Lecture 26
November 23, 2022

Firewalls

- Host that mediates access to a network
  - Allows, disallows accesses based on configuration and type of access
- Example: block Conficker worm
  - Conficker connects to botnet, which can use system for many purposes
    - Spreads through a vulnerability in a particular network service
  - Firewall analyze packets using that service remotely, and look for Conficker and its variants
    - If found, packets discarded, and other actions may be taken
  - Conficker also generates list of host names, tried to contact botnets at those hosts
    - As set of domains known, firewall can also block outbound traffic to those hosts

Filtering Firewalls

- Access control based on attributes of packets and packet headers
  - Such as destination address, port numbers, options, etc.
  - Also called a *packet filtering firewall*
  - Does not control access based on content
  - Examples: routers, other infrastructure systems

Proxy

- Intermediate agent or server acting on behalf of endpoint without allowing a direct connection between the two endpoints
  - So each endpoint talks to proxy, thinking it is talking to other endpoint
  - Proxy decides whether to forward messages, and whether to alter them

Proxy Firewall

- Access control done with proxies
  - Usually bases access control on content as well as source, destination addresses, etc.
  - Also called an *applications level* or *application level firewall*
  - Example: virus checking in electronic mail
    - Incoming mail goes to proxy firewall
    - Proxy firewall receives mail, scans it
    - If no virus, mail forwarded to destination
    - If virus, mail rejected or disinfected before forwarding

Example

- Want to scan incoming email for malware
- Firewall acts as recipient, gets packets making up message and reassembles the message
  - It then scans the message for malware
  - If none, message forwarded
  - If some found, mail is discarded (or some other appropriate action)
- As email reassembled at firewall by a mail agent acting on behalf of mail agent at destination, it's a proxy firewall (application layer firewall)

