other topics related to VPNs are covered in more detail in "SAFE VPN: IPSec Virtual Private Networks in Depth" at the following URL: http://www.cisco.com/warp/public/cc/so/cuso/epso/sqfr/safev_wp.htm. Like VPNs, identity strategies (including certificate authorities [CAs]) are not discussed at any level of detail in this paper. Similarly, CAs require a level of focus that this document could not provide and still adequately address all the other relevant areas of network security. Also, because most enterprise networks have yet to deploy fully functional CA environments, it is important to discuss how to securely deploy networks without them. Finally, certain advanced networked applications and technologies (such as content networking, caching, and server load balancing) are not included in this document. Although their use within SAFE is to be expected, this paper does not cover their specific security needs.

SAFE uses the products of Cisco Systems and its partners. However, this document does not specifically refer to products by name. Instead, components are referred to by functional purpose rather than model number or name. During the validation of SAFE, real products were configured in the exact network implementation described in this document. Specific configuration snapshots from the lab are included in Appendix A, “Validation Lab.”

Throughout this document the term “hacker” denotes an individual who attempts to gain unauthorized access to network resources with malicious intent. While the term “cracker” is generally regarded as the more accurate word for this type of individual, hacker is used here for readability.

Design Fundamentals

SAFE emulates as closely as possible the functional requirements of today's enterprise networks. Implementation decisions varied depending on the network functionality required. However, the following design objectives, listed in order of priority, guided the decision-making process.

- Security and attack mitigation based on policy
- Security implementation throughout the infrastructure (not just on specialized security devices)
- Secure management and reporting
- Authentication and authorization of users and administrators to critical network resources
- Intrusion detection for critical resources and subnets
- Support for emerging networked applications

First and foremost, SAFE is a security architecture. It must prevent most attacks from successfully affecting valuable network resources. The attacks that succeed in penetrating the first line of defense, or originate from inside the network, must be accurately detected and quickly contained to minimize their effect on the rest of the network. However, in being secure, the network must continue to provide critical services that users expect. Proper network security and good network functionality can be provided at the same time. The SAFE architecture is not a revolutionary way of designing networks, but merely a blueprint for making networks secure.

SAFE is also resilient and scalable. Resilience in networks includes physical redundancy to protect against a device failure whether through misconfiguration, physical failure, or network attack. Although simpler designs are possible, particularly if a network's performance needs are not great, this document uses a complex design as an example because designing security in a complex environment is more involved than in simpler environments. Options to limit the complexity of the design are discussed throughout this document.

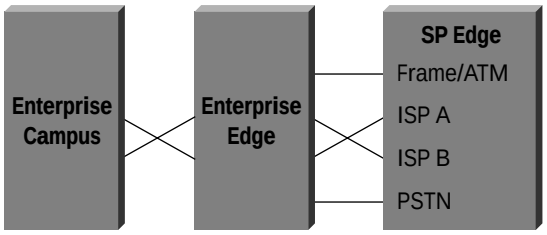
At many points in the network design process, you need to choose between using integrated functionality in a network device versus using a specialized functional appliance. The integrated functionality is often attractive because you can implement it on existing equipment, or because the features can interoperate with the rest of the device to provide a better functional solution. Appliances are often used when the depth of functionality required is very advanced or when performance needs require using specialized hardware. Make your decisions based on the capacity and functionality of the appliance versus the integration advantage of the device. For example, sometimes you can chose an integrated higher-capacity Cisco IOS™ router with IOS firewall software as opposed to a smaller IOS router with a separate firewall. Throughout this architecture, both types of systems are used. Most critical security functions migrate to dedicated appliances because of the performance requirements of large enterprise networks.

Module Concept

Although most enterprise networks evolve with the growing IT requirements of the enterprise, the SAFE architecture uses a green-field modular approach. A modular approach has two main advantages. First, it allows the architecture to address the security relationship between the various functional blocks of the network. Second, it permits designers to evaluate and implement security on a module by module basis, instead of attempting the complete architecture in a single phase.

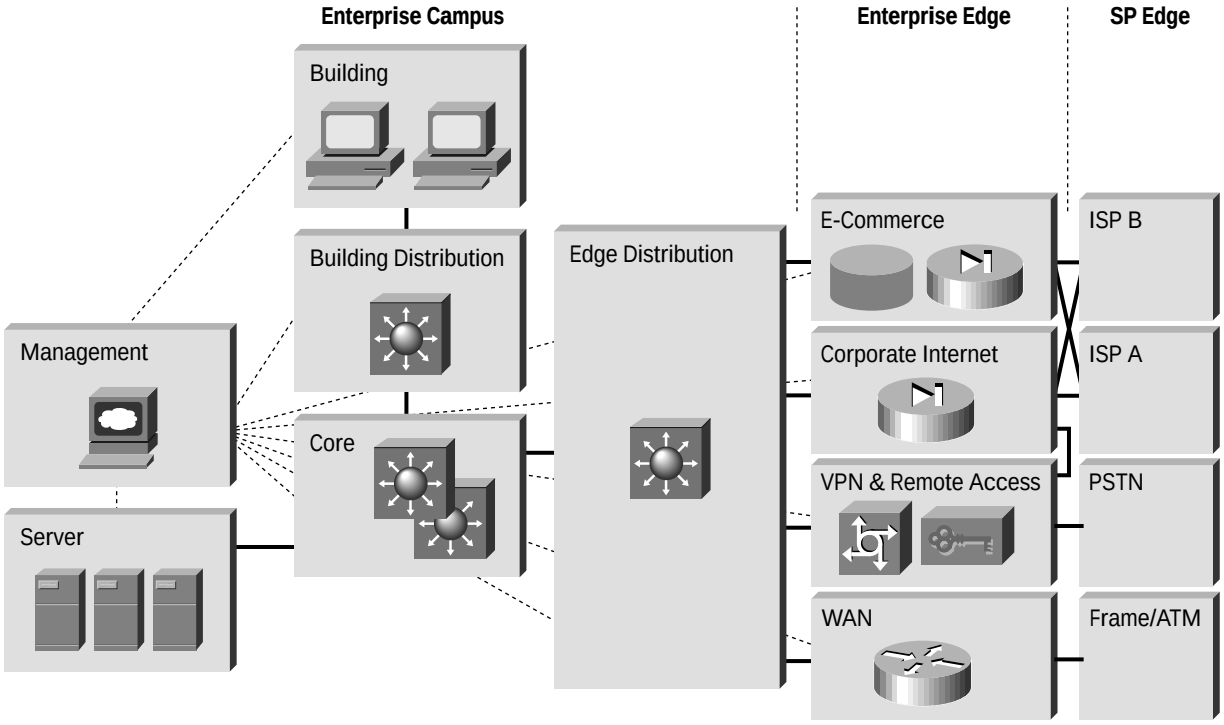
Figure 1 illustrates the first layer of modularity in SAFE. Each block represents a functional area. The Internet service provider (ISP) module is not implemented by the enterprise, but is included to the extent that specific security features should be requested of an ISP in order to mitigate against certain attacks.

Figure 1 Enterprise Composite Module



The second layer of modularity, which is illustrated in Figure 2, represents a view of the modules within each functional area. These modules perform specific roles in the network and have specific security requirements, but their sizes are not meant to reflect their scale in a real network. For example, the building module, which represents the end-user devices, may include 80 percent of the network devices. The security design of each module is described separately, but is validated as part of the complete enterprise design.

Figure 2 Enterprise SAFE Block Diagram



While it is true that most existing enterprise networks cannot be easily dissected into clear-cut modules, this approach provides a guide for implementing different security functions throughout the network. The authors do not expect network engineers to design their networks identical to the SAFE implementation, but rather use a combination of the modules described and integrate them into the existing network.

SAFE Axioms

This section outlines general best practices that apply to the entire SAFE blueprint. They are addressed here in a single location to avoid duplication throughout the individual modules.

Routers Are Targets

Routers control access from every network to every network. They advertise networks and filter who can use them, and they are potentially a hacker's best friend. Router security is a critical element in any security deployment. By their nature, routers provide access and, therefore, you should secure them to reduce the likelihood that they can be directly compromised. You can refer to other documents that have been written about router security, which provide more detail on the following subjects:

- Locking down Telnet access to a router
- Locking down Simple Network Management Protocol (SNMP) access to a router
- Controlling access to a router through the use of Terminal Access Controller Access Control System Plus (TACACS+)
- Turning off unneeded services
- Logging at appropriate levels
- Authentication of routing updates

The most current document on router security is available at the following URL:
http://www.cisco.com/warp/public/707/21.html

Switches Are Targets

Like routers, switches (both Layer 2 and Layer 3) have their own set of security considerations. Unlike routers, not as much public information is available about the security risks in switches and what can be done to mitigate those risks. Switches typically rely on virtual LANs (VLANs) for Layer 2 traffic segmentation. Most of the security techniques detailed in the preceding section, “Routers Are Targets,” apply to switches. In addition, you should take the following precautions:

- Disable all unused ports on a switch. This setup prevents hackers from plugging into unused ports and communicating with the rest of the network.
- Ports without any need to trunk should have any trunk settings set to off, as opposed to auto. This setup prevents a host from becoming a trunk port and receiving all traffic that would normally reside on a trunk port.
- For ports that require trunking, always use a dedicated VLAN identifier. The use of VLAN 1 may have implications for some switch vendors. Eliminate native VLANs from 802.1q trunks.
- When feasible for user ports, limit each port to associate a limited number of MAC address (say 2-3). This will mitigate MAC flooding and other attacks.
- As VLANs do not inherently provide security functions such as confidentiality and authentication, care must be taken to follow the security guidelines defined by Cisco and in this section when implementing VLANs in any environment. For instance, filtering and/or stateful firewalling in addition to VLAN segmentation provides a defense-in-depth approach to securing the access between two subnets.
- Procedures for carrying out change control and configuration analysis must be in place to ensure that a secure configuration results after changes are made. This is especially valuable in cases where multiple organizational groups may control the same switch and even more valuable in security deployments where even greater care must be taken.
- Recent testing of Cisco software has shown that as long as care is taken in configuration, specifically following the best practices in this section, VLANs provide Layer 2 separation. For more information please refer to: http://www.cisco.com/warp/public/cc/pd/si/casi/ca6000/tech/stake_wp.pdf.

Within an existing VLAN, private VLANs provide some added security to specific network applications. Private VLANs work by limiting which ports within a VLAN can communicate with other ports in the same VLAN. Isolated ports within a VLAN can communicate only with promiscuous ports. Community ports can communicate only with other members of the same community and promiscuous ports. Promiscuous ports can communicate with any port. This is an effective way to mitigate the

effects of a single compromised host. Consider a standard public services segment with a Web, File Transfer Protocol (FTP), and Domain Name System (DNS) server. If the DNS server is compromised, a hacker can pursue the other two hosts without passing back through the firewall. If private VLANs are deployed, if one system is compromised, it cannot communicate with the other systems. The only targets a hacker can pursue are hosts on the other side of the firewall. Because they restrict layer 2 connectivity, private VLANs make troubleshooting network problems more difficult. Remember that private VLANs are not supported on all Ethernet switches available on the market today. In particular, most low-end switches do not yet support this feature.

Hosts Are Targets

The most likely target during an attack, the host presents some of the most difficult challenges from a security perspective. There are numerous hardware platforms, operating systems, and applications, all of which have updates, patches, and fixes available at different times. Because hosts provide the application services to other hosts that request them, they are extremely visible within the network. For example, many people have visited www.whitehouse.gov, which is a host, but few have attempted to access s2-0.whitehouseisp.net, which is a router. Because of this visibility, hosts are the most frequently attacked devices in any network intrusion attempt.

In part because of the security challenges mentioned above, hosts are also the most successfully compromised devices. For example, a given Web server on the Internet might run a hardware platform from one vendor, a network card from another, an operating system from still another vendor, and a Web server that is either open source or from yet another vendor. Additionally, the same Web server might run applications that are freely distributed via the Internet, and might communicate with a database server that starts the variations all over again. That is not to say that the security vulnerabilities are specifically caused by the multisource nature of all of this, but rather that as the complexity of a system increases, so does the likelihood of a failure.

To secure hosts, pay careful attention to each of the components within the systems. Keep any systems up-to-date with the latest patches, fixes, and so forth. In particular, pay attention to how these patches affect the operation of other system components. Evaluate all updates on test systems before you implement them in a production environment. Failure to do so might result in the patch itself causing a denial of service (DoS).

Networks Are Targets

Network attacks are among the most difficult attacks to deal with because they typically take advantage of an intrinsic characteristic in the way your network operates. These attacks include *Address Resolution Protocol* (ARP) and *Media Access Control* (MAC)-based Layer 2 attacks, sniffers, and distributed *denial-of-service* (DDoS) attacks. Some of the ARP and MAC-based Layer 2 attacks can be mitigated through best practices on switches and routers. Sniffers are discussed in the primer at the end of this document. DDoS, however, is a unique attack that deserves special attention.

The worst attack is the one that you cannot stop. When performed properly, DDoS is just such an attack. As outlined in Appendix B, “Network Security Primer,” DDoS works by causing tens or hundreds of machines to simultaneously send spurious data to an IP address. The goal of such an attack is generally not to shut down a particular host, but rather to make the entire network unresponsive. For example, consider an organization with a DS1 (1.5 Mbps) connection to the Internet that provides e-commerce services to its Web site users. Such a site is very security conscious and has intrusion detection, firewalls, logging, and active monitoring. Unfortunately, none of these security devices helps when a hacker launches a successful DDoS attack.Consider 100 devices around the world, each with DSL (500 Kbps) connections to the Internet. If these systems are remotely told to flood the serial interface of the e-commerce organization's Internet router, they can easily flood the DS1 with erroneous data. Even if each host is able to generate only 100 Kbps of traffic (lab tests indicate that a stock PC can easily generate 50 Mbps with a popular DDoS tool), that amount is still almost ten times the amount of traffic that the e-commerce site can handle. As a result, legitimate Web requests are lost, and the site appears to be down for most users. The local firewall drops all the erroneous data, but by then the damage is done. The traffic has crossed the WAN connection and filled up the link.

Only through cooperation with its Internet service provider (ISP) can this fictitious e-commerce company hope to thwart such an attack. An ISP can configure rate limiting on the outbound interface to the company's site. This rate limiting can drop most undesired traffic when it exceeds a prespecified amount of the available bandwidth. The key is to correctly flag traffic as undesired.

Common forms of DDoS attacks are Internet Control Message Protocol (ICMP) floods, TCP SYN floods, or User Datagram Protocol (UDP) floods. In an e-commerce environment, this type of traffic is fairly easy to categorize. Only when limiting a TCP SYN attack on port 80 (Hypertext Transfer Protocol [HTTP]) does an administrator run the risk of locking out legitimate users during an attack. Even then, it is better to temporarily lock out new legitimate users and retain routing and management connections than to have the router overrun and lose all connectivity.

More sophisticated attacks use port 80 traffic with the ACK bit set so that the traffic appears to be legitimate Web transactions. It is unlikely that an administrator could properly categorize such an attack because acknowledged TCP communications are exactly the sort that you want to allow into your network.

One approach to limiting this sort of attack is to follow filtering guidelines for networks outlined in RFC 1918 and RFC 2827. RFC 1918 specifies the networks that are reserved for private use and should never be seen across the public Internet. RFC 2827 filtering is discussed in the “IP Spoofing” section of Appendix B, “Network Security Primer." For example, for inbound traffic on a router that is connected to the Internet, you employ RFC 1918 and 2827 filtering to prevent this unauthorized traffic from reaching the corporate network. When implemented at the ISP, this filtering prevents DDoS attack packets that use these addresses as sources from traversing the WAN link, potentially saving bandwidth during the attack. Collectively, if ISPs worldwide were to implement the guidelines in RFC 2827, source address spoofing would be greatly diminished. Although this strategy does not directly prevent DDoS attacks, it does prevent such attacks from masking their source, making traceback to the attacking networks much easier. Ask your ISP about which DDoS mitigation options they make available to their customers.

Applications Are Targets

Applications are coded by human beings (mostly) and, as such, are subject to numerous errors. These errors can be benign-for example, an error that causes your document to print incorrectly-or malignant-for example, an error that makes the credit card numbers on your database server available via anonymous FTP. It is the malignant problems, as well as other more general security vulnerabilities, that need careful attention. Care needs to be taken to ensure that commercial and public domain applications are up-to-date with the latest security fixes. Public domain applications, as well as custom developed applications, also require code review to ensure that the applications are not introducing any security risks caused by poor programming. This programming can include scenarios such as how an application makes calls to other applications or the OS itself, the privilege level at which the application runs, the degree of trust that the application has for the surrounding systems, and finally, the method the application uses to transport data across the network. The following section discusses intrusion detection systems (IDSs) and how they can help mitigate some of the attacks launched against applications and other functions within the network.

Intrusion Detection Systems

Intrusion detection systems (IDSs) act like an alarm system in the physical world. When an IDS detects something that it considers an attack, it can either take corrective action itself or notify a management system for actions by the administrator. Some systems are more or less equipped to respond and prevent such an attack. Host-based intrusion detection can work by intercepting OS and application calls on an individual host. It can also operate by after-the-fact analysis of local log files. The former approach allows better attack prevention, whereas the latter approach dictates a more passive attack-response role. Because of the specificity of their role, host-based IDS (HIDS) systems are often better at preventing specific attacks than network IDS (NIDS) systems, which usually issue only an alert upon discovery of an attack. However, that specificity causes a loss of perspective to the overall network. This is where NIDS excels. Cisco recommends a combination of the two systems-HIDS on critical hosts and NIDS looking over the whole network-for a complete intrusion detection system.

When an IDS is deployed, you must tune its implementation to increase its effectiveness and remove "false positives." False-positives are defined as alarms caused by legitimate traffic or activity. False negatives are attacks that the IDS system fails to see. When the IDS is tuned, you can configure it more specifically as to its threat-mitigation role. As mentioned above, you should configure HIDS to stop most valid threats at the host level because it is well prepared to determine that certain activity is, indeed, a threat.

When deciding on mitigation roles for NIDS, you have two primary options. Remember that the first step prior to implementing any threat-response option is to adequately tune NIDS to ensure that any perceived threat is legitimate.

The first option-and potentially the most damaging if improperly deployed-is to "shun" traffic through the addition of access control filters on routers and firewalls. When a NIDS detects an attack from a particular host over a particular protocol, it can block that host from coming into the network for a predetermined amount of time. Although on the surface this might seem like a great aid to a security administrator, in reality it must be very carefully implemented, if at all. The first problem is that of spoofed addresses. If traffic that matches an attack is seen by the NIDS, and that particular alarm triggers a shun situation, the NIDS will deploy the access list to the device. However, if the attack that caused the alarm used a spoofed address, the NIDS has now locked out an address that never initiated an attack. If the IP address that the hacker used happens to be the IP address of a major ISP's outbound HTTP proxy server, a huge number of users could be locked out. This by itself could be an interesting DoS threat in the hands of a creative hacker.

To mitigate the risks of shunning, you should generally use it only on TCP traffic, which is much more difficult to successfully spoof than UDP. Use it only in cases where the threat is real and the chance that the attack is a false positive is very low. Also consider setting the shun length very short. This setup will block the user long enough to allow the administrator to decide what permanent action (if any) he/she wants to take against that IP address. However, in the interior of a network, many more options exist. With effectively deployed RFC 2827 filtering, spoofed traffic should be very limited. Also, because customers are not generally on the internal network, you can take a more restrictive stance against internally originated attack attempts. Another reason for this is that internal networks do not often have the same level of stateful filtering that edge connections possess. As such, IDS needs to be more heavily relied upon than in the external environment.

The second option for NIDS mitigation is the use of TCP resets. As the name implies, TCP resets operate only on TCP traffic and terminate an active attack by sending TCP reset messages to the attacking and attacked host. Because TCP traffic is more difficult to spoof, you should consider using TCP resets more often than shunning. Keep in mind that TCP resets in a switched environment are more challenging than when a standard hub is used, because all ports don't see all traffic without the use of a Switched Port Analyzer (SPAN) or mirror port. Make sure this mirror port supports bidirectional traffic flows and can have SPAN port MAC learning disabled.

Both of these mitigation options require 24x7 staffing to watch the IDS consoles. Because IT staff are often overworked, consider outsourcing your IDS management to a third party.

From a performance standpoint, NIDS observes packets on the wire. If packets are sent faster than the NIDS can process them, there is no degradation to the network because the NIDS does not sit directly in the flows of data. However, the NIDS will lose effectiveness and packets could be missed, causing both false negatives and false positives. Be sure to avoid exceeding the capabilities of IDS so that you can get their benefit. From a routing standpoint, IDS, like many state-aware engines, does not operate properly in an asymmetrically routed environment. Packets sent out from one set of routers and switches and returning through another will cause the IDS systems to see only half the traffic, causing false positives and false negatives.

Secure Management and Reporting

“If you’re going to log it, read it.” So simple a proposition, that almost everyone familiar with network security has said it at least once. Yet logging and reading information from hundreds of devices can prove to be a challenging proposition. Which logs are most important? How do I separate important messages from mere notifications? How do I ensure that logs are not tampered with in transit? How do I ensure my time-stamps match each other when multiple devices report the same alarm?

What information is needed if log data is required for a criminal investigation? How do I deal with the volume of messages that can be generated by a large network? You must address all these questions when considering managing log files effectively. From a management standpoint, a different set of questions needs to be asked: How do I securely manage a device? How can I push content out to public servers and ensure that it is not tampered with in transit? How can I track changes on devices to troubleshoot when attacks or network failures occur?

From an architectural point of view, providing out-of-band management of network systems is the best first step in any management and reporting strategy. Out-of-band (OOB), as its name implies, refers to a network on which no production traffic resides. Devices should have a direct local connection to such a network where possible, and where impossible, (due to geographic, or system-related issues) the device should connect via a private encrypted tunnel over the production network. Such a tunnel should be preconfigured to communicate only across the specific ports required for management and reporting. The tunnel should also be locked down so that only appropriate hosts can initiate and terminate tunnels. Be sure that the out-of-band network does not itself create security issues. See the “Management Module” section of this document for more details.

After implementing an OOB management network, dealing with logging and reporting becomes more straightforward. Most networking devices can send syslog data, which can be invaluable when troubleshooting network problems or security threats. Send this data to one or more syslog analysis hosts on the management network. Depending on the device involved, you can choose various logging levels to ensure that the correct amount of data is sent to the logging devices. You also need to flag device log data within the analysis software to permit granular viewing and reporting. For example, during an attack the log data provided by Layer 2 switches might not be as interesting as the data provided by the intrusion detection system. Specialized applications, such as IDS, often use their own logging protocols to transmit alarm information. Usually this data should be logged to separate management hosts that are better equipped to deal with attack alarms. When combined, alarm data from many different sources can provide information about the overall health of the network. To ensure that log messages are time-synchronized to one another, clocks on hosts and network devices must be in sync. For devices that support it, network time protocol (NTP) provides a way to ensure that accurate time is kept on all devices. When dealing with attacks, seconds matter because it is important to identify the order in which a specified attack took place.

OOB management is not always desirable. Often it depends on the type of management application you are running and the protocols that are required. For example, consider a management tool whose goal is determining reachability of all the devices on the production network. If a critical link failed between two core switches, you would want this management console to alert an administrator. If this management application was configured to use an OOB network, it may never determine that the link has failed since the OOB network makes all devices appear to be attached to a single network. With management applications such as these, it is preferred to run the management application in-band. This in-band management needs to be configured in as secure a manner as possible. Often this in-band and OOB management can be configured from the same management network provided there is a firewall between the management hosts and the devices needing management. Please see the "Management Module" of this document for more details.

When in-band management of a device is required, you should consider several factors. First, what management protocols does the device support? For devices with IP Security (IPSec), devices should be managed by simply creating a tunnel from the management network to the device. This setup allows many insecure management protocols to flow over a single encrypted tunnel. When IPSec is not possible because it is not supported on a device, other less-secure alternatives must be chosen. For configuration of the device, SSH or Secure Sockets Layer (SSL) can often be used instead of Telnet to encrypt any configuration modifications made to a device. These same protocols can sometimes also be used to push and pull data to a device instead of insecure protocols such as TFTP and FTP. Often, however, TFTP is required on Cisco equipment to back up configurations or to update software versions. This leads to the second question: Does this management channel need to be active at all times? If not, then temporary holes can be placed in a firewall while the management functions are performed and then later removed. This process does not scale with large numbers of devices, however, and should be used sparingly,

if at all, in enterprise deployments. If the channel needs to be active at all times, such as with SNMP, the third question should be considered: Do you really need this management tool? Often SNMP managers are used on the inside of a network to ease troubleshooting and configuration. However, SNMP should be treated with the utmost care because the underlying protocol has its own set of security vulnerabilities. If required, consider providing read-only access to devices via SNMP and treat the SNMP community string with the same care you might treat a root password on a critical Unix host. Know that by introducing SNMP into your production network you are introducing a potential vulnerability into your environment.

Configuration change management is another issue related to secure management. When a network is under attack, it is important to know the state of critical network devices and when the last known modifications took place. Creating a plan for change management should be a part of your comprehensive security policy, but, at a minimum, record changes using authentication systems on the devices, and archive configurations via FTP or TFTP.

Enterprise Module

The enterprise comprises two functional areas: the campus and the edge. These two areas are further divided into modules that define the various functions of each area in detail. Following the detailed discussion of the modules in the "Enterprise Campus" and "Enterprise Edge" sections, the "Enterprise Options" section of this document describes various options for the design.

Expected Threats

From a threat perspective, the Enterprise network is like most networks connected to the Internet. There are internal users who need access out and external users who need access in. There are several common threats that can generate the initial compromise that a hacker needs to further penetrate the network with secondary exploits.

First is the threat from internal users. Though statistics vary on the percentage, it is an established fact that the majority of all attacks come from the internal network. Disgruntled employees, corporate spies, visiting guests, and inadvertent bumbling users are all potential sources of such attacks. When designing security, it is important to be aware of the potential for internal threats.

Second is the threat to the publicly addressable hosts that are connected to the Internet. These systems will likely be attacked with application layer vulnerabilities and DoS attacks.

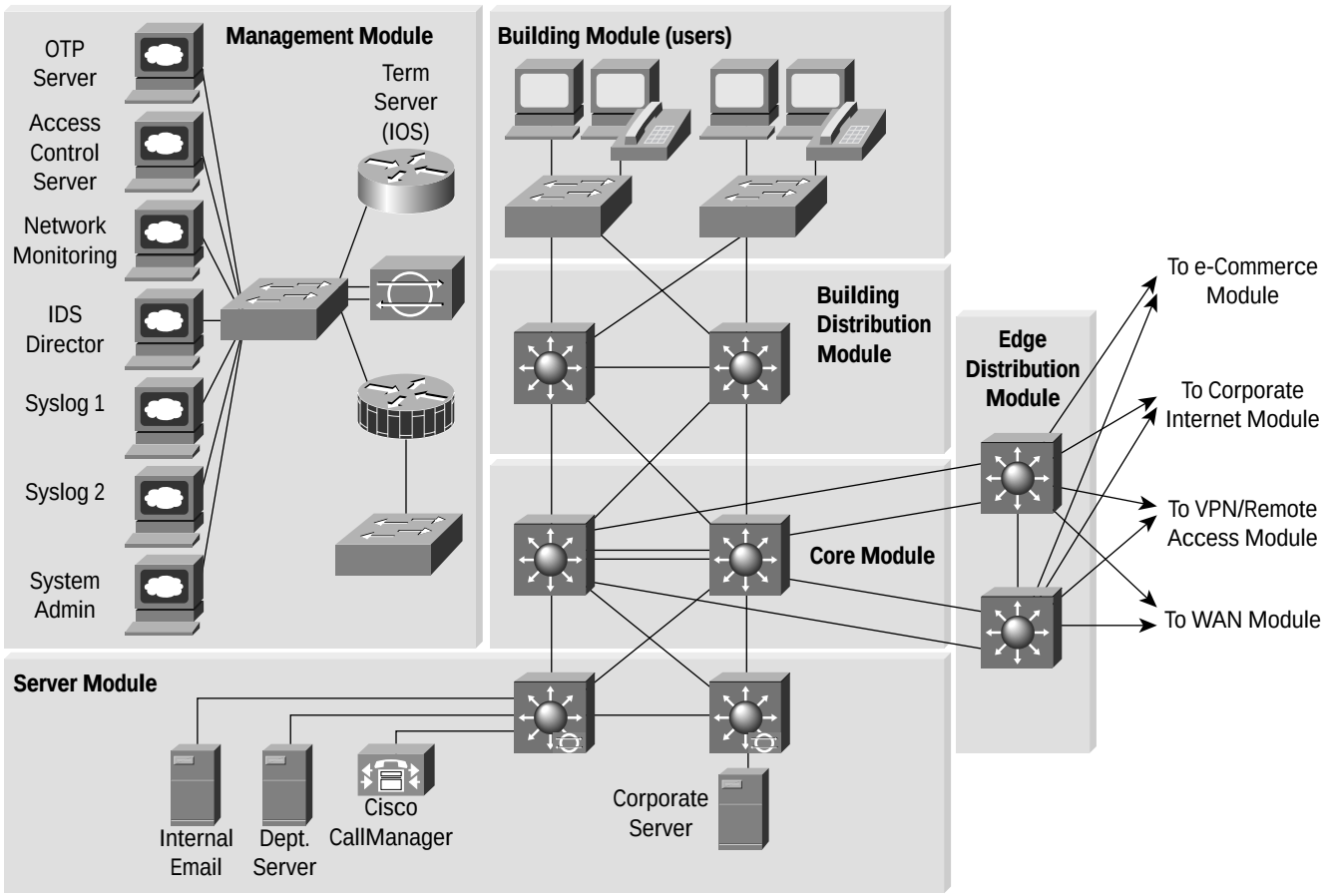
The final threat is that a hacker might try to determine your data phone numbers by using a "war-dialer" and try to gain access to the network. War-dialers are software and/or hardware that are designed to dial many phone numbers and determine the type of system on the other end of the connection. Personal systems with remote-control software installed by the user are the most vulnerable, because they typically are not very secure. Because these devices are behind the firewall, once hackers have access via the host they dialed in to, they can impersonate users on the network.

For a complete discussion of threat details, refer to Appendix B, "Network Security Primer."

Enterprise Campus

The following is a detailed analysis of all the modules contained within the Enterprise Campus.

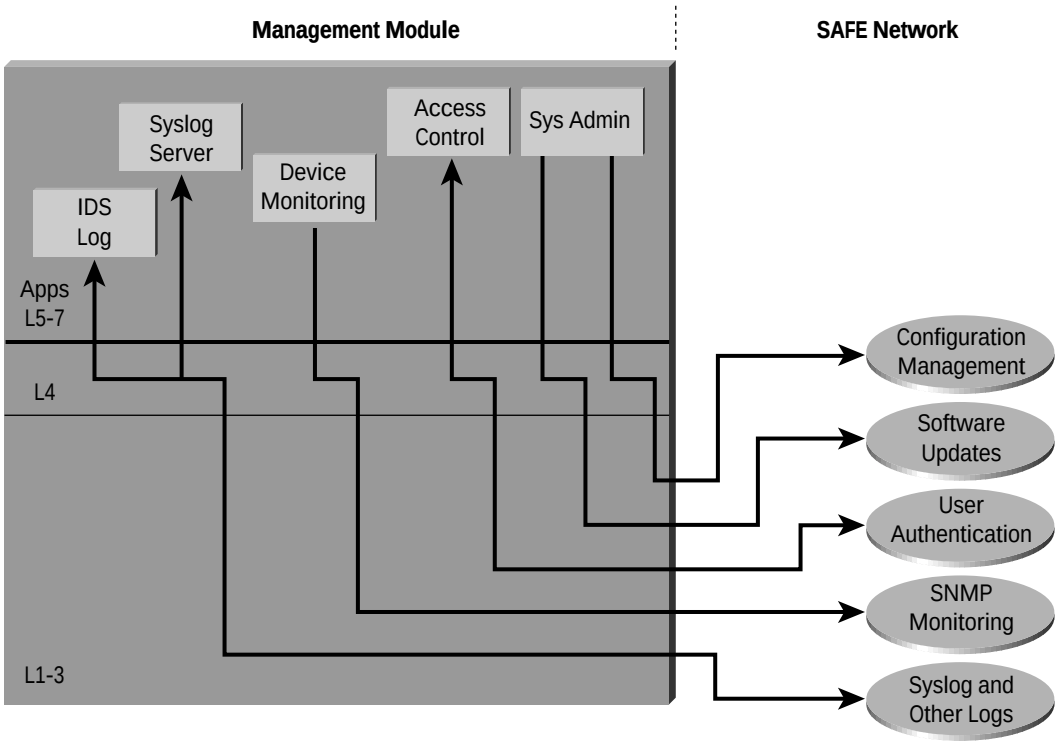
Figure 3 Enterprise Campus Detail



Management Module

The primary goal of the management module is to facilitate the secure management of all devices and hosts within the enterprise SAFE architecture. Logging and reporting information flow from the devices through to the management hosts, while content, configurations, and new software flow to the devices from the management hosts.

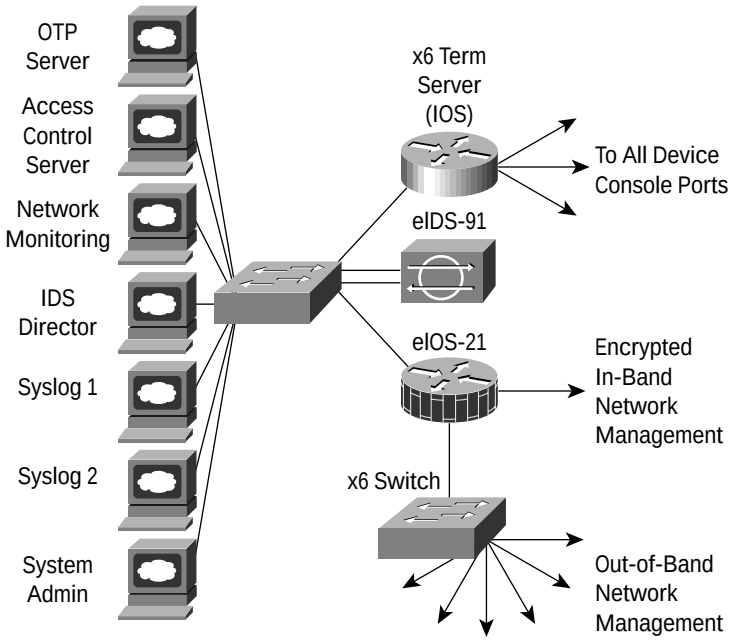
Figure 4 Management Traffic Flow



Key Devices

- *SNMP Management host* – provides SNMP management for devices
- *NIDS host* – provides alarm aggregation for all NIDS devices in the network
- *Syslog host(s)* – aggregates log information for Firewall and NIDS hosts
- *Access Control Server* – delivers one-time, two-factor authentication services to the network devices
- *One-Time Password (OTP) Server* – authorizes one-time password information relayed from the access control server
- *System Admin host* – provides configuration, software, and content changes on devices
- *NIDS appliance* – provides Layer 4 to Layer 7 monitoring of key network segments in the module
- *Cisco IOS Firewall* – allows granular control for traffic flows between the management hosts and the managed devices
- *Layer 2 switch (with private VLAN support)* – ensures data from managed devices can only cross directly to the IOS firewall

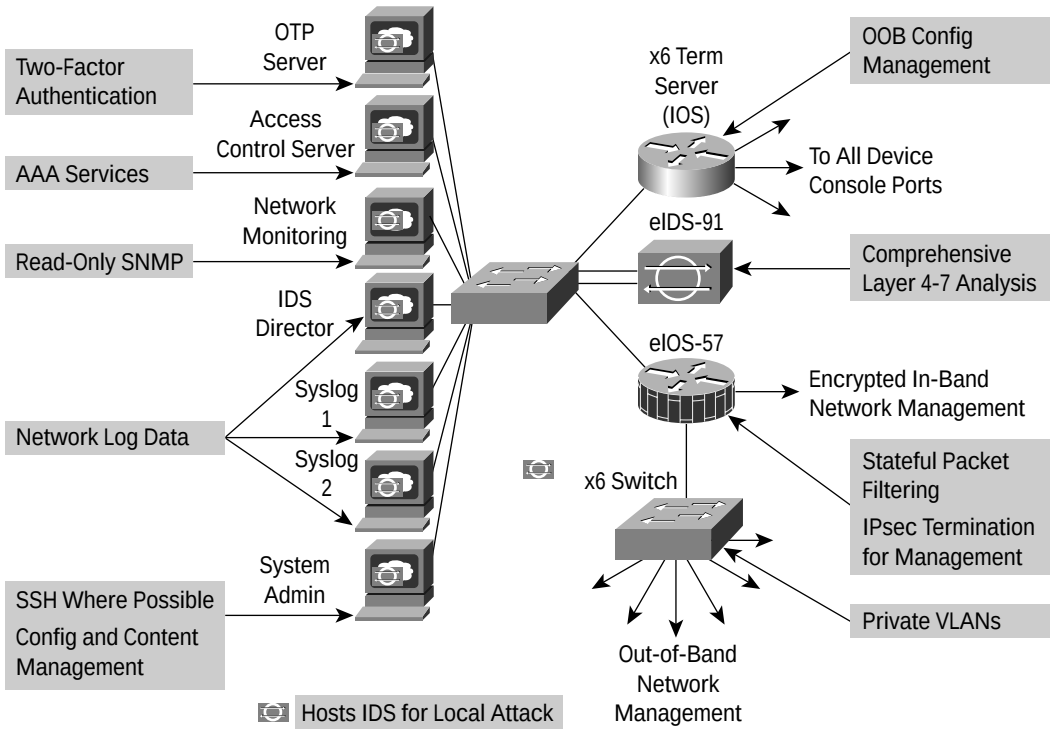
Figure 5 Management Module: Detail



Threats Mitigated

- *Unauthorized Access* – filtering at the IOS firewall stops most unauthorized traffic in both directions
- *Man-in-the-Middle Attacks* – management data is crossing a private network making man-in-the-middle attacks difficult
- *Network Reconnaissance* – because all management traffic crosses this network, it does not cross the production network where it could be intercepted
- *Password Attacks* – the access control server allows for strong two-factor authentication at each device
- *IP Spoofing* – spoofed traffic is stopped in both directions at the IOS firewall
- *Packet Sniffers* – a switched infrastructure limits the effectiveness of sniffing
- *Trust Exploitation* – private VLANs prevent a compromised device from masquerading as a management host

Figure 6 Attack Mitigation Roles for Management Module



Design Guidelines

As can be seen in the above diagram, the SAFE enterprise management network has two network segments that are separated by an IOS router that acts as a firewall and a VPN termination device. The segment outside the firewall connects to all the devices that require management. The segment inside the firewall contains the management hosts themselves and the IOS routers that act as terminal servers. The remaining interface connects to the production network but only for selective Internet access, limited in-band management traffic, and IPSec-protected management traffic from predetermined hosts.

As discussed in the "Axioms" section, in-band management only occurs when the application itself would not function OOB or if the Cisco device being managed did not physically have enough interfaces to support the normal management connection. It is this latter case that employes IPSec tunnels. It is the latter case that employs IPSec tunnels. The IOS firewall is configured to allow syslog information into the management segment, as well as telnet, SSH, and SNMP if these are first initiated by the inside network.

Both management subnets operate under an address space that is completely separate from the rest of the production network. This ensures that the management network will not be advertised by any routing protocols. This also enables the production network devices to block any traffic from the management subnets that appears on the production network links. Any in-band management or Internet access occurs through a NAT process on the IOS router that translates the non-routable management IP addresses to prespecified production IP ranges.

The management module provides configuration management for nearly all devices in the network through the use of two primary technologies: Cisco IOS routers acting as terminal servers and a dedicated management network segment. The routers provide a reverse-telnet function to the console ports on the Cisco devices throughout the enterprise. More extensive management features (software changes, content updates, log and alarm aggregation, and SNMP management) are provided through the dedicated management network segment with caveats as noted above.

Because the management network has administrative access to nearly every area of the network, it can be a very attractive target to hackers. The management module has been built with several technologies designed to mitigate those risks. The first primary threat is a hacker attempting to gain access to the management network itself. This threat can only be mitigated through the effective deployment of security features in the remaining modules in the enterprise. All the remaining threats assume that the primary line of defense has been breached. To mitigate the threat of a compromised device, access control is implemented at the firewall, and at every other possible device, to prevent exploitation of the management channel. A compromised device cannot even communicate with other hosts on the same subnet because private VLANs on the management segment switches force all traffic from the managed devices directly to the IOS firewall where filtering takes place. Password sniffing only reveals useless information because of the one-time password environment. Host and Network IDS are also implemented on the management subnet and are configured in a very restrictive stance. Because the types of traffic on this network should be very limited, any signature match on this segment should be met with an immediate response.

SNMP management has its own set of security needs. Keeping SNMP traffic on the management segment allows it to traverse an isolated segment when pulling management information from devices. With SAFE, SNMP management pulls information only from devices rather than allowing it to push changes. To ensure this, each device is only configured with a “read-only” string.

Proper aggregation and analysis of the syslog information is critical to the proper management of a network. From a security perspective, syslog provides important information regarding security violations and configuration changes. Depending on the device in question, different levels of syslog information might be required. Having full logging with all messages sent might provide too much information for an individual or syslog analysis algorithm to sort. Logging for the sake of logging does not improve security. SNMP "read-write" may be configured when using an OOB network but be aware of the increased security risk due to a clear text string allowing modification of device configurations.

For the SAFE validation lab, all configurations were done using standalone management applications and the command-line interface (CLI). Nothing in SAFE, however, precludes using more advanced management systems for configuration. Establishing this management module makes deployments of such technology completely viable. CLI and standalone management applications were chosen because the majority of current network deployments use this configuration method.

Alternatives

As mentioned in the “Axioms” section, complete out-of-band management is not always possible. When in-band management is required, more emphasis needs to be placed on securing the transport of the management protocols. This can be through the use of IPSec, SSH, SSL, or any other encrypted and authenticated transport that allows management information to traverse it. When management happens on the same interface that a device uses for user data, importance needs to be placed on passwords, community strings, cryptographic keys, and the access-lists that control communications to the management services.

Additionally, if the throughput requirements in the management module are high, consider the use of a dedicated firewall as opposed the router with firewall functionality. The router was chosen because of its flexibility in IPSec configuration and its routing options.

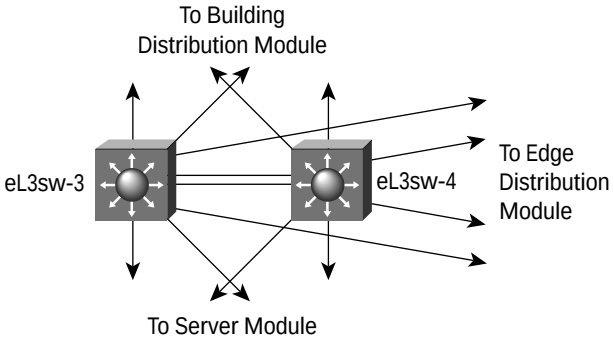
Core Module

The core module in the SAFE architecture is nearly identical to the core module of any other network architecture. It merely routes and switches traffic as fast as possible from one network to another.

Key Devices

• *Layer 3 switching* – route and switch production network data from one module to another

Figure 7 Core Module: Detail



Threats Mitigated

• *Packet Sniffers* – a switched infrastructure limits the effectiveness of sniffing

Design Guidelines

Standard implementation guidelines were followed in accordance with the "core, distribution, and access layer" deployments commonly seen in well-designed Cisco-based networks.

Though no unique requirements are defined by the SAFE architecture for the core of enterprise networks, the core switches follow the switch security axiom in the "Switches Are Targets" section, to ensure that they are well protected against direct attacks.

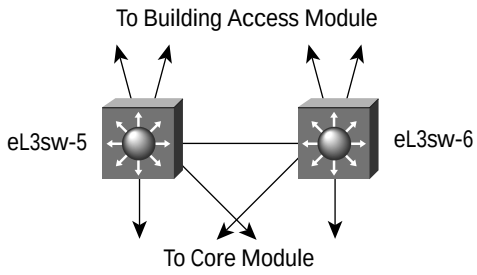
Building Distribution Module

The goal of this module is to provide distribution layer services to the building switches; these include routing, quality of service (QoS), and access control. Requests for data flow into these switches and onto the core, and responses follow the identical path in reverse.

Key Devices

• *Layer 3 switches* – aggregate Layer 2 switches in building module and provide advanced services

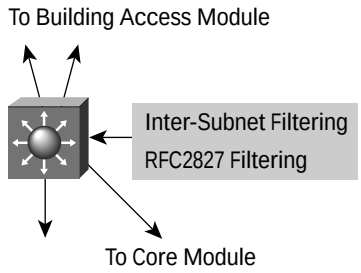
Figure 8 Building Distribution Module: Detail



Threats Mitigated

- *Unauthorized Access* – attacks against server module resources are limited by Layer 3 filtering of specific subnets
- *IP Spoofing* – RFC 2827 filtering stops most spoofing attempts
- *Packet Sniffers* – a switched infrastructure limits the effectiveness of sniffing

Figure 9 Attack Mitigation Roles for Building Distribution Module



Design Guidelines

In addition to standard network design fundamentals, the optimizations described in the "Switches Are Targets" section were implemented to provide added security within the enterprise user community. Intrusion detection is not implemented at the building distribution module because it is implemented in the modules that contains the resources that are likely to be attacked for their content (server, remote access, Internet, and so forth). The building distribution module provides the first line of defense and prevention against internally originated attacks. It can mitigate the chance of a department accessing confidential information on another department's server through the use of access control. For example, a network that contains marketing and research and development might segment off the R&D server to a specific VLAN and filter access to it ensuring that only R&D staff have access to it. For performance reasons, it is important that this access control be implemented on a hardware platform that can deliver filtered traffic at near wire rates. This generally dictates the use of Layer 3 switching as opposed to more traditional dedicated routing devices. This same access control can also prevent local source-address spoofing through the use of RFC 2827 filtering. Finally, subnet isolation is used to route voice-over-IP (VoIP) traffic to the call manager and any associated gateways. This prevents VoIP traffic from crossing the same segments that all other data traffic crosses, reducing the likelihood of sniffing voice communications, and allows a smoother implementation of QoS. Complete secure IP Telephony deployment details are outside the scope of this document.

Alternatives

Depending on the size and performance requirements of the network, the distribution layer can be combined with the core layer to reduce the number of devices required in the environment.

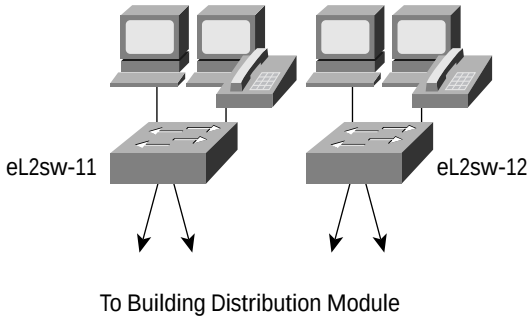
Building Module

SAFE defines the building module as the extensive network portion that contains end-user workstations, phones, and their associated Layer 2 access points. Its primary goal is to provide services to end users.

Key Devices

- *Layer 2 switch* – provides Layer 2 services to phones and user workstations
- *User workstation* – provides data services to authorized users on the network
- *IP phone* – provides IP telephony services to users on the network

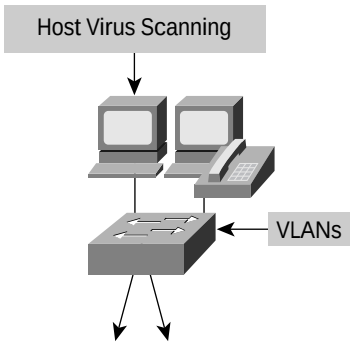
Figure 10 Building Access Module: Detail



Threats Mitigated

- *Packet sniffers* – a switched infrastructure and default VLAN services limit the effectiveness of sniffing
- *Virus and Trojan horse applications* – host-based virus scanning prevents most viruses and many Trojan horses

Figure 11 Attack Mitigation Roles for Building Access Module



Design Guidelines

Because user devices are generally the largest single element of the network, implementing security in a concise and effective manner is challenging. From a security perspective, the building distribution module, rather than anything in the building module, provides most of the access control that is enforced at the end-user level. This is because the Layer 2 switch that the workstations and phones connect to has no capability for Layer 3 access control. In addition to the network security guidelines described in the switch security axiom, host-based virus scanning is implemented at the workstation level.

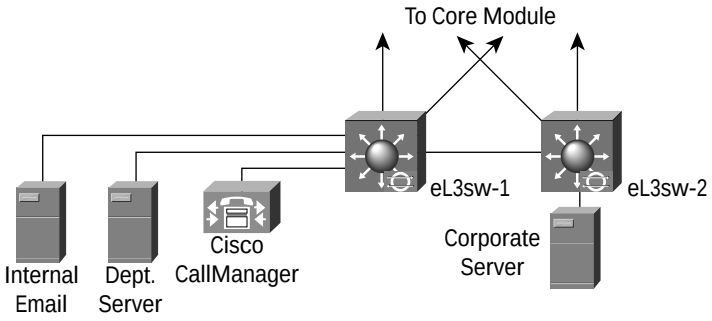
Server Module

The server module's primary goal is to provide application services to end users and devices. Traffic flows on the server module are inspected by on-board intrusion detection within the Layer 3 switches.

Key Devices

- *Layer 3 Switch* – provides layer three services to the servers and inspects data crossing the server module with NIDS
- *Call Manager* – performs call routing functions for IP telephony devices in the enterprise
- *Corporate and Department Servers* – delivers file, print, and DNS services to workstations in the building module
- *E-Mail Server* – provide SMTP and POP3 services to internal users

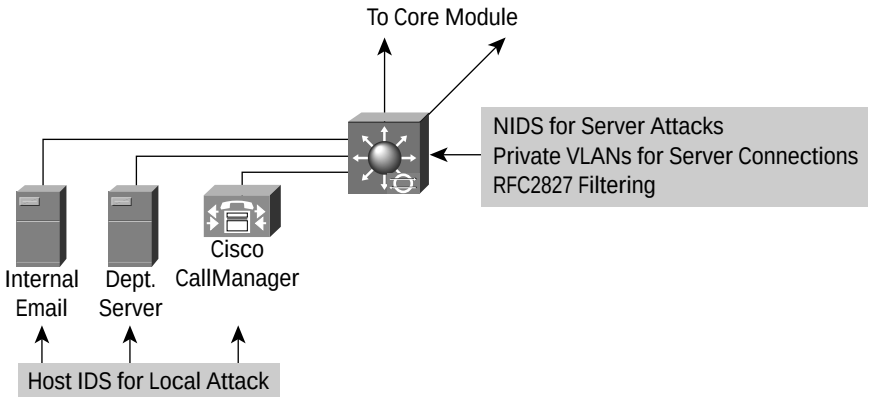
Figure 12 Server Module: Detail



Threats Mitigated

- *Unauthorized Access* – mitigated through the use of host-based intrusion detection and access control
- *Application Layer Attacks* – operating systems, devices, and applications are kept up to date with the latest security fixes and protected by host-based IDS
- *IP Spoofing* – RFC 2827 filtering prevents source address spoofing
- *Packet Sniffers* – a switched infrastructure limits the effectiveness of sniffing
- *Trust Exploitation* – trust arrangements are very explicit, private VLANs prevent hosts on the same subnet from communicating unless necessary
- *Port Redirection* – host-based IDS prevents port redirection agents from being installed

Figure 13 Attack Mitigation Roles for Server Module



Design Guidelines

The server module is often overlooked from a security perspective. When examining the levels of access most employees have to the servers to which they attach, the servers can often become the primary goal of internally originated attacks. Simply relying on effective passwords does not provide for a comprehensive attack mitigation strategy. Using host and network-based IDS, private VLANs, access control, and good system administration practices (such as keeping systems up to date with the latest patches), provides a much more comprehensive response to attacks.

Because the NIDS system is limited in the amount of traffic it can analyze, it is important to send it attack-sensitive traffic only. This varies from network to network, but should likely include SMTP, Telnet, FTP, and WWW. The switch-based NIDS was chosen because of its ability to look only at interesting traffic across all VLANs as defined by the security policy. Once properly tuned, this IDS can be set up in a restrictive manner, because required traffic streams should be well known.

Alternatives

Like the building distribution module, the server module can be combined with the core module if performance needs does not dictate separation. For very sensitive high-performance server environments, bladesinstalling more than one NIDS blade and directing policy-matched traffic to specific blades can scale the NIDS capability in the Layer 3 switch. For critical systems such as the IP telephony call manager or an accounting database, consider separating these hosts from the rest of the module with a stateful firewall.

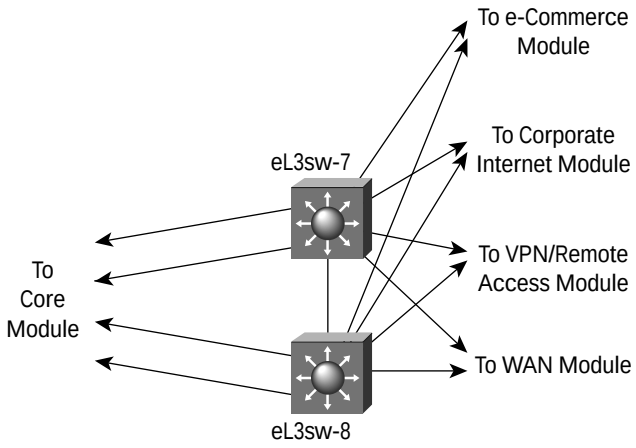
Edge Distribution Module

This module's goal is to aggregate the connectivity from the various elements at the edge. Traffic is filtered and routed from the edge modules and routed into the core.

Key Devices

- *Layer 3 switches* – aggregate edge connectivity and provide advanced services

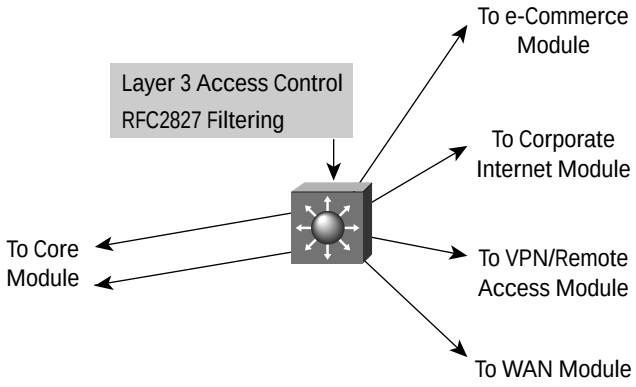
Figure 14 Edge Distribution Module: Detail



Threats Mitigated

- *Unauthorized Access* – filtering provides granular control over specific edge subnets and their ability to reach areas within the campus
- *IP Spoofing* – RFC 2827 filtering limits locally initiated spoof attacks
- *Network Reconnaissance* – filtering limits nonessential traffic from entering the campus limiting a hackers ability to perform network recon
- *Packet Sniffers* – a switched infrastructure limits the effectiveness of sniffing

Figure 15 Attack Mitigation Roles for Edge Distribution Module



Design Guidelines

The edge distribution module is similar in some respects to the building distribution module in terms of overall function. Both modules employ access control to filter traffic, although the edge distribution module can rely somewhat on the entire edge functional area to perform additional security functions. Both modules use Layer 3 switching to achieve high performance, but the edge distribution module can add additional security functions because the performance requirements are not as great. The edge distribution module provides the last line of defense for all traffic destined to the campus module from the edge module. This includes mitigation of spoofed packets, erroneous routing updates, and provisions for network layer access control.

Alternatives

Like the server and building distribution modules, the edge distribution module can be combined with the core module if performance requirements are not as stringent as the SAFE reference implementation. NIDS is not present in this module, but could be placed here through the use of IDS line cards in the Layer 3 switches. It would then reduce the need for NIDS appliances at the exit from the critical edge modules as they connect to the campus. However, performance reasons may dictate, as they did in SAFE's reference design, that dedicated intrusion detection be placed in the various edge modules as opposed to the edge distribution module.

Enterprise Edge

The following is a detailed analysis of all the modules contained within the Enterprise Edge.

Figure 16 Enterprise Edge Detail – Part 1

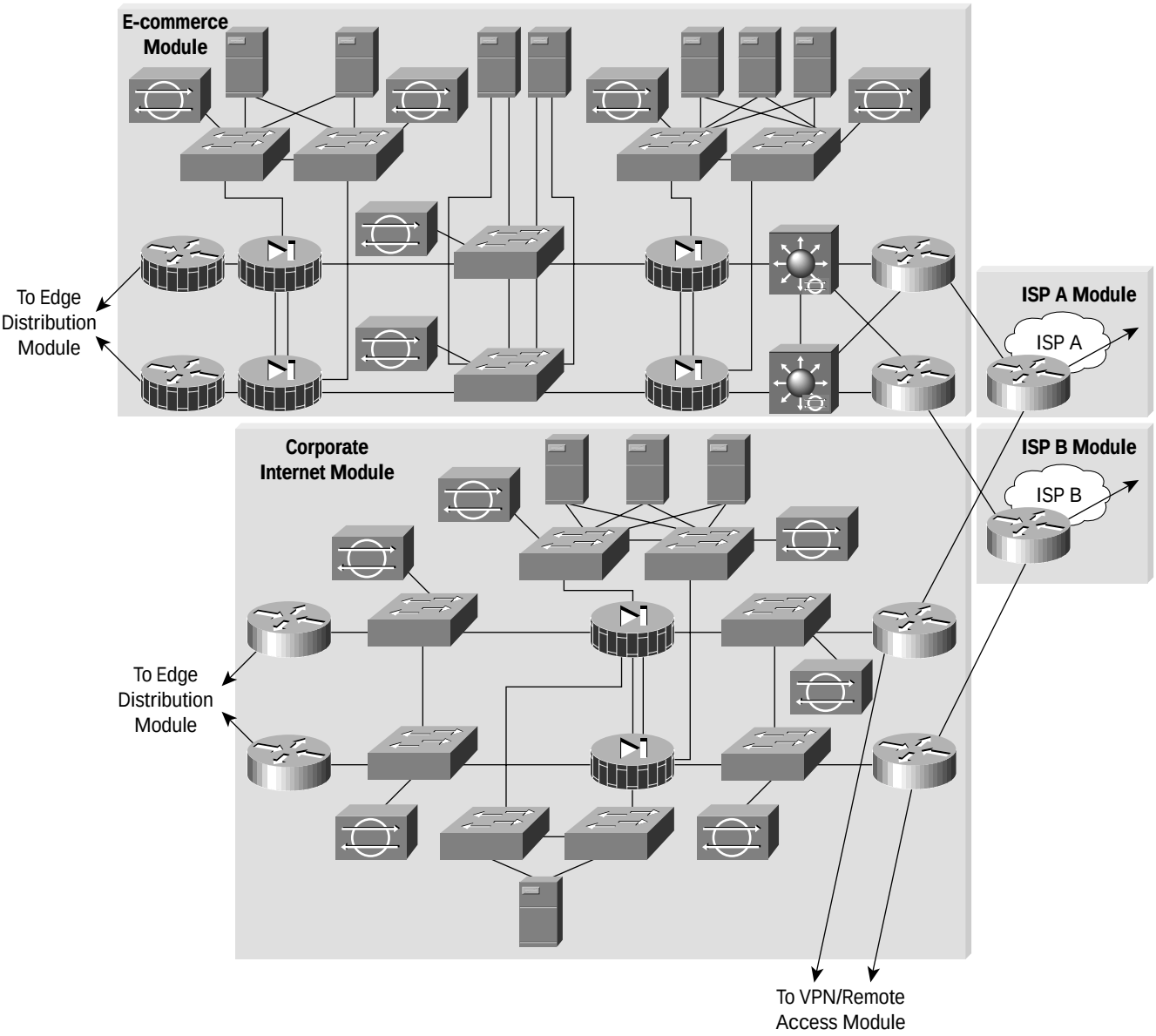
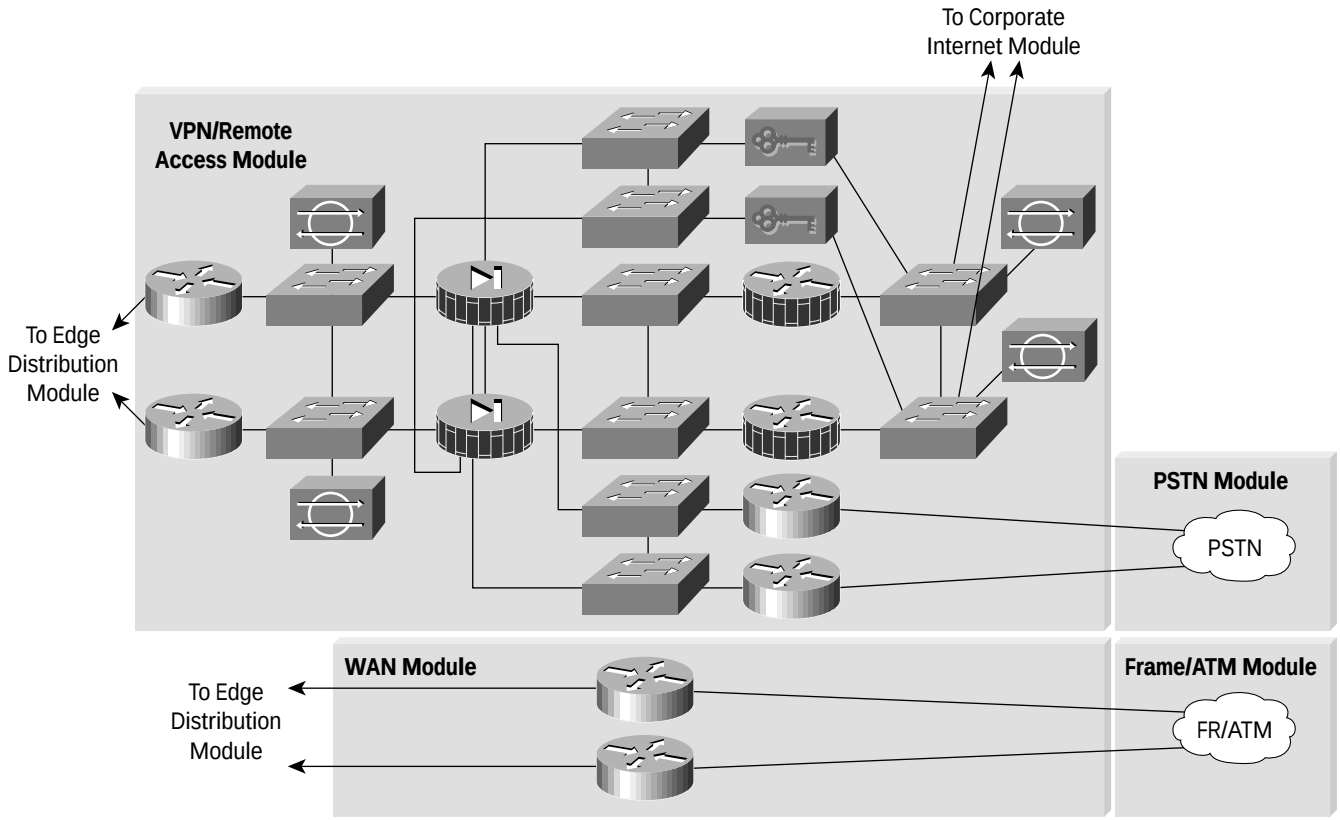


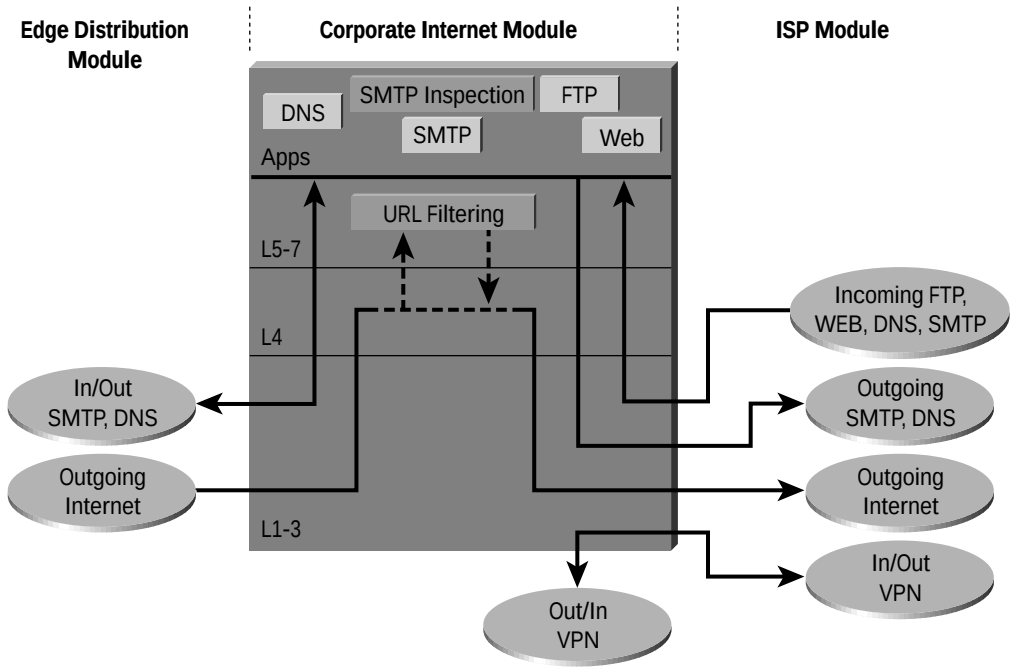
Figure 17 Enterprise Edge Detail – Part 2



Corporate Internet Module

The Corporate Internet module provides internal users with connectivity to Internet services and Internet users access to information on public servers. Traffic also flows from this module to the VPN and remote access module where VPN termination takes place. This module is not designed to serve e-commerce type applications. Refer to the "E-Commerce Module" section later in this document for more details on providing Internet commerce.

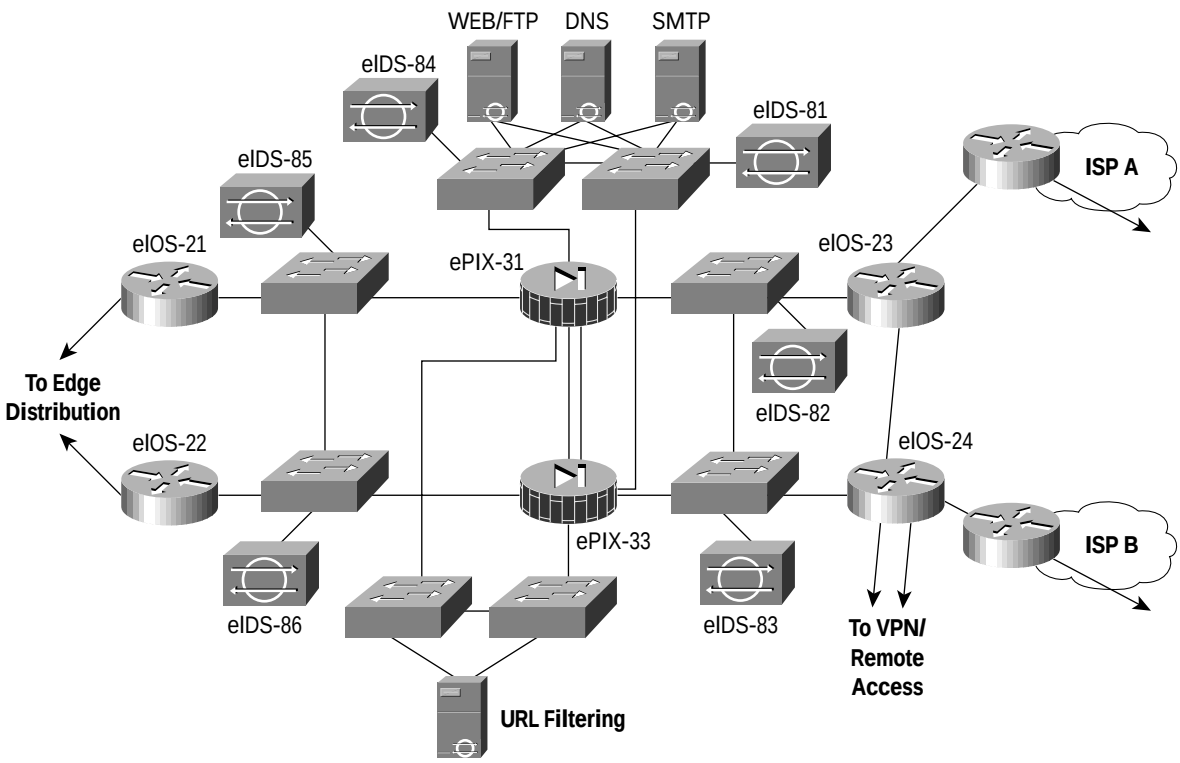
Figure 18 Corporate Internet Traffic Flow



Key Devices

- *SMTP server* – acts as a relay between the Internet and the Internet mail servers – inspects content
- *DNS server* – serves as authoritative external DNS server for the enterprise, relays internal requests to the Internet
- *FTP/HTTP server* – provides public information about the organization
- *Firewall* – provides network-level protection of resources and stateful filtering of traffic
- *NIDS appliance* – provides Layer 4 to Layer 7 monitoring of key network segments in the module
- *URL Filtering Server* – filters unauthorized URL requests from the enterprise

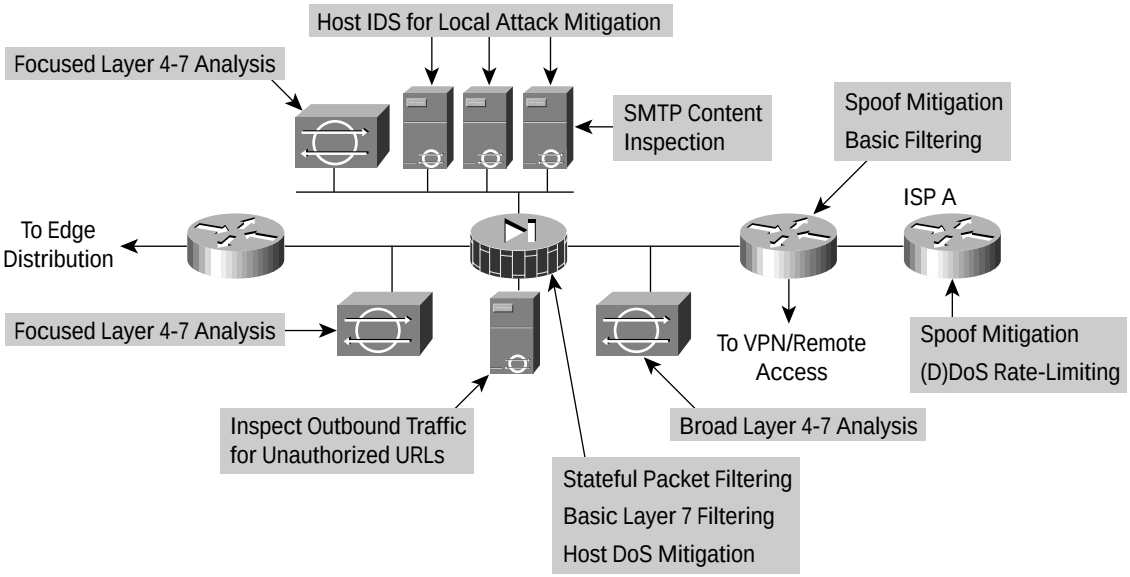
Figure 19 Corporate Internet Module: Detail



Threats Mitigated

- *Unauthorized Access* – mitigated through filtering at the ISP, edge router, and corporate firewall
- *Application Layer Attacks* – mitigated through IDS at the host and network levels
- *Virus and Trojan Horse* – mitigated through e-mail content filtering and host IDS
- *Password Attacks* – limited services available to brute force, OS and IDS can detect the threat
- *Denial of Service* – rate limiting at ISP edge and TCP setup controls at firewall
- *IP Spoofing* – RFC 2827 and 1918 filtering at ISP edge and enterprise edge router
- *Packet Sniffers* – switched infrastructure and host IDS limits exposure
- *Network Reconnaissance* – IDS detects recon, protocols filtered to limit effectiveness
- *Trust Exploitation* – restrictive trust model and private VLANs limit trust-based attacks
- *Port Redirection* – restrictive filtering and host IDS limit attack

Figure 20 Attack Mitigation Roles for Corporate Internet Module



Design Guidelines

The heart of the module is a pair of resilient firewalls, which provide protection for the Internet public services and internal users. Stateful inspection examines traffic in all directions ensuring only legitimate traffic crosses the firewall. Aside from the Layer 2 and Layer 3 resilience built into the module and the stateful failover capability of the firewall, all other design considerations center around security and attack mitigation.

Starting at the customer-edge router in the ISP, the egress out of the ISP rate-limits nonessential traffic that exceeds prespecified thresholds in order to mitigate against (D)DoS attacks. Also at the egress of the ISP router, RFC 2827and RFC 1918 filtering mitigate against source-address spoofing of local networks and private address ranges.

At the ingress of the first router on the Enterprise network, basic filtering limits the traffic to the expected (addresses and IP services) traffic, providing a coarse filter for the most basic attacks. RFC 1918 and 2827 filtering is also provided here as a verification of the ISP's filtering. In addition, because of the enormous security threat that they create, the router is configured to drop most fragmented packets that should not generally be seen for standard traffic types on the Internet. Any legitimate traffic lost because of this filtering is considered acceptable when compared to the risk of allowing such traffic. Finally, any IPSec traffic destined for the VPN and remote access module is routed appropriately. Filtering on the interface connected to the VPN module is configured to allow only IPSec traffic to cross, and only when originated from and sent to authorized peers. With remote access VPNs you generally do not know the IP address of the system coming in so filtering can be specific only to the head-end peers with which the remote users are communicating.

The NIDS appliance at the public side of the firewall is monitoring for attacks based on Layer 4 to Layer 7 analysis and comparisons against known signatures. Because the ISP and enterprise edge router are filtering certain address ranges and ports, this allows the NIDS appliance to focus on some of the more complex attacks. Still, this NIDS should have alarms set to a lower level than appliances on the inside of the firewall because alarms seen here do not represent actual breaches, but merely attempts.

The firewall provides connection state enforcement and detailed filtering for sessions initiated through it. Publicly addressable servers have some protection against TCP SYN floods through the use of half-open connection limits on the firewall. From a filtering standpoint, in addition to limiting traffic on the public services segment to relevant addresses and ports, filtering in the opposite direction also takes place. If an attack compromises one of the public servers (by circumventing the firewall, host-based IDS, and network-based IDS) that server should not be able to further attack the network. To mitigate against this type of attack, specific filtering prevents any unauthorized requests from being generated by the public servers to any other location. As an example, the Web server should be filtered so that it cannot originate requests of its own, but merely respond to requests from clients. This helps prevent a hacker from downloading additional utilities to the compromised box after the initial attack. It also helps stop unwanted sessions from being triggered by the hacker during the primary attack. An attack that generates an xterm from the Web server through the firewall to the hacker's machine is an example of such an attack. In addition, private VLANs prevent a compromised public server from attacking other servers on the same segment. This traffic is not even detected by the firewall, which is why private VLANs are critical.

Traffic on the content inspection segment is limited to URL filtering requests from the firewall to the URL filtering device. In addition, authenticated requests are allowed from the enterprise URL filtering device out to a master server for database updates. The URL filtering device inspects outbound traffic for unauthorized WWW requests. It communicates directly with the firewall and approves or rejects URL requests sent to its URL inspection engine by the firewall. Its decision is based on a policy managed by the enterprise using classification information of the WWW provided by a third-party service. URL inspection was preferred over standard access filtering because IP addresses often change for unauthorized Web sites, and such filters can grow to be very large. Host-based IDS software on this server protects against possible attacks that somehow circumvent the firewall. Remember with URL filtering you are sacrificing performance of your HTTP traffic for the greater control this inspection provides.

The public services segment includes an NIDS appliance in order to detect attacks on ports that the firewall is configured to permit. These most often are application layer attacks against a specific service or a password attack against a protected service. You need to set this NIDS in a more restrictive stance than the NIDS on the outside of the firewall because signatures matched here have successfully passed through the firewall. Each of the servers have host intrusion detection software on them to monitor against any rogue activity at the OS level, as well as activity in common server applications (HTTP, FTP, SMTP, and so forth). The DNS host should be locked down to respond only to desired commands and eliminate any unnecessary responses that might assist hackers in network reconnaissance. This includes preventing zone-transfers from anywhere but the internal DNS servers. The SMTP server includes mail content inspection services that mitigate against virus and Trojan-type attacks generated against the internal network that are usually introduced through the mail system. The firewall itself filters SMTP messages at Layer 7 to allow only necessary commands to the mail server.

The NIDS appliance on the inside interface of the firewall provides a final analysis of attacks. Very few attacks should be detected on this segment because only responses to initiated requests, and a few select ports from the public services segment, are allowed to the inside. Only sophisticated attacks should be seen on this segment because they generally mean a system on the public services segment has been compromised and the hacker is attempting to leverage this foot-hold to attack the internal network. For example, if the public SMTP server were compromised, a hacker might try to attack the internal mail server over TCP port 25, which is permitted to allow mail transfer between the two hosts. If attacks are seen on this segment, the responses to those attacks should be more severe than those on other segments because they probably indicate that a compromise has already occurred. The use of TCP resets to thwart, for example, the SMTP attack mentioned above, should be seriously considered.

Alternatives

There are several alternative designs for this module. For example, depending on your attitude towards attack awareness, the NIDS appliances might not be required in front of the firewall. In fact, without basic filtering on the access router, this type of monitoring is not recommended. With the appropriate basic filters, which exist in this design, the IDS outside the firewall can provide important alarm information that would otherwise be dropped by the firewall. Because the amount of alarms generated on this segment is probably large, alarms generated here should have a lower severity than alarms generated behind a firewall. Also, consider logging alarms from this segment to a separate management station to ensure that legitimate alarms from other segments get the appropriate attention. With the visibility that NIDS outside the firewall provides, evaluation of the attack types your organization is attracting can be better seen. In addition, evaluation of the effectiveness of ISP and enterprise edge filters can be performed.

Another possible alternative to the proposed design is the elimination of the router between the firewall and the edge distribution module. Though its functions can be integrated into the edge distribution module, the functional separation between modules would be lost because the edge distribution switches would need to be aware of the entire topology of the corporate Internet module to ensure proper routing. In addition, this limits your ability to deploy this architecture in a modular fashion. If an enterprise's current core is Layer 2, for example, the routing provided in the corporate Internet module would be required.

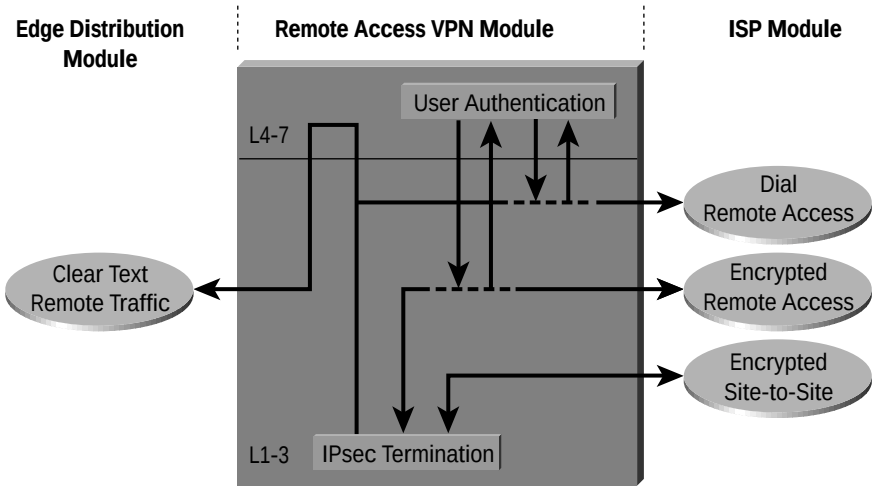
Near-Term Architecture Goals

Developing Cisco firewall technology that can communicate directly with other content inspection devices is needed (for example, network-based virus scanning). Currently, URL filtering is the only supported content filtering function that is directly integrated with Cisco firewall technology. Nonintegrated products rely on users operating in a proxy mode that does not properly scale.

VPN and Remote Access Module

As the name implies, the primary objective of this module is three-fold: terminate the VPN traffic from remote users, provide a hub for terminating VPN traffic from remote sites, and terminate traditional dial-in users. All the traffic forwarded to the edge distribution is from remote corporate users that are authenticated in some fashion before being allowed through the firewall.

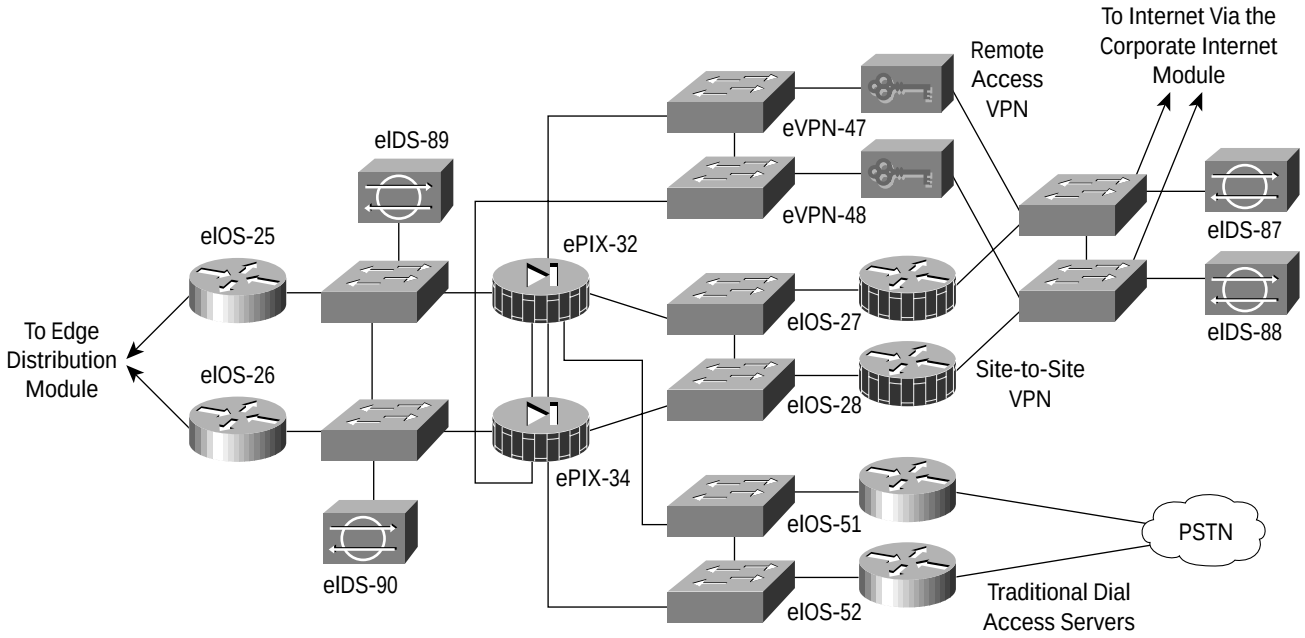
Figure 21 Remote Access VPN Module Traffic Flow



Key Devices

- *VPN Concentrator* – authenticate individual remote users using Extended Authentication (XAUTH) and terminate their IPSec tunnels
- *VPN Router* – authenticate trusted remote sites and provide connectivity using GRE/IPSec tunnels
- *Dial-In Server* – authenticate individual remote users using TACACS+ and terminate their analog connections
- *Firewall* – provide differentiated security for the three different types of remote access
- *NIDS appliance* – provide Layer 4 to Layer 7 monitoring of key network segments in the module

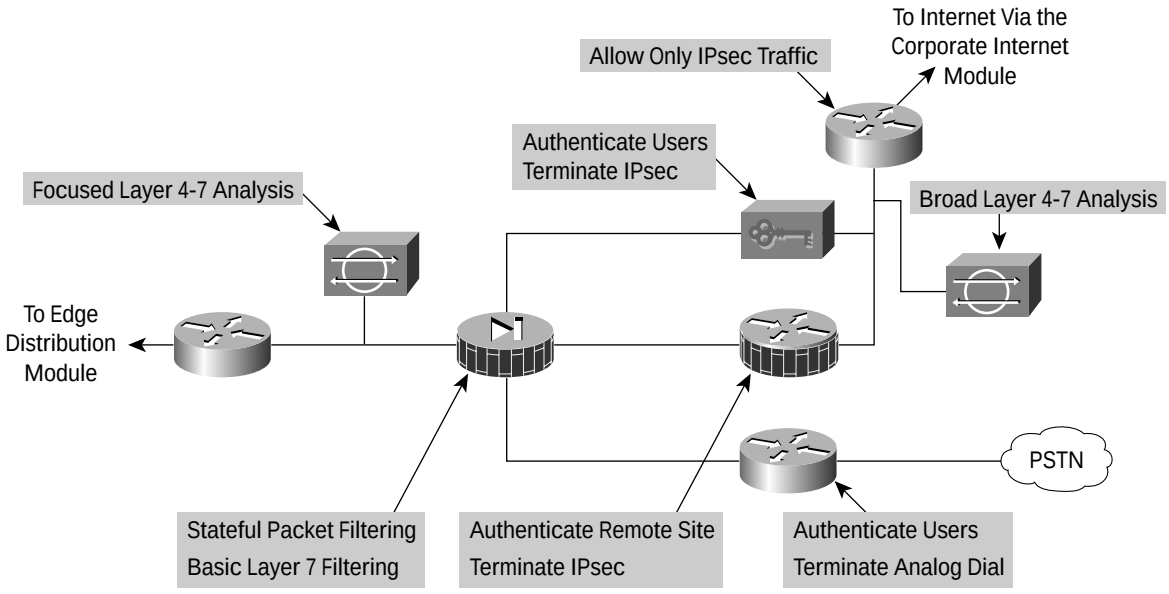
Figure 22 Remote Access VPN Module: Detail



Threats Mitigated

- *Network Topology Discovery* – only Internet Key Exchange (IKE) and Encapsulating Security Payload (ESP) are allowed into this segment from the Internet
- *Password Attack* – OTP authentication reduces the likelihood of a successful password attack
- *Unauthorized Access* – firewall services after packet decryption prevent traffic on unauthorized ports
- *Man-in-the-Middle* – mitigated through encrypted remote traffic
- *Packet Sniffers* – a switched infrastructure limits the effectiveness of sniffing

Figure 23 Attack Mitigation Roles for Remote Access VPN Module



Design Guidelines

Resilience aside, the core requirement of this module is to have three separate external user services authenticate and terminate. Because the traffic comes from different sources outside of the Enterprise network, the decision was made to provide a separate interface on the firewall for each of these three services. The design consideration for each of these services are addressed below.

Remote-Access VPN

The VPN traffic is forwarded from the corporate Internet module access routers, where it is first filtered at the egress point to the specific IP addresses and protocols that are part of the VPN services. Today's remote-access VPNs can use several different tunneling and security protocols. Although IPSec is the tunneling protocol of choice, many organizations choose Point-to-Point Tunneling Protocol (PPTP) and Layer 2 Tunneling Protocol (L2TP) because they are natively supported by popular desktop operating systems. In SAFE, IPSec was chosen because the clients require minimal configuration and at the same time provide good security.

The remote-access VPN traffic will be addressed to one specific public address using the IKE (UDP 500) protocol, ESP (IP 50) protocol, and UDP Port 10000. IKE provides tunnel setup, ESP encrypts the data, and UDP 10000 is optionally used if ESP traffic is tunneled inside of UDP to get around remote site firewalling restrictions or NAT. Because the IKE connection is not completed until the correct authentication information is provided, this provides a level of deterrence for the potential hacker. As part of the extensions (draft RFCs) of IKE, XAUTH provides an additional user authentication mechanism before the remote user is assigned any IP parameters. The VPN concentrator is "connected" to the access control server on the management subnet via its management interface. Strong passwords are provided via the one-time password server.

Once authenticated, the remote user is provided with access by receiving IP parameters using another extension of IKE, MODCFG. Aside from an IP address and the location of name servers (DNS and WINS), MODCFG also provides authorization services to control the access of the remote user. For example in SAFE, users are prevented from enabling split tunneling, thereby forcing the user to access the Internet via the corporate connection. The IPSec parameters that are being

used are Triple DES for encryption and SHA-HMAC for data integrity. The hardware encryption modules in the VPN concentrator allow remote access VPN services to be scalably deployed to thousands of remote users. Following termination of the VPN tunnel, traffic is sent through a firewall to ensure that VPN users are appropriately filtered.

Secure management of this service is achieved by pushing all IPSec and security parameters to the remote users from the central site. Additionally, connections to all management functions are on a dedicated management interface.

Dial-in access users

The traditional dial-in users are terminated on one of the two access routers with built-in modems. Once the Layer 1 connection is established between the user and the server, three-way CHAP is used to authenticate the user. As in the remote-access VPN service the AAA and one-time password servers are used to authenticate and provide passwords. Once authenticated the users are provided with IP addresses from an IP pool through PPP.

Site-to-site VPN

The VPN traffic associated with site-to-site connections consists of GRE tunnels protected by an IPSec protocol in transport mode using Encapsulated Security Payload (ESP). As in the remote-access case, the traffic that is forwarded from the corporate Internet module can be limited to the specific destination addresses on the two VPN routers and the source addresses expected from the remote sites. The ESP protocol and the IKE protocol will be the only two expected on this link.

GRE is used to provide a full-service routed link that will carry multiprotocol, routing protocol, and multicast traffic. Because routing protocols (Enhanced Interior Gateway Routing Protocol [EIGRP] is being used between remote sites) can detect link failure, the GRE tunnel provides a resilience mechanism for the remote sites if they build two generic routing encapsulation (GRE) connections one to each of the central VPN routers.

As in remote-access VPN, 3DES and SHA-HMAC are used for IKE and IPSec parameters to provide the maximum security with little effect on performance. IPSec hardware accelerators are used in the VPN routers.

Rest of the module

The traffic from the three services is aggregated by the firewall onto one private interface before being sent to the edge distribution module via a pair of routers. The firewall must be configured with the right type of constraining access control to allow only the appropriate traffic through to the inside interface of the firewall from each of the services. In addition to access control, the firewalls provide a point of auditing for all VPN traffic and an enforcement point for NIDS threat response. A pair of NIDS appliances are positioned at the public side of the module to detect any network “reconnaissance” activity targeted at the VPN termination devices. On this segment, only IPSec (IKE/ESP) traffic should be seen. Because the NIDS system can not see inside the IPSec packets, any alarm on this network indicates a failure or compromise of the surrounding devices. As such, these alarms should be set to high severity levels. A second pair of NIDS are positioned after the firewall to detect any attacks that made it through the rest of the module. All users crossing this segment should be bound to, or coming from a remote location so any shunning or TCP resets will only affect those users. This allows a more restrictive stance for the NIDS as opposed to, say, the corporate Internet module where some of the NIDS devices have the potential to shut out legitimate users if too loosely configured.

Alternatives

In VPN and authentication technology, there are many alternatives available depending on the requirements of the network. These alternatives are listed below for reference, but the details are not addressed in this document.

- Smart-card and/or Bio-metric authentication
- L2TP and/or PPTP remote-access VPN tunnels
- Certificate Authorities (CAs)
- IKE keep-alive resilience mechanism
- Multiprotocol Label Switching (MPLS) VPNs

In the SAFE VPN document an alternative VPN design is proposed which significantly increases the scalability of the VPN solution. This design adds L3 switches as a routing distribution layer before the clear-text traffic is sent through the firewall. Interested readers should refer to SAFE VPN at the following URL: http://www.cisco.com/warp/public/cc/so/cuso/epso/sqfr/safev_wp.htm.

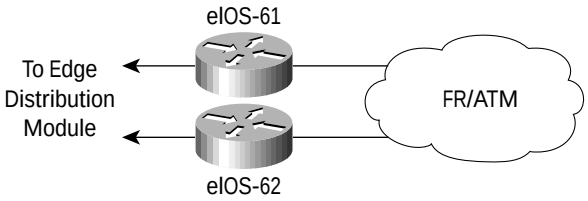
WAN MModule

Rather than being all-inclusive of potential WAN designs, this module shows resilience and security for WAN termination. Using Frame Relay encapsulation, traffic is routed between remote sites and the central site.

Key Devices

• *IOS Router* – using routing, access-control, QoS mechanisms

Figure 24 WAN Module: Detail

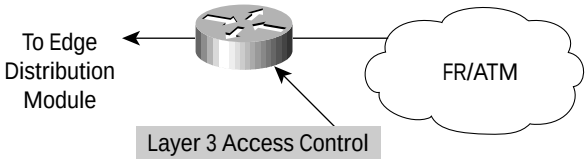


Threats Mitigated

• *IP Spoofing* – mitigated through L3 filtering

• *Unauthorized Access* – simple access control on the router can limit the types of protocols to which branches have access

Figure 25 Attack Mitigation Roles for WAN Module



Design Guidelines

The resilience is provided by the dual connection from the service provider, through the routers, and to the edge distribution module. Security is provided by using IOS security features. Input access-lists are used to block all unwanted traffic from the remote branch.

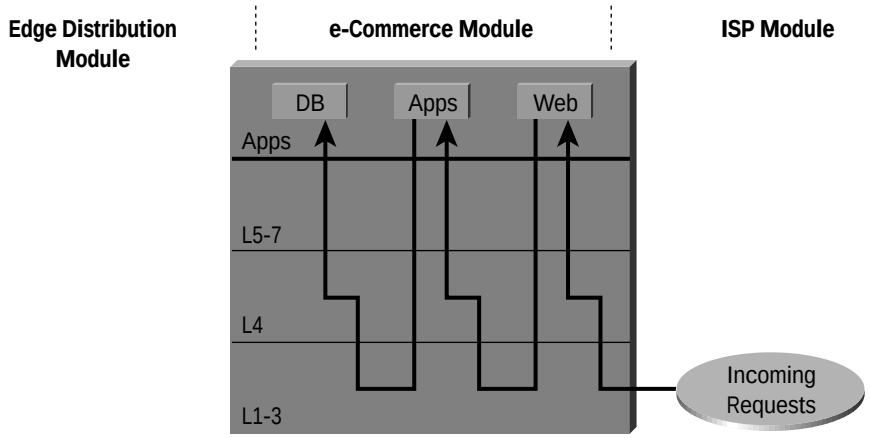
Alternatives

Some organizations that are very concerned about information privacy encrypt highly confidential traffic on their WAN links. Similarly to site-to-site VPNs, you can use IPSec to achieve this information privacy.

E-Commerce Module

Because e-commerce is the primary objective of this module, the balance between access and security must be carefully weighed. Splitting the e-commerce transaction into three components allows the architecture to provide various levels of security without impeding access.

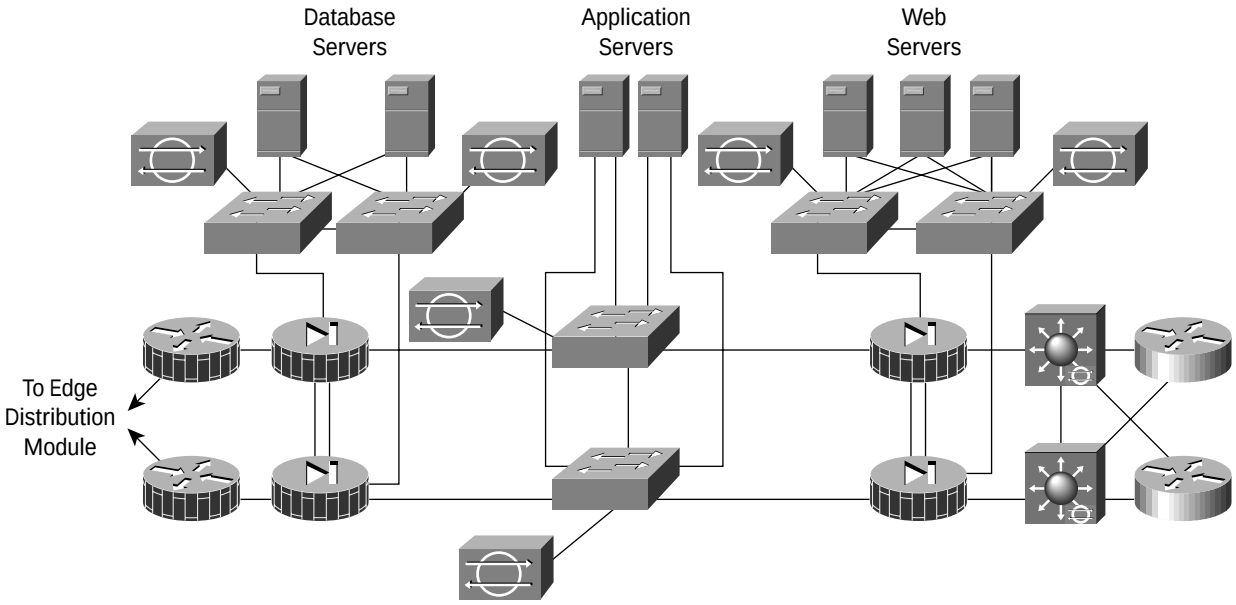
Figure 26 E-Commerce Traffic Flow



Key Devices

- *Web server* – acts as the primary user interface for the navigation of the e-commerce store
- *Application server* – is the platform for the various applications required by the Web server
- *Database server* – is the critical information that is the heart of the e-commerce business implementation
- *Firewall* – governs communication between the various levels of security and trust in the system
- *NIDS appliance* – provides monitoring of key network segments in the module
- *Layer 3 switch with IDS module* – is the scalable e-commerce input device with integrated security monitoring

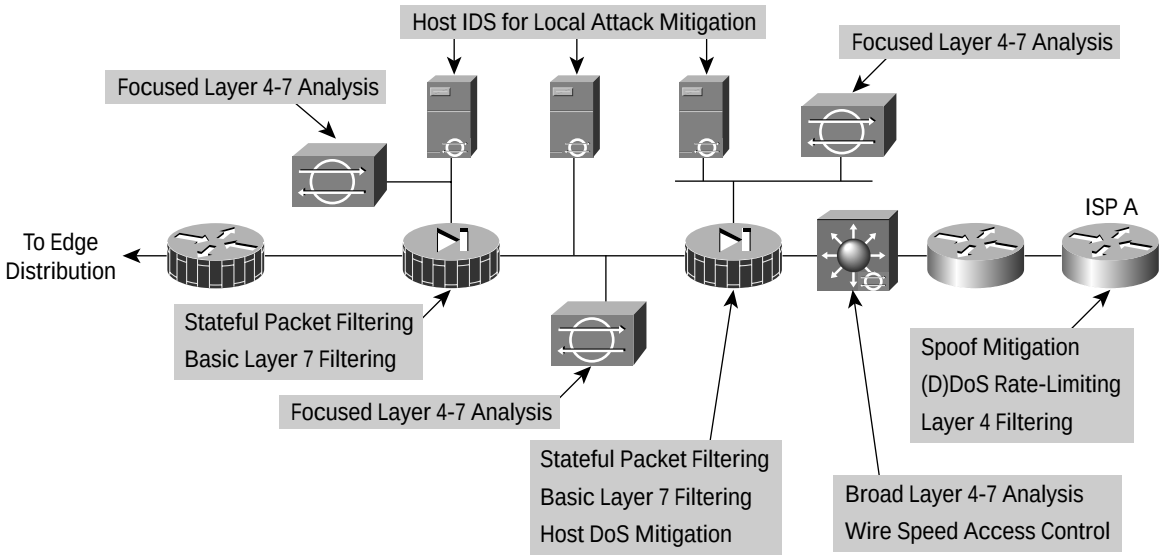
Figure 27 E-Commerce Module: Detail



Threats Mitigated

- *Unauthorized Access* – stateful firewalling and ACLs limit exposure to specific protocols
- *Application Layer Attacks* – attacks are mitigated through the use of IDS
- *Denial of Service* – ISP filtering and rate-limiting reduce (D)DoS potential
- *IP Spoofing* – RFC 2827 and 1918 prevent locally originated spoofed packets and limit remote spoof attempts
- *Packet Sniffers* – a switched infrastructure and HIDS limits the effectiveness of sniffing
- *Network Reconnaissance* – ports are limited to only what is necessary, ICMP is restricted
- *Trust Exploitation* – firewalls ensure communication flows only in the proper direction on the proper service
- *Port Redirection* – HIDS and firewall filtering limit exposure to these attacks

Figure 28 Attack Mitigation Roles for E-Commerce Module



Design Implementation Description

The heart of the module is two pairs of resilient firewalls that provide protection for the three levels of servers: Web, application, and database. Some added protection is provided by the ISP edge routers at the ISP and the Enterprise. The design is best understood by considering the traffic flow sequence and direction for a typical e-commerce transaction.

The e-commerce customer initiates an HTTP connection to the Web server after receiving the IP address from a DNS server hosted at the ISP network. The DNS is hosted on a different network to reduce the amount of protocols required by the e-commerce application. The first set of firewalls must be configured to allow this protocol through to that particular address. The return traffic for this connection is allowed back, but there is no need for any communication initiated by the Web server back out the Internet. The firewall should block this path in order to limit the options of hackers if they had control of one of the Web servers.

As the user navigates the Web site, certain link selections cause the Web server to initiate a request to the application server on the inside interface. This connection must be permitted by the first firewall, as well as the associated return traffic. As in the case with the Web server, there is no reason for the application server to initiate a connection to the Web server or even out to the Internet. Likewise, the user's entire session runs over HTTP and SSL with no ability to communicate directly with the application server or the database server.

At one point, the user will want to perform a transaction. The Web server will want to protect this transaction and the SSL protocol will be required from the Internet to the Web server. At the same time, the application server might want to query or pass information on to the database server. These are typically SQL queries that are initiated by the application server to the database server and not vice versa. These queries run through the second firewall to the database server. Depending on the specific applications in use, the database server might need to communicate with back-end systems located in the server module of the enterprise.

In summary, the firewalls must allow only three specific communication paths, each with its own protocol, and block all other communication unless it is the return path packets that are associated with the three original paths.

The servers themselves must be fully protected—especially the Web server—which is a publicly-addressable host. The operating system and Web server application must be patched to the latest versions and monitored by the host intrusion detection software. This should mitigate against most application layer primary and secondary attacks such as port redirection and root kits. The other servers should have similar security in case the first server or firewall is compromised.

Beyond the Firewall

The e-commerce firewalls are initially protected by the customer edge router at the ISP. At the router egress point, towards the enterprise, the ISP can limit the traffic to the small number of protocols required for e-commerce with a destination address of the Web servers only. Routing protocol updates (generally Border Gateway Protocol [BGP]) are required by the edge routers, and all other traffic should be blocked. The ISP should implement rate limiting as specified in the “SAFE Axioms” section in order to mitigate (D)DoS attacks. In addition, filtering according to RFC1918 and RFC2827 should also be implemented by the ISP.

On the enterprise premises, the initial router serves only as an interface to the ISP. The Layer 3 switch does all the network processing because it has features off-loaded to hardware processors. The Layer 3 switches participate in the full BGP routing decision in order to decide which ISP has the better route to the particular user. The Layer 3 switches also provide verification filtering in keeping with the ISP filtering described above; this provides overlapping security. Thirdly, the Layer 3 switches provide built-in IDS monitoring. If the connection to the Internet exceeds the capacity of the IDS line card, you might need to look only at inbound Web requests from the Internet on the IDS line card. While this will miss some http alarm signatures (approximately 10 percent), it is better than looking at the entire stream in both directions, where many misses would occur. The other NIDS appliances behind the various interfaces of the firewall monitor the segments for any attacks that might have penetrated the first line of defense. For example, if the Web server is out of date, hackers could compromise it over an application layer attack assuming they were able to circumvent the HIDS. As in the corporate Internet module, the false-positives must be removed so that all true attack detections are treated with the correct level of priority. In fact, because only certain types of traffic exist on certain segments, you can tune NIDS very tightly.

From an application standpoint, the communications paths between the various layers (web, apps, dbase) should be encrypted, transactional, and highly authenticated. For example, if the apps server were to get data from the database over some type of scripted interactive session (SSH, FTP, Telnet, and so forth) a hacker could leverage that interactive session to initiate an application layer attack. By employing secure communications, you can limit potential threats.

The Layer 2 switches that supporting the various firewall segments provide the ability to implement private VLANs, thereby implementing a trust model that matches the desired traffic communication on a particular segment and eliminates all others. For example, there is usually no reason for one Web server to communicate with another Web server.

The management of the entire module is done completely out of band as in the rest of the architecture.

Alternatives

The principle alternative to this deployment is co-locating the entire system at an ISP. Though the design remains the same, there are two primary differences. The first is that bandwidth is generally larger to the ISP and uses a LAN connection. Though not recommended, this potentially eliminates the need for the edge routers in the proposed design. The additional bandwidth also creates different requirements for (D)DoS mitigation. The second is the connection back to the enterprise, which needs to be managed in a different way. Alternatives include encryption and private lines. Using these technologies creates additional security considerations depending on the location of the connections and their intended use.

There are several variations on the primary design for this module. Aside from listing the alternatives, further discussion is beyond the scope of this paper.

- The use of additional firewalls is one alternative. Sample communications would be edge routing -> firewall -> web server -> firewall -> applications server -> firewall -> database server. This allows each firewall to only control communications for one primary system.
- Load-balancing and caching technologies are not specifically discussed in this paper, but can be overlaid onto this architecture without major modifications.
- For very high security requirements, the use of multiple firewall types may be considered. Note that this creates additional management overhead in duplicating policy on disparate systems. The goal of these designs is to avoid a vulnerability in one firewall from circumventing the security of the entire system. These types of designs tend to be very firewall centric and do not adequately take advantage of IDS and other security technologies to mitigate the risk of a single firewall vulnerability.

Enterprise Options

The design process is often a series of trade-offs. This short subsection of the document highlights some of the high-level options that a network designer could implement if faced with tighter budget constraints. Some of these trade-offs are done at the module level, while others are done at the component level.

A first option is to collapse the distribution modules into the core module. This reduces the number of Layer 3 switches by 50 percent. The cost savings would be traded-off against performance requirements in the core of the network and flexibility to implement all the distribution security filtering.

A second option is to merge the functionality of the VPN and Remote Access module with the corporate Internet module. Their structure is very similar, with a pair of firewalls at the heart of the module, surrounded by NIDS appliances. This may be possible without loss of functionality if the performance of the components matches the combined traffic requirements of the modules and if the firewall has enough interfaces to accommodate the different services. Keep in mind that as functions are aggregated to single devices the potential for human error increases. Some organizations go even further and include the e-commerce functions in the corporate Internet/VPN module. The authors feel that the risk of doing this far outweighs any cost savings unless the e-commerce needs are minimal. Separation of the e-commerce traffic from general Internet traffic allows the e-commerce bandwidth to be better optimized by allowing the ISP to place more restrictive filtering and rate-limiting technology to mitigate against DDoS attacks.

A third option is to eliminate some of the NIDS appliances. Depending on your operational threat response strategy, you might need fewer NIDS appliances. This number is also affected by the amount of Host IDS deployed because this might reduce the need for NIDS in certain locations. This is discussed, where appropriate, in the specific modules.

Clearly, network design is not an exact science. Choices must always be made depending on the specific requirements facing the designer. The authors are not proposing that any designer would implement this architecture verbatim, but would encourage designers to make educated choices about network security grounded in this proven implementation.

Migration Strategies

SAFE is a guide for implementing security on the enterprise network. It is not meant to serve as a security policy for any enterprise networks, nor is it meant to serve as the all-encompassing design for providing full security for all existing networks. Rather, SAFE is a template that enables network designers to consider how they design and implement their enterprise network in order to meet their security requirements.

Establishing a security policy should be the first activity in migrating the network to a secure infrastructure. Basic recommendations for a security policy can be found at the end of the document in Appendix B, "Network Security Primer." After the policy is established, the network designer should consider the security axioms described in the first section of this document and see how they provide more detail to map the policy on the existing network infrastructure.

There is enough flexibility in the architecture and detail about the design considerations to enable the SAFE architecture elements to be adapted to most enterprise networks. For example, in the VPN and Remote Access module, the various flows of traffic from public networks are each given a separate pair of terminating devices and a separate interface on the firewall. The VPN traffic could be combined in one pair of devices, if the load requirements permitted it and the security policy was the same for both types of traffic. On another network, the traditional dial-in and remote-access VPN users might be allowed directly into the network because the security policy puts enough trust in the authentication mechanisms that permit the connection to the network in the first place.

SAFE allows the designer to address the security requirements of each network function almost independently of each other. Each module is generally self-contained and assumes that any interconnected module is only at a basic security level. This allows network designers to use a phased approach to securing the enterprise network. They can address securing the most critical network functions as determined by the policy without redesigning the entire network. The exception to this is the management module. During the initial SAFE implementation, the management module should be implemented in parallel with the first module. As the rest of the network is migrated, the management module can be connected to the remaining locations.

Appendix A: Validation Lab

A reference SAFE implementation exists to validate the functionality described in this document. This appendix details the configurations of the specific devices within each module as well as the overall guidelines for general device configuration. The following are configuration snap-shots from the live devices in the lab. The authors do not recommend applying these configurations directly to a production network.

Overall Guidelines

The configurations presented here correspond in part to the SAFE Axioms presented earlier in this document.

Routers

Here are the basic configuration options present on nearly all routers in the SAFE lab:

```
! turn off unnecessary services
!
no ip domain-lookup
no cdp run
no ip http server
no ip source-route
no service finger
no ip bootp server
no service udp-small-s
no service tcp-small-s
!
!turn on logging and snmp
!
service timestamp log datetime localtime
logging 192.168.253.56
logging 192.168.253.51
snmp-server community Txo~QbW3XM ro 98
!
!set passwords and access restrictions
!
service password-encryption
enable secret %Z<)|z9~zq
no enable password
no access-list 99
access-list 99 permit 192.168.253.0 0.0.0.255
access-list 99 deny any log
no access-list 98
access-list 98 permit host 192.168.253.51
access-list 98 deny any log
line vty 0 4
access-class 99 in
login
password 0 X)[^j+#T98
exec-timeout 2 0
line con 0
login
password 0 X)[^j+#T98
exec-timeout 2 0
line aux 0
transport input none
password 0 X)[^j+#T98
no exec
exit
banner motd #

        This is a private system operated for and by Cisco VSEC BU.
    Authorization from Cisco VSEC management is required to use this system.
                Use by unauthorized persons is prohibited.
```

```
#
!
!Turn on NTP
!
clock timezone PST -8
clock summer-time PST recurring
ntp authenticate
ntp authentication-key 1 md5 -UN&/6[oh6
ntp trusted-key 1
ntp access-group peer 96
ntp server 192.168.254.57 key 1
access-l 96 permit host 192.168.254.57
access-l 96 deny any log
!
!Turn on AAA
!
aaa new-model
aaa authentication login default tacacs+
aaa authentication login no_tacacs line
aaa authorization exec tacacs+
aaa authorization network tacacs+
aaa accounting network start-stop tacacs+
aaa accounting exec start-stop tacacs+
tacacs-server host 192.168.253.54 single
tacacs-server key SJj)j~t]6-
line con 0
login authentication no_tacacs
```

The following configuration snapshot defines the OSPF authentication and filtering parameters for all OSPF routers within the network. Note the MD5 authentication, as well as the distribute lists ensuring the OOB network is not advertised.

```
interface Vlan13
 ip address 10.1.13.3 255.255.255.0
 ip ospf authentication message-digest
 ip ospf message-digest-key 1 md5 7 024D105641521F0A7E
 ip ospf priority 3
!
router ospf 1
 area 0 authentication message-digest
 network 10.1.0.0 0.0.255.255 area 0
 distribute-list 1 out
 distribute-list 1 in
!
access-list 1 deny   192.168.0.0 0.0.255.255
access-list 1 permit any
```

The following configuration snapshot defines the access control present on all the OOB interfaces throughout the network. Keep in mind that this is in addition to the private VLANs which block access between managed host IP addresses.

```
interface FastEthernet1/0
 ip address 192.168.254.15 255.255.255.0
 ip access-group 101 in
 ip access-group 102 out
 no cdp enable
!
access-list 101 permit icmp any any
access-list 101 permit tcp 192.168.253.0 0.0.0.255 host 192.168.254.15 established
access-list 101 permit udp 192.168.253.0 0.0.0.255 host 192.168.254.15 gt 1023
access-list 101 permit tcp 192.168.253.0 0.0.0.255 host 192.168.254.15 eq telnet
access-list 101 permit udp host 192.168.253.51 host 192.168.254.15 eq snmp
access-list 101 permit udp host 192.168.253.53 host 192.168.254.15 eq tftp
access-list 101 permit udp host 192.168.254.57 host 192.168.254.15 eq ntp
access-list 101 deny   ip any any log
access-list 102 deny   ip any any log
```

Switches

Here is the base security configuration present on nearly all CAT OS switches in the SAFE lab. IOS switches use a configuration nearly identical to the router configuration.

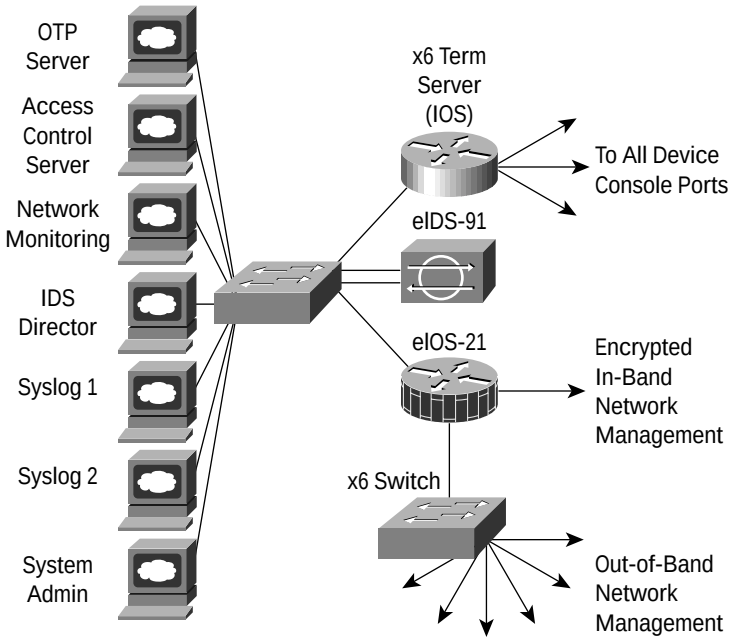
```
!
!Turn on NTP
!
set timezone PST -8
set summertime PST
set summertime recurring
set ntp authentication enable
set ntp key 1 trusted md5 -UN&/6[oh6
set ntp server 192.168.254.57 key 1
set ntp client enable
!
! turn off un-needed services
!
set cdp disable
set ip http server disable
!
!turn on logging and snmp
!
set logging server 192.168.253.56
set logging server 192.168.253.51
set logging timestamp enable
set snmp community read-only Txo~QbW3XM
set ip permit enable snmp
set ip permit 192.168.253.51 snmp
!
!Turn on AAA
!
set tacacs server 192.168.253.54 primary
set tacacs key SJj)j~t]6-
set authentication login tacacs enable telnet
set authentication login local disable telnet
set authorization exec enable tacacs+ deny telnet
set accounting exec enable start-stop tacacs+
set accounting connect enable start-stop tacacs+
!
!set passwords and access restrictions
!
set banner motd <c>
```

```
                This is a private system operated for and by Cisco VSEC BU.

          Authorization from Cisco VSEC management is required to use this system.

                        Use by unauthorized persons is prohibited.

<c>
!console password is set by 'set password'
!enter old password followed by new password
!console password = X)[^j+#T98
!
!enable password is set by 'set enable'
!enter old password followed by new password
!enable password = %Z<)|z9~zq
!
!the following password configuration only works the first time
!
set password

X)[^j+#T98
X)[^j+#T98
set enable
cisco
%Z<)|z9~zq
%Z<)|z9~zq
!
!the above password configuration only works the first time
!
set logout 2
set ip permit enable telnet
set ip permit 192.168.253.0 255.255.255.0 telnet
```

Hosts

Hosts were patched with the latest fixes. HIDS was applied as well.

Figure 29 Management Module: Detail



Products Used

- Cisco Catalyst 3500XL Layer 2 switches (all switching)
- Cisco 3640 IOS Router with Firewall Feature Set (eIOS-57)
- Cisco 2511 IOS Router (terminal servers)
- Cisco Secure Intrusion Detection System (CSIDS) sensor
- RSA SecureID OTP Server
- Cisco Secure Access Control Server
- Cisco Works 2000
- Cisco Secure Policy Manager
- Cisco IDS Host Sensor
- netForensics syslog analysis tool

EIOS-57

The following configuration sets the default IOS Firewall parameters:

```
ip inspect audit-trail
ip inspect max-incomplete low 150
ip inspect max-incomplete high 250
ip inspect one-minute low 100
ip inspect one-minute high 200
ip inspect udp idle-time 20
ip inspect dns-timeout 3
ip inspect tcp idle-time 1800
ip inspect tcp finwait-time 3
ip inspect tcp synwait-time 15
ip inspect tcp max-incomplete host 40 block-time 0
ip inspect name mgmt_fw tcp timeout 300
ip inspect name mgmt_fw udp
ip inspect name mgmt_fw tftp
ip inspect name mgmt_fw http
ip inspect name mgmt_fw fragment maximum 256 timeout 1
ip audit notify log
ip audit po max-events 100
```

The following configuration sets up the encrypted in-band network management:

```
crypto isakmp policy 1
 encr 3des
 authentication pre-share
 group 2
crypto isakmp key A%Xr)7,_) address 172.16.224.24
crypto isakmp key A%Xr)7,_) address 172.16.224.23
!
crypto ipsec transform-set vpn_module_mgmt esp-3des esp-sha-hmac
!
crypto map mgmt1 100 ipsec-isakmp
 set peer 172.16.224.24
 set transform-set vpn_module_mgmt
 match address 111
crypto map mgmt1 200 ipsec-isakmp
 set peer 172.16.224.23
 set transform-set vpn_module_mgmt
 match address 110
access-list 110 permit ip 192.168.253.0 0.0.0.255 host 172.16.224.23
access-list 110 permit udp 192.168.254.0 0.0.0.255 host 172.16.224.23
access-list 111 permit ip 192.168.253.0 0.0.0.255 host 172.16.224.24
access-list 111 permit udp 192.168.254.0 0.0.0.255 host 172.16.224.24
```

The following configuration defines inbound access control from the managed host network. Port 45000 is for CSIDS and port 5000 is for Click Net's HIDS.

```
access-list 114 permit icmp 192.168.254.0 0.0.0.255 192.168.253.0 0.0.0.255 echo-reply
access-list 114 permit udp 192.168.254.0 0.0.0.255 host 192.168.253.56 eq syslog
access-list 114 permit udp 192.168.254.0 0.0.0.255 host 192.168.253.51 eq syslog
access-list 114 permit udp 192.168.254.0 0.0.0.255 host 192.168.253.50 eq 45000
access-list 114 permit tcp 192.168.254.0 0.0.0.255 host 192.168.253.50 eq 5000
access-list 114 permit udp 192.168.254.0 0.0.0.255 host 192.168.253.53 eq tftp
access-list 114 permit udp 192.168.254.0 0.0.0.255 host 192.168.254.57 eq ntp
access-list 114 permit tcp 192.168.254.0 0.0.0.255 host 192.168.253.54 eq tacacs
access-list 114 permit udp 192.168.254.0 0.0.0.255 host 192.168.253.54 eq 1645
access-list 114 permit udp 192.168.254.0 0.0.0.255 host 192.168.253.52 eq syslog
access-list 114 deny   ip any any log
```

The following configuration defines inbound access control from the management host network:

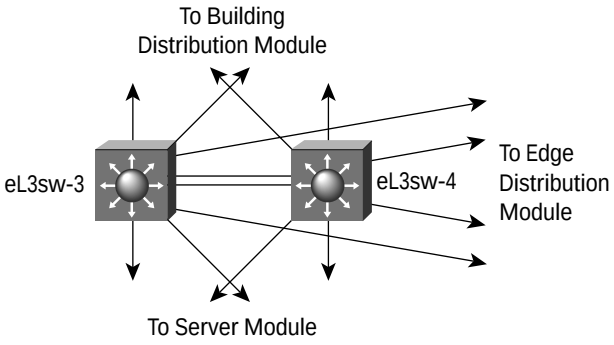
```
access-list 113 permit icmp 192.168.253.0 0.0.0.255 192.168.254.0 0.0.0.255
access-list 113 permit icmp 192.168.253.0 0.0.0.255 host 192.168.253.57
access-list 113 permit tcp 192.168.253.0 0.0.0.255 host 192.168.253.57 eq telnet
access-list 113 permit tcp 192.168.253.0 0.0.0.255 192.168.254.0 0.0.0.255 eq telnet
access-list 113 permit tcp 192.168.253.0 0.0.0.255 192.168.254.0 0.0.0.255 eq 443
access-list 113 permit tcp 192.168.253.0 0.0.0.255 192.168.254.0 0.0.0.255 eq 22
access-list 113 permit udp host 192.168.253.50 192.168.254.0 0.0.0.255 eq 45000
access-list 113 permit tcp host 192.168.253.50 192.168.254.0 0.0.0.255 eq 5000
access-list 113 permit udp host 192.168.253.51 192.168.254.0 0.0.0.255 eq snmp
access-list 113 permit udp host 192.168.253.53 gt 1023 host 192.168.253.57 gt 1023
access-list 113 permit udp 192.168.253.0 0.0.0.255 host 192.168.254.57 eq ntp
access-list 113 permit tcp host 192.168.253.54 eq tacacs host 192.168.253.57 gt 1023
access-list 113 permit icmp 192.168.253.0 0.0.0.255 host 172.16.224.23
access-list 113 permit icmp 192.168.253.0 0.0.0.255 host 172.16.224.24
access-list 113 permit tcp 192.168.253.0 0.0.0.255 host 172.16.224.23 eq telnet
access-list 113 permit tcp 192.168.253.0 0.0.0.255 host 172.16.224.24 eq telnet
access-list 113 permit udp host 192.168.253.51 host 172.16.224.23 eq snmp
access-list 113 permit udp host 192.168.253.51 host 172.16.224.24 eq snmp
access-list 113 deny   ip any any log
```

The following configuration defines inbound access control from the production network. This access allows only encrypted traffic, since that is the only communication allowed into the management module from the production network. The first four lines define access for the encrypted traffic. After decryption, traffic must again pass through the access list in order to be allowed into the management module.

```
access-list 112 permit esp host 172.16.224.23 host 10.1.20.57
access-list 112 permit esp host 172.16.224.24 host 10.1.20.57
access-list 112 permit udp host 172.16.224.24 host 10.1.20.57 eq isakmp
access-list 112 permit udp host 172.16.224.23 host 10.1.20.57 eq isakmp
access-list 112 permit udp host 172.16.224.24 host 192.168.253.56 eq syslog
access-list 112 permit udp host 172.16.224.23 host 192.168.253.56 eq syslog
access-list 112 permit udp host 172.16.224.24 host 192.168.253.51 eq syslog
access-list 112 permit udp host 172.16.224.23 host 192.168.253.51 eq syslog
access-list 112 permit udp host 172.16.224.24 host 192.168.253.53 eq tftp
access-list 112 permit udp host 172.16.224.23 host 192.168.253.53 eq tftp
access-list 112 permit udp host 172.16.224.24 host 192.168.253.57 eq ntp
access-list 112 permit udp host 172.16.224.23 host 192.168.253.57 eq ntp
access-list 112 permit tcp host 172.16.224.24 host 192.168.253.54 eq tacacs
access-list 112 permit tcp host 172.16.224.23 host 192.168.253.54 eq tacacs
access-list 112 permit icmp host 172.16.224.24 192.168.253.0 0.0.0.255 echo-reply
access-list 112 permit icmp host 172.16.224.23 192.168.253.0 0.0.0.255 echo-reply
access-list 112 deny   ip any any log
```

Core Module

Figure 30 Core Module: Detail

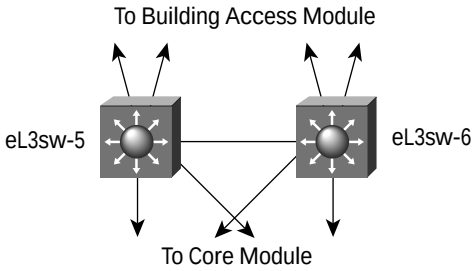


Products Used

Cisco Catalyst 6500 Layer 3 switches

Building Distribution Module

Figure 31 Building Distribution Module: Detail



Products Used

Cisco Catalyst 6500 Layer 3 switches

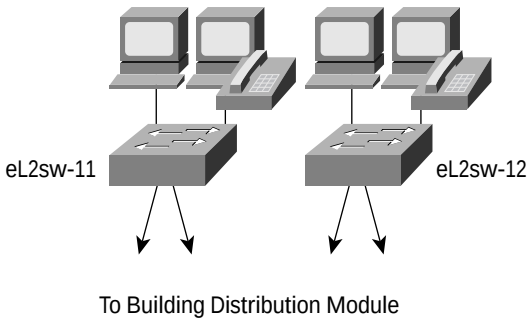
EL3SW-5

The following configuration snapshot defines the Layer 3 access control between subnets in this module. VLAN 5 defines the marketing subnet, VLAN 6 defines the R&D subnet, VLAN 7 defines the marketing IP phones, and VLAN 8 defines the R&D IP phones.

```
interface Vlan5
 ip address 10.1.5.5 255.255.255.0
 ip access-group 105 in
!
interface Vlan6
 ip address 10.1.6.5 255.255.255.0
 ip access-group 106 in
!
interface Vlan7
 ip address 10.1.7.5 255.255.255.0
 ip access-group 107 in
!
interface Vlan8
 ip address 10.1.8.5 255.255.255.0
 ip access-group 108 in
!
access-list 105 deny   ip 10.1.5.0 0.0.0.255 10.1.6.0 0.0.0.255
access-list 105 deny   ip 10.1.5.0 0.0.0.255 10.1.7.0 0.0.0.255
access-list 105 deny   ip 10.1.5.0 0.0.0.255 10.1.8.0 0.0.0.255
access-list 105 deny   ip 10.1.5.0 0.0.0.255 10.1.16.0 0.0.0.255
access-list 105 permit ip 10.1.5.0 0.0.0.255 any
access-list 105 deny   ip any any log
access-list 106 deny   ip 10.1.6.0 0.0.0.255 10.1.5.0 0.0.0.255
access-list 106 deny   ip 10.1.6.0 0.0.0.255 10.1.7.0 0.0.0.255
access-list 106 deny   ip 10.1.6.0 0.0.0.255 10.1.8.0 0.0.0.255
access-list 106 deny   ip 10.1.6.0 0.0.0.255 10.1.15.0 0.0.0.255
access-list 106 deny   ip 10.1.6.0 0.0.0.255 10.1.16.0 0.0.0.255
access-list 106 permit ip 10.1.6.0 0.0.0.255 any
access-list 106 deny   ip any any log
access-list 107 permit ip 10.1.7.0 0.0.0.255 10.1.8.0 0.0.0.255
access-list 107 permit ip 10.1.7.0 0.0.0.255 10.1.16.0 0.0.0.255
access-list 107 permit ip 10.1.7.0 0.0.0.255 host 10.1.11.50
access-list 107 deny   ip any any log
access-list 108 permit ip 10.1.8.0 0.0.0.255 10.1.7.0 0.0.0.255
access-list 108 permit ip 10.1.8.0 0.0.0.255 10.1.16.0 0.0.0.255
access-list 108 permit ip 10.1.8.0 0.0.0.255 host 10.1.11.50
access-list 108 deny   ip any any log
```

Building Access Module

Figure 32 Building Access Module: Detail



Products Used

Cisco Catalyst 4003 Layer 2 switches

Cisco IP Phone

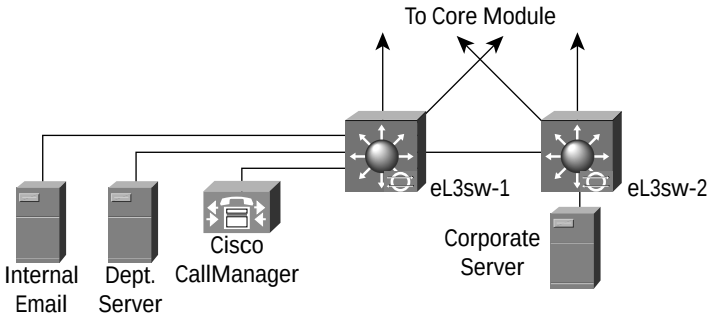
EL2SW-11 and 12

The following configuration snapshot show some of the VLAN settings on the Layer 2 switches in this module. Notice that unneeded ports are disabled and set to a non-routable VLAN. Also, trunking is turned off on all ports except those connecting to IP phones which use trunking for VLAN separation between phone and workstation.

```
set vlan 5    2/5,2/17
set vlan 6    2/6,2/18
set vlan 99   2/34
set vlan 999  2/1-3,2/7-16,2/19-33
set port disable    2/7-33
set trunk 2/1-34 off
set trunk 2/4 on dot1q 1,5-8
```

Server Module

Figure 12: Server Module: Detail



Products Used

Cisco Catalyst 6500 Layer 3 switches

Cisco Catalyst 6500 Intrusion Detection Blade

Cisco Call Manager

Cisco IDS Host Sensor

EL3SW-1 and 2

The following configuration sets the private VLAN mappings for several of the ports within the same VLAN. This config prevents the internal email server from communicating with the corporate server.

```
! CAT OS Config
!
#private vlans
set pvlan 11 437
set pvlan 11 437 3/3-4,3/14
set pvlan mapping 11 437 15/1
!
! MSFC Config
!
interface Vlan11
 ip address 10.1.11.1 255.255.255.0
 ip access-group 111 in
 no ip redirects
```

The following configuration sets the interface filtering on several of the interfaces in this module. This includes RFC 2827 filtering.

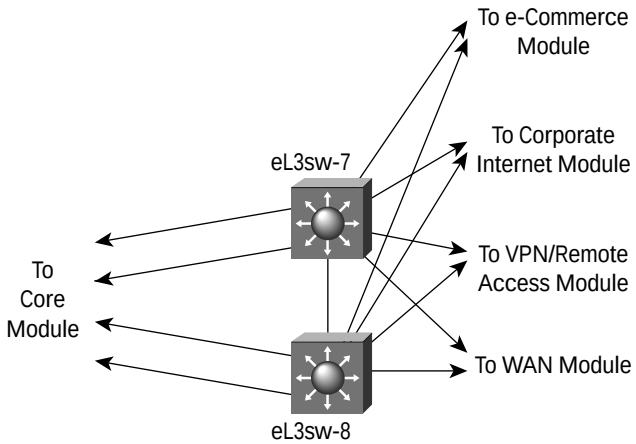
```
interface Vlan11
 ip address 10.1.11.1 255.255.255.0
 ip access-group 111 in
!
interface Vlan15
 ip address 10.1.15.1 255.255.255.0
 ip access-group 115 in
!
interface Vlan16
 ip address 10.1.16.1 255.255.255.0
 ip access-group 116 in
 ip access-group 126 out
!
access-list 111 permit ip 10.1.11.0 0.0.0.255 any
access-list 111 deny   ip any any log
access-list 115 permit ip 10.1.15.0 0.0.0.255 any
access-list 115 deny   ip any any log
access-list 116 permit ip 10.1.16.0 0.0.0.255 10.1.7.0 0.0.0.255
access-list 116 permit ip 10.1.16.0 0.0.0.255 10.1.8.0 0.0.0.255
access-list 116 permit ip 10.1.16.0 0.0.0.255 10.1.11.0 0.0.0.255
access-list 116 deny   ip any any log
access-list 126 permit ip 10.1.7.0 0.0.0.255 10.1.16.0 0.0.0.255
access-list 126 permit ip 10.1.8.0 0.0.0.255 10.1.16.0 0.0.0.255
access-list 126 permit ip 10.1.11.0 0.0.0.255 10.1.16.0 0.0.0.255
```

The following configuration sets up the capture port for the Cat 6000 IDS module:

```
#module 4 : 2-port Intrusion Detection System
set module name    4
set module enable  4
set vlan 1    4/1
set vlan 99   4/2
set port name       4/1  Sniff-4
set port name       4/2  CandC-4
set trunk 4/1  nonegotiate dot1q 1-1005,1025-4094
set security acl capture-ports 4/1
```

Edge Distribution Module

Figure 33 Edge Distribution Module: Detail

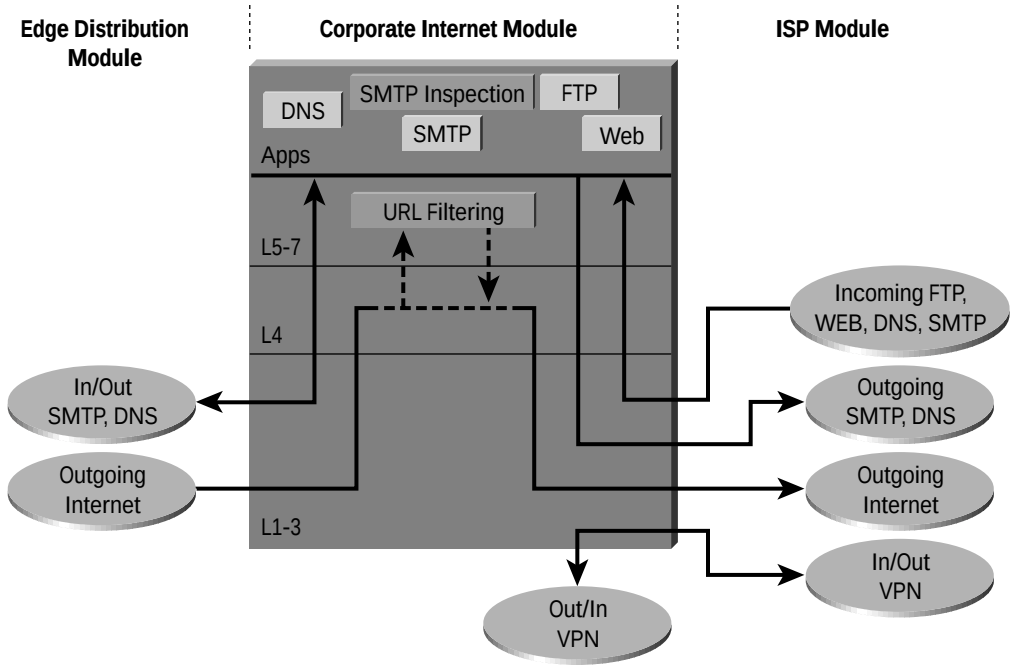


Products Used

Cisco Catalyst 6500 Layer 3 switches

Corporate Internet Module

Figure 34 Corporate Internet Module: Detail



Products Used

Cisco PIX Firewall

CSIDS Sensor

Catalyst 3500 Layer 2 switches

Cisco 7100 IOS Router

Cisco IDS Host Sensor

Websense URL Filtering Server

EPIX-31 and 33

This configuration snapshot details the access control in place on the PIX firewall. The name of the access list denotes the location the inbound ACL is placed. "In" is inbound, "out" is outbound, "pss" is the public services segment (DMZ), "url" is the content filtering segment, and "mgmt" is the OOB interface.

```
access-list out deny ip any 192.168.254.0 255.255.255.0
access-list out deny ip any 192.168.253.0 255.255.255.0
access-list out permit icmp any any echo-reply
access-list out permit tcp any host 172.16.225.52 eq www
access-list out permit tcp any host 172.16.225.52 eq ftp
access-list out permit tcp any host 172.16.225.50 eq smtp
access-list out permit udp any host 172.16.225.51 eq domain
access-list out permit esp host 172.16.224.23 host 172.16.224.57
access-list out permit esp host 172.16.224.24 host 172.16.224.57
access-list out permit udp host 172.16.224.23 host 172.16.224.57 eq isakmp
access-list out permit udp host 172.16.224.24 host 172.16.224.57 eq isakmp
access-list in deny ip any 192.168.254.0 255.255.255.0
access-list in deny ip any 192.168.253.0 255.255.255.0
access-list in permit icmp any any echo
access-list in permit udp host 10.1.11.50 host 172.16.225.51 eq domain
access-list in permit tcp 10.0.0.0 255.0.0.0 host 172.16.225.52 eq www
access-list in permit tcp 10.0.0.0 255.0.0.0 host 10.1.103.50 eq 15871
access-list in permit tcp host 10.1.11.51 host 172.16.225.50 eq smtp
access-list in permit tcp host 10.1.11.51 host 172.16.225.50 eq 20389
access-list in permit tcp 10.0.0.0 255.0.0.0 host 172.16.225.52 eq ftp
access-list in deny ip any 172.16.225.0 255.255.255.0
access-list in permit ip 10.0.0.0 255.0.0.0 any
access-list in permit esp host 10.1.20.57 host 172.16.224.23
access-list in permit esp host 10.1.20.57 host 172.16.224.24
access-list in permit udp host 10.1.20.57 host 172.16.224.23 eq isakmp
access-list in permit udp host 10.1.20.57 host 172.16.224.24 eq isakmp
access-list pss deny ip any 192.168.254.0 255.255.255.0
access-list pss deny ip any 192.168.253.0 255.255.255.0
access-list pss permit tcp host 172.16.225.50 host 10.1.11.51 eq 20025
access-list pss permit tcp host 172.16.225.50 host 10.1.11.51 eq 20389
access-list pss deny ip 172.16.225.0 255.255.255.0 10.0.0.0 255.0.0.0
access-list pss permit tcp host 172.16.225.50 any eq smtp
access-list pss permit udp host 172.16.225.51 any eq domain
access-list url permit udp host 10.1.103.50 host 172.16.225.51 eq domain
access-list url permit ip any any
access-list mgmt permit icmp 192.168.253.0 255.255.255.0 any
```

EIOS-23 and 24

This configuration snapshot details the hot standby router protocol (HSRP) commands on many routers using HSRP for high availability.

```
interface FastEthernet0/0
 ip address 172.16.226.23 255.255.255.0
 standby 2 timers 5 15
 standby 2 priority 110 preempt delay 2
 standby 2 authentication k&>9NG@6
 standby 2 ip 172.16.226.100
 standby 2 track ATM4/0 50
```

The following sets up the encrypted in-band network management link to the management module:

```
crypto isakmp policy 1
 encr 3des
 authentication pre-share
 group 2
crypto isakmp key A%Xr)7,_) address 172.16.224.57
!
crypto ipsec transform-set vpn_module_mgmt esp-3des esp-sha-hmac
!
crypto map mgmt1 100 ipsec-isakmp
 set peer 172.16.224.57
 set transform-set vpn_module_mgmt
 match address 103

access-list 103 permit ip host 172.16.224.23 192.168.253.0 0.0.0.255
access-list 103 permit udp host 172.16.224.23 192.168.254.0 0.0.0.255
```

The following ACL sits inbound from the enterprise network:

```
access-list 112 permit udp host 172.16.224.57 host 172.16.224.23 eq isakmp
access-list 112 permit esp host 172.16.224.57 host 172.16.224.23
access-list 112 permit tcp 192.168.253.0 0.0.0.255 host 172.16.224.23 established
access-list 112 permit udp 192.168.253.0 0.0.0.255 host 172.16.224.23 gt 1023
access-list 112 permit tcp 192.168.253.0 0.0.0.255 host 172.16.224.23 eq telnet
access-list 112 permit udp host 192.168.253.51 host 172.16.224.23 eq snmp
access-list 112 permit udp host 192.168.254.57 host 172.16.224.23 eq ntp
access-list 112 permit icmp any any
access-list 112 deny   ip any host 172.16.224.23 log
access-list 112 deny   ip any host 172.16.226.23 log
access-list 112 deny   ip any host 172.16.145.23 log
access-list 112 permit ip 172.16.224.0 0.0.0.255 any
access-list 112 permit ip 172.16.225.0 0.0.0.255 any
```

The following ACL sits inbound from the ISP. Note RFC 1918 filtering is not complete since these addresses are used as production addresses in the lab. Actual networks should implement full RFC 1918 filtering.

```
access-list 150 deny   ip 10.0.0.0 0.255.255.255 any
access-list 150 deny   ip 192.168.0.0 0.0.255.255 any
access-list 150 deny   ip 172.16.224.0 0.0.7.255 any
access-list 150 permit ip any 172.16.224.0 0.0.7.255
access-list 150 permit ip any 172.16.145.0 0.0.0.255
access-list 150 permit esp any 172.16.226.0 0.0.0.255 fragments
access-list 150 deny   ip any any fragments
access-list 150 deny   ip any any log
```

The following filtering exists outbound to the RA & VPN module. Note only IKE and ESP are permitted:

```
access-list 160 permit esp any host 172.16.226.27
access-list 160 permit esp any host 172.16.226.28
access-list 160 permit esp any host 172.16.226.48
access-list 160 permit udp any host 172.16.226.27 eq isakmp
access-list 160 permit udp any host 172.16.226.28 eq isakmp
access-list 160 permit udp any host 172.16.226.48 eq isakmp
access-list 160 deny   ip any any log
```

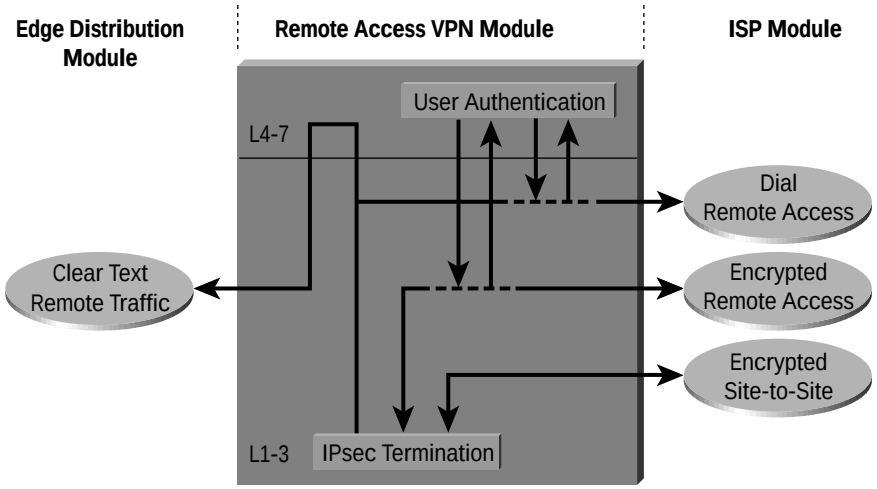
Catalyst 3500XL Private VLANs

This configuration snapshot details the configuration for private VLANs on the public services segment:

```
interface FastEthernet0/1
 port protected
!
interface FastEthernet0/2
 port protected
```

VPN and Remote Access Module

Figure 35 Figure 21: VPN and Remote Access Module: Detail



Products Used

- Cisco PIX Firewall
- CSIDS Sensor
- Catalyst 3500 Layer 2 switches
- Cisco 7100 IOS Router
- Cisco VPN 3060 Concentrator
- Cisco IOS Access Server
- Cisco IDS Host Sensor
- Websense URL Filtering Server

EPIX-32 and 34

This configuration snapshot details the access control in place on the PIX firewall. The name of the access list denotes the location the inbound ACL is placed. “In” is inbound, “out” is the site-to-site VPN, “dun” is the PSTN dial-up, “ra” is the remote access VPN, and “mgmt” is the OOB interface.

```
access-list in deny ip any 192.168.253.0 255.255.255.0
access-list in deny ip any 192.168.254.0 255.255.255.0
access-list in permit icmp any any
access-list in permit tcp 10.0.0.0 255.0.0.0 10.0.0.0 255.0.0.0 eq smtp
access-list in permit tcp 10.0.0.0 255.0.0.0 10.0.0.0 255.0.0.0 eq pop3
access-list in permit tcp 10.0.0.0 255.0.0.0 10.0.0.0 255.0.0.0 eq www
access-list in permit tcp 10.0.0.0 255.0.0.0 10.0.0.0 255.0.0.0 eq ftp
access-list in permit udp 10.0.0.0 255.0.0.0 10.0.0.0 255.0.0.0 eq netbios-ns
access-list in permit udp 10.0.0.0 255.0.0.0 10.0.0.0 255.0.0.0 eq netbios-dgm
access-list in permit udp 10.0.0.0 255.0.0.0 10.0.0.0 255.0.0.0 eq domain
access-list out deny ip any 192.168.253.0 255.255.255.0
access-list out deny ip any 192.168.254.0 255.255.255.0
access-list out permit icmp any any
access-list out permit tcp 10.0.0.0 255.0.0.0 10.0.0.0 255.0.0.0 eq smtp
access-list out permit tcp 10.0.0.0 255.0.0.0 10.0.0.0 255.0.0.0 eq pop3
access-list out permit tcp 10.0.0.0 255.0.0.0 10.0.0.0 255.0.0.0 eq www
access-list out permit tcp 10.0.0.0 255.0.0.0 10.0.0.0 255.0.0.0 eq ftp
access-list out permit udp 10.0.0.0 255.0.0.0 10.0.0.0 255.0.0.0 eq netbios-ns
access-list out permit udp 10.0.0.0 255.0.0.0 10.0.0.0 255.0.0.0 eq netbios-dgm
access-list out permit udp 10.0.0.0 255.0.0.0 10.0.0.0 255.0.0.0 eq domain
access-list out permit tcp 10.0.0.0 255.0.0.0 172.16.255.0 255.255.255.0 eq www
access-list out permit tcp 10.0.0.0 255.0.0.0 172.16.255.0 255.255.255.0 eq ftp
access-list ra deny ip any 192.168.253.0 255.255.255.0
access-list ra deny ip any 192.168.254.0 255.255.255.0
access-list ra permit icmp any any
access-list ra permit tcp 10.1.198.0 255.255.254.0 10.0.0.0 255.0.0.0 eq smtp
access-list ra permit tcp 10.1.198.0 255.255.254.0 10.0.0.0 255.0.0.0 eq pop3
access-list ra permit tcp 10.1.198.0 255.255.254.0 10.0.0.0 255.0.0.0 eq www
access-list ra permit tcp 10.1.198.0 255.255.254.0 10.0.0.0 255.0.0.0 eq ftp
access-list ra permit udp 10.1.198.0 255.255.254.0 10.0.0.0 255.0.0.0 eq netbios-ns
access-list ra permit udp 10.1.198.0 255.255.254.0 10.0.0.0 255.0.0.0 eq netbios-dgm
access-list ra permit udp 10.1.198.0 255.255.254.0 10.0.0.0 255.0.0.0 eq domain
access-list ra deny ip 10.1.198.0 255.255.254.0 10.0.0.0 255.0.0.0
access-list ra permit tcp 10.1.198.0 255.255.254.0 172.16.225.0 255.255.255.0 eq www
access-list ra permit tcp 10.1.198.0 255.255.254.0 172.16.225.0 255.255.255.0 eq ftp
access-list ra deny ip 10.1.198.0 255.255.254.0 172.16.224.0 255.255.248.0
access-list ra permit ip 10.1.198.0 255.255.254.0 any
access-list dun deny ip any 192.168.253.0 255.255.255.0
access-list dun deny ip any 192.168.254.0 255.255.255.0
access-list dun permit icmp any any
access-list dun permit tcp 10.1.196.0 255.255.254.0 10.0.0.0 255.0.0.0 eq smtp
access-list dun permit tcp 10.1.196.0 255.255.254.0 10.0.0.0 255.0.0.0 eq pop3
access-list dun permit tcp 10.1.196.0 255.255.254.0 10.0.0.0 255.0.0.0 eq www
access-list dun permit tcp 10.1.196.0 255.255.254.0 10.0.0.0 255.0.0.0 eq ftp
access-list dun permit udp 10.1.196.0 255.255.254.0 10.0.0.0 255.0.0.0 eq netbios-ns
access-list dun permit udp 10.1.196.0 255.255.254.0 10.0.0.0 255.0.0.0 eq netbios-dgm
access-list dun permit udp 10.1.196.0 255.255.254.0 10.0.0.0 255.0.0.0 eq domain
access-list dun deny ip 10.1.196.0 255.255.254.0 10.0.0.0 255.0.0.0
access-list dun permit tcp 10.1.196.0 255.255.255.0 172.16.225.0 255.255.255.0 eq www
access-list dun permit tcp 10.1.196.0 255.255.255.0 172.16.225.0 255.255.255.0 eq ftp
access-list dun deny ip 10.1.196.0 255.255.254.0 172.16.224.0 255.255.248.0
access-list dun permit ip 10.1.196.0 255.255.254.0 any
access-list mgmt permit icmp 192.168.253.0 255.255.255.0 any
```

This configuration snapshot details the static NAT translations required to allow VPN traffic to pass back out the corporate internet module to the internet in the clear:

```
static (inside,ravpn) 128.0.0.0 128.0.0.0 netmask 128.0.0.0 0 0
static (inside,ravpn) 64.0.0.0 64.0.0.0 netmask 192.0.0.0 0 0
static (inside,ravpn) 32.0.0.0 32.0.0.0 netmask 224.0.0.0 0 0
static (inside,ravpn) 16.0.0.0 16.0.0.0 netmask 240.0.0.0 0 0
static (inside,ravpn) 8.0.0.0 8.0.0.0 netmask 248.0.0.0 0 0
static (inside,ravpn) 4.0.0.0 4.0.0.0 netmask 252.0.0.0 0 0
static (inside,ravpn) 2.0.0.0 2.0.0.0 netmask 254.0.0.0 0 0
static (inside,ravpn) 1.0.0.0 1.0.0.0 netmask 255.0.0.0 0 0
```

EIOS-27 and 28

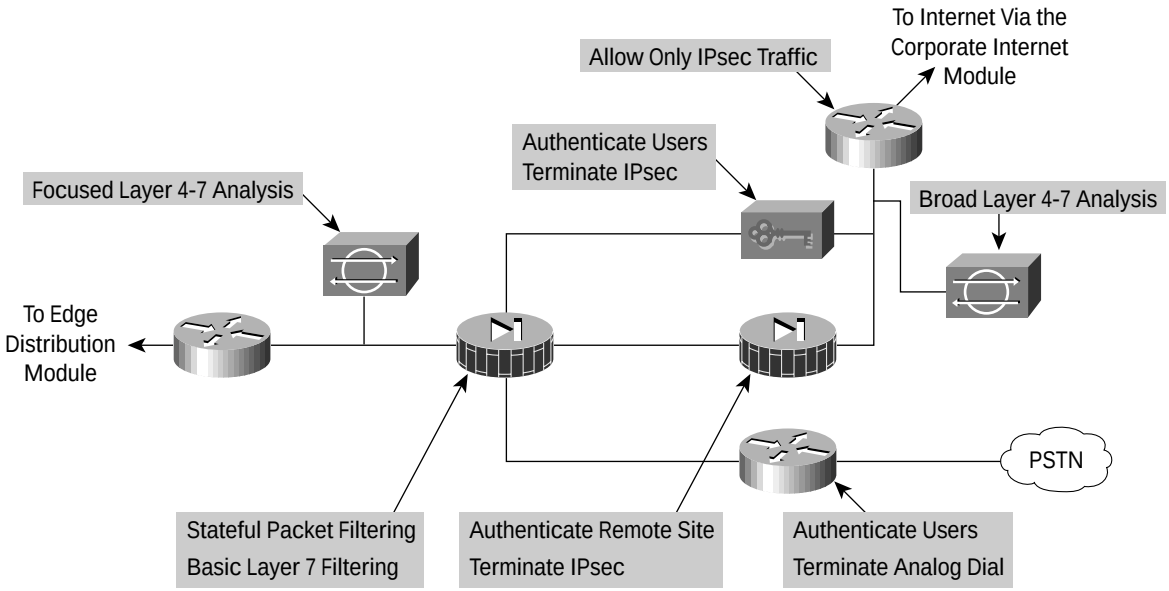
This configuration snapshot details the crypto configuration for the site-to-site VPN:

```
!
! Basic Crypto Information
!
crypto isakmp policy 1
 encr 3des
 authentication pre-share
 group 2
crypto isakmp key 7Q!r$y$+xE address 172.16.132.2
crypto isakmp key 52TH^m&^qu address 172.16.131.2
!
!
crypto ipsec transform-set smbranch esp-3des esp-sha-hmac
 mode transport
!
crypto map secure1 100 ipsec-isakmp
 set peer 172.16.132.2
 set transform-set smbranch
 match address 105
crypto map secure1 300 ipsec-isakmp
 set peer 172.16.131.2
 set transform-set smbranch
 match address 107
!
!
! GRE Tunnel Information
!
interface Tunnel0
 ip address 10.1.249.27 255.255.255.0
 tunnel source 172.16.226.27
 tunnel destination 172.16.132.2
 crypto map secure1
!
interface Tunnel1
 ip address 10.1.247.27 255.255.255.0
 tunnel source 172.16.226.27
 tunnel destination 172.16.131.2
 crypto map secure1
!
!
! EIGRP Routing to keep links up
!
router eigrp 1
 redistribute static
 passive-interface FastEthernet0/1
 passive-interface FastEthernet4/0
 network 10.0.0.0
 distribute-list 2 out
```

```
 distribute-list 2 in
!
! Crypto ACLs
!
access-list 105 permit gre host 172.16.226.27 host 172.16.132.2
access-list 107 permit gre host 172.16.226.27 host 172.16.131.2
!
! Inbound ACLs from Internet
!
access-list 110 permit udp 172.16.0.0 0.0.255.255 host 172.16.226.27 eq isakmp
access-list 110 permit esp 172.16.0.0 0.0.255.255 host 172.16.226.27
access-list 110 permit gre 172.16.0.0 0.0.255.255 host 172.16.226.27
access-list 110 deny   ip any any log
```

WAN Module

Figure 36 WAN Module: Detail



Products Used

Cisco 3640 IOS Router

EIOS-61

The following configuration details the access control on the routers in the WAN module:

```
!
! Inbound from the WAN
!
access-list 110 deny   ip any 192.168.253.0 0.0.0.255 log
access-list 110 deny   ip any 192.168.254.0 0.0.0.255 log
access-list 110 permit ospf any any
access-list 110 permit ip 10.2.0.0 0.0.255.255 10.1.0.0 0.0.255.255
access-list 110 permit ip 10.2.0.0 0.0.255.255 10.3.0.0 0.0.255.255
access-list 110 permit ip 10.2.0.0 0.0.255.255 10.4.0.0 0.0.255.255
access-list 110 permit ip 10.2.0.0 0.0.255.255 172.16.224.0 0.0.7.255
access-list 110 deny   ip any any log
!
! Inbound from the Campus
!
access-list 111 deny   ip any 192.168.253.0 0.0.0.255 log
access-list 111 deny   ip any 192.168.254.0 0.0.0.255 log
access-list 111 permit ospf any any
access-list 111 permit ip 10.1.0.0 0.0.255.255 10.2.0.0 0.0.255.255
access-list 111 permit ip 10.3.0.0 0.0.255.255 10.2.0.0 0.0.255.255
access-list 111 permit ip 10.4.0.0 0.0.255.255 10.2.0.0 0.0.255.255
access-list 111 permit ip 172.16.224.0 0.0.7.255 10.2.0.0 0.0.255.255
access-list 111 deny   ip any any log
```

Appendix B: Network Security Primer

The Need for Network Security

The Internet is changing the way we work, live, play, and learn. These changes are occurring both in the ways that we currently experience (e-commerce, real-time information access, e-learning, expanded communication options, and so forth), and in ways we have yet to experience. Imagine a day when your enterprise can make all its telephone calls over the Internet for free. Or perhaps on a more personal note, consider logging on to a daycare provider's Web site to check how your child is doing throughout the day. As a society, we are just beginning to unlock the potential of the Internet. But with the Internet's unparalleled growth comes unprecedented exposure of personal data, critical enterprise resources, government secrets, and so forth. Every day hackers pose an increasing threat to these entities with several different types of attacks. These attacks, outlined in the next section, have become both more prolific and easier to implement. There are two primary reasons for this problem.

First is the ubiquity of the Internet. With millions of devices currently connected to the Internet, and millions more on the way, a hacker's access to vulnerable devices will continue to increase. The ubiquity of the Internet has also allowed hackers to share knowledge on a global scale. A simple Internet search on the words "hack," "crack," or "phreak" yields thousands of sites, many of which contain malicious code, or the means with which to use that code.

Second is the pervasiveness of easy-to-use operating systems and development environments. This factor has reduced the overall ingenuity and knowledge required by hackers. A truly remarkable hacker can develop easy-to-use applications that can be distributed to the masses. Several hacker tools that are available in the public domain merely require an IP address or host name and a click of a mouse button to execute an attack.

Network Attack Taxonomy

Network attacks can be as varied as the systems that they attempt to penetrate. Some attacks are elaborately complex, while others are performed unknowingly by a well-intentioned device operator. It is important to understand some of the inherent limitations of the TCP/IP protocol when evaluating the types of attacks. When the Internet was formed, it linked various government entities and universities to one another with the express purpose of facilitating learning and research. The

original architects of the Internet never anticipated the kind of widespread adoption the Internet has achieved today. As a result, in the early days of the Internet Protocol (IP), security was not designed into the specification. For this reason, most IP implementations are inherently insecure. Only after many years and thousands of Requests for Comments (RFCs), do we have the tools to begin to deploy IP securely. Because specific provisions for IP security were not designed from the onset, it is important to augment IP implementations with network security practices, services, and products to mitigate the inherent risks of the Internet Protocol. The following is a brief discussion of the types of attacks commonly seen on IP networks and how these attacks can be mitigated.

Packet Sniffers

A packet sniffer is a software application that uses a network adapter card in promiscuous mode (a mode in which the network adapter card sends all packets received on the physical network wire to an application for processing) to capture all network packets that are sent across a particular collision domain. Sniffers are used legitimately in networks today to aid in troubleshooting and traffic analysis. However, because several network applications send data in clear text (telnet, FTP, SMTP, POP3, and so forth), a packet sniffer can provide meaningful and often sensitive information, such as usernames and passwords.

One serious problem with acquiring usernames and passwords is that users often reuse their login names and passwords across multiple applications and systems. In fact, many users employ a single password for access to all accounts and applications. If an application is run in client-server mode and authentication information is sent across the network in clear text, then it is likely that this same authentication information can be used to gain access to other corporate or external resources. Because hackers know and use human characteristics (attack methods known collectively as social engineering attacks), such as using a single password for multiple accounts, they are often successful in gaining access to sensitive information. In a worst-case scenario, a hacker gains access to a system-level user account, which the hacker uses to create a new account that can be used at any time as a back door to break into a network and its resources.

You can mitigate the threat of packet sniffers in several ways:

- *Authentication* – Using strong authentication is a first option for defense against packet sniffers. Strong authentication can be broadly defined as a method of authenticating users that cannot easily be circumvented. A common example of strong authentication is one-time-passwords (OTPs). An OTP is a type of two-factor authentication. Two-factor authentication involves using something you have combined with something you know. Automated teller machines (ATMs) use two-factor authentication. A customer needs both an ATM card and a personal identification number (PIN) to make transactions. With OTP you need a PIN and your token card to authenticate to a device or software application. A token card is a hardware or software device that generates new, seemingly random, passwords at specified intervals (usually 60 seconds). A user combines that random password with a PIN to create a unique password that only works for one instance of authentication. If a hacker learns that password by using a packet sniffer, the information is useless because the password has already expired. Note that this mitigation technique is effective only against a sniffer implementation that is designed to grab passwords. Sniffers deployed to learn sensitive information (such as mail messages) will still be effective.
- *Switched infrastructure* – Another method to counter the use of packet sniffers in your environment is to deploy a switched infrastructure. For example if an entire organization deploys switched Ethernet, hackers usually can only gain access to the traffic that flows on the specific port to which they connect. Due to layer 2 issues such as MAC flooding and ARP spoofing, a switched infrastructure does not eliminate the threat of packet sniffers, but it can reduce their effectiveness.
- *Anti-sniffer tools* – A third method used against sniffers is to employ software and hardware designed to detect the use of sniffers on a network. Such software and hardware does not completely eliminate the threat, but like many network security tools, they are part of the overall system. These so-called “anti-sniffers” detect changes in the response time of hosts to determine if the hosts are processing more traffic than their own. One such network security software tool, which is available from Security Software Technologies, is called AntiSniff. For more information, refer to the URL http://www.securitysoftwaretech.com/antisniff/

- *Cryptography* – The most effective method for countering packet sniffers does not prevent or detect packet sniffers, but rather renders them irrelevant. If a communication channel is cryptographically secure, the only data a packet sniffer will detect is cipher text (a seemingly random string of bits) and not the original message. Cisco's deployment of network-level cryptography is based on IP Security (IPSec). IPSec is a standard method for networking devices to communicate privately using IP. Other cryptographic protocols for network management include Secure Shell (SSH) and Secure Sockets Layer (SSL).

IP Spoofing

An IP spoofing attack occurs when a hacker inside or outside a network pretends to be a trusted computer. A hacker can do this in one of two ways. The hacker either uses an IP address that is within the range of trusted IP addresses for a network or an authorized external IP address that is trusted and to which access is provided to specified resources on a network. IP spoofing attacks are often a launch point for other attacks. The classic example is to launch a DoS attack using spoofed source addresses to hide the hacker's identity.

Normally, an IP spoofing attack is limited to the injection of malicious data or commands into an existing stream of data that is passed between a client and server application or a peer-to-peer network connection. To enable bidirectional communication, the hacker must change all routing tables to point to the spoofed IP address. Another approach hackers sometimes take is to simply not worry about receiving any response from the applications. If a hacker tries to obtain a sensitive file from a system, application responses are unimportant.

However, if a hacker manages to change the routing tables to point to the spoofed IP address, the hacker can receive all the network packets that are addressed to the spoofed address and reply just as any trusted user can.

The threat of IP spoofing can be reduced, but not eliminated, through the following measures.

Access control – The most common method for preventing IP spoofing is to properly configure access control. To reduce the effectiveness of IP spoofing, configure access control to deny any traffic from the external network that has a source address that should reside on the internal network. Note that this only helps prevent spoofing attacks if the internal addresses are the only trusted addresses. If some external addresses are trusted, this method is not effective.

RFC 2827 filtering – You can also prevent a network's users from spoofing other networks (and be a good 'Net citizen at the same time) by preventing any outbound traffic on your network that does not have a source address in your organization's own IP range. Your ISP can also implement this type of filtering, which is collectively referred to as RFC 2827 filtering. This filtering denies any traffic that does not have the source address that was expected on a particular interface. For example, if an ISP is providing a connection to the IP address 15.1.1.0/24, the ISP could filter traffic so that only traffic sourced from address 15.1.1.0/24 can enter the ISP router from that interface. Note that unless all ISPs implement this type of filtering, its effectiveness is significantly reduced. Also, the further you get from the devices you want to filter, the more difficult it becomes to do that filtering at a granular level. For example, performing RFC 2827 filtering at the access router to the Internet requires that you allow your entire major network number (that is, 10.0.0.0/8) to traverse the access router. If you perform filtering at the distribution layer, as in this architecture, you can achieve more specific filtering (that is, 10.1.5.0/24).

The most effective method for mitigating the threat of IP spoofing is the same as the most effective method for mitigating the threat of packet sniffers: namely eliminating its effectiveness. IP spoofing can function correctly only when devices use IP address-based authentication. Therefore, if you use additional authentication methods, IP spoofing attacks are irrelevant. Cryptographic authentication is the best form of additional authentication, but when that is not possible, strong two-factor authentication using OTP can also be effective.

Denial of Service

Certainly the most publicized form of attack, denial of service (DoS) attacks are also among the most difficult to completely eliminate. Even among the hacker community, DoS attacks are regarded as trivial and considered bad form because they require so little effort to execute. Still, because of their ease of implementation and potentially significant damage, DoS attacks deserve special attention from security administrators. If you are interested in learning more about DoS attacks, researching the methods employed by some of the better known attacks can be useful. These attacks include the following:

- TCP SYN Flood
- Ping of Death
- Tribe Flood Network (TFN) and Tribe Flood Network 2000 (TFN2K)
- Trinoo
- Stacheldraht
- Trinity
- Shaft

Another excellent source on the topic of security is the Computer Emergency Response Team (CERT). They have published an excellent paper on dealing with DoS attacks which you can find at the following URL: http://www.cert.org/tech_tips/denial_of_service.html

DoS attacks are different from most other attacks because they are generally not targeted at gaining access to your network or the information on your network. These attacks focus on making a service unavailable for normal use, which is typically accomplished by exhausting some resource limitation on the network or within an operating system or application.

When involving specific network server applications, such as a Web server or an FTP server, these attacks can focus on acquiring and keeping open all the available connections supported by that server, effectively locking out valid users of the server or service. DoS attacks can also be implemented using common Internet protocols, such as TCP and Internet Control Message Protocol (ICMP). Most DoS attacks exploit a weakness in the overall architecture of the system being attacked rather than a software bug or security hole. However, some attacks compromise the performance of your network by flooding the network with undesired, and often useless, network packets and by providing false information about the status of network resources. This type of attack is often the most difficult to prevent as it requires coordination with your upstream network provider. If traffic meant to consume your available bandwidth is not stopped there, denying it at the point of entry into your network will do little good because your available bandwidth has already been consumed. When this type of attack is launched from many different systems at the same time it is often referred to as a distributed denial of service attack (DDoS).

The threat of Denial of Service attacks can be reduced through the following three methods:

- *Anti-spoof features* – Proper configuration of anti-spoof features on your routers and firewalls can reduce your risk. This includes RFC 2827 filtering at a minimum. If hackers can't mask their identities, they might not attack.
- *Anti-DoS features* – Proper configuration of anti-DoS features on routers and firewalls can help limit the effectiveness of an attack. These features often involve limits on the amount of half-open connections that a system allows open at any given time.
- *Traffic rate limiting* – An organization can implement traffic rate limiting with your ISP. This type of filtering limits the amount of nonessential traffic that crosses network segments to a certain rate. A common example is to limit the amount of ICMP traffic allowed into a network because it is used only for diagnostic purposes. ICMP-based (D)DoS attacks are common.

Password Attacks

Hackers can implement password attacks using several different methods, including brute-force attacks, Trojan horse programs, IP spoofing, and packet sniffers. Although packet sniffers and IP spoofing can yield user accounts and passwords, password attacks usually refer to repeated attempts to identify a user account and/or password. These repeated attempts are called brute-force attacks.

Often, a brute-force attack is performed using a program that runs across the network and attempts to log in to a shared resource, such as a server. When hackers successfully gain access to resources, they have the same rights as the users whose accounts have been compromised to gain access to those resources. If the compromised accounts have sufficient privileges, the hackers can create back doors for future access without concern for any status and password changes to the compromised user accounts.

Another problem exists whereby users have the same (possibly strong) password on every system they connect to. Often, this includes personal systems, corporate systems, and systems on the Internet. Because that password is only as secure as the most weakly administered host that contains it, if that host is compromised hackers have a whole range of hosts on which they can try the same password.

You can most easily eliminate password attacks by not relying on plain-text passwords in the first place. Using OTP and/or cryptographic authentication can virtually eliminate the threat of password attacks. Unfortunately, not all applications, hosts, and devices support these authentication methods. When standard passwords are used, it is important to choose a password that is difficult to guess. Passwords should be at least eight characters long and contain uppercase letters, lower case letters, numbers, and special characters (#%$ and so forth). The best passwords are randomly generated but are very difficult to remember, often leading users to writing write their passwords down.

Several advances have been made relative to password maintenance—both for the user and the administrator. Software applications are now available that encrypt a list of passwords to be stored on a handheld computer. This allows the user to remember only one complex password and have the remaining passwords stored securely within the application. From the standpoint of the administrator, several methods exist to brute-force attack your own users' passwords. One such method involves a tool used by the hacker community called LC3 (formerly L0phtCrack). LC3 brute-force attacks Windows NT passwords and can point out when a user has chosen a password that is very easy to guess. For more information, refer to the following URL: http://www.atstake.com/research/lc3/index.html.

Man-in-the-Middle Attacks

A man-in-the-middle attack requires that the hacker have access to network packets that come across a network. An example of such a configuration could be someone who is working for an ISP, who has access to all network packets transferred between his employer's network and any other network. Such attacks are often implemented using network packet sniffers and routing and transport protocols. The possible uses of such attacks are theft of information, hijacking of an ongoing session to gain access to private network resources, traffic analysis to derive information about a network and its users, denial of service, corruption of transmitted data, and introduction of new information into network sessions.

Man-in-the-middle attacks can be effectively mitigated only through the use of cryptography. If someone hijacks data in the middle of a cryptographically private session, all the hacker will see is cipher text and not the original message. Note that if a hacker can learn information about the cryptographic session (such as the session key) man-in-the-middle attacks are still possible.

Application Layer Attacks

Application layer attacks can be implemented using several different methods. One of the most common methods is exploiting well-known weaknesses in software that are commonly found on servers, such as sendmail, HTTP, and FTP. By exploiting these weaknesses, hackers can gain access to a computer with the permissions of the account running the application, which is usually a privileged system-level account. These application layer attacks are often widely publicized in an effort to allow administrators to rectify the problem with a patch. Unfortunately, many hackers also subscribe to these same mailing lists, which results in their learning about the attack at the same time (if they haven't discovered it already).

The primary problem with application-layer attacks is that they often use ports that are allowed through a firewall. For example, a hacker executing a known vulnerability against a Web server often uses TCP port 80 in the attack. Because the Web server serves pages to users, a firewall needs to allow access on that port. From a firewall's perspective, it is merely standard port 80 traffic.

Application layer attacks can never be completely eliminated. New vulnerabilities are always being discovered and publicized to the Internet community. The best way to reduce your risk is by practicing good system administration. The following are a few measures you can take to reduce your risks:

- Read OS and network log files and/or have them analyzed by log analysis applications
- Subscribe to mailing lists that publicize vulnerabilities such as Bugtraq (http://www.securityfocus.com) and the CERT (http://www.cert.org)
- Keep your OS and applications current with the latest patches
- In addition to proper system administration, using Intrusion Detection Systems (IDSs) can aid in this effort. There are two complementary IDS technologies:
- Network-based IDS (NIDS) operates by watching all packets traversing a particular collision domain. When NIDS sees a packet or series of packets that match a known or suspect attack, it can flag an alarm and/or terminate the session.
- Host-based IDS (HIDS) operates by inserting agents into the host to be protected. It is then concerned only with attacks generated against that one host.
- IDS systems operate by using attack signatures. Attack signatures are the profile for a particular attack or kind of attack. They specify certain conditions that must be met before traffic is deemed to be an attack. In the physical world, IDS can be most closely compared to an alarm system or security camera. IDS system's greatest limitation is the amount of false-positive alarms a particular system generates. Tuning IDS to prevent such false alarms is critical to the proper operation of IDS in a network.

Network Reconnaissance

Network Reconnaissance refers to the overall act of learning information about a target network by using publicly available information and applications. When hackers attempt to penetrate a particular network, they often need to learn as much information as possible about the network before launching attacks. This can take the form of DNS queries, ping sweeps, and port scans. DNS queries can reveal such information as who owns a particular domain and what addresses have been assigned to that domain. Ping sweeps of the addresses revealed by the DNS queries can present a picture of the live hosts in a particular environment. After such a list is generated, port scanning tools can cycle through all well-known ports to provide a complete list of all services running on the hosts discovered by the ping sweep. Finally, the hackers can examine the characteristics of the applications are running on the hosts. This can lead to specific information that is useful when the hacker attempts to compromise that service.

Network recon cannot be prevented entirely. If ICMP echo and echo-reply is turned off on edge routers, for example, ping sweeps can be stopped, but at the expense of network diagnostic data. However, port scans can easily be run without full ping sweeps; they simply take longer because they need to scan IP addresses that might not be live. IDS at the network and

host levels can usually notify an administrator when a reconnaissance gathering attack is underway. This allows the administrator to better prepare for the coming attack or to notify the ISP who is hosting the system that is launching the reconnaissance probe.

Trust Exploitation

While not an attack in and of itself, trust exploitation refers to an attack where an individual takes advantage of a trust relationship within a network. The classic example is a perimeter network connection from a corporation. These network segments often house DNS, SMTP, and HTTP servers. Because they all reside on the same segment, a compromise of one system can lead to the compromise of other systems because they might trust other systems attached to their same network. Another example is a system on the outside of a firewall that has a trust relationship with a system on the inside of a firewall. When the outside system is compromised, it can leverage that trust relationship to attack the inside network.

You can mitigate trust exploitation-based attacks through tight constraints on trust levels within a network. Systems on the outside of a firewall should never be absolutely trusted by systems on the inside of a firewall. Such trust should be limited to specific protocols and should be authenticated by something other than an IP address where possible.

Port Redirection

Port Redirection attacks are a type of trust exploitation attack that uses a compromised host to pass traffic through a firewall that would other wise be dropped. Consider a firewall with three interfaces and a host on each interface. The host on the outside can reach the host on the public services segment (commonly referred to as a DMZ), but not the host on the inside. The host on the public services segment can reach the host on both the outside and the inside. If hackers were able to compromise the public services segment host, they could install software to redirect traffic from the outside host directly to the inside host. Though neither communication violates the rules implemented in the firewall, the outside host has now achieved connectivity to the inside host through the port redirection process on the public services host. An example of an application that can provide this type of access is netcat. For more information, refer to the following URL: http://insecure.org/tools.html

Port redirection can primarily be mitigated through the use of proper trust models (as mentioned earlier). Assuming a system under attack, host-based IDS can help detect and prevent a hacker installing such utilities on a host.

Unauthorized Access

While not a specific type of attack, unauthorized access attacks refer to the majority of attacks executed in networks today. In order for someone to brute-force a telnet login, they must first get the telnet prompt on a system Upon connection to the telnet port, a message might indicate: “authorization required to use this resource.” If the hacker continues to attempt access, his actions become “unauthorized”. These kinds of attacks can be initiated both on the outside and inside of a network.

Mitigation techniques for unauthorized access attacks are very simple. They involve reducing or eliminating the ability of a hacker to gain access to a system using an unauthorized protocol. An example would be preventing hackers from having access to the telnet port on a server that needs to provide Web services to the outside. If a hacker cannot reach that port, it is very difficult to attack it. The primary function of a firewall in a network is to prevent simple unauthorized access attacks.

Virus and Trojan Horse Applications

The primary vulnerabilities for end-user workstations are viruses and Trojan horse attacks. Viruses refer to malicious software that is attached to another program to execute a particular unwanted function on a user’s workstation. An example of a virus is a program that is attached to command.com (the primary interpreter for windows systems) which deletes certain files and infects any other versions of command.com that it can find. A Trojan horse is different only in that the entire application was written to look like something else, when in fact it is an attack tool. An example of a Trojan horse is a software application that runs a simple game on the user’s workstation. While the user is occupied with the game, the Trojan horse mails a copy of itself to every user in the user’s address book. Then other users get the game and play it, thus spreading the Trojan horse.

These kinds of applications can be contained through the effective use of anti-virus software at the user level and potentially at the network level. Anti-virus software can detect most viruses and many Trojan horse applications and prevent them from spreading in the network. Keeping up-to-date with the latest developments in these sorts of attacks can also lead to a more effective posture against these attacks. As new virus or Trojan applications are released, enterprises need to keep up-to-date with the latest anti-virus software, and application versions.

What Is a "Security Policy"?

A security policy can be as simple as an acceptable use policy for network resources or can be several hundred pages in length and detail every element of connectivity and associated policies. Although somewhat narrow in scope, RFC 2196 suitably defines a security policy as follows:

"A security policy is a formal statement of the rules by which people who are given access to an organization's technology and information assets must abide."

This document does not attempt to go into detail on the development of a security policy. RFC 2196 has some good information available on the subject, and numerous locations on the Web have example policies and guidelines. The following Web pages may assist the interested reader:

- RFC 2196 "Site Security Handbook" http://www.ietf.org/rfc/rfc2196.txt
- A sample security policy for the University of Illinois http://www.aits.uillinois.edu/security/securestandards.html
- Design and Implementation of the Corporate Security Policy http://www.sans.org/resources/policies/

The Need for a Security Policy

It is important to understand that network security is an evolutionary process. No one product can make an organization "secure". True network security comes from a combination of products and services, combined with a comprehensive security policy and a commitment to adhere to that policy from the top of the organization down. In fact, a properly implemented security policy without dedicated security hardware can be more effective at mitigating the threat to enterprise resources than a comprehensive security product implementation without an associated policy.

Appendix C: Architecture Taxonomy

Application Server – Provides application services directly or indirectly for enterprise end-users. Services can include: work-flow, general office, and security applications.

Firewall (Stateful) – Stateful packet filtering device which maintain state tables for IP-based protocols. Traffic is only allowed to cross the firewall if it conforms to the access-control filters defined, or if it is part of an already established session in the state table.

Host IDS – Host Intrusion Detection System is a software application that monitors activity on an individual host. Monitoring techniques can include validating operating system and application calls, checking log files, file system information and network connections.

Network IDS – Network Intrusion Detection System. Typically used in a non-disruptive manner, this device captures traffic on a LAN segment and tries to match the real-time traffic against known attack signatures. Signatures range from atomic (single packet and direction) signatures to composite (multipacket) signatures requiring state tables and Layer 7 application tracking.

IOS Firewall – A stateful packet filtering firewall running natively on Cisco IOS (Internetwork Operating System).

IOS Router – A wide spectrum of flexible network devices, which provide many routing and security services for all performance requirements. Most devices are modular and have a range of LAN and WAN physical interfaces.

Layer 2 Switch – Provides bandwidth and VLAN services to network segments at the Ethernet level. Typically these devices offer 10/100 individual switched ports, Gigabit Ethernet uplinks, VLAN trunking, and L2 filtering features.

Layer 3 Switch – Provides similar high throughput functions of a Layer 2 switch with added routing, QoS, and security features. These switches often has the capability of special function processors.

Management Server – Provides network management services for the operators of enterprise networks. Services can include: general configuration management, monitoring of network security devices, and operation of the security functions.

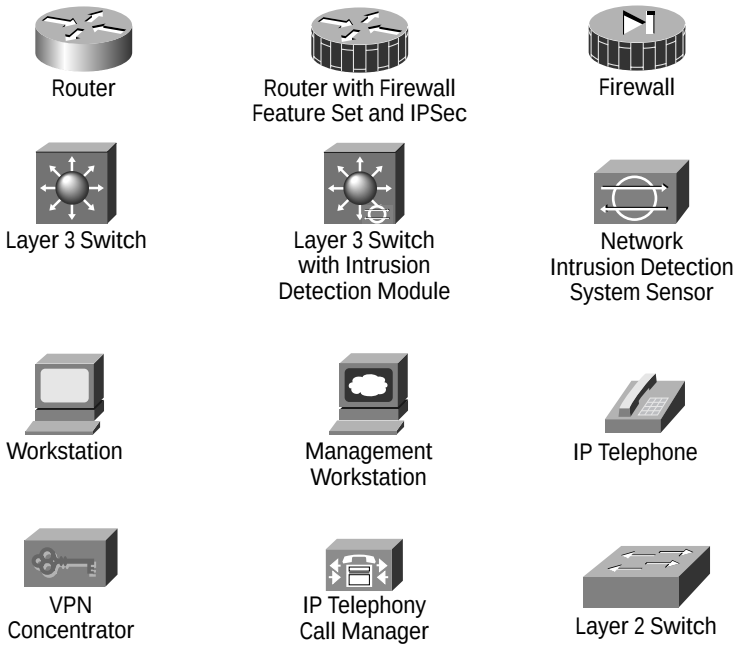
SMTP Content Filtering Server – An application typically running on an external SMTP server which monitors the content (including attachments) of incoming and outgoing mail in order to decide whether that mail is authorized to be forwarded as is, altered and forwarded, or dropped.

URL Filtering Server – An application typically running on a standalone server which monitors URL requests forwarded to it by a network device and informs the network device whether the request should be forwarded on to the Internet. This allows an enterprise to implement a security policy dictating what categories of Internet sites are unauthorized.

VPN Termination device – Terminates IPSec tunnels for either site-to-site or remote-access VPN connections. The device should provide additional services in order to offer the same network functionality as a classic WAN or dial-in connection.

Workstation or User Terminal – Any device on the network which is used directly by the end-user. This includes PCs, IP phones, wireless devices, and so forth.

Diagram Legend



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- RFC 1918 “Address Allocation for Private Internets” – http://www.ietf.org/rfc/rfc1918.txt
- RFC 2827 “Network Ingress Filtering: Defeating Denial of Service Attacks which employ IP Source Address Spoofing” – http://www.ietf.org/rfc/rfc2827.txt

SAFE White Papers

- SAFE: A Security Blueprint for Enterprise Networks: http://www.cisco.com/warp/public/cc/so/cuso/epso/sqfr/safe_wp.htm
- SAFE: Extending the Security Blueprint to Small, Midsize, and Remote-User Networks: http://www.cisco.com/warp/public/cc/so/cuso/epso/sqfr/safes_wp.htm
- SAFE VPN: IPSec Virtual Private Networks in Depth: http://www.cisco.com/warp/public/cc/so/cuso/epso/sqfr/safev_wp.htm
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- SAFE: Code-Red Attack Mitigation: http://www.cisco.com/warp/public/cc/so/cuso/epso/sqfr/scdam_wp.htm

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"Computer Emergency Response Team" – http://www.cert.org

"Security Focus (Bugtraq)" – http://www.securityfocus.com

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Baltimore Technologies MIMESweeper Email Filtering System – http://www.mimesweeper.com

Websense URL Filtering – http://www.websense.com/products/integrations/ciscopix.cfm

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