NORWICH UNIVERSITY

Gateway Security Devices

CSH6 Chapter 26

"Gateway Security Devices"

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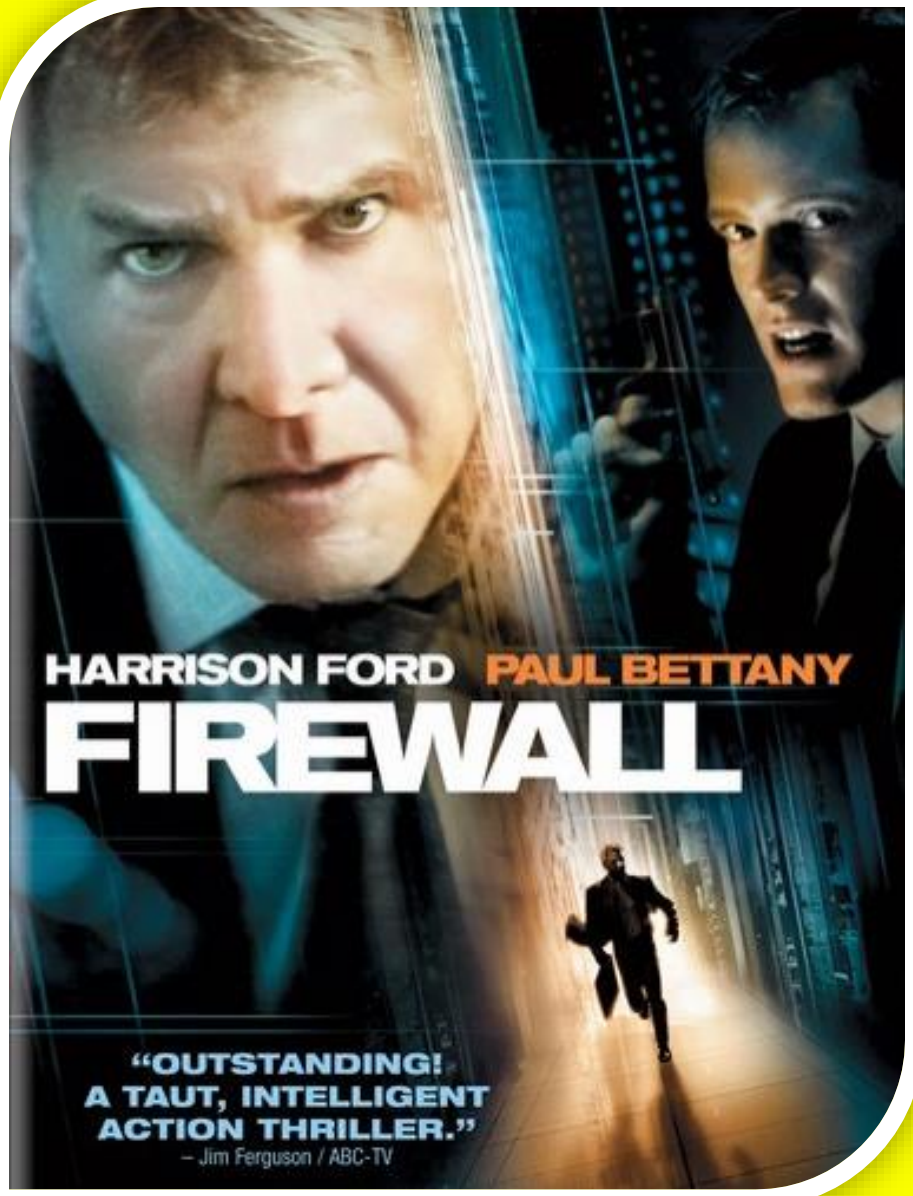
Topics

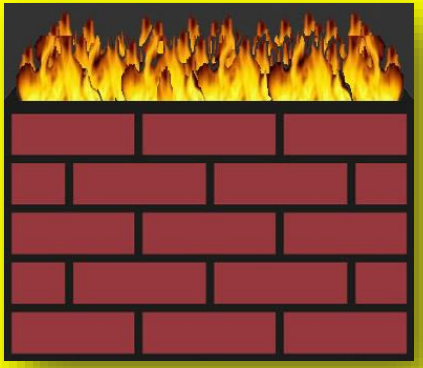
- Introduction
- History & Background
- Network Security Mechanisms
- Deployment
- Network Security Device Evaluation

Introduction



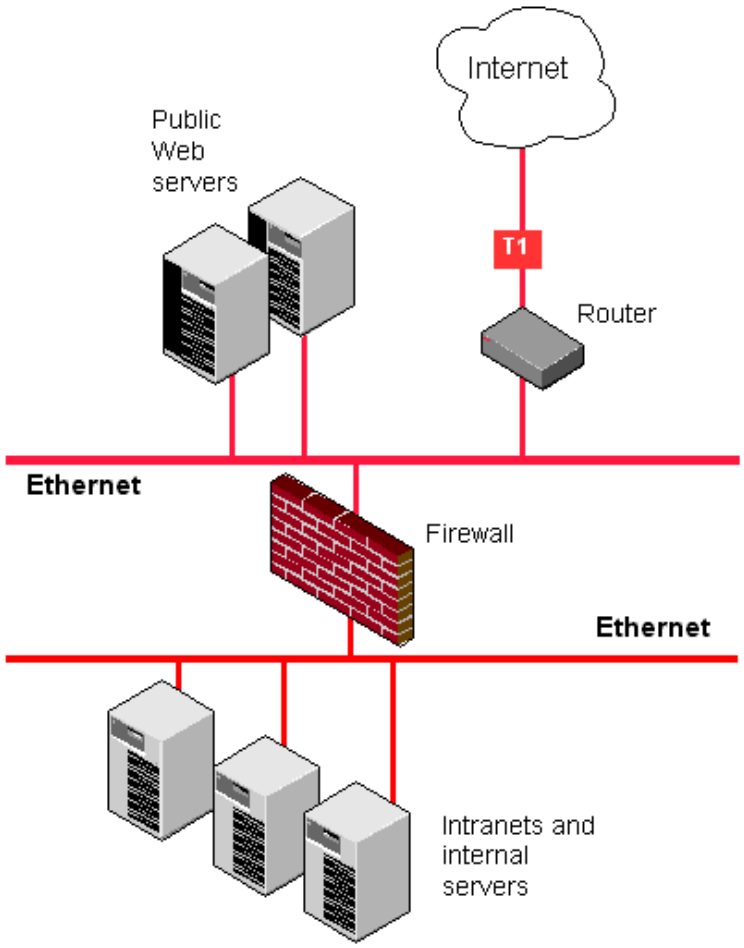
- Overview
- Changing Security Landscape
- Rise of Gateway Security Device
- Application Firewall: Beyond the Proxy

Overview



- What is a Firewall?
- Firewall rapidly accepted as perimeter security device
  - Even CEOs know about firewalls
- Original conception
  - Allow explicitly allowed communications
  - Deny all others
- Allowed paths became weakest links
  - Involve different (and insecure) protocols
  - Firewalls evolved to compensate for weak security in allowed protocols
- Successful use of firewalls depends on proper configuration

What is a Firewall?



Firewall Placement
An organization's public Web sites reside outside the firewall, but intranet servers and all internal computing resources are inside the firewall.

