

INF3510 Information Security

University of Oslo

Spring 2011

Lecture 10

Perimeter Security



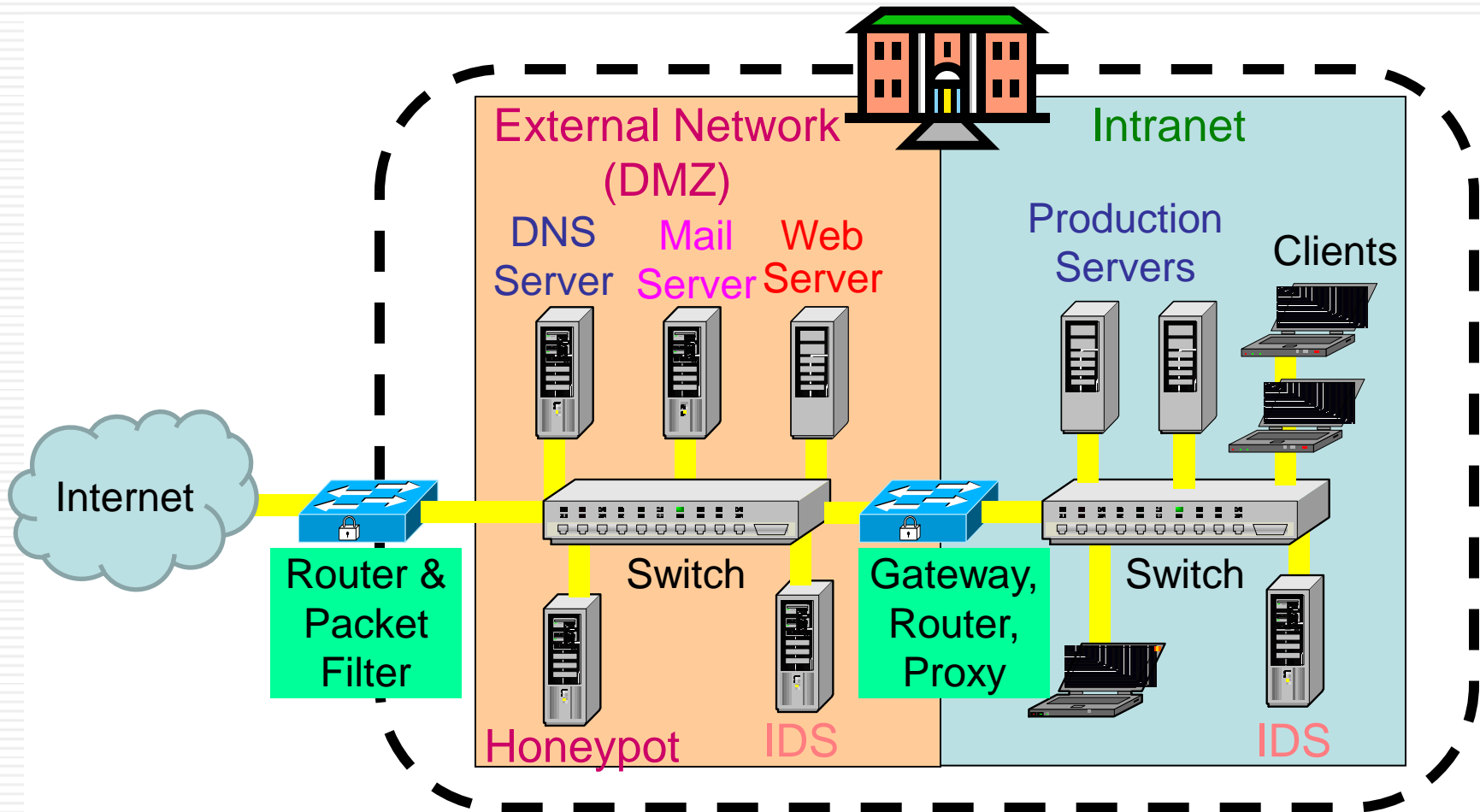
Audun Jøsang

Outline

- Firewalls
 - Routers
 - Proxies
 - Architectures
- Intrusion Detection Systems
 - Host-based
 - Network based
 - Dealing with false alarms
- Wireless LAN Security
 - Evolution & history
 - RSN (Robust Security Network) architecture