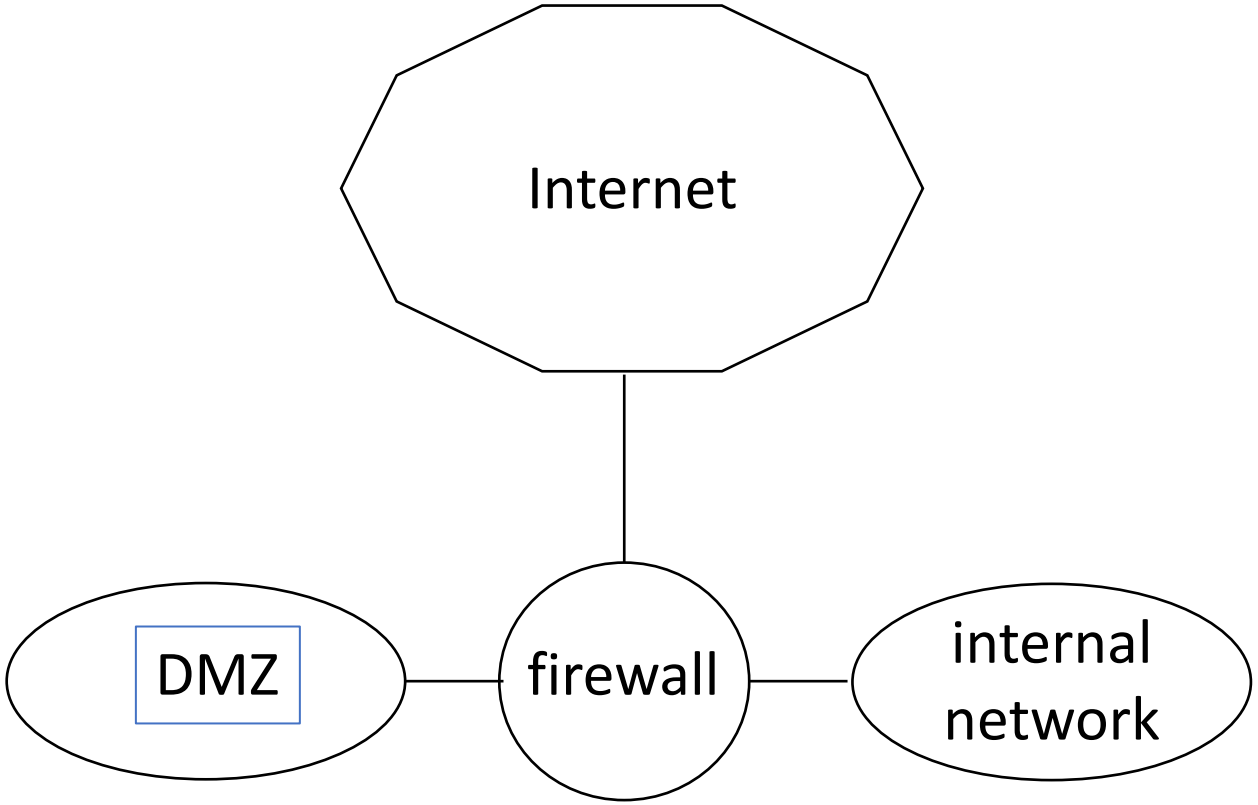
Stateful Firewall

- Keeps track of the state of each connection
- Similar to a proxy firewall
  - No proxies involved, but this can examine contents of connections
  - Analyzes each packet, keeps track of state
  - When state indicates an attack, connection blocked or some other appropriate action taken

Network Organization: DMZ

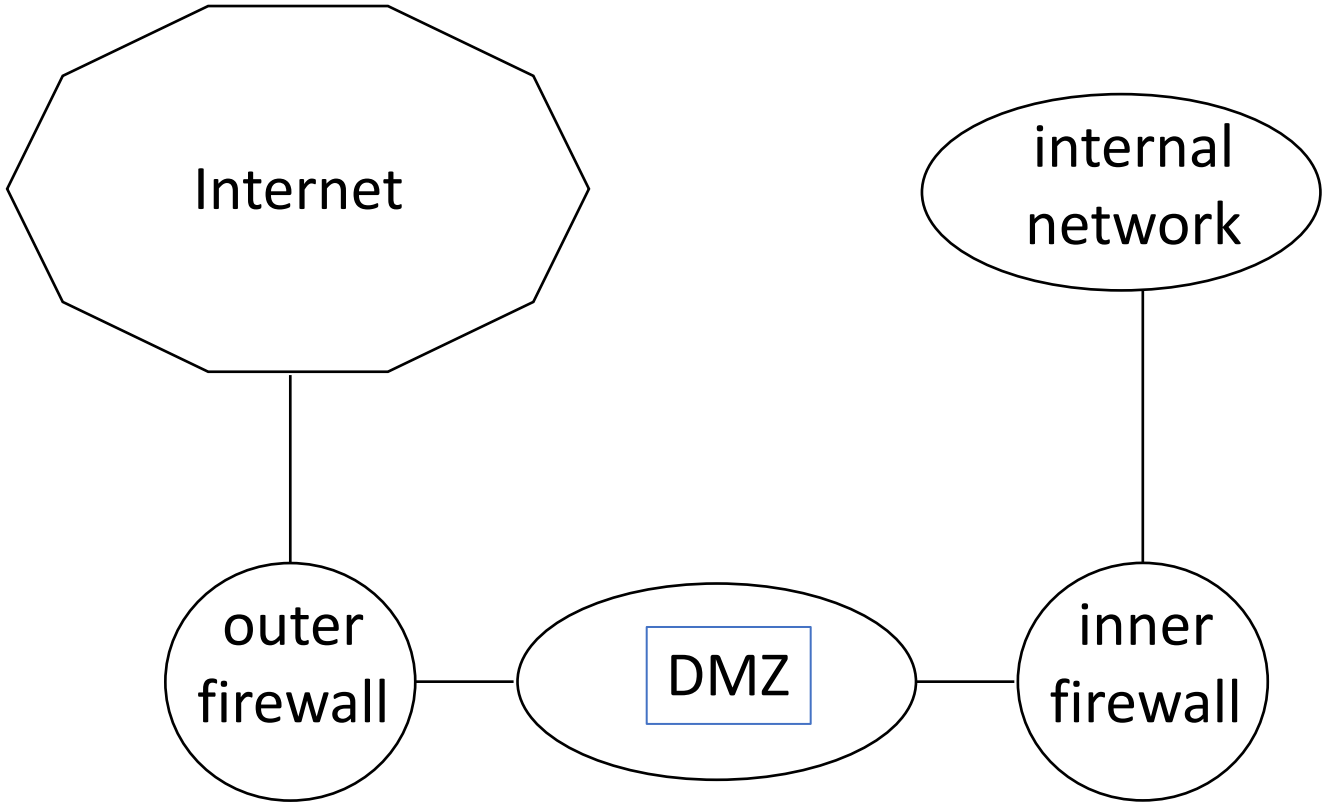
- DMZ is portion of network separating a purely internal network from external network
- Usually put systems that need to connect to the Internet here
- Firewall separates DMZ from purely internal network
- Firewall controls what information is allowed to flow through it
  - Control is bidirectional; it control flow in both directions