A firewall is any *network-security device* that implements *security policies* by *restricting* the *ingress* and *egress* of TCP/IP *packets* according to *specific rules*.

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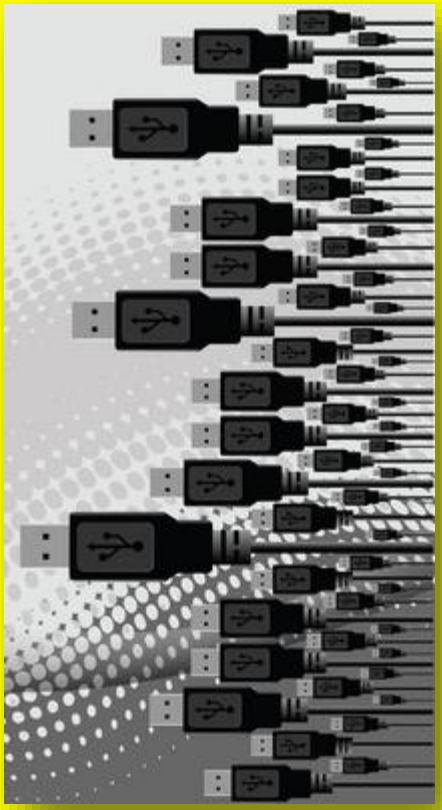
Changing Security Landscape (1)

- Pervasive changes in network architectures
  - Applications & work patterns require more open interactions
  - Perimeter less clearly defined
  - Increased centralization (e.g., servers)
  - Increased scrutiny of protocol traffic
- Borders dissolving
  - Outsourcing, hosted applications (e.g., CRM, e-mail, external storage, Web apps, cloud computing)
  - Enterprise applications linked to customer & 3rd party applications

Changing Security Landscape (2)



- Mobility (physical and logical)
  - Employees work from home, while traveling
  - Use kiosks, home systems, phones
  - Opens networks to attacks via compromised client systems
- Regulatory compliance
  - Increased demands for security
  - In USA, laws such as Gramm-Leach-Bliley (GLB), Health Information Portability and Accountability Act (HIPAA), and Sarbanes-Oxley (SOX) force protection of personally identifiable information (PII)

Rise of Gateway Security Devices (GSDs) (1)

- Firewalls originally defined allowed paths for access (ports)
- Evolved into GSD to provide many security functions as shown below
- Gateway security device capabilities:
  - Processing power has increased
  - Now see multifunction platforms; e.g., role-based access controls (RBAC)
- Enterprise directory integration:
  - Lightweight Directory Access Protocol (LDAP) infrastructure for authorization

Rise of GSDs (2)

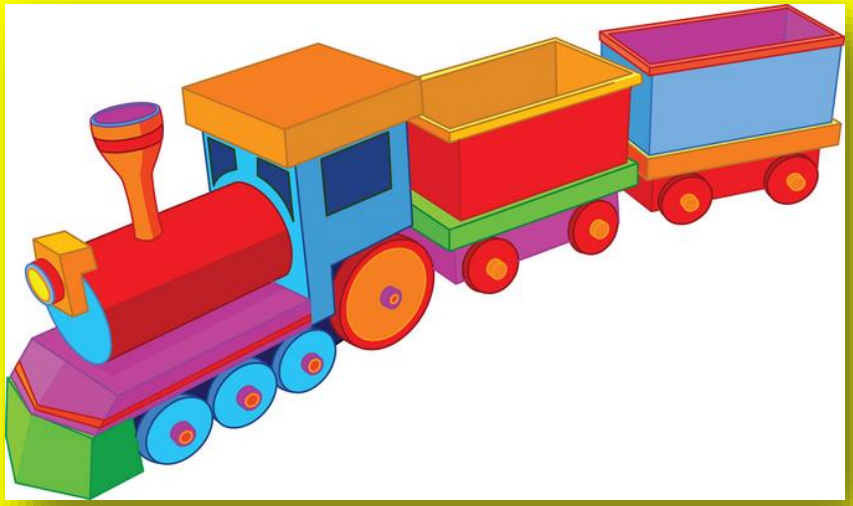
- Unified threat management:
  - Perimeter-based antivirus, antimalware, antispyware, antispam
  - Intrusion detection & intrusion prevention
  - Content control
- Content control & data leakage prevention:
  - Deep inspection of packets in protocols such as HTTP, SMTP, IM
  - Dictionary-based and URL-list filters
  - Requiring encryption for sensitive data
- Archive & discovery
  - Message security & records for legal compliance

Application Firewall: Beyond the Proxy

- Most significant allowed paths for most firewalls: Web access
  - HTTP & HTTPS (HTTP with SSL)
- Increased complexity
  - Rich-client applications; e.g., using AJAX
    - ✓Asynchronous JavaScript & XML
    - ✓AKA *remote scripting*
    - ✓Allows user to interact *a field at a time* instead of *a page at a time*
  - Firewall now has to guard against misconfiguration & vulnerability in custom Web applications running over allowed HTTP

History & Background

- Changing Network Models
  - Mainframe
  - Client/Server
  - Web
- Firewall Architectures
- Firewall Platforms



Cross References in *CSH6*:

- Overview of computing and security history, see Chapter 1.
- Introduction to data communication basics, see Chapter 5.
- Introduction to local area networks, see Chapter 25.

Changing Network Models (1)

- Shift from mainframe-centric to LAN-centric to Internet-centric computing through 1980s through 1990s & 2000s
- Mainframe architectures
  - *Glass house* approach
  - Solitary systems with hardwired dumb or smart terminals (*green screens*)
  - Multiple mainframes linked within single data centers
  - WANs used leased lines (telephony)

- Virtualization began on mainframes
  - IBM MVS/VM
  - Strict partitions, mandatory access control

Changing Network Models (2)

