

CISSE

The Colloquium for
Information Systems
Security Education

THE COLLOQUIUM 2012
LAKE BUENA VISTA, FL

Monday, June 11 - Wednesday, June 13, 2012

**Teaching Stateless and Stateful Firewall
Packet Filtering:
A Hands-on Approach**

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Information Security Program at UAEU

Cryptography

Firewall & VPN

**Intrusion Detection
and Prevention
(IDS/IPS)**

Database security

OS security

Biometrics

**Virus &
Malicious Code**



**Web application
security**

**Network Traffic
Analysis**

Ethical Hacking

**Secure
e-transactions**

**Wireless
Security**

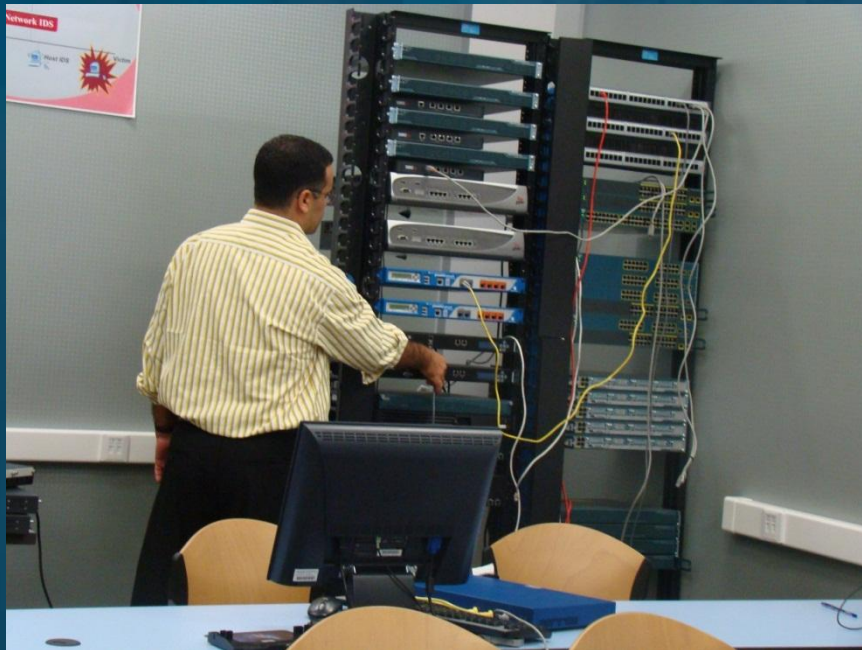
**Security Auditing,
Penetration testing**

State-of-the-Art Security Labs

1 million US\$

Intrusion Detection & Prevention
Lab

Firewall & VPN Lab



Wireless Security Lab

Cryptography Lab

Biometrics

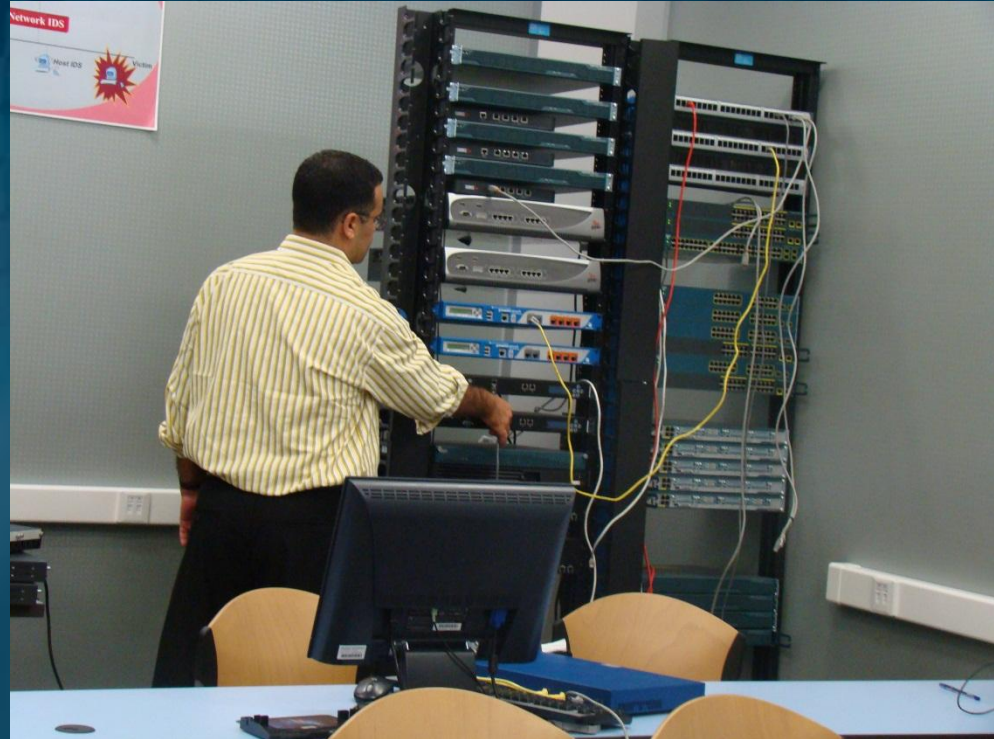
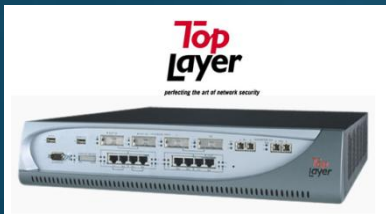
Firewall & VPN Lab