One Setup of DMZ



One dual-homed firewall that routes messages to internal network or DMZ as appropriate

Another Setup of DMZ



Two firewalls, one (outer firewall) connected to the Internet, the other (inner firewall) connected to internal network, and the DMZ is between the firewalls

Identity

- *Principal*: a unique entity
- *Identity*: specifies a principal
- *Authentication*: binding of a principal to a representation of identity internal to the system
  - All access, resource allocation decisions assume binding is correct

Files and Objects

- Identity depends on system containing object
- Different names for one object
  - Human use, *eg*. file name
  - Process use, *eg.* file descriptor or handle
  - Kernel use, *eg*. file allocation table entry, inode

More Names

- Different names for one context
  - Human: aliases, relative *vs*. absolute path names
  - Kernel: deleting a file identified by name can mean two things:
    - Delete the object that the name identifies
    - Delete the name given, and do not delete actual object until *all* names have been deleted
- Semantics of names may differ

Example: Names and Descriptors

- Interpretation of UNIX file name
  - Kernel maps name into an inode using iterative procedure
  - Same name can refer to different objects at different times without being deallocated
    - Causes race conditions
- Interpretation of UNIX file descriptor
  - Refers to a specific inode
  - Refers to same inode from creation to deallocation

Example: Different Systems

- Object name must encode location or pointer to location
  - *SSH* style: *host*:*object*
  - URLs: *protocol*://*host*/*object*
- Need not name actual object
  - *SSH* style may name pointer (link) to actual object
  - URL may forward to another host

Users

- Exact representation tied to system
- Example: UNIX/Linux systems
  - Login name: used to log in to system
    - Logging usually uses this name
  - User identification number (UID): unique integer assigned to user
    - Kernel uses UID to identify users
    - One UID per login name, but multiple login names may have a common UID

Multiple Identities

- UNIX systems again
  - Real UID: user identity at login, but changeable
  - Effective UID: user identity used for access control
    - Setuid changes effective UID
  - Saved UID: UID before last change of UID
    - Used to implement least privilege
    - Work with privileges, drop them, reclaim them later
  - Audit/Login UID: user identity used to track original UID
    - Cannot be altered; used to tie actions to login identity

Groups

- Used to share access privileges
- First model: alias for set of principals
  - Processes assigned to groups
  - Processes stay in those groups for their lifetime
- Second model: principals can change groups
  - Rights due to old group discarded; rights due to new group added

Roles

- Group with membership tied to function
  - Rights given are consistent with rights needed to perform function
- Uses second model of groups
- Example: DG/UX
  - User *root* does not have administration functionality
  - System administrator privileges are in *sysadmin* role
  - Network administration privileges are in *netadmin* role
  - Users can assume either role as needed

Naming and Certificates

- Certificates issued to a principal
  - Principal uniquely identified to avoid confusion
- Problem: names may be ambiguous
  - Does the name “Matt Bishop” refer to:
    - The author of this book?
    - A programmer in Australia?
    - A stock car driver in Muncie, Indiana?
    - Someone else who was named “Matt Bishop”