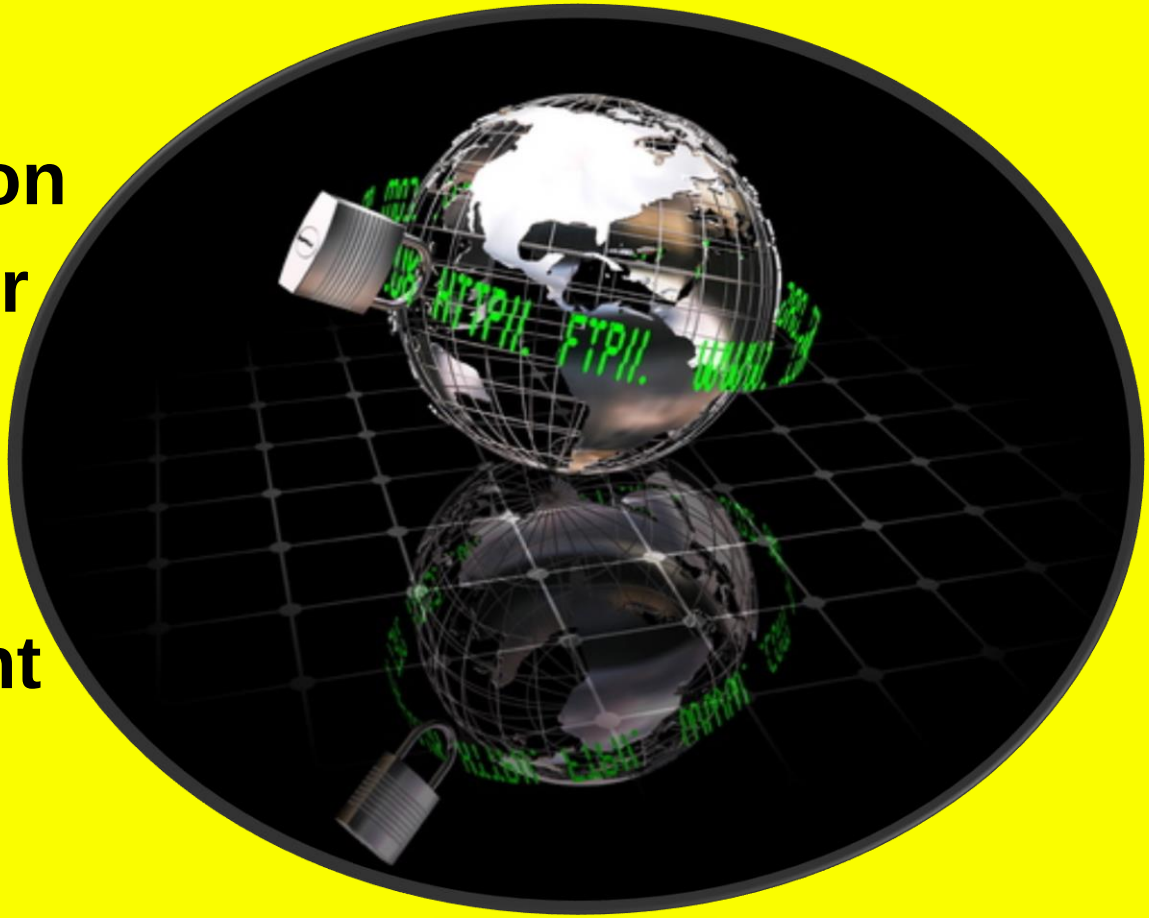
- Client/Server (1980s, early 1990s)
  - Midrange servers running Unix, NetWare, OS/2, Windows NT
  - Rapid increase in # & type of connections
  - Switch to PCs with local processing
- Security perimeter expanded
  - Out of data center to desktop
  - WANs expanded beyond enterprise
- Application security expanded across systems
  - Multiple allowed paths
  - Multiple possible attack paths

Changing Network Models (3)

- Web
  - HTTP/HTML started expanding 1989
  - Commercial Internet exploded starting in 1993 when .com opened in big way
  - Web applications replaced fat clients
- Mobile code complicated security issues
  - Asynchronous JavaScript & XML (AJAX)
  - Many customized & ad hoc protocols carry data over http
  - Firewalls increasingly focused on HTTP traffic

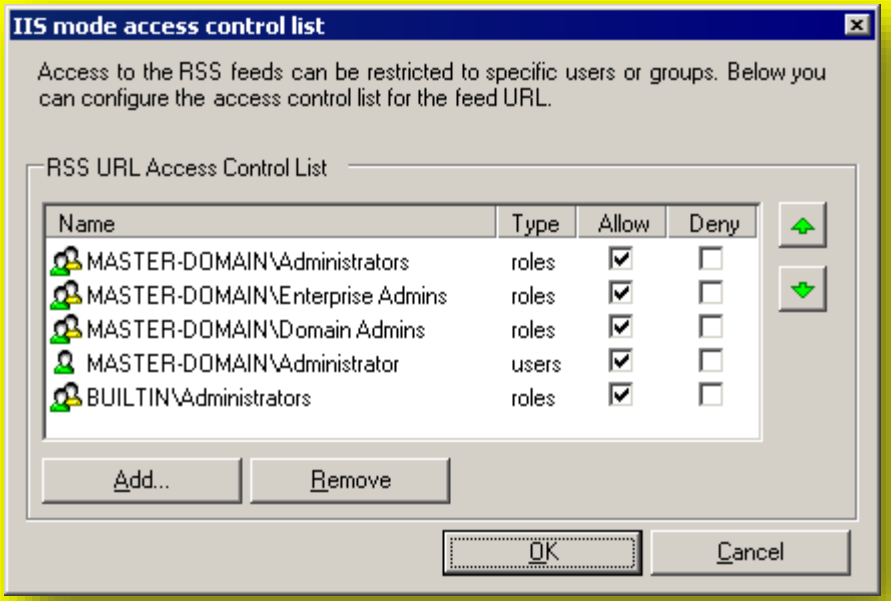
Firewall Architectures

- Access Control List
- Packet Filtering
- Stateful Inspection
- Application-Layer Gateway
- Multifunction Hybrid
- Host Environment Context



Access Control List (ACL)

- First FW were routers
  - Dedicated appliances
  - UNIX-based bastion hosts
- Routing appliances w/ ACLs
  - Still widely used
  - Decide on whether to allow packet into or out of network strictly one packet at a time
  - Examine packet data
    - ✓Source, target addresses
    - ✓Port, packet flags (e.g., SYN flag)
- Vulnerable to misconfigured packets
  - Fix problems using patches