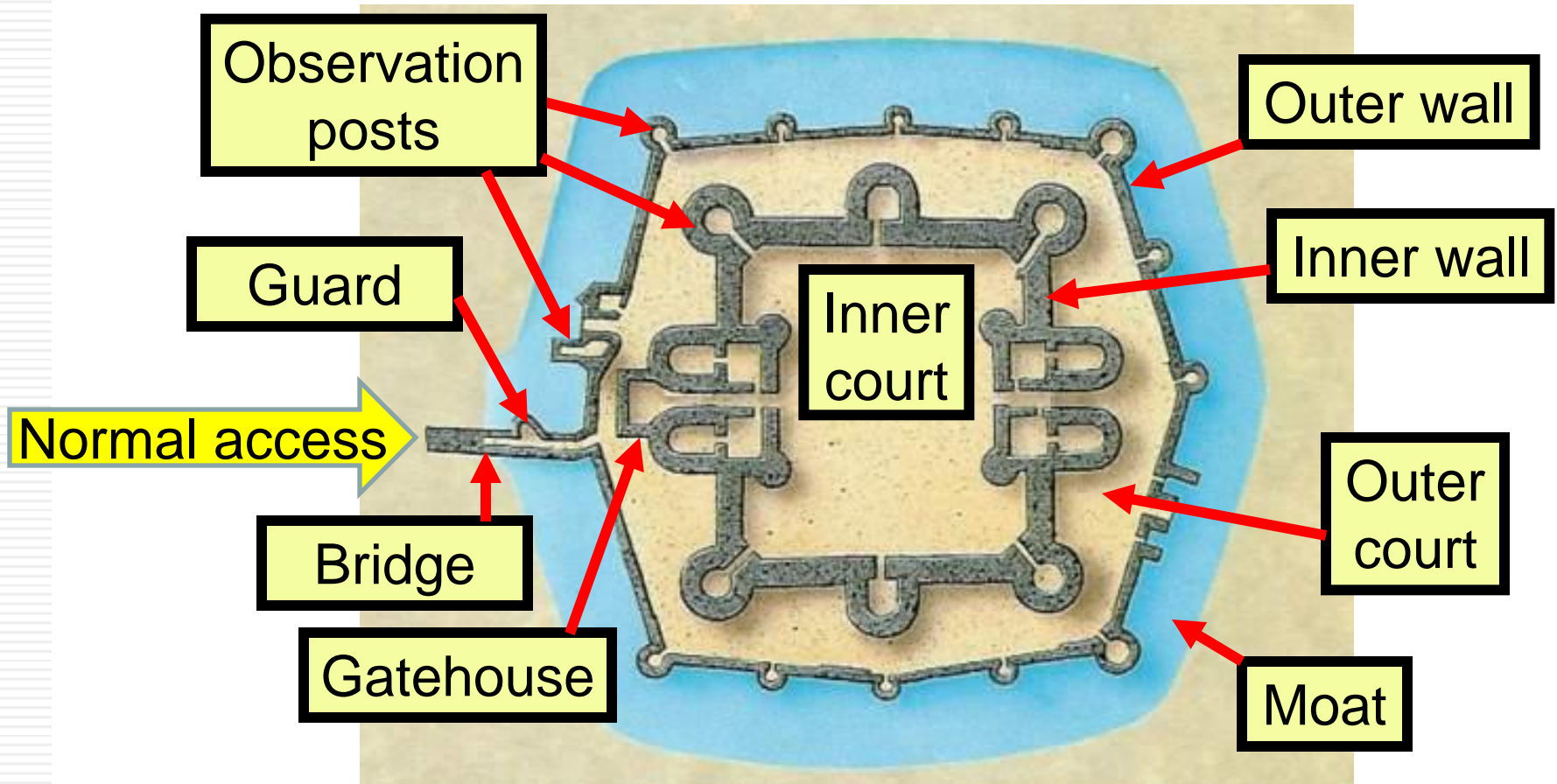
Perimeter Security Paradigm

Organisation network defences



Perimeter Security Analogy

Castle Defences



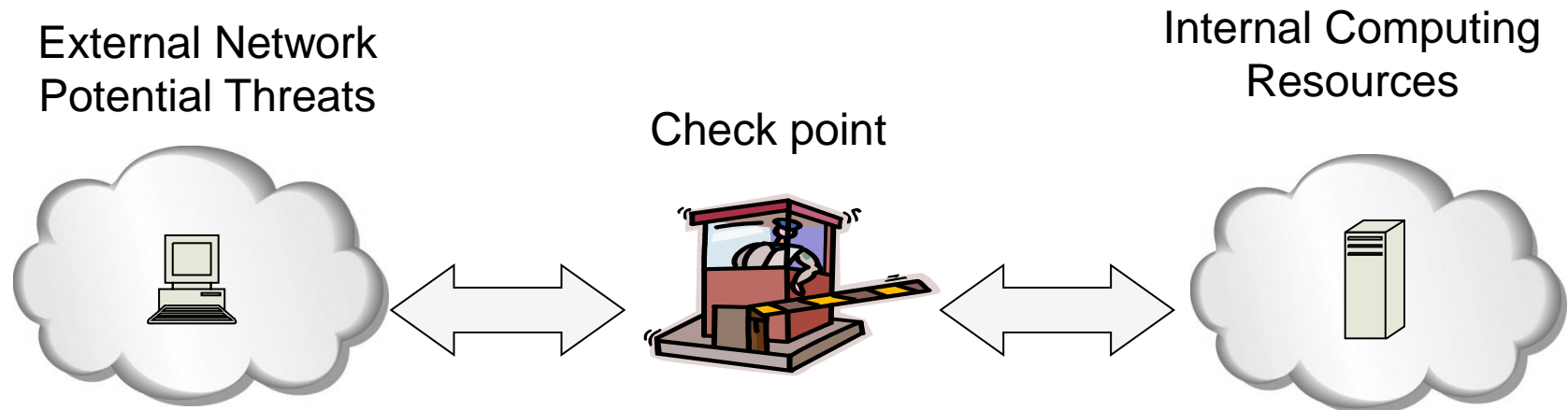
Network Perimeter Security Functions

- Firewalls operate as a checkpoint to filter traffic going in and out: e.g. routers, gateways, proxies
 - The term “firewall” can give false associations and therefore be bad for security usability
 - Can also detect and reject worms, viruses, ...
- Intrusion detection: internal controls to monitor and analyze activity in order to detect intruders.
- Honeypots: traps with non-published network services. Access is by definition malicious

Firewalls

Network Perimeter Security Model: Firewalls

- A firewall is a check point that protects the internal networks against attack from outside network
- The check point function applies rules to decide which traffic can pass in and out



Firewalls:

Overview

- A firewall is a system designed to prevent unauthorized access to or from a private network.
- Firewalls can be implemented in both hardware and software, or a combination of both.
- Firewalls are frequently used to prevent unauthorized Internet users from accessing private networks connected to the Internet, especially intranets.
- All messages entering or leaving the intranet pass through the firewall, which examines each message and blocks those that do not meet the specified security criteria.

Firewalls:

Overview

- If the level of risk associated with maintaining a connection between an organisation's internal network and the Internet (or some other network(s)) is unacceptable, the most effective way of treating the risk is to avoid the risk altogether and disconnect completely.
- If this is not possible, then firewalls may provide an effective control suitable for reducing the level of risk to an acceptable level.
- A firewall is a component or set of components that restricts access between a protected network and other sets of networks
 - Firewalls are often the first line of defence against attackers but should not be the only defence

Firewalls:

Overview

- Firewalls must be effectively administered, updated with the latest patches and monitored.
- Firewalls are only effective if they are set up to implement a well formulated security policy
 - i.e. the most important aspect of a firewall is a clear conception of what it is meant to protect.
- Under the security policy, acceptable traffic must be clearly specified so that only specific traffic passes through the firewall; everything else is considered unacceptable and must be stopped by the firewall.

Firewalls:

Types of Firewall Technology

- Simple Packet Filters
- Stateful Packet Filters
- Application Gateways
- Circuit Level Gateways

Firewalls:

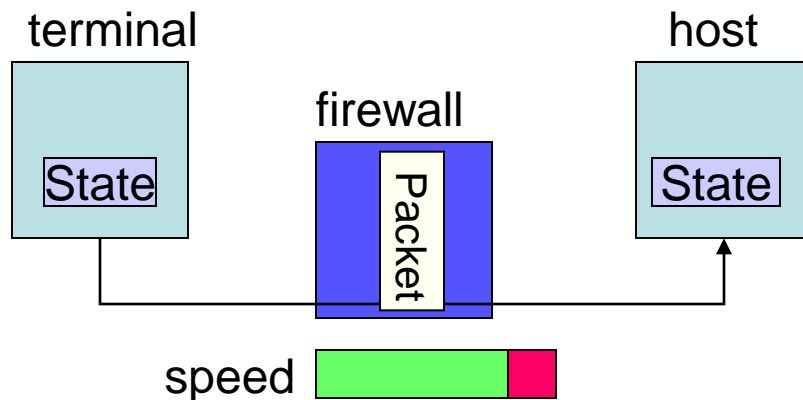
Router Packet Filter

- A network router function that accepts/rejects packets based on headers is referred to as a packet filter.
- Packet filters examine each packet's headers and make decisions based on attributes such as:
 - Source or Destination IP Addresses
 - Source or Destination Port Numbers
 - Protocol (UDP, TCP or ICMP)
 - ICMP message type
 - And which interface the packet arrived on

Firewalls:

Router Packet Filters

- A packet filter examines each packet that attempts to pass through the filter.
 - Usually this is done for both directions (entering and leaving a network/host)
- Each packet is examined independently of other packets that may be part of the same connection



Router Packet Filtering:
Packet header is inspected
Single packet attacks caught
Very little overhead in firewall
High volume filter

Firewalls:

Host-based Packet Filters

- Routers are commonly used as packet filters, in addition to normal routing duties
- A host can perform packet filtering as well as other duties, such as web serving
 - in this case the packet filter is designed to protect the host itself, not other hosts
- Common packet filter software includes:
 - IPChains for Linux (superseded)
 - TCP Wrappers for various Unix
 - IP Filter for Sun Solaris

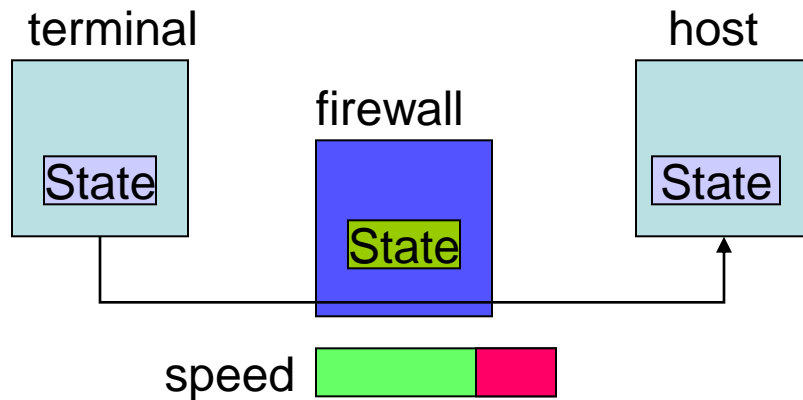
Firewalls:

Stateful Packet Filters

- Stateful packet filters take account of the current state of a connection
- Stateful packet filters are more 'intelligent' than simple packet filters.
- Stateful packet filters are able to recognise if a particular packet is part of an established connection by 'remembering' recent traffic history.
- This makes the definition of filtering rules easier to accomplish and therefore potentially more secure.

Stateful packet filter

- A stateful packet filter keeps track of sessions
- Requires memory
- Can be subject to DOS (Denial of Service) attacks



Stateful Inspection

Most multi-packet attacks caught
More fields in packet header inspected
Little overhead in firewall: quick

Firewalls:

Stateful Packet Filters

- Sometimes called dynamic packet filters due to their ability to add rules 'on the fly'. For example:
 - Can recognise an outgoing connection request from an internal client being sent to an external server,
 - And will add a temporary rule to allow the reply traffic back through the firewall.
 - When session is finished, the temporary rule is deleted.
- Common software packages include:
 - IPTables for Linux
 - Checkpoint Firewall-1
 - Cisco PIX (integrated hardware & software)
 - Microsoft Internet Security and Acceleration Server

Firewalls:

Packet Filter Strengths and Weaknesses

- Strengths:
 - Low overhead and high throughput
 - Supports almost any application
- Weaknesses:
 - Do not usually interpret application layer data/commands
 - may allow insecure operations to occur
 - Allows direct connection between hosts inside & outside firewall
 - Non-stateful packet filters only: less secure and more difficult to write complex rules

Firewalls:

Personal Firewalls

- A personal firewall is a program that is designed to protect the computer on which it is installed.
- Personal firewalls are frequently used by home users to protect themselves from the Internet.
- Personal firewalls are usually a stateful packet filter.
- Some products include anti-virus software as well (usually at extra cost).
 - Vendors such as ZoneAlarm, and Sygate provide a free version of their product for personal use.
 - Windows clients (XP, W7) and Windows servers ship with Internet Connection Firewall (ICF).