Disambiguating Identity

- Include ancillary information in names
  - Enough to identify principal uniquely
  - X.509v4 Distinguished Names do this
- Example: X.509v4 Distinguished Names
  - /O=University of California/OU=Davis campus/OU=Department of Computer Science/CN=Matt Bishop/

    refers to the Matt Bishop (CN is *common name*) in the Department of Computer Science (OU is *organizational unit*) on the Davis Campus of the University of California (O is *organization*)

CAs and Policies

- Matt Bishop wants a certificate from Certs-from-Us
  - How does Certs-from-Us know this is “Matt Bishop”?
    - CA’s *authentication policy* says what type and strength of authentication is needed to identify Matt Bishop to satisfy the CA that this is, in fact, Matt Bishop
  - Will Certs-from-Us issue this “Matt Bishop” a certificate once he is suitably authenticated?
    - CA’s *issuance policy* says to which principals the CA will issue certificates

Example: Verisign CAs

- Class 1 CA issued certificates to individuals
  - Authenticated principal by email address
    - Idea: certificate used for sending, receiving email with various security services at that address
- Class 2 CA issued certificates to individuals
  - Authenticated by verifying user-supplied real name and address through an online database
    - Idea: certificate used for online purchasing

Example: Verisign CAs

- Class 3 CA issued certificates to individuals
  - Authenticated by background check from investigative service
    - Idea: higher level of assurance of identity than Class 1 and Class 2 CAs
- Fourth CA issued certificates to web servers
  - Same authentication policy as Class 3 CA
    - Idea: consumers using these sites had high degree of assurance the web site was not spoofed

Registration Authority

- Third party. delegated by CA the authority to check data to be put into certificate
  - This includes identity
- RA determines whether CA's requirements are met
- If do, then it informs CA to issue certificates

Internet Certification Hierarchy

- Tree structured arrangement of CAs
  - Root is *Internet Policy Registration Authority*, or IPRA
    - Sets policies all subordinate CAs must follow
    - Certifies subordinate CAs (called *policy certification authorities*, or PCAs), each of which has own authentication, issuance policies
    - Does not issue certificates to individuals or organizations other than subordinate CAs
  - PCAs issue certificates to ordinary CAs
    - Does not issue certificates to individuals or organizations other than subordinate CAs
  - CAs issue certificates to organizations or individuals

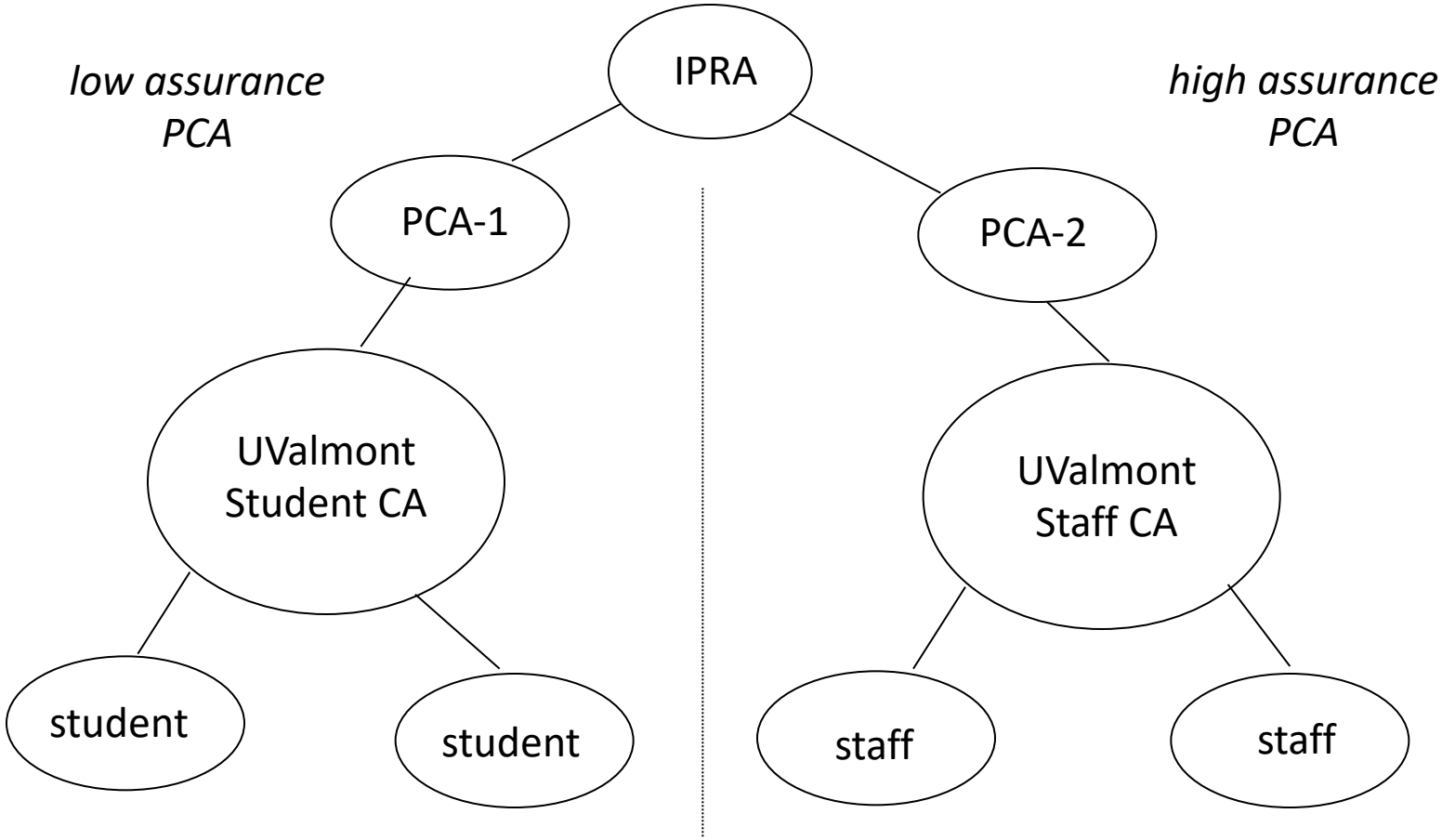
Example

- University of Valmont issues certificates to students, staff
  - Students must present valid reg cards (considered low assurance)
  - Staff must present proof of employment and fingerprints, which are compared to those taken when staff member hired (considered high assurance)

UValmont and PCAs

- First PCA: requires subordinate CAs to make good-faith effort to verify identities of principals to whom it issues certificates
  - Student authentication requirements meet this
- Second PCA: requires use of biometrics to verify identity
  - Student authentication requirements do not meet this
  - Staff authentication requirements do meet this
- UValmont establishes to CAs, one under each PCA above

UValmont and Certification Hierarchy



Certificate Differences

- Student, staff certificates signed using different private keys (for different CAs)
  - Student's signed by key corresponding to low assurance certificate signed by first PCA
  - Staff's signed by key corresponding to high assurance certificate signed by second PCA
- To see what policy used to authenticate:
  - Determine CA signing certificate, check its policy
  - Also go to PCA that signed CA's certificate
    - CAs are restricted by PCA's policy, but CA can restrict itself further

Types of Certificates

- Organizational certificate
  - Issued based on principal's affiliation with organization
  - Example Distinguished Name

    /O=University of Valmont/OU=Computer Science Department/CN=Marsha Merteuille/
- Residential certificate
  - Issued based on where principal lives
  - No affiliation with organization implied
  - Example Distinguished Name

    /C=US/SP=Louisiana/L=Valmont/PA=1 Express Way/CN=Marsha Merteuille/

Certificates for Roles

- Certificate tied to a role
- Example
  - UValmont wants comptroller to have a certificate
    - This way, she can sign contracts and documents digitally
  - Distinguished Name

    /O=University of Valmont/OU=Office of the Big Bucks/RN=Comptroller/

    where “RN” is *role name*; note the individual using the certificate is not named, so no CN

Certificate Principal Identifiers

- Need not be Distinguished Names
  - Example: PGP certificates usually have email addresses, not Distinguished Names
- Permits ambiguity, so the user of the certificate may not be sure to whom it refers
  - Email addresses change often, particularly if work email addresses used
- Problem: how do you prevent naming conflicts?

Naming Conflicts

- X.509, PGP silent
  - Assume CAs will prevent name conflicts as follows
    - No two distinct CAs have the same Distinguished Name
    - No two principals have certificates issued containing the same Distinguished Name by a single CA

Internet Certification Hierarchy

- In theory, no naming collisions
  - IPRA requires each PCA to have a unique Distinguished Name
  - No PCA may certify two distinct CAs with same Distinguished Name
- In practice, considerable confusion possible!

Example Collision

John Smith, John Smith Jr. live at same address

- John Smith Jr. applies for residential certificate from Certs-from-Us, getting the DN of:

  /C=US/SP=Maine/L=Portland/PA=1 First Ave./CN=John Smith/

- Now his father applies for residential certificate from Quick-Certs, getting DN of:

  /C=US/SP=Maine/L=Portland/PA=1 First Ave./CN=John Smith/

  because Quick-Certs has no way of knowing that DN is taken

Solutions

- Organizational certificates
  - All CA DNs must be superior to that of the principal
  - Example: for Marsha Merteuille's DN:

    /O=University of Valmont/OU=Computer Science Department/CN=Marsha Merteuille/

    DN of the CA must be either:

    /O=University of Valmont/

    (the issuer being the University) or

    /O=University of Valmont/OU=Computer Science Department/

    (the issuer being the Department)

Solutions

- Residential certificates
  - DN collisions explicitly allowed (in above example, no way to force disambiguation)

    /C=US/SP=Maine/L=Portland/PA=1 First Ave./CN=John Smith/

    Unless names of individuals are different, how can you force different names in the certificates?

Related Problem

- Single CA issues two types of certificates under two different PCAs
- Example
  - UValmont issues both low assurance, high assurance certificates under two different PCAs
  - How does validator know under which PCA the certificate was issued?
    - Reflects on assurance of the identity of the principal to whom certificate was issued

Solution

- CA Distinguished Names need *not* be unique
- CA (Distinguished Name, public key) pair *must* be unique
- Example
  - In earlier UValmont example, student validation required using first PCA's public key; validation using second PCA's public key would fail
  - Keys used to sign certificate indicate the PCA, and the policy, under which certificate is issued

Meaning of Identity

- Authentication validates identity
  - CA specifies type of authentication
  - If incorrect, CA may misidentify entity unintentionally
- Certificate binds *external* identity to crypto key and Distinguished Name
  - Need confidentiality, integrity, anonymity
    - Recipient knows same entity sent all messages, but *not* who that entity is

Persona Certificate

- Certificate with meaningless Distinguished Name
  - If DN is
    /C=US/O=Microsoft Corp./CN=Bill Gates/
    the real subject may not (or may) be Mr. Gates
  - Issued by CAs with persona policies under a PCA with policy that supports this
- PGP certificates can use any name, so provide this implicitly

Example

- Government requires all citizens with gene X to register
  - Anecdotal evidence people with this gene become criminals with probability 0.5.
  - Law to be made quietly, as no scientific evidence supports this, and government wants no civil rights fuss
- Government employee wants to alert media
  - Government will deny plan, change approach
  - Government employee will be fired, prosecuted
- Must notify media anonymously

Example

- Employee gets persona certificate, sends copy of plan to media
  - Media knows message unchanged during transit, but not who sent it
  - Government denies plan, changes it
- Employee sends copy of new plan signed using same certificate
  - Media can tell it's from original whistleblower
  - Media cannot track back whom that whistleblower is