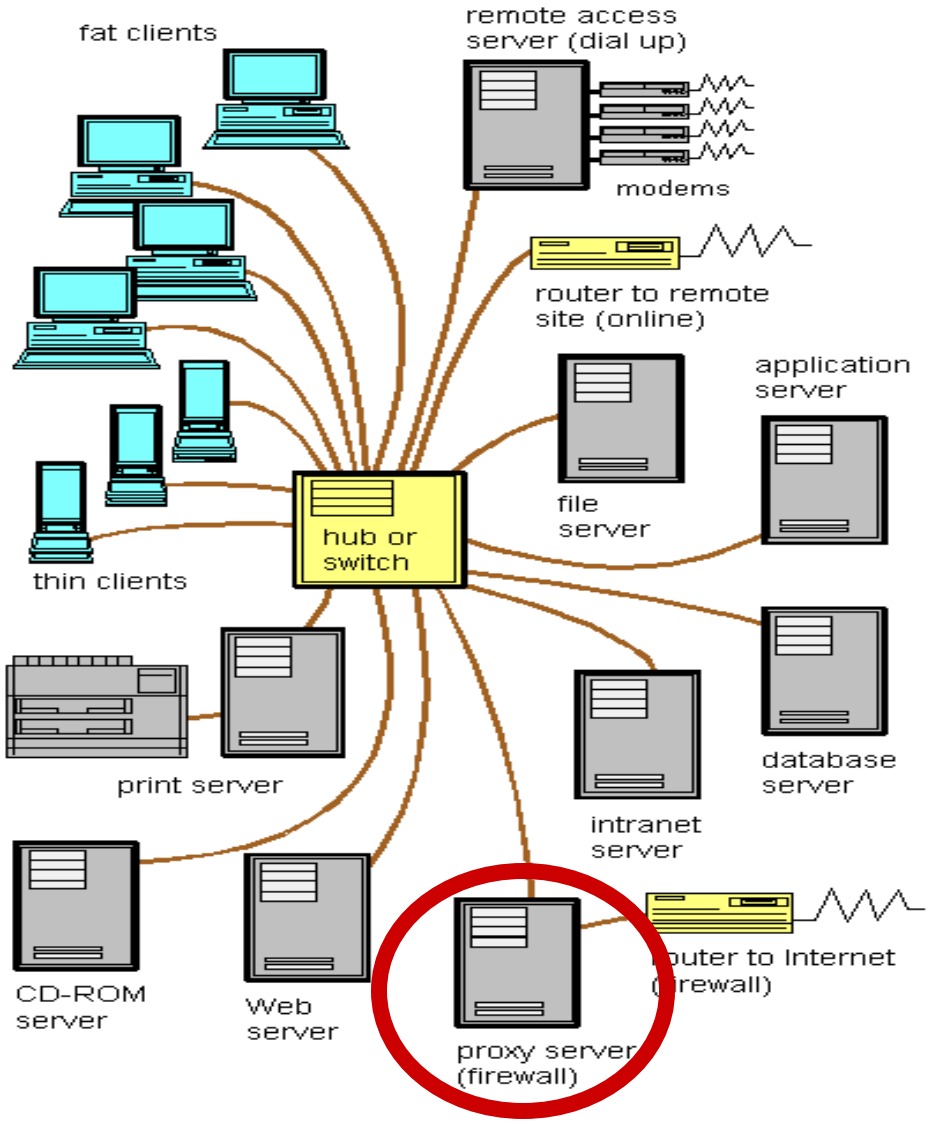
Packet Filtering

- Pure packet-filtering FWs no longer common
  - Appliance or host-based
  - Use ACLs to apply policies
  - Typically provide logging
  - Support user-based authorization
  - Include intrusion detection & alerts
- Strengths
  - Ideally suited to load-balanced, high-availability environments
  - Can automatically share load among devices
- Weaknesses
  - Lack context information
  - Underlying operating system vulnerabilities affect security of FW
- Packet filtering has moved to non-security appliances such as load balancers, Web caches, switches

Stateful Inspection

- HTTP is a *connectionless protocol*
  - A communications architecture that does not require the establishment of a session between two nodes before transmission can begin. *[Computer Desktop Encyclopedia]*
- Stateful-inspection FW maintain connection information locally
  - Table in memory stores packet header data
  - Compare current packet info to session
  - Identify some abnormal packets used in attacks
  - But attacks that use uninspected portions can succeed
- Fast mode reduces inspection once connection opened successfully – strongly discouraged
- Performance can be good
  - Provide load balancing & failover with out-of-band data synchronization among devices running in parallel

What is a Proxy Server?



A Proxy Server in a LAN

This illustration of a variety of servers in a LAN shows the proxy server connected to an Internet router.

- **"[An] application that breaks the connection between sender and receiver. All input is forwarded out a different port, closing a straight path between two networks and preventing a cracker from obtaining internal addresses and details of a private network."**

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Application-Layer Gateway

- Proxy servers
  - Receive packets from outside
  - Inspect and approve according to rules
  - Discard unused portions of received packets
  - REBUILD new packets for internal network
  - Effective against unknown attack types
  - Analogous to *air gap* in network topologies
- Heavy processing loads
  - Typically configure load-balancing at system startup – not dynamically changed
  - Failover more disruptive – interrupt connections in progress

Multifunction Hybrid

- Most commercial firewalls today are hybrids
- Apply stateful inspection techniques to most protocols
- Use application-layer gateway proxies for specific protocols (e.g., HTTP, SMTP)
- Can shift to fast mode for stateful inspection once connection established

Host Environment Context

- Host-based security more granular than perimeter-based devices
  - Define specific applications / services
  - Regulate types of data allowed per process
  - Use sandbox or virtual machine to test code
- FWs can run on host or communicate with host
  - Use protocols such as Universal Plug and Play (UPnP) for data exchange
  - E.g., evaluate processes running when packet inspection being performed
  - Open and close specific ports as function of need

Firewall Platforms

- Routing
- Host Based
- Appliance
- Personal and Desktop Agent
- Virtual
- Embedded

FW Platforms: Routing

- Router
  - Heart of TCP/IP networks
  - Forwards packets from one network to another
  - Internal routing tables allow determination of where to forward each incoming packet
  - Destination address determines where outgoing packets are sent
  - Current load on different connections determine which line to use for each packet or group of packets
- ACL allow / deny statements restrict packets
- Hardware modules (blades) can share processing to increase throughput (bandwidth)

FW Platforms: Host-Based

- Dedicated server-based firewalls provide additional functions
  - Protocol traffic inspection
  - Contextual traffic inspection
  - Comprehensive logging & alerts
  - Air-gap proxy servers

- Typically run on Unix or Windows
  - Often have special *hardening* (security features) such as modifications of network stack
  - Consequences of increased complexity include increased bugs, vulnerabilities