Firewalls:

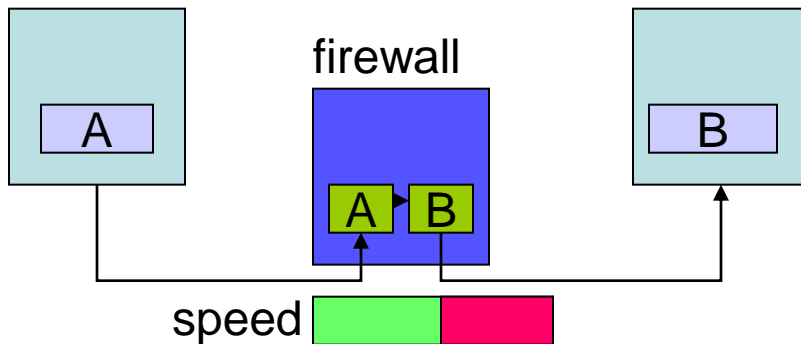
Circuit Level Gateways

- A circuit level gateway is a special type of application level gateway with reduced security checking.
- It acts as a relay of TCP/UDP layer data rather than application data, and usually no analysis of the application layer data is performed.
- Connections are validated before allowing data to be exchanged.
- Able to identify a particular packet as being part of a particular connection
 - Limited additional security checking once packet has been identified

Firewalls:

Circuit Level Gateway

- High performance possible due to limited security checking
- Similar strengths and weaknesses to stateful packet filters except
 - Can examine application layer data to a certain extent, but not up to application level gateway standards
 - E.g: Some control/blocking of insecure FTP commands



Circuit-Level Firewall:

Packet session terminated and recreated via a Proxy Server

All multi-packet attacks caught

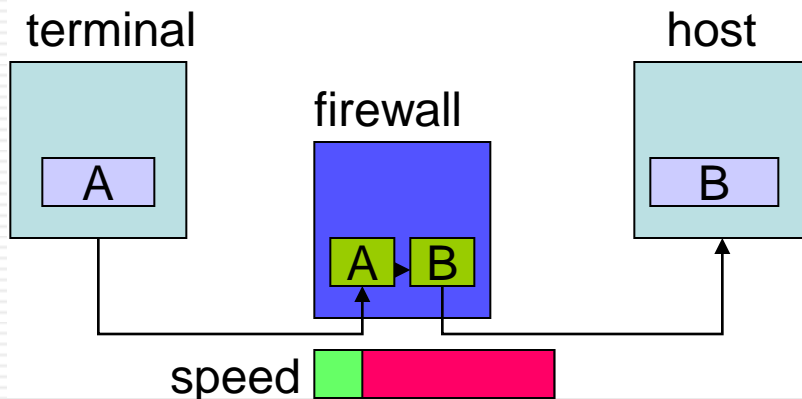
Packet header completely inspected

High overhead in firewall: slow

Firewalls:

Application Level Gateway

- Acts as a relay of application level traffic
- Also known as an application proxy because the firewall needs to act on behalf of the client
- Usually configured to support only specific applications or specific features of an application
 - each application supported by a specific gateway in the firewall



Application-Level Firewall

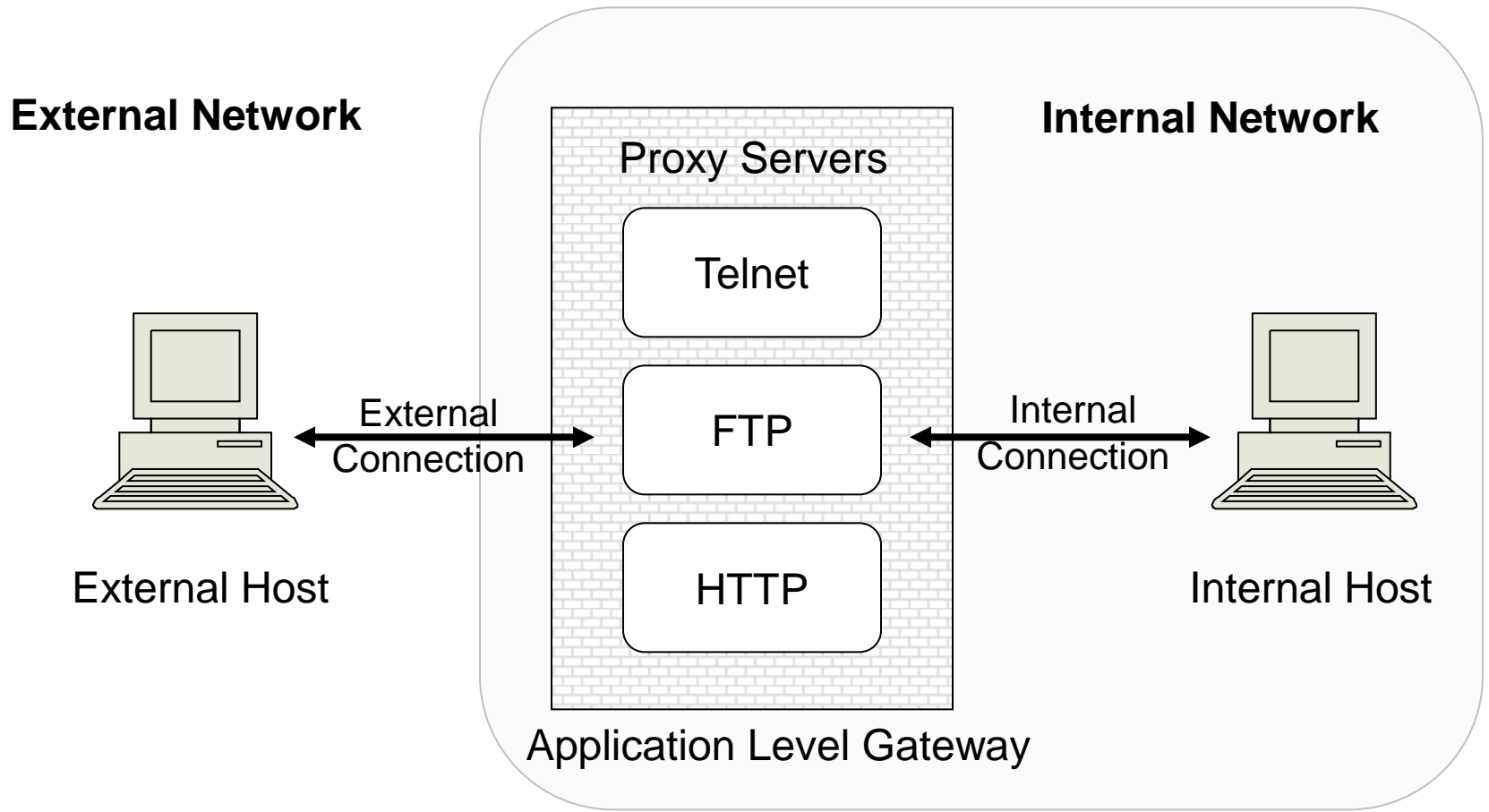
Packet session terminated and recreated via a Proxy Server

Packet header completely inspected

Most or all of application inspected

Highest overhead: slow & low volume

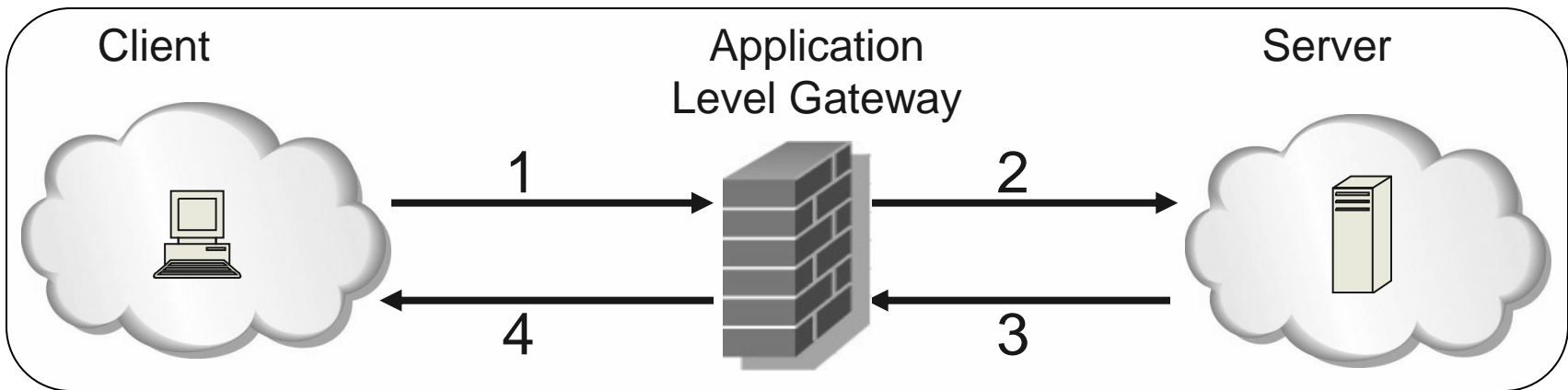
Firewalls: Application Level Gateway



Firewalls:

Application Level Gateway

- Client sends a request to the server, which is intercepted by the firewall (application gateway)
- Firewall sends the request to the server on behalf of client.
- Server sends reply back to the firewall.
- Firewall sends reply to the client.
- Both client and server think they are communicating with each other, not knowing the firewall exists. It is **transparent**.