- **Basic packet filtering**
- **Application traffic filtering**
- **Deep inspection,...**

Intrusion Detection & Prevention Lab

Top IDS/IPS devices



- Generate attacks: DoS, MiM,...
- Detect and prevent attacks
- Create attack signatures,...

Biometrics Lab

Iris Recognition



Fingerprint Recognition



Face & Voice Recognition



Handwriting Recognition System



Security Tools (Open source & Commercial)



Penetration testing



Penetration testing



LanGuard: Network Security Auditing

- CommView sniffer for wired LANs
- CommView for WiFi sniffer for WLAN
- AirCrack
- Can & Abel, ...

Information Security Program (Undergraduate)



Hands-on Lab Exercises

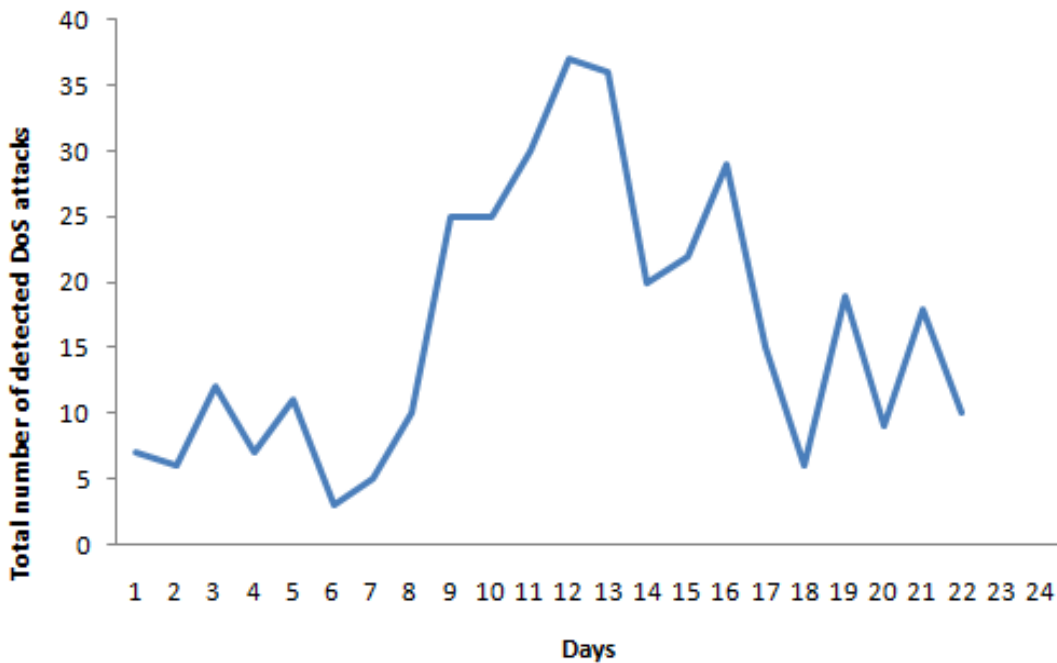


Defense techniques