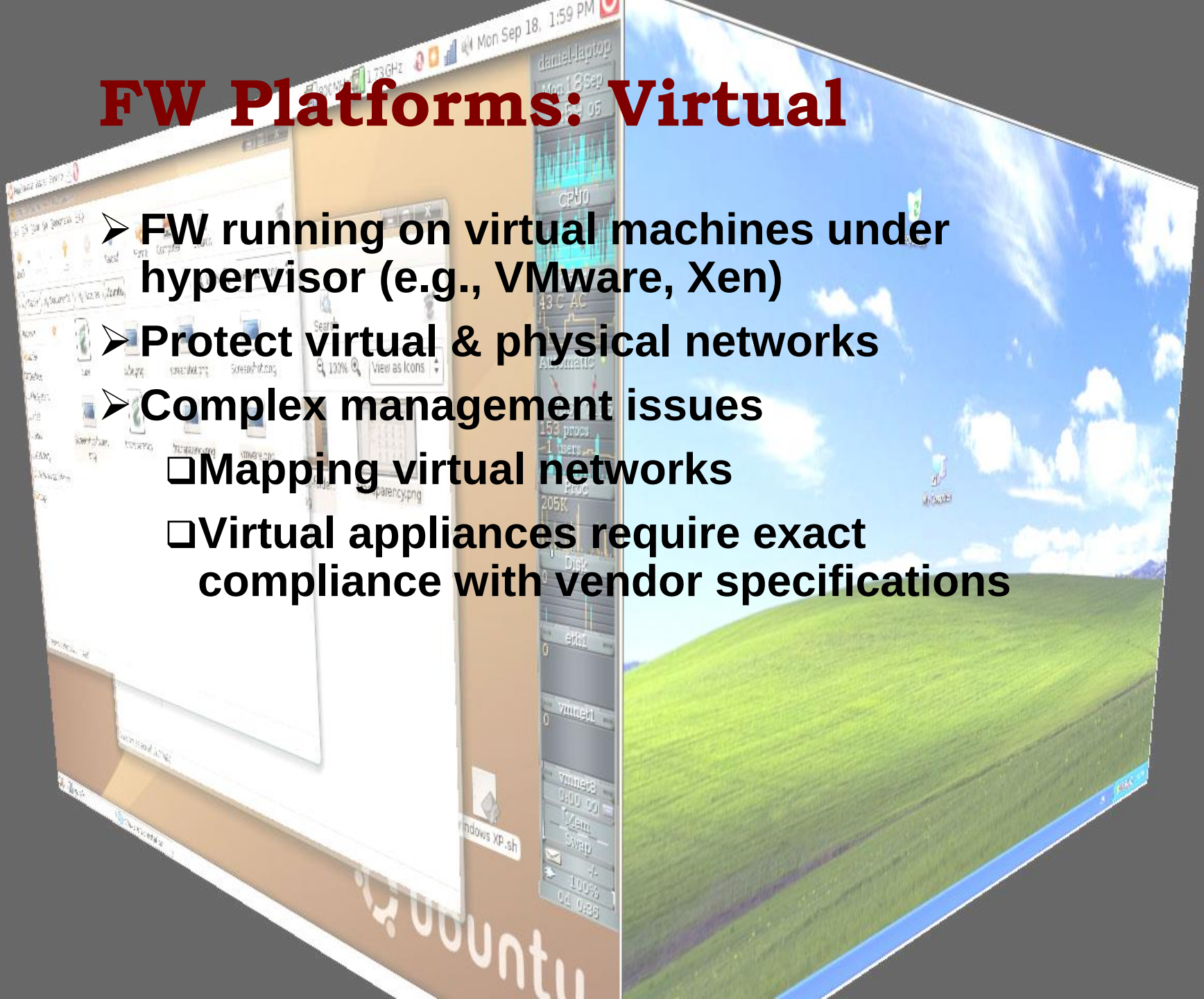
FW Platforms: Appliance

- Extension of host-based FW: put FW into its own specialized processor w/ no other functions
- Total control of operating system
  - Control versions, patches specifically for functionality of FW
  - Prevent unauthorized, unwanted changes
- *Soft appliances*
  - Vendor specifies exact characteristics of hardware for user to buy & install
  - Provides full software – boot from vendor-supplied disk

FW Platforms: Personal and Desktop Agent

- Software FW
  - Host-based systems
  - Commonplace today
  - Running on workstations
  - Integrated systems often include antivirus functions
- Evolve into host intrusion-prevention system (H-IPS)
- Require more maintenance than network-based FW
  - Constant signature updates
  - Regular patches of client software
  - Difficulties for management in wide-area networks

FW Platforms: Virtual



- FW running on virtual machines under hypervisor (e.g., VMware, Xen)
- Protect virtual & physical networks
- Complex management issues
  - Mapping virtual networks
  - Virtual appliances require exact compliance with vendor specifications

FW Platforms: Embedded

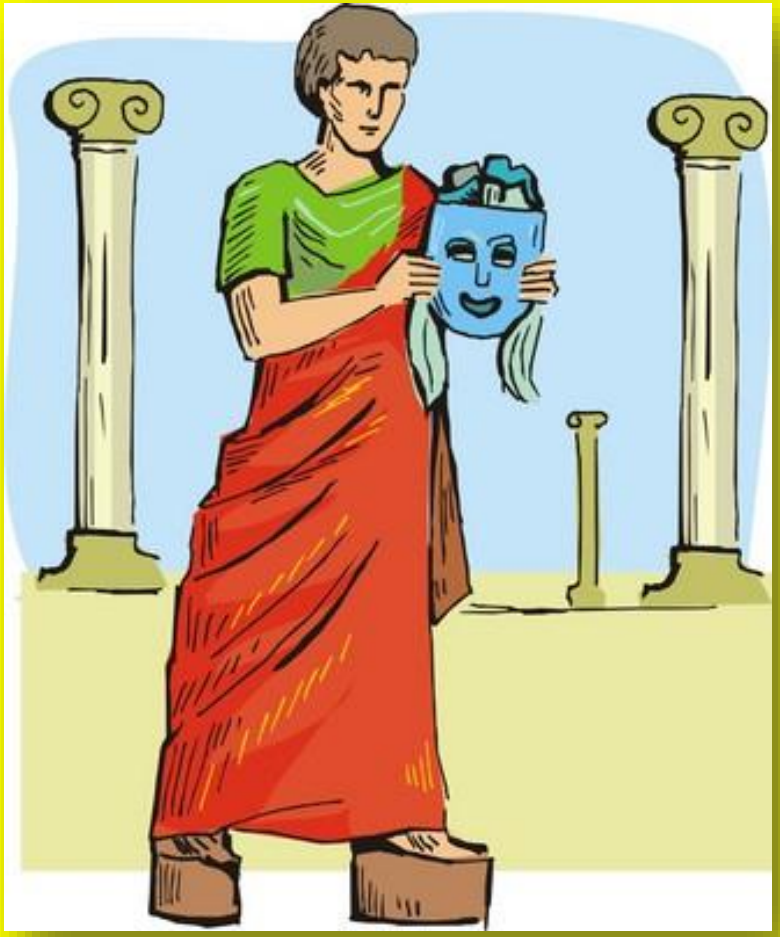
- Web-server-based plugins
  - Create customized *application* FWs
  - Scale to support consumers, small/medium business requirements
- Integrate tightly with Web server
  - Use downloaded signatures
  - Develop specific protection for specific applications
  - Allows contextual scanning unavailable to application gateways
- Often become all-in-one security appliances
  - Integrate FW, network intrusion-prevention, antivirus….

Network Security Mechanisms

- Recognition of value of network security mechanisms
  - IT managers have increased expertise
  - Increasingly recognized need
  - Often have unrealistic expectations
- Next slides:
  - Basic Roles
  - Personal & Desktop Agents
  - Additional Roles

Basic Roles

- Allowed Paths
- Intrusion Detection
- Intrusion Prevention/Response

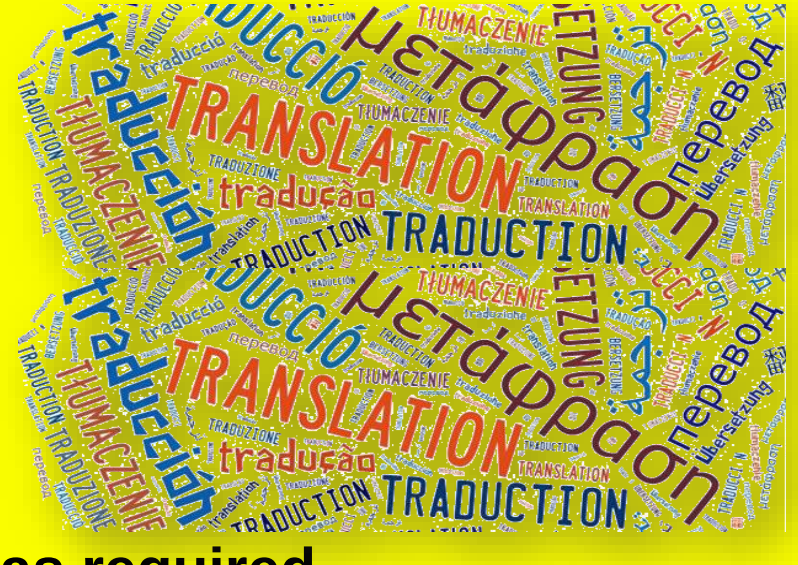


Allowed Paths

- GSDs create physical perimeters
- Also create logical perimeter extending within protected networks
- Constitute least-privilege gateway
- Mechanisms for regulating access
  - Tunneling: Transmitting data structured in one protocol within the format of another." *(Computer Desktop Encyclopedia)*
  - Antispoofing: preventing forged network addresses (e.g., blocking *inbound* packets with *internal* addresses and vice versa; blocking packets with originating addresses in *reserved address-space*)
  - Network Address Translation (NAT): see following slide

Network Address Translation (NAT)

- Masks address of internal nodes
  - Private address space accessed by internal tables
  - Limits determination of internal network size & topology
  - Restricts access to specific endpoints
- Static NAT
  - Manual, permanent assignment of IP address to each internal node
- Dynamic NAT
  - Pool of addresses assigned as required
- Port Address Translation (PAT)
  - AKA Nat overloading
  - Different TCP port # used for each client session



Intrusion Detection

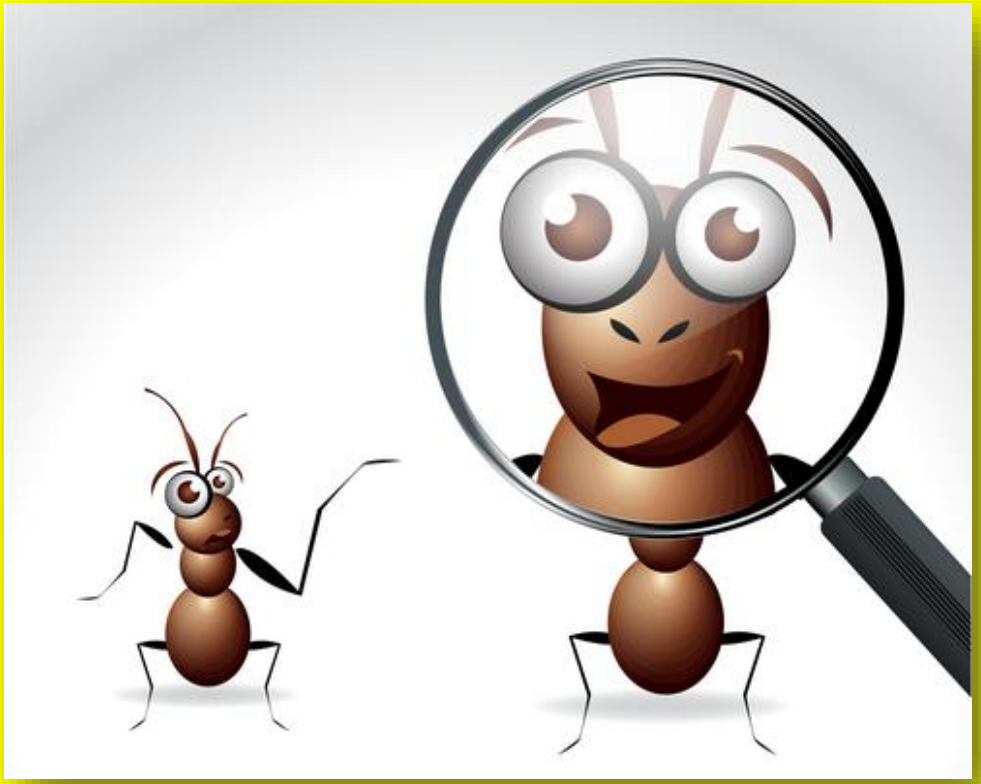
- Alerts may be good or bad
  - Appropriate deployment of alarms over new attacks & actual intrusions good
  - Torrent of excessive information about routine attempted attacks → shutoff
- Internet hosts probed & attacked within hours of being put online
- Observing which GSDs are reporting attacks can signal failure of upstream devices (more external perimeter defenses)
  - Can provide early warning of impending security system failure

Intrusion Prevention & Response (1)

Several types of reaction to intrusions:

- Connection termination:
  - Stop traffic using RST (connection reset)
  - On User Datagram Protocol (UDP), can use packet dropping to terminate connection
  - Good for known attacks on allowed paths
  - Can allow denial of service
  - Not useful in preventing unknown types
- Dynamic rule modification
  - Target specific originating addresses
  - But opens even more to denial of service

Intrusion Prevention & Response (2)



- System-level actions
  - Monitor for compromise
  - Firewall deactivation
  - But be sure that shutting down FW STOPS traffic, not leaves it open!
- Application inspection
  - Check for known protocol-specific exploits
  - E.g., use signatures to spot HTTP-specific attacks such as cross-site scripting (XSS) & SQL query injection attacks
- Antimalware
  - Spot malware in transit
  - Hijack Web session to divert download to quarantine

Personal & Desktop Agents

- Individual hosts (workstations)
  - Must be protected individually
  - Can use sophisticated contextual scanning
- End Point Protection
  - Mobile devices (laptop, phone) become extensions of network protection profile
  - Network location: Rules may vary depending on whether device is inside or outside perimeter
  - Application access: restrict inbound and outbound access depending on which program is running
  - Hybrid protections: spot particular patterns tied to known attack scenarios

Additional Roles

- Encryption
- Acceleration
- Content Control
- IPv6

Encryption (1)

- Many GSDs support encryption
  - Important because encrypted packets could contain dangerous payload
- Inspection
  - Termination: packet decrypted at perimeter
    - ✓Contents inspected
    - ✓May be re-encrypted for transmission to internal end-point
  - Alternative is passive (simultaneous) decryption using escrowed keys
    - ✓But original encrypted packet continues to target while FW decrypts contents
    - ✓Thus there are issues of synchronization

Encryption (2): VPNs

- Virtual Private Networks
- Extend security perimeter to include remote systems
- Increasingly popular
- But should consider special rules for VPN clients
  - May not be owned by organization
  - Need to establish clean operating environment
  - Especially important to prevent malware from entering corporate systems

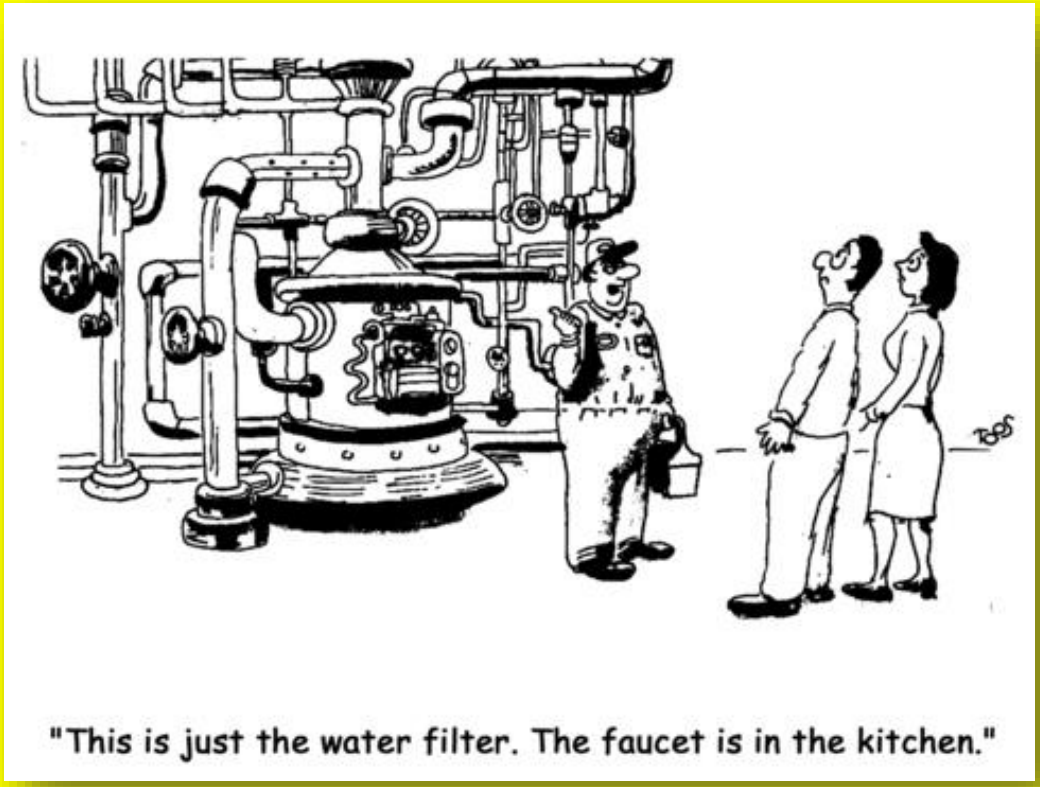
See CSH6 Chapter 32 for more about VPNs

Acceleration

- SSL (Secure Sockets Layer)
  - Most frequently used encryption protocol
  - Defines HTTPS
  - Widely used on Web for e-commerce
- Many high-volume servers equipped with dedicated encryption appliances
  - Manage throughput
  - Avoid letting encryption/decryption become bottleneck on processing

Content Control (1)

- Content filtering
  - Policy enforcement
  - Address-based filtering can block some sites (sometimes by mistake)
  - Keyword scanning has many false positives
- Antimalware
  - Pervasive element of all networks and workstations
  - Includes scans for harmful e-mail attachments, spam
  - Often uses appliances on network side to speed throughput



Content Control (2)

See CSH6 Chapter 17 for more about mobile code

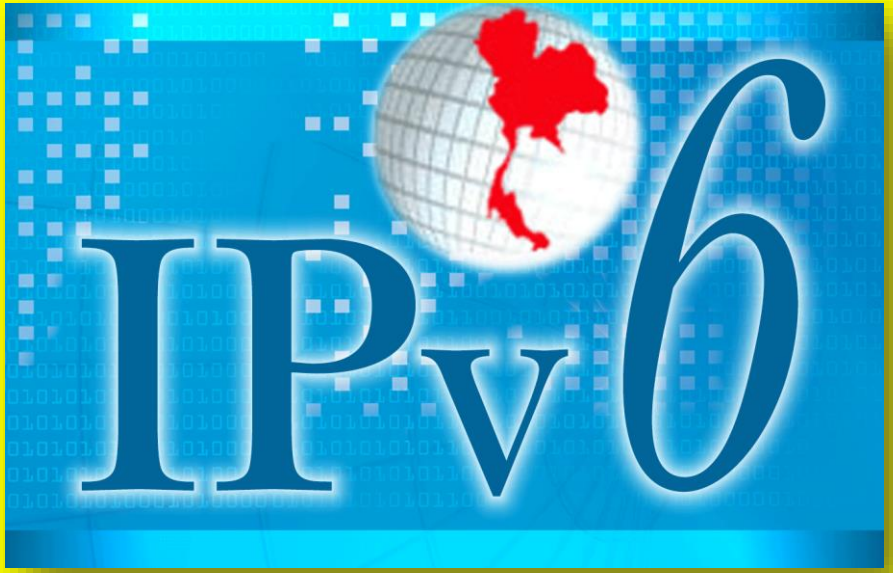
- Active Content
  - Flash, QuickTime, ActiveX, VBScript, JavaScript
  - Many GSDs scan for and block such code
  - Others use signatures and sandboxes to screen hostile code
- Caching
  - Proxy servers keep copies of frequently-used items
  - Typically for HTTP, FTP, streaming media
- Policy Enforcement
  - Can scan e-mail for sensitive keywords
  - Can require encryption for specific communications

IPv6 (1)

- Successor to IPv4 (current standard)
- Support & compatibility
  - GSDs must support appropriate protocols
    - ✓Neighbor discovery (ND)
    - ✓Router solicitation/advertisement (RS/RA)
    - ✓Multicast listener discovery (MLD)
  - Stateless autoconfiguration
    - ✓IPv6 nodes may assign their own addresses
    - ✓Can discover their own routers using NS, RS/RA – but may break user/address audit trail (use MAC addresses for hardware nodes)

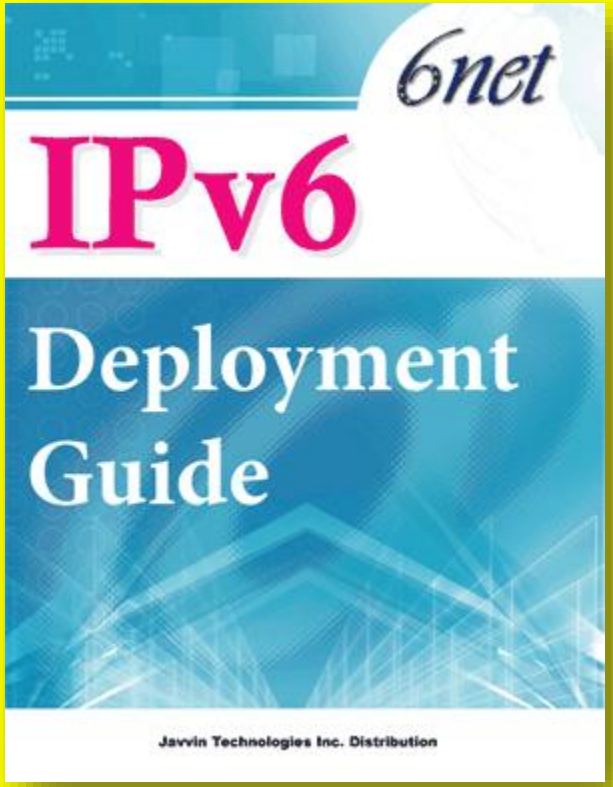
IPv6 (2)

- Address shortage resolved
  - IPv4 address space = $2^{32} \approx 10^{9}$
  - IPv6 address space = $2^{128} \approx 10^{38}$
  - Ratio is IPv6:IPv4::solar system:stamp!
- Be careful about IPv6 traffic tunneling through IPv4 infrastructure
  - E.g., antispoofing benefits of IPv6 lost when using IPv4-to-IPv6 gateways



IPv6 (3)

- NAT not intended to survive transition
  - IPv6 may expose IPv4 nodes when NAT removed
- Single IP address associated with specific device (node)
  - Can carry address from internal network to external network
  - Example: laptop starts session in office but moves to café – same IP address
  - Will need new developments to cope with device-specific IPv6 addresses



Deployment

- Screened Subnet FW Architectures
- Gateway Protection Device Positioning
- Management & Monitoring Strategies

Screened Subnet FW Architectures

- Service Networks
  - New design strategy: don't lump Web, DNS, e-mail into single network (NW)
  - Break functional components into separate, protected NW
  - Defines *service NW* with their own security configurations, policies

- Redirect Back-End Traffic Through FW
  - Just because FW decrypts packet doesn't mean it's necessarily safe
  - Reroute decrypted packet through FW before allowing it to reach internal destination

Gateway Protection Device Positioning (1)

- Encrypting protocols (e.g., SSL & IPSec) can pose problems
  - Bandwidth chokepoints due to processing requirements
  - Ideally, deploy GSDs where there is little encrypted traffic
- Two major approaches (details on following slides):
  - Put GSDs inline
  - Avoid encrypted traffic

Gateway Protection Device Positioning (2)

- Inline
  - Configure *span port* to replicate data from one or more switch ports to monitoring port
  - Problems
    - ✓Can overload the monitor (too many inputs)
    - ✓Passive devices don't offer protection, only alerts (so dangerous packets already gone)

  - Thus should put GSD inline with traffic
    - ✓Provides choke point (but device can have *wire speed* bandwidth)
    - ✓Allows active prevention (blockage)
    - ✓But be sure to configure properly to avoid DoS

Gateway Protection Device Positioning (3)

- Avoid encrypted traffic
  - Encrypted packets defeat GSDs
  - Therefore GSD must evaluate packets on unencrypted side of encrypted connection
    - ✓E.g., on backside of SSL terminator
    - ✓On unencrypted side of VPN connection
  - Implies likelihood of more than one GSD

Management & Monitoring Strategies

- Monitoring
- Policy
- Auditing/Testing
- Maintenance
- Logging & Alerting
- Secure Configurations
- Disaster Recovery

Monitoring

- Device Health (may be part of GSD system)
  - Processor utilization
  - Available RAM
  - Number of connections
  - May have to use SNMP, RMON tools
  - Restrict access by monitoring tools
  - Examine trends
- Availability
  - Periodically test functionality
  - *ping, traceroute*
- Integrity
  - Ensure that operating code cannot be / has not been modified without authorization
  - Checksums, utility scanner….

Policy (1)

- *GSDs instantiate policy!*
  - Look for centralized management consoles
- Firewall-allowed paths
  - Every allowed path must relate to specific *required* external service
  - Start with deny-all basis and add allowed paths
  - To degree possible, identify endpoints in rules
  - Keep track of *direction* of connections (inbound vs outbound)

Policy (2)

- Complexity of GSD policies
  - Standard FW rules are simple Boolean logic
  - But GSDs may require multistage rules
    - ✓Origination addresses
    - ✓Message contents
    - ✓Attachments virus-free
- Change management
  - Must control & track policy changes & implementation
  - Can thus backout mistakes
  - Audit trail important for security incident analysis

Policy (3)

- Secondary validation
  - Making changes can be easy
  - But complex systems can result in unexpected errors
  - Having second network / system admin check proposed change helpful
    - ✓Avoid errors
    - ✓Share knowledge
    - ✓Enforce security principle of shared responsibility, checks-and-balances

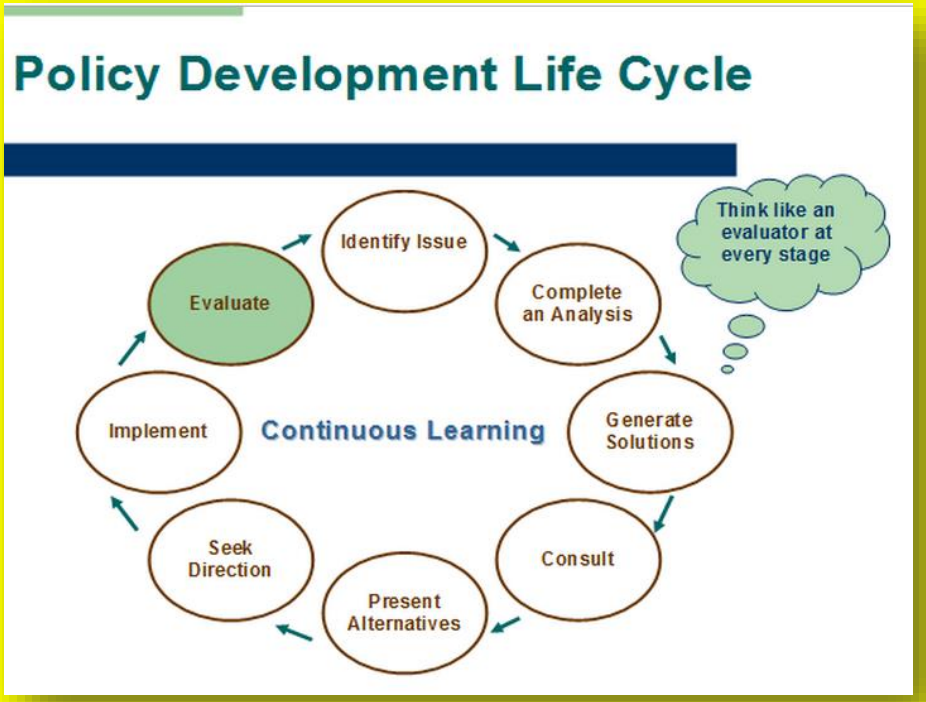


Image from http://www.policynl.ca/policydevelopment/images/policy-development-life-cycle.png

Auditing/Testing

- How do we know our GSDs are working?
  - Auditing: do the actual rules comply with the rules we claim to want according to policy?
  - Assessment: are the rules working as we want / expect?
- Vulnerability assessment (VA)
  - Walkthrough, tools for examining parameters
- Penetration ("Pen") testing
  Actually trying to break through the GSD

See *CSH6* Chapter 46 for VA/Pen Testing & Chapter 54 for audits

Maintenance

- Patching – see *CSH6* Chapter 40
- Pattern updates
  - Automatic updates a must to get files promptly
  - But production environment cannot automatically trust patches
    - ✓Have monitor-mode to see if new signatures work properly & safely
    - ✓Then enable for action as approved by QA team
  - Alternative is to install on completely separate non-production systems for testing

Logging & Alerting

- Logging essential
  - Must be able to access data on allowed / denied packets
  - Record of system changes
- Alert mechanisms
  - Configurable
  - Whom to alert?
  - How (e-mail? IM? Phone w/ robot voice?)
- Log files
  - Can eat up disk space
  - Plan for backups to cheaper media
  - May configure to exclude safe traffic
  - Need log file utilities to extract & format data

Secure Configurations

- Ensure that GSDs are themselves secure against tampering, error
- Define baseline secure configurations
- Default configuration may be inadequate
- Implied rules
  - Must be made explicit & examined
  - May modify or disable as required
- Ancillary exposures
  - Administrative console can reveal unsuspected functions, services
  - Can disable unused functions, services

Disaster Recovery

See CSH6 Chapters 56-59

- FW or GSD outage can cripple system or leave it wide open to attack
- Fail-over/high availability
  - May need to configure active/standby units
    - ✓Instant cutover
- Load-balancing configurations
  - Provide better throughput
  - Also serves for business continuity
- Backup/restore
  - Be sure all configuration scripts are backed up
  - Be able to re-establish known-good configuration ASAP

Network Security Device Evaluation

- Current Infrastructure Limitations
- New Infrastructure Requirements
- Performance
- Management
- Usability
- Price
- Vendor Considerations
- Managed Security Service Providers

§26.5 provides checklists for evaluating GDSs

Will Firewalls Ever Be Perfect?

Now go and study