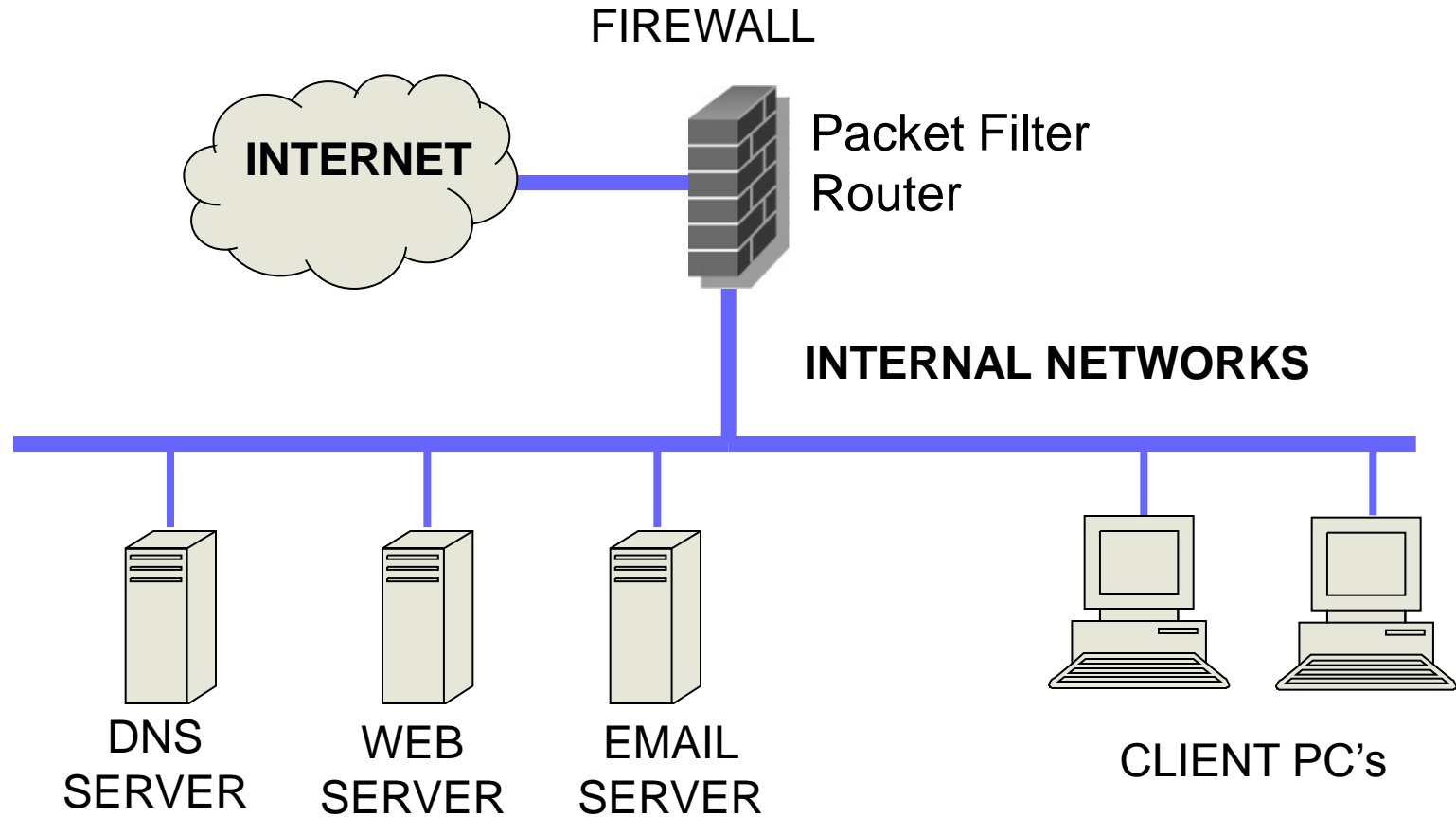
Firewalls:

Application Gateway

- **Strengths:**
 - Easy logging and audit of all incoming traffic
 - Provides potential for best security through control of application layer data/commands
- **Weaknesses:**
 - May require some time for vendor to write new gateways for new applications
 - Requires one more additional connection (including processing resources) for each new connection
 - Slower than packet filters

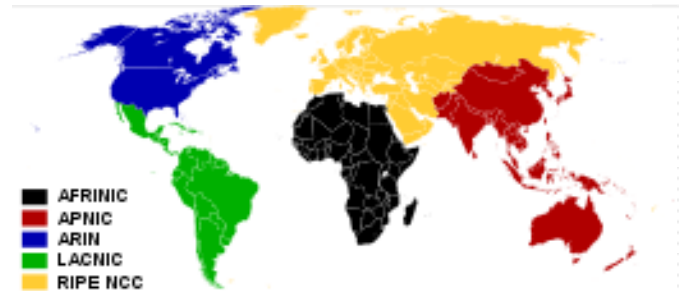
Firewalls:

Simple Firewall Architecture



IPv4 addresses

- IPv4 addresses of 32 bits $\rightarrow 2^{32} = 4,294,967,296$ unique addresses
- Represented as 4 decimal bytes separated by dots
 - e.g. www.uio.no = 129.240.8.200
- IANA (Internet Assigned Numbers Authority) assigns address blocks to the 5 different RIR (Regional Internet Registry) in the world
 - Last five remaining 24-bit-blocks (= /8 blocks) assigned in February 2011
 - APNIC RIR (Asia-Pacific Netw. Inf. Centre) runs out of addresses in April 2011
 - The 5 RIRs are:
 - AfriNIC (African Network Information Centre)
 - ARIN (American Registry for Internet Numbers)
 - APNIC (Asia-Pacific Network Information Centre)
 - LACNIC (Latin America and Caribbean Network Information Centre)
 - RIPE (Réseaux IP Européens Network Coordination Centre)
- Private non-routable address ranges:
 - 10.0.0.0 - 10.255.255.255 $\rightarrow 2^{24} = 16,777,216$ addresses
 - 172.16.0.0 - 172.31.255.255 $\rightarrow 2^{20} = 1,048,576$ addresses
 - 192.168.0.0 - 192.168.255.255 $\rightarrow 2^{16} = 65,536$ addresses



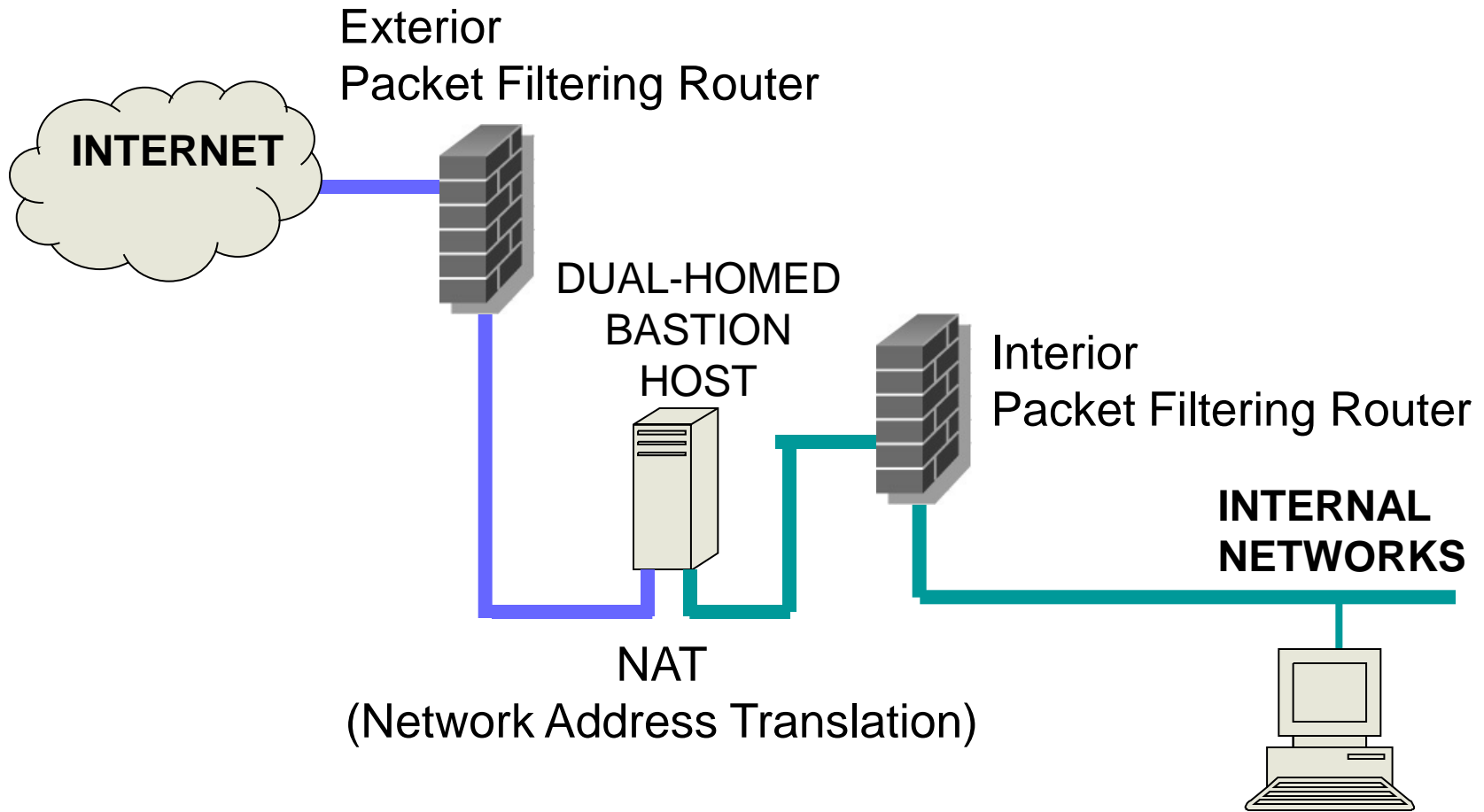
Network Address Translation (NAT)

- Translates public ↔ private addresses and ports
- Possibilities:
 - Static mapping
 - permanent mapping of public to private address
 - Dynamic mapping
 - mapping of public to private address when needed
 - unmapped when no longer needed
 - PAT (Port Address Translation)
 - multiple internal addresses mapped to same public address but with different port numbers

Network Address Translation (NAT)

- Advantages
 - Helps enforce control over outbound connections
 - Helps restrict incoming traffic
 - Helps conceal internal network configuration
 - Prevents port scanning
- Can't be used with:
 - protocols that require a separate back-channel
 - protocols that encrypt TCP headers
 - embed TCP address info
 - specifically use original IP for some security reason

Dual-Homed Screened Bastion Host and Network Address Translation



Screened Bastion-Host

- The Screened Bastion-Host is a dedicated firewall that comes in addition to the packet filtering routers
- Functions
 - Proxy for services in the internal network
 - Dual-homed, i.e. with separate NICs (Network Interface Cards)
 - Network Address Translation (NAT)
 - Protocol gateway for different link layer protocols

Intrusion Detection Systems

Intrusion Detection Systems: Overview

- Intrusion detection systems (IDS) are automated systems (programs) that detect suspicious events
- IDS can be either host-based or network-based.
- A host based IDS is designed to detect intrusions only on the host it is installed on
 - monitor changes to host's operating system files and traffic sent to the host
- Network based IDS are designed to detect intrusions on one or more network segments, usually deployed to protect a number of hosts
 - monitor network/s looking for suspicious traffic

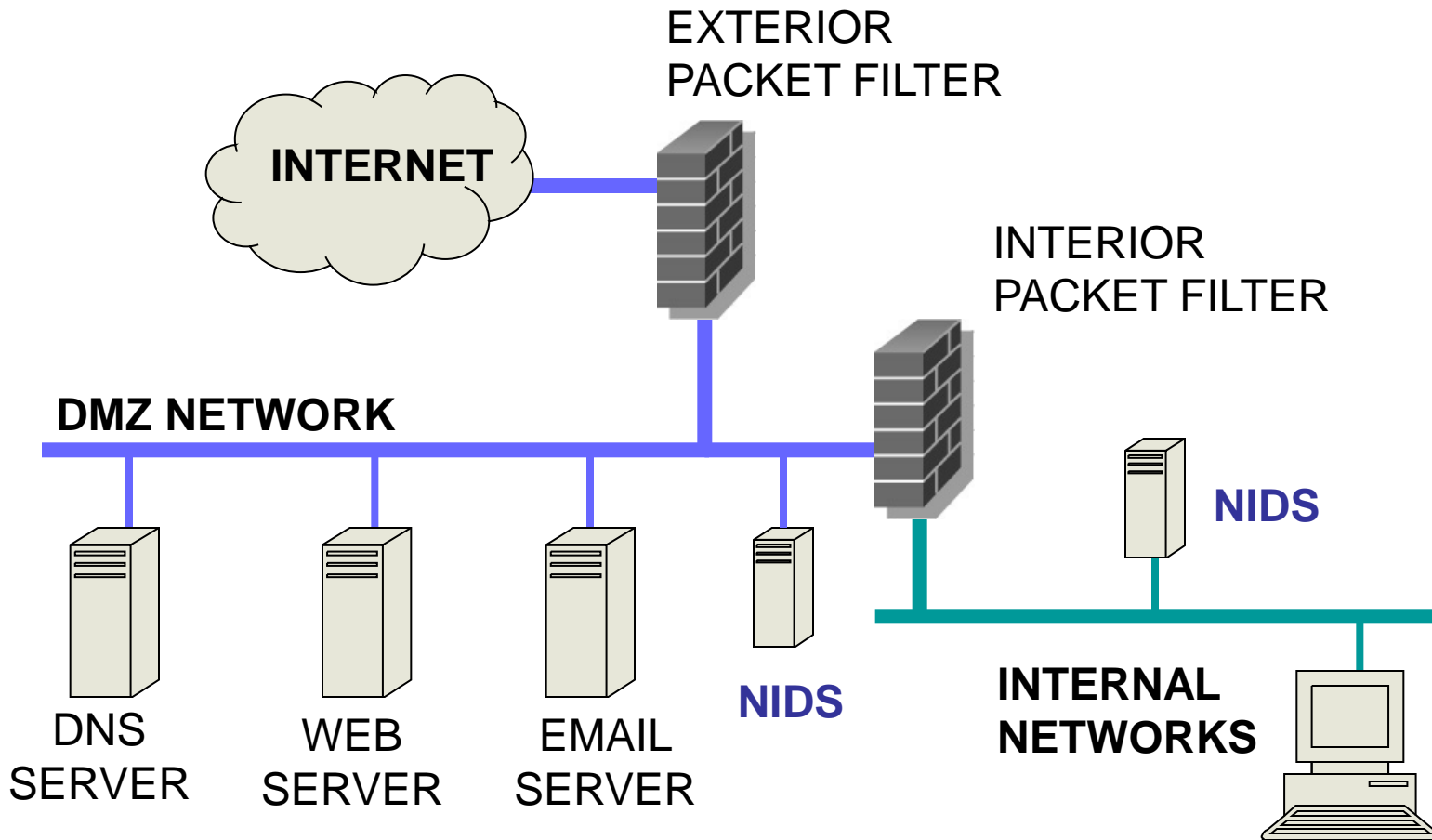
What Should Be Detected?

- Attempted and successful break-ins
- Attacks by legitimate users
 - For example, illegitimate use of root privileges
 - Unauthorized access to resources and data
- Trojan horses
- Viruses and worms
- Denial of service attacks

Where Are IDS Deployed?

- Host-based
 - Monitor activity on a single host
 - Advantage: better visibility into behavior of individual applications running on the host
- Network-based (NIDS)
 - Often placed on a router or firewall
 - Monitor traffic, examine packet headers and payloads
 - Advantage: single NIDS can protect many hosts and look for global patterns

IDS: Network IDS Deployment



Intrusion Detection Techniques

- **Misuse** detection
 - Use attack “signatures” (need a **model of the attack**)
 - Sequences of system calls, patterns of network traffic, etc.
 - Must know in advance what attacker will do (how?)
 - Can only detect known attacks
- **Anomaly** detection
 - Using a **model of normal system behavior**, try to detect deviations and abnormalities
 - E.g., raise an alarm when a statistically rare event(s) occurs
 - Can potentially detect unknown attacks
- Which is harder to do?

IDS:

Major IDS Operational Issue

- A major problem with IDS in general is the number of false positive alarms they generate
 - Can lead to a sense of mistrust, then apathy by security administrator
- Despite this, IDS are becoming more popular
- Common products include:
 - ISS RealSecure
 - Snort (open source NIDS)

Level of Monitoring

- Which types of events to monitor?
 - OS system calls
 - Command line
 - Network data (e.g., from routers and firewalls)
 - Processes
 - Keystrokes
 - File and device accesses

Popular NIDS



- Snort (popular open-source tool)
 - Large rule sets for known vulnerabilities, e.g.
 - **2009-03-31**: A programming error in MySQL Server may allow a remote attacker to cause a Denial of Service (DoS) against a vulnerable machine.
 - **2009-03-27**: Microsoft Windows GDI Buffer Overflow: A programming error in the Microsoft Windows kernel may allow a remote attacker to execute code with system level privileges. This may be exploited when specially crafted EMF files are viewed using Microsoft Internet Explorer.
- Bro (developed by Vern Paxson)
 - Separates data collection and security decisions
 - **Event Engine** distills the packet stream into high-level events describing what's happening on the network
 - **Policy Script Interpreter** uses a script defining the network's security policy to decide what to do in response



Port Scanning

- Many vulnerabilities are OS-specific
 - Bugs in specific implementations, default configuration
- **Port scan** is often a prelude to an attack
 - Attacker tries many ports on many IP addresses
 - For example, looking for an old version of some daemon with an unpatched buffer overflow
 - If characteristic behavior detected, mount attack
 - “The Art of Intrusion”: virtually every attack involves port scanning and password cracking

Attacking and Evading NIDS

- Overload NIDS with huge data streams, then attempt the intrusion
 - Bro solution: watchdog timer
 - Check that all packets are processed by Bro within T seconds; if not, terminate Bro, use tcpdump to log all subsequent traffic
- Use encryption to hide packet contents
- Split malicious data into multiple packets
 - NIDS does not have full TCP state and does not always understand every command of receiving application
 - Simple example: send “ROB<BS><BS>OT”, receiving application may reassemble to “ROOT”

Intrusion Detection Problems

- Lack of training data with real attacks
 - But lots of “normal” network traffic, system call data
- Data drift
 - Statistical methods detect changes in behavior
 - Attacker can attack gradually and incrementally
- Discriminating characteristics hard to specify
 - Many attacks may be within bounds of “normal” range of activities
- False identifications are very costly
 - Sysadm will spend many hours examining evidence

