An Architectural View of LAN Security: In-Band versus Out-of-Band Solutions

Which Approach Offers the Best Performance, Security and Manageability?

By Nevis Networks

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Executive Summary

Network Access Control (NAC) and integrated LAN Security solutions generally fall into one of two categories, depending on how and where they are deployed in the network. The product can be said to be either an “in-band” (a.k.a. in-line) or “out-of-band” solution, and the categories are generally mutually exclusive (although there is potential for in-band appliances to optionally be deployed out-of-band, the converse is not possible). The fundamental differences between the two approaches will have a major impact on the performance, security functionality and manageability of the deployment and should be a prime consideration for enterprises as they consider layering this type of security into their network.

The terms in-band and out-of-band generally refer to whether the solution sits in the flow of all network traffic, or out of the flow, analyzing instead only some of the live data streams. It has always been accepted that being in-band can offer better security and greater functionality than an out-of-band approach, but could represent a performance bottleneck or a potential point-of-failure in a mission critical network. With the maturity of the Nevis solution, its high-availability and failover features, and its primary design objective for matching and handling peak network performance, the merits of an in-band solution now greatly outweigh the perceived disadvantages.

This paper provides an in-depth comparison of leading edge in-band and out-of-band approaches, along with the features that customers should ask their potential solution providers for before making their decision. The paper also debunks five common myths often put forth by out-of-band vendors as arguments against in-band solutions. It starts by describing the two solutions in order to gain a common understanding of what each actually provides. It then goes into the myths, closing with a summary comparison of the two approaches in terms of six common evaluation metrics.

1 What Do We Mean By In-Band and Out-Of-Band?

LAN security is all about reducing the risks posed by endpoint clients (PCs, laptops, remote systems, and mobile devices) connecting to the internal enterprise network. Risk management and policy enforcement are becoming critical business initiatives as the network perimeter dissolves and as organizations open up their internal LANs to guests, contractors and business partners. Further complicating matters are the emerging need to apply security policies to mobile and remote employees, deal with employee-owned endpoints such as iPhones, and meet compliance requirements for access controls and auditing. "**LAN security**" is designed to address these challenges by implementing a broad layer of network security services that protect the network and sensitive resources from "untrusted" users and systems connecting to the internal enterprise network.

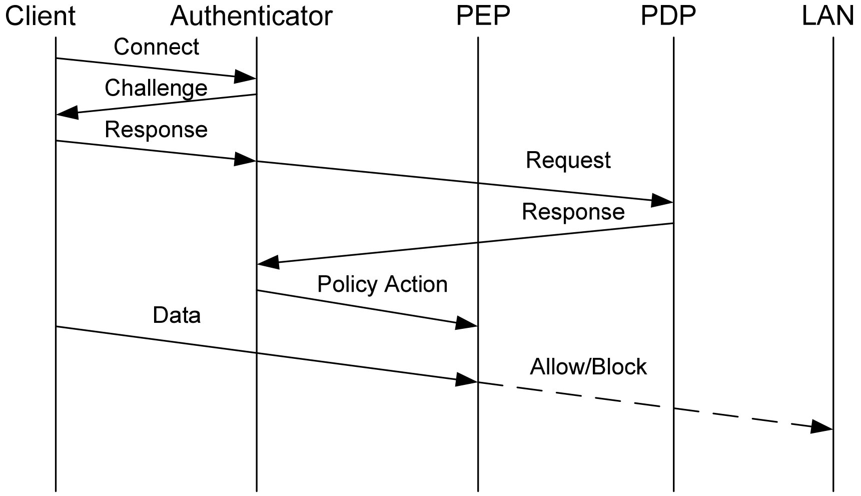
The integrated security services required to achieve this level of LAN security can be broadly categorized into "**pre-connect**" (prior to connecting to the network) and "**post-connect**" features.

Pre-connect mechanisms are applied before an endpoint is allowed to join the network and to send and receive traffic. Endpoint compliance posture checking and user authentication are examples of pre-connect mechanisms. Based on the posture status and user identity, a decision can be made as to whether to allow the endpoint to access the network at all, and, if so, what resources it should be allowed to access, and what visibility it should have to the network. A typical pre-connect posture check would verify that the endpoint system in question is running the latest version of the anti-virus software, and has incorporated required system patches to plug known vulnerabilities.