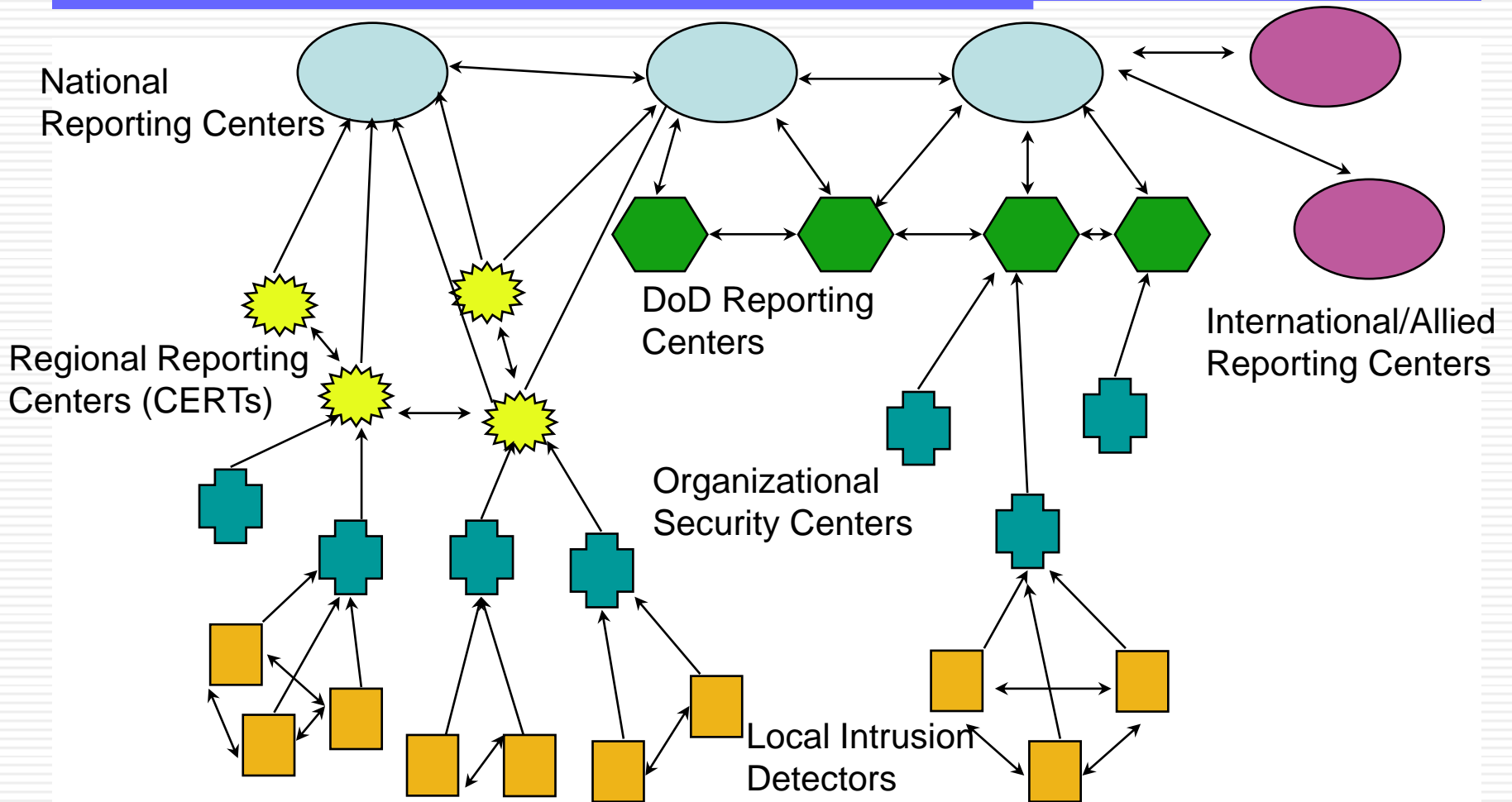
Intrusion Detection Errors

- **False negatives:** attack is not detected
 - Big problem in signature-based misuse detection
- **False positives:** harmless behavior is classified as an attack
 - Big problem in statistical anomaly detection
- Both types of IDS suffer from both error types
- Which is a bigger problem?
 - Attacks are fairly rare events
 - IDS often suffer from “base-rate fallacy”

Base Rate Fallacy

- Consider statements: r : “attack occurs”, s : “signature detected”
- Consider the probabilities:
 - $p(s | r)$: probability of detecting signature given that attack occurs
 - $p(r | s)$: probability of attack given that signature is detected
 - $a(r)$: base rate of attacks (i.e. average rate of attack per connection)
- Attack learning produces $p(s | r)$, but attack detection requires $p(r | s)$
- Deriving $p(r | s)$ requires $a(r)$:
$$p(r | s) = \frac{a(r) p(s | r)}{a(r) p(s | r) + (1 - a(r)) p(s | \neg r)}$$
 - $p(r | s) = 1$, is a good approximation when $a(r) \gg 0$ and $p(s | \neg r) \approx 0$
 - $p(r | s) = 1$, is a bad approximation when $a(r) \approx 0$
- Base rate fallacy is to assume $p(r | s) = 1$ without considering $a(r)$

Strategic Intrusion Assessment



Strategic Intrusion Assessment

- Test over two-week period by Air Force Information Warfare Center
 - Intrusion detectors at 100 Air Force bases alarmed on 2,000,000 sessions
 - Manual review identified 12,000 suspicious events
 - Further manual review => four actual incidents
- Conclusion
 - Most alarms are false positives
 - Most true positives are trivial incidents which can be ignored, i.e. the attacks will never be able to penetrate any system
 - Of the significant incidents, most are isolated attacks to be dealt with locally

Honeypots

- A honeypot:
 - is a computer configured to detect network attacks or malicious behaviour,
 - appears to be part of a network, and seems to contain information or a resource of value to attackers.
- But honeypots are isolated, are never advertised and are continuously monitored
- All connections to honeypots are per definition malicious
- Can be used to extract attack signatures

Intrusion Prevention Systems

- Intrusion Prevention System (IPS) is a relatively new term that can mean different things
- Most commonly, an IPS is a combination of an IDS and a firewall
- A system that detects an attack and can stop it as well
- Can be application specific
 - Deployed on a host to stop attacks on specific applications such as IIS
- Can be an extension of an NIDS
- Can be used to defend systems that cannot be patched

WLAN Security

IEEE 802.11 Standards for WLAN

- IEEE 802.11 formed in 1990's
 - charter to develop a protocol & transmission specifications for wireless LANs (WLANs)
- since then demand for WLANs, at different frequencies and data rates, has exploded
- hence seen ever-expanding list of standards issued
 - from 10Mbps to 1Gbps transmission rate
- Original WEP (Wired Equivalent Privacy) was very weak
- WPA (WiFi Protected Access) offered better security
- New **IEEE 802.11i** standard specifies the modern RSN (Robust Security Network) architecture for WLAN

802.11 Wireless LAN Security

- Only authorized terminals (or users) may get access through WLAN
- Should be impossible to set up rogue AP
- Interception of traffic by radios within range should be impossible

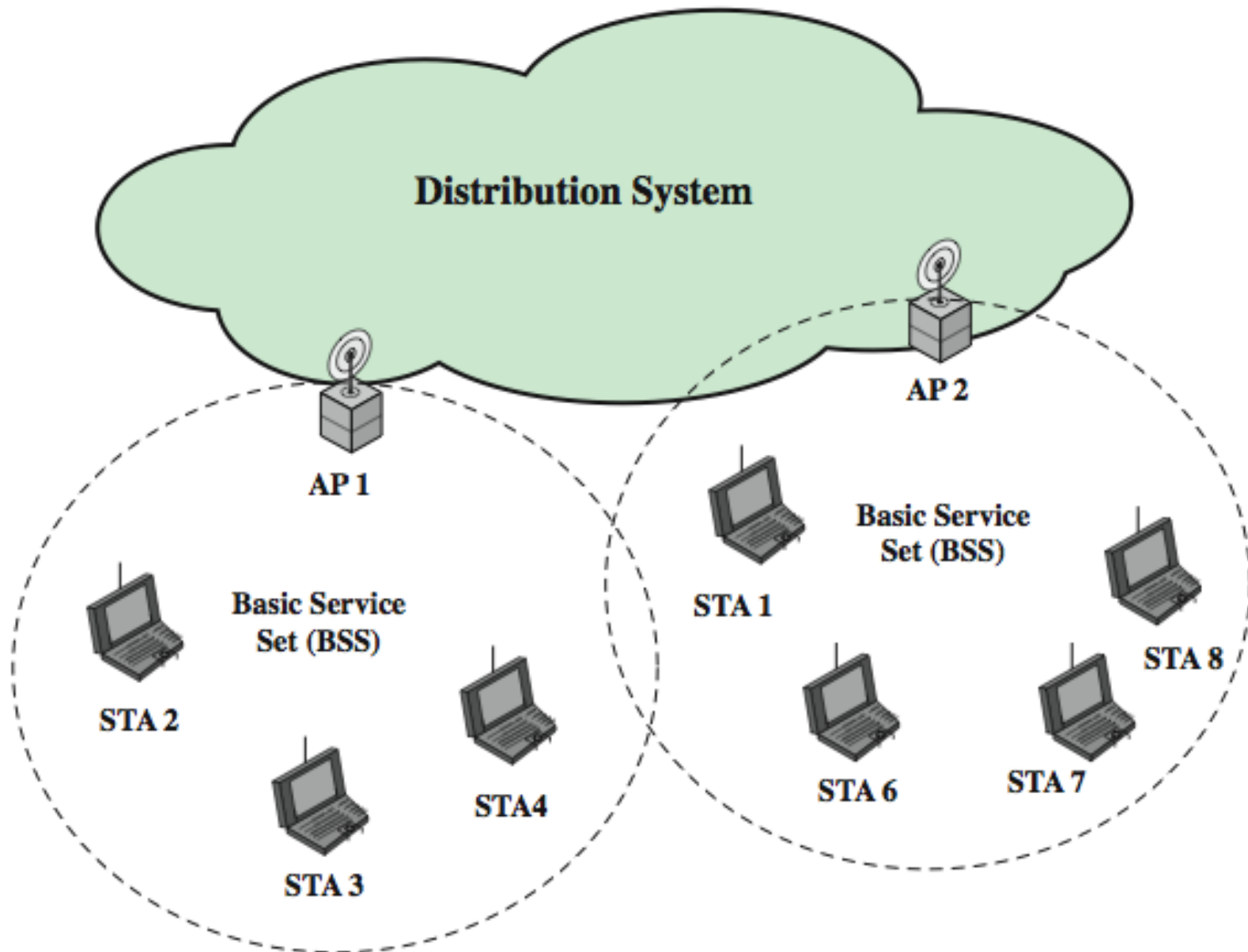
	WEP (1999)	WPA (2003)	RSN (2004) (aka. WPA2)
Auth. & key gen.	WEP	EAP	EAP
Encryption	RC4	RC4+TKIP	CCMP AES CTR (or TKIP)
Integrity	None	Michael MIC	CCMP AES CBC-MAC

- WPA: WiFi Protected Access
- EAP: Extensible Authentication Protocol
- RC4: Rivest Cipher 4 (a stream cipher)
- TKIP: Temporal-Key Integrity Protocol
- Michael MIC: A type of Message Integrity Check
- CCMP: Counter Mode with Cipher Block Chaining Message Authentication Protocol

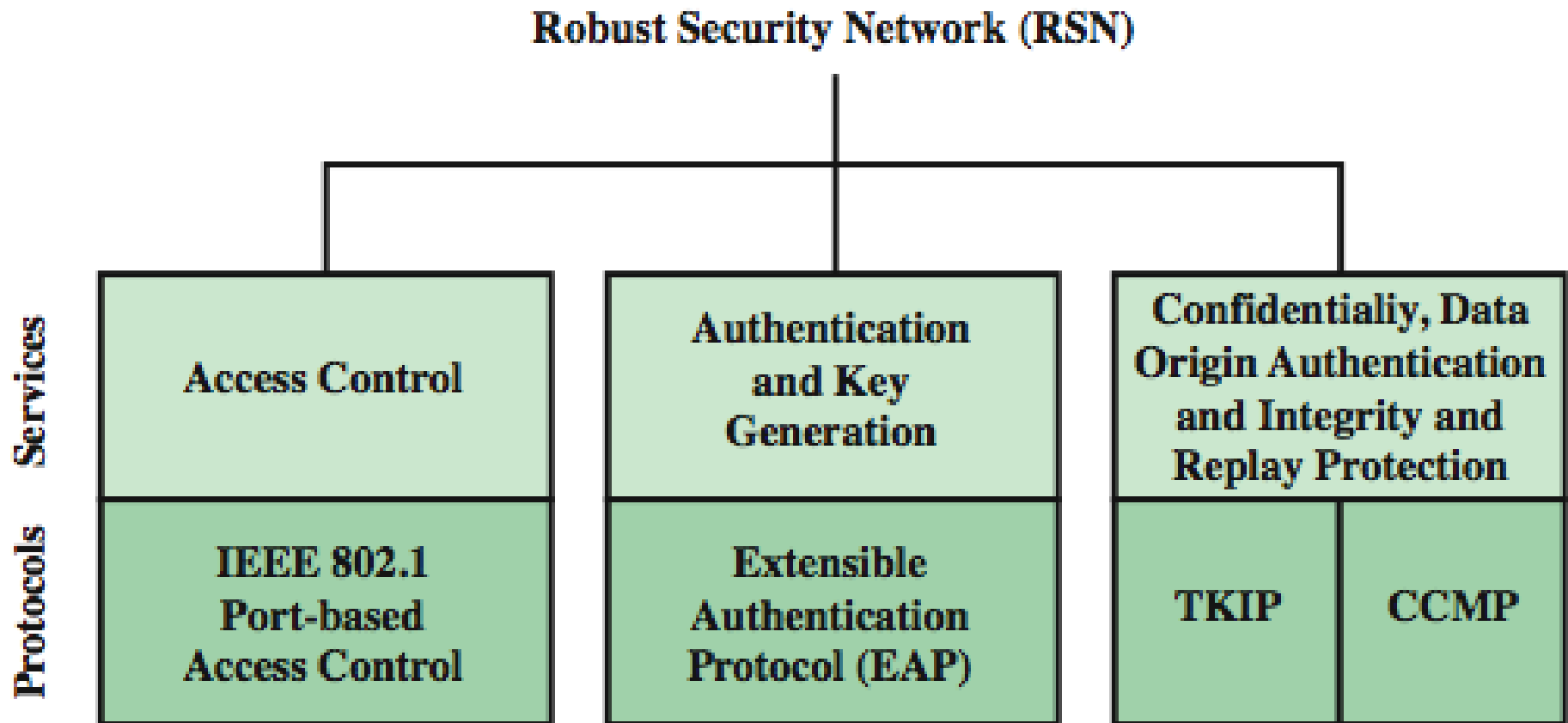
IEEE 802 Terminology

- Station (STA)
 - Wireless terminal that communicates with 802.11 functionality
- Access Point (AP)
 - Receives radio signals and controls access to network
- Basic Service Set (BSS)
 - Set of stations and one AP
- Extended Service Set (ESS)
 - Set of multiple BSSs
- Distribution System (DS)
 - Contains an Authentication Server (AS)
 - Integrates multiple BSSs into one ESS

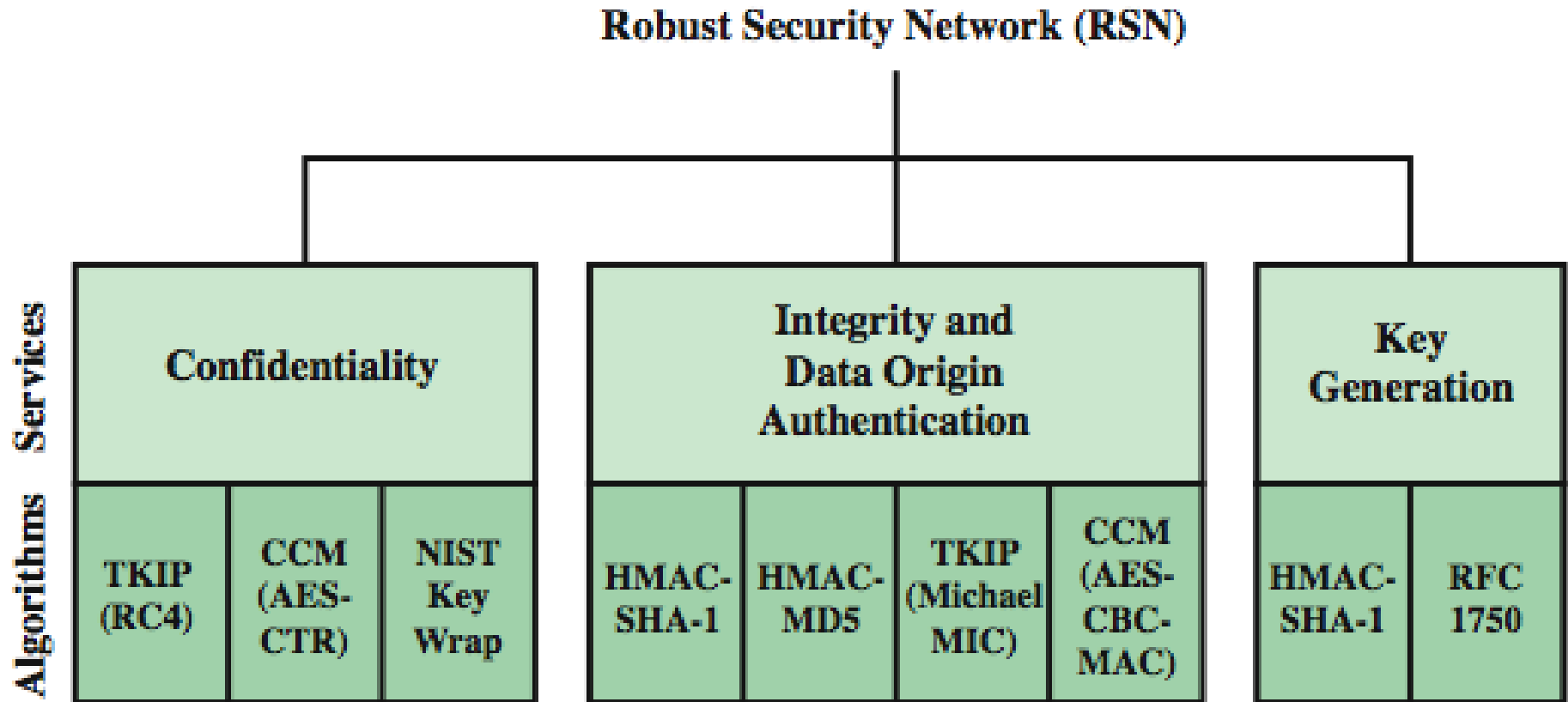
Network Components & Architecture



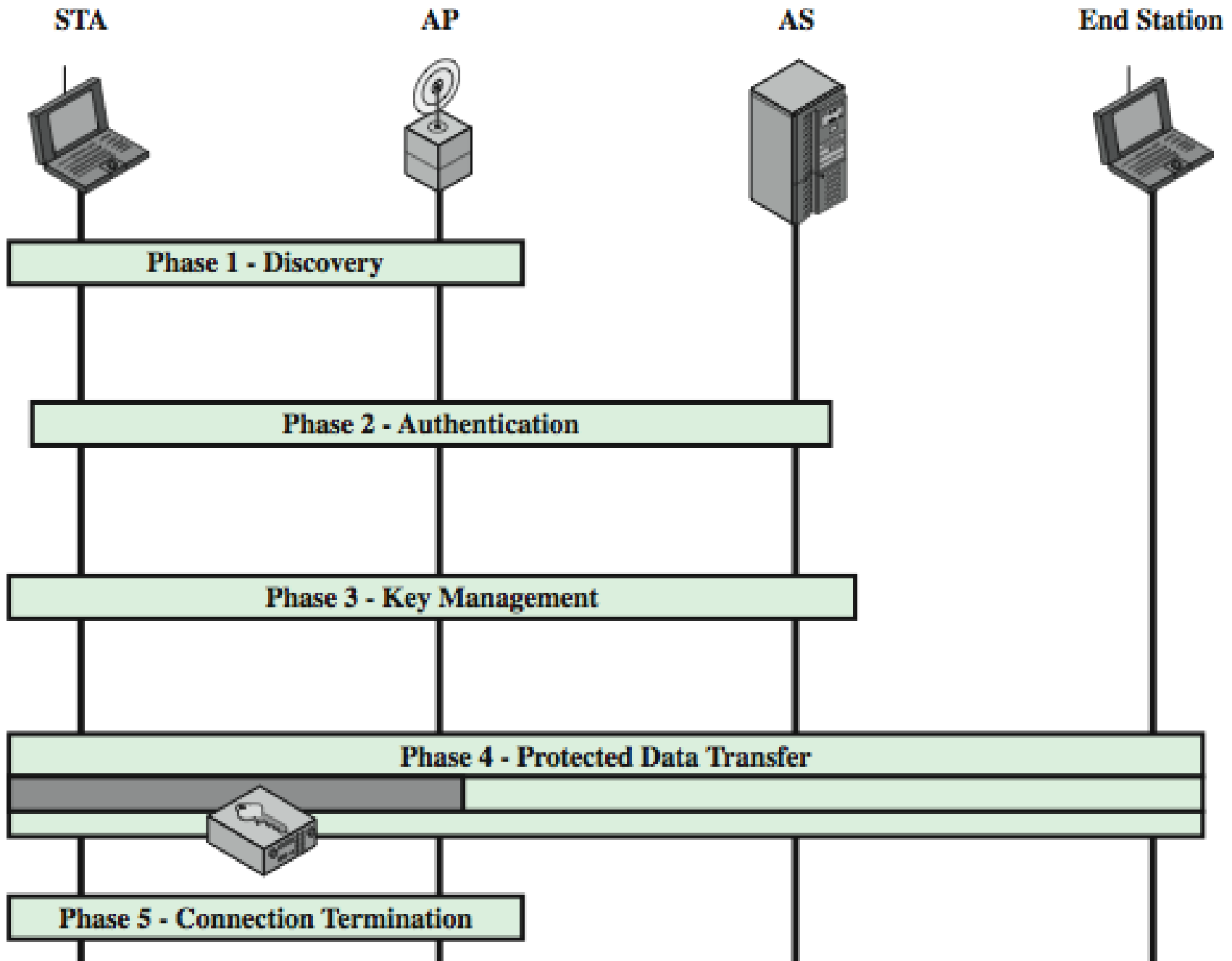
802.11i RSN Services and Protocols



802.11i RSN Cryptographic Algorithms



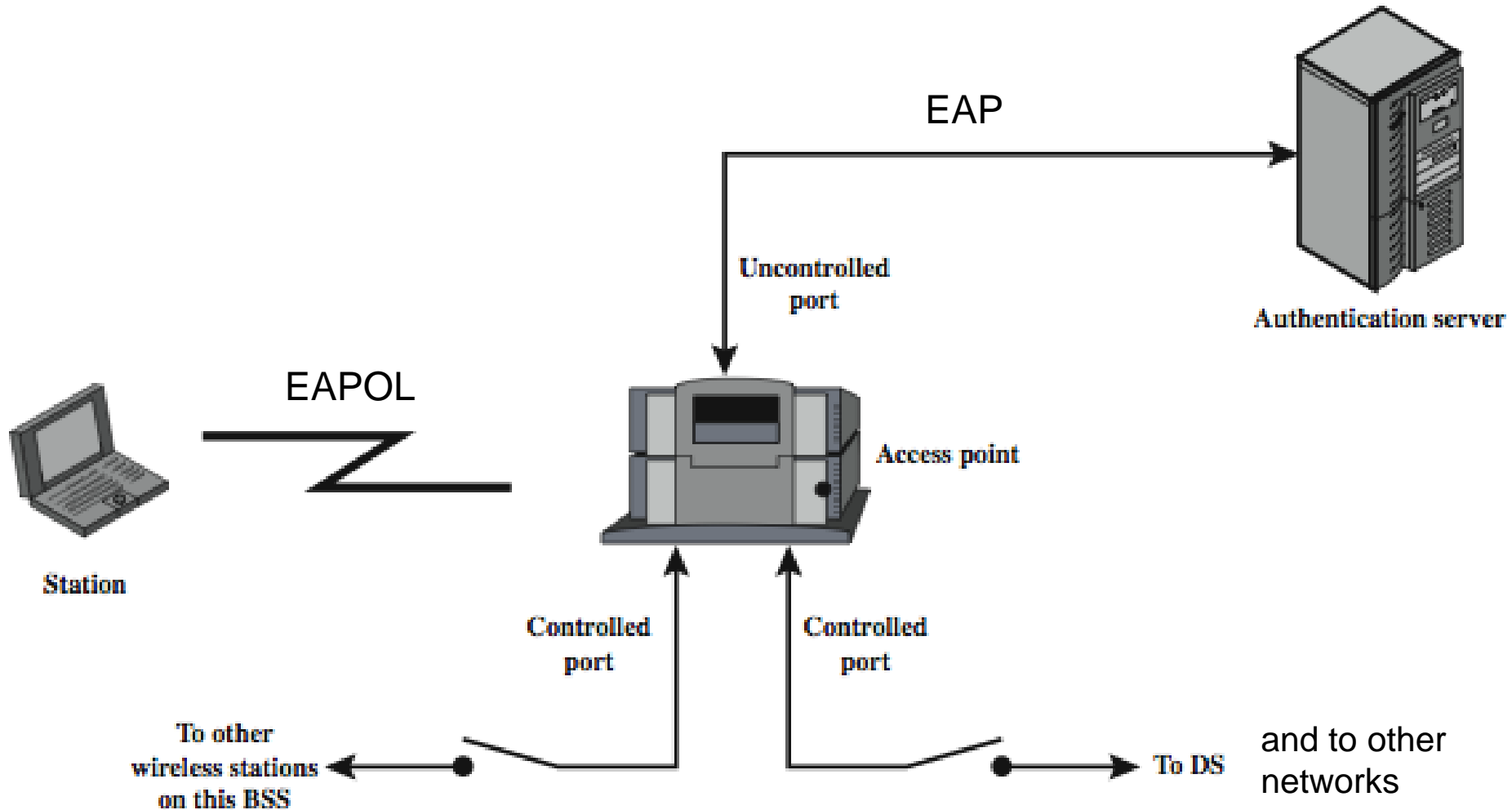
802.11i Phases of Operation



802.1X Access Control for WLAN

- IEEE802.1X defines encapsulation of EAP over IEEE802 which is known as "EAP over LAN" or EAPOL
- involves three parties:
 - supplicant (STA),
 - authenticator (AP),
 - authentication server (AS).
- Any STA has always access to AS through AP.
- AP controls access to DS/ESS and to other networks.
- Authorized STA (or user) must be authenticated before AP approves access to DS/ESS and to other networks

IEEE 802.1X Access Control Approach



802.11i Protected Data Transfer Phase

- Two possible schemes for protecting data over radio link
- 1) Temporal Key Integrity Protocol (TKIP)
 - s/w changes only to older WEP
 - adds 64-bit Michael message integrity code (MIC)
 - encrypts MPDU plus MIC value using RC4
- 2) Counter Mode-CBC MAC Protocol (CCMP)
 - uses the cipher block chaining message authentication code (CBC-MAC) for integrity
 - uses the CTR block cipher mode of operation for encryption

End of Lecture

We have discussed:

- Firewall techniques
- Intrusion detection techniques
- WLAN Security