Post-connect mechanisms provide identity-based access controls, traffic monitoring and visualization, and continued assurance that the endpoint should be allowed access based on its acceptable behavior. Certain parts of the network may be off-limits to, if even visible at all by, unauthorized clients. Traffic anomaly detection, intrusion detection using threat signatures, and activity monitoring are examples of post-connect mechanisms. If the client's behavior deviates from the accepted norm, it may raise an alarm, and, depending on the severity, have its access restricted to a quarantine network, or even find itself blocked from further access. Post-connect monitoring would include the ability to detect worm propagation or a bot network that would evade endpoint anti-virus software, and start malicious behavior well after the client logged into the network.

The pre-connect phase is inherently driven by compliance checks during the login process and involves at least three network subsystems to determine access policies during this login phase. The first such subsystem, sometimes referred to as the "authenticator," interfaces with clients to authenticate users and to gather information about the client's security configuration and other "health" or "security posture" attributes. The second subsystem is for making policy decisions, and is commonly referred to as a policy decision point, or PDP. The third is for enforcing policy decisions, and is known as a policy enforcement point, or PEP.

The following diagram illustrates the flow of traffic between these architectural components during a typical client login.



Considering these mechanisms and architectural contexts, the differences between the "in-band" and "out-of-band" approaches to LAN security can be fully contrasted in terms of:

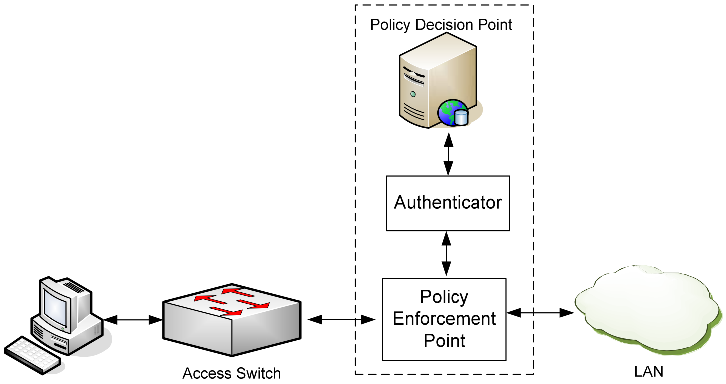
- Which security services they provide, whether pre-connect, post-connect, or a combination of the two, and
- How and where they implement the different architectural components in the network, and its impact on how effectively they can provide these security services.

Note: In many cases an agent executing on the endpoint may be used to facilitate things like pre-connect posture checks or user authentication. This discussion is focused on the differences between in-band and out-of-band approaches, independent of any agent functionality. Agents of any type communicate to the in-band or out-of-band appliances residing in the network.

1.1 In-Band Described

In-band appliances sit in the flow of live network traffic, frequently close to where endpoints access the network (potentially in the access layer switch itself), so that all client-side traffic into and out of the network must pass through them. As such, they are able to directly provide both pre-connect and post-connect security services. Most in-line LAN security appliances co-locate the authenticator, PEP, and PDP functions in a single, stand-alone device. In other words, because they are analyzing and passing live network traffic, in-band devices act as the enforcement point themselves rather than relying on another network system. This co-location of the analysis and enforcement offers major performance advantages and are thus much more effective in thwarting the spread of malware or malicious attacks. Even when in-band appliances are not deployed at the network edge, they are still configured to capture all traffic flows at network choke points, such as into the datacenter, or behind a wireless gateway.

Architecturally, in-band enforcement is shown in the following diagram of network sub-systems.



In-line appliances can provide high-quality security mechanisms such as a full stateful firewall for access control and content inspection for continuous malware detection, applied throughout the user session.

Although in-band appliances sit anywhere in the network, ideally the PEP should be right at the network edge, to the granularity of a single endpoint. Eventually, it is expected that this level of policy enforcement would migrate right into the access switches themselves. While secure switch products are rapidly gaining broad acceptance, most enterprises today are not in a position to replace their existing access infrastructure en masse to get LAN security, so in actuality they deploy some combination of secure access switches, say in conference rooms at first, and in-band network security appliances at other locations throughout the enterprise LAN.

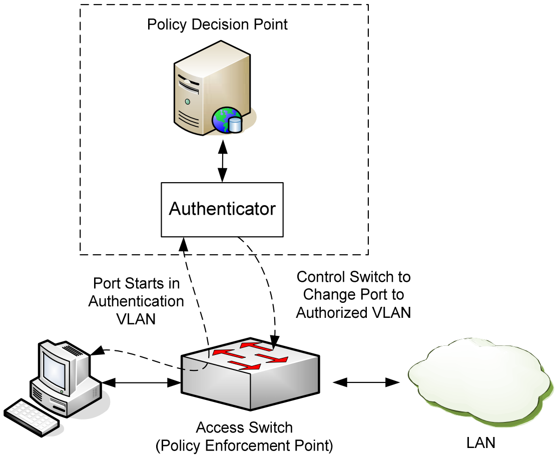
1.2 Out-of-Band Described

Out-of-band appliances are actually in-line for the login phase of the user session, and so can provide pre-connect compliance checks and policy enforcement. However, once the posture check is done, the user is authenticated, and policy decisions are made, they typically switch themselves out of the user traffic path for the remainder of the session. They do this by providing the authenticator and PDP components, either packaged together or separately, but must leverage the infrastructure access switches as PEPs. Unfortunately, the communication back to a downstream switch to effect some sort of remediation takes substantial time in network terms, while the offending network traffic is already flowing upstream to its intended target.

Also, the remediation available from general purpose access switches or other leveraged PEPs is very crude. Access switches were engineered to provide network connectivity but not particularly granular policy enforcement. As such, the enforcement options available tend to be limited to VLAN steering and dynamic ACLs, the same as for 802.1X-based "infrastructure" NAC approaches. See, for example, Microsoft NAP 802.1X-based EAP enforcement. In contrast, in-band solutions can analyze and block traffic on a packet by packet basis with a co-located PEP, filtering only malicious traffic and allowing legitimate business activity to proceed unimpeded, reducing support calls and business disruptions.

Out-of-band NAC "overlay" appliances integrate with potential enforcement points without requiring infrastructure upgrades to 802.1X. These products use SNMP or CLI scripts to control ports on existing access switches in order to make them function as PEPs, although there are a few that can actually leverage 802.1X. Initially, ports are in a provisional "authentication" VLAN so that the appliance, which presents the only route for endpoints to get to the rest of the network, can perform pre-connect checks. Based on policy checks and compliance requirements, it can decide which VLAN to set on the switch port for the remainder of the user session.

The following diagram shows the same architectural components as above, but in an out-of-band configuration.


Policy Decision Point
Authenticator
Port Starts in Authentication VLAN
Control Switch to Change Port to Authorized VLAN
Access Switch (Policy Enforcement Point)
LAN

To confuse matters, there are other NAC vendors that refer to their products as out-of-band, but that use protocol manipulation to do policy enforcement rather than switch control. These can, for example, use crafted DHCP leases to limit client access just to a single appliance that performs pre-connect health checking and user authentication, and then, based on the result, reassign the user session IP address and other network configuration parameters as appropriate. Or, they can inject spoofed ARP responses in order to redirect endpoints to their appliance until it completes the pre-connect checks. Such approaches can at best provide limited security assurances, and so are not discussed further.

2 The Myths and the Truths about In-Band

This section lists five myths about an in-band approach that are often spread by out-of-band proponents.

2.1 Easier to Deploy / Less Disruptive to Network Operations

Myth: *In-line appliances are intrusive and impact the network more than out-of-band. For example, the inserted device can interfere with normal network operations, such as debugging.*

Reality: Out-of-band approaches rely on VLAN steering, using one of two popular methods: controlling switch ports directly using SNMP/CLI access, or using serial 802.1X authentication exchanges. In either case, networks have to be reconfigured to varying degrees, if not physically then certainly logically. This often requires significant effort in network redesign and planning. This invariably involves more effort that a corresponding in-band deployment entails.

VLAN steering using a management interface to control ports requires that the out-of-band appliance be given sensitive management passwords that control the affected network infrastructure components. Switch port control that uses SNMP over UDP can be unreliable during periods of network load and introduce unpredictable delays in user logins.

To use 802.1X for VLAN steering, supplicants need to be configured and possibly installed, and infrastructure changes are required, starting with upgrades to the RADIUS policy servers. This may involve adding a plug-in, which limits the RADIUS servers supported by a particular vendor, or inserting a new RADIUS proxy server and reconfiguring switches to contact the proxy. Many enterprises have had to roll back plans for 802.1X due to difficulties encountered in deployment.

In either case, the network VLAN plan will have to be modified in order to introduce additional VLANs. Furthermore, the ports to which endpoints connect on access switches will need to be reconfigured to initialize in the authentication VLAN. In addition, the ports where the out-of-band servers themselves attach will need to be specially configured.

By contrast, an in-line appliance can be transparently inserted by simply patching it in the existing uplinks from switches or routers to the distribution or core tier. No infrastructure components need be reconfigured, and no additional ports are taken up on switches. This also makes it easier to remove an in-line device, and in-fact many in-line devices provide management facilities to allow themselves to be temporarily bypassed internally.

2.2 More Scalable

Myth: *Out-of-band solutions are more scalable since they are only in-line during the initial user attachment to the network. This means they have less performance impact and can scale to larger networks.*

Reality: In-line solutions with purpose-built ASICs can provide all the performance required to authenticate users as well as to inspect, monitor, and control every packet of every flow on the network. Typically, in order to provide just the authentication functionality, an out-of-band server is needed in every switch domain in addition to some kind of central controller, so that the number of boxes actually deployed tends to be comparable. Also, the “9 AM” simultaneous login load needs to be taken into account as the number of users scales up, very likely requiring additional out-of-band appliances.

2.3 Greater Risk

Myth: *In-band affects multiple users, so the network is more sensitive to failure, affecting many users or large sections of the network. Furthermore, in-line is incapable of preventing users from accessing the network at all if they are non-compliant as 802.1X can, since some minimal unauthenticated access must be provided in order for endpoints to get IP addresses, etc.*

Reality: Out-of-band affects all subsequent user logins, so a failure of a server or controller can prevent users from logging in or even worse, insecurely leave ports in an authorized VLAN after users log out. In reality, both in-band and out-of-band approaches use redundant devices and failover, but in-line devices have the additional option of failing open, or enforcing a default policy with basic access privileges.

On the second point, out-of-band methods require clients to be given some access in order to evaluate compliance, since it needs to be done by communicating with an agent using TCP/IP. The only way to do compliance checking prior to L2 attachment is to integrate it with the 802.1X EAP processing, which requires an upgrade to the infrastructure as well as to the supplicants on the endpoints.

2.4 Better Security

Myth: *Out of band approaches apply enforcement at the access switch. Since in-band controls the user session further up in the network, users can mount man in the middle (MITM) attacks against peers on the same switch, or spoof/insert traffic undetected.*

Reality: Clearly, the best security is that applied right at the point of entry to the network. Ideally this would be done using a secure switch with integrated pre-connect and post-connect security, and some in-band vendors, such as Nevis, offer a secure switch option. However, not all networks may be in a position to upgrade their access switches, and in-band appliances can offer an acceptable tradeoff of security granularity in order to accelerate their security deployments.

However, since out-of-band solutions are only capable of providing pre-connect security without the same degree of continuous post-connect security, just because these products enforce at the port level does not imply that they will be effective against spoofing or MITM attacks. Since

VLANs are the only enforcement mechanism, users cannot be isolated from each other, except broad classes such as unauthenticated from authenticated, and even this is only enforced pre-connect. Once a user is placed in an authorized VLAN, that user's activities cannot be monitored by the security appliance, and so that user can mount attacks against whomever they wish in the authorized VLAN or on the rest of the LAN, for that matter. In-band appliances can continuously block individual users from others on different access switches, even post-connect, providing a greater degree of security and more effective remediation.

2.5 Lower Cost

Myth: *Out-of-band solutions are less expensive to acquire and maintain, since they are built on commodity server hardware without the need for custom ASICs or other exotic hardware.*

Reality: These appliances tend to be priced comparable to in-band appliances, so the acquisition costs are comparable. However since the networks need to be reconfigured for the new VLANs, the costs in administrative overhead need to be taken into account, and often tip the balance. An additional consideration is that out-of-band solutions are primarily focused on pre-connect compliance checks, and not the complete pre- and post-connect security services of in-band solutions, which include identity-firewall, application use policies and intrusion prevention capability on top of the pre-connect NAC features (i.e., a full LAN security solution). When the additional in-band functionality is considered, the cost-benefit ratio tips strongly towards the in-band solutions.

3 Potential Out-of-Band Deployment Issues the Vendors Don't Want You to Know About

Out-of-band methods do have a number of limitations that tend to only be discovered once placed in the network, and some of these are listed in this section. It is advised that these issues be brought up specifically with potential solution providers before making a decision.

One major issue is that out-of-band devices have difficulty supporting the full normal Microsoft boot and login sequences. For this, some out-of-band approaches require an agent, and even then they can maybe update Group Policy Objects (GPOs), but not provide full support for all Microsoft login features, such as domain controller logging. In effect, deploying an out-of-band NAC solution can break Microsoft network management and patch management provisions, including the ability to do off-hours upgrades. In-band enforcement can be provisioned to allow controlled outbound access from endpoints to specific Active Directory servers, and controlled inbound access to endpoints from specific management servers, with simultaneous malware detection and control.

Not all infrastructure switches may be able to participate in out-of-band enforcement schemes, and non-conforming devices would need to be upgraded or replaced, adding further cost and complexity to an out-of-band deployment. In particular, not all legacy devices can be securely controlled by out-of-band appliances unless they support advanced features such as SNMP v3 security or MIB-based VLAN port control. Switches that do support SNMP-based VLAN steering typically use vendor specific MIBs, so each vendor and possibly each switch model will need a different configuration. Similarly, CLI approaches are limited to specific switches from specific vendors, as CLI syntax varies, sometimes in subtle ways, and can further change after a switch upgrade, requiring reconfiguration of the out-of-band appliances to keep up. By contrast, in-band approaches are infrastructure neutral and can be deployed in mixed vendor environments.

Out-of-band re-authentication and re-scan, if done at all, typically has to be done over different network paths than initial authentication and compliance check sequences. Hence, either the servers must have interfaces on all authorized VLANs or at least be L3-reachable via routing. So either endpoint firewalls need to let the server initiate connections to the clients, or endpoint agents need to be given an address to periodically call back to. If re-scan is done by connecting back to the controller, it introduces bottlenecks as well as additional loads on the so-called inexpensive server platforms.

4 Why Out-of-Band Enforcement is Suboptimal Compared to In-band

This section lists a number of additional realities about out-of-band enforcement mechanisms that are generally avoided by the “in-the-box” enforcement of in-band solutions:

- There are too many moving parts for equivalent security. Out-of-band typically requires multiple devices to achieve the same effects of a single in-band device, and each of these will have its own management console and policy settings. Scalability and cost for these will be at best comparable to, but most likely inferior to in-band. The following is a representative list of the separate components and integration issues required in a comparable out-of-band deployment:

  - Appliances will need to be plugged into switches in each layer 2 switch domain (to provide a server in the authentication VLANs for endpoint compliance checks and user login)

  - A central management controller with replicas (if high availability is desired) for the various enforcement points is required (VLAN enforcement using SNMP or 802.1X edge switch port control, track user sessions by IP/MAC/switch port)

- IPS (intrusion protection system) is often deployed on upstream SPAN ports for malware detection and control (these typically enforce by injecting TCP RSTs, but some are integrated with the NAC appliances and so can use VLAN enforcement for post-connect). In-band solutions are in a position to incorporate their own IPS capability. In particular, the Nevis appliance includes full traffic, protocol and behavior anomaly detection, as well as full signature analysis.
- A security event manager (SEM) would be needed to correlate NAC and IPS events for early warning of security incidents. However, these would only get traffic samples but no record of every traffic flow for real-time visualization. Nevis provides detailed network activity monitoring and application visualization, and incorporates its own monitoring capabilities for network-wide correlation of events.
- Multiple, independent, syntactically and semantically differentiated vendor-specific management consoles result in more configuration steps, e.g., black lists and white lists have to be manually synchronized across different platforms, with administrators becoming proficient on each.

➢ Degraded user experience of multi-component authentication and enforcement

- Delays in login with little or no user feedback as the pre-connect data flow traverses the network components.
- Agentless NAC, for example using vulnerability scanning technology, confuses users as to why they can’t get network access, or else compromises security by giving premature access prior to scans.

➢ Deployment complications of out-of-band solutions which actually require much greater integration with other network components:

- Need to reconfigure switch controlled ports, as described above.
- Need to reconfigure VLANs to accommodate authentication VLANs.
- Need to reconfigure switch management to send SNMP traps to out-of-band controllers, and to allow secure control either by RADIUS proxies or by means of SNMP SETs.
- Clients need to get new IP addresses after VLAN changes, requiring port bounces or agent-initiated address renew.
- Out of band deployments allow for only a single endpoint per controlled port, causing such potential issues as not working for IP phones with tandem PC’s.
- Controlled port synchronization issues if an access switch or controller appliance reboots.

  - Manual updates at NAC controller are needed to track switch additions/deletions, which can be a major problem in large networks.
  - May need to install RADIUS proxy or server plug-in for 802.1X enforcement, as described earlier.

- Incomplete security coverage, since out-of-band is generally restricted to pre-connect compliance checks and security services:
  - No or difficult compliance re-scans – must be initiated by agent to a reachable security appliance.
  - SPAN ports miss packets during burst traffic periods.
  - Disrupts normal communication flow with Active Directory - Windows startup GPO configuration must be done after user login and requires agent initiation, user login must be with cached credentials (no transparent snooping)
- Reliability options are limited. Failures can leave the network or ports in unusable state.
  - SNMP is intrinsically unreliable, since not all vendors consider all possible failure modes to maintain edge switches and controllers in synchronization.
  - Director failure needs to be detected and controlled switch ports bypassed so that users can login.
  - Recovery from management controller failure requires fully synchronized replicas.

5 Summary

The table on the following page summarizes the differences between the in-band and out-of-band approaches.

Feature	In-band	Out-of-band	Benefit
Endpoint Compliance and User Authentication	Performed in straightforward manner, with remediation options that avoid VLAN steering.	Must be done in a provisional VLAN, then client traffic steered to an assigned or quarantine VLAN. Threats can spread within VLAN.	Does not ever require client to re-acquire IP address, which adds delays in users logging in.
Identity-Based Access Controls	Internal stateful firewall policies based on source, destination, and traffic content.	VLAN steering would work if different roles are placed in different VLANs. Finer granularity requires upstream firewalls.	In-band provides fine-grained identity based access controls as basic security feature.
Malware Detection	Continuous malware detection using various techniques, including behavior and signatures	No visibility into user traffic since out of flow of network traffic during session. Requires additional upstream IPS for comparable security.	In-band provides persistent malware detection and prevention as a basic feature.
Visibility and Monitoring	Continuous monitoring of and visibility into all user activities, with associated user-based reports	No visibility into user traffic since out of circuit. Requires additional sensors, displays and reporting infrastructure for comparable security.	In-band provides persistent role-based monitoring and visibility as a basic feature.
Quarantine Enforcement	Done using stateful firewall approach, shielding all users from each other	Places non-compliant users in a common quarantine VLAN	In-band protects vulnerable or infected clients from each other.
Cost	No hidden deployment or reconfiguration costs, no upgrades to existing infrastructure required.	Initial capital expense for devices and controllers, but higher operational costs, and potential upgrades of enforcement points	In-band offers lower overall cost of deployment and management.

Glossary

802.1X – an IEEE standard for port-based Network Access Control; it is part of the IEEE 802 (802.1) group of protocols. It provides authentication to devices attached to a LAN port, establishing a point-to-point connection or preventing access from that port if authentication fails.

ACL – an access control list (ACL) is a list of permissions attached to an object. The list specifies who or what is allowed to access the object and what operations are allowed to be performed on the object.

ASIC – An application-specific integrated circuit (ASIC) is an integrated circuit (IC) customized for a particular use, rather than intended for general-purpose use. For example, a chip designed solely to run a cell phone is an ASIC. Nevis' LANsecure ASIC is customized designed for deep-packet analysis on network traffic, including signature analysis.

CLI – Command Line Interface

DHCP - Dynamic Host Configuration Protocol (DHCP) is a protocol used by networked devices (clients) to obtain various parameters necessary for the clients to operate in an Internet Protocol (IP) network. By using this protocol, system administration workload greatly decreases, and devices can be added to the network with minimal or no manual configurations.

IPS – An intrusion prevention system is a computer security device that monitors network and/or system activities for malicious or unwanted behavior and can react, in real-time, to block or prevent those activities. Network-based IPS, for example, will operate in-line to monitor all network traffic for malicious code or attacks. When an attack is detected, it can drop the offending packets while still allowing all other traffic to pass.

LAN Security – LAN security is a holistic approach to securing the internal network of an organization that includes not only the pre-connect NAC security services, but persistent post-connect security checks that prevent the spread of malicious malware, and ensure that access to servers and applications by end users conform to the desired policy of the organization. LAN security goes beyond alternative network security approaches by monitoring which user ID and system maps to each network packet, allowing more sophisticated network access controls and more granular policy enforcement.

MIB – A management information base (MIB) stems from the OSI/ISO Network management model and is a type of database used to manage the devices in a communications network. It comprises a collection of objects in a (virtual) database used to manage entities (such as routers and switches) in a network. SNMP, a communication protocol between management stations (consoles, for example) and managed objects (such as routers, gateways, and switches), makes use of MIBs. Components controlled by the management console need a so-called SNMP agent — a software module that can communicate with the SNMP manager.

NAC – Network Access Control or Network Admission Control (NAC), is a set of protocols and systems used to secure the network nodes prior to the nodes accessing the network. NAC also integrates the automatic remediation process (fixing non-compliant nodes before allowing access) into the network, allowing the network infrastructure (routers, switches and firewalls, etc..) to work together with back office servers and end user nodes (computers/servers, printers, and IP phones, etc..) to insure the system is operating securely before interoperability is allowed.

NAP – Network Access Protection (NAP) is a Microsoft technology for controlling network access of a computer host based on the system health of the host, first utilized in Windows Vista and Windows Server 2008 (in beta testing).

RADIUS – Remote Authentication Dial In User Service (RADIUS) is an AAA (authentication, authorization, and accounting) protocol for applications such as network access or IP mobility. It is intended to work in both local and roaming situations.

RST – TCP Command to ReSeT the connection.

SEM – A Security Event Manager (SEM) is a network tool used to centralize the storage and interpretation of logs, or events, generated by other network devices.

SNMP – The Simple Network Management Protocol (SNMP) forms part of the internet protocol suite as defined by the Internet Engineering Task Force (IETF). SNMP is used in network management systems to monitor network-attached devices for conditions that warrant administrative attention.

SPAN port – Also known as port mirroring, allows a network switch to send a copy of all packets on one port to another switch port, typically for analysis purposes by another network device.

VLAN – A VLAN can be thought of as a broadcast domain that exists within a defined set of switches. Ports on a switch can be grouped into VLANs in order to limit traffic flooding since it is limited to ports belonging to that VLAN and its trunk ports. Any switch port can belong to a VLAN. Packets are forwarded and flooded only to stations in the same VLAN. Each VLAN is a logical network, and packets destined for stations that do not belong to the same VLAN must be forwarded through a routing device. Each VLAN can also run a separate instance of the spanning-tree protocol (STP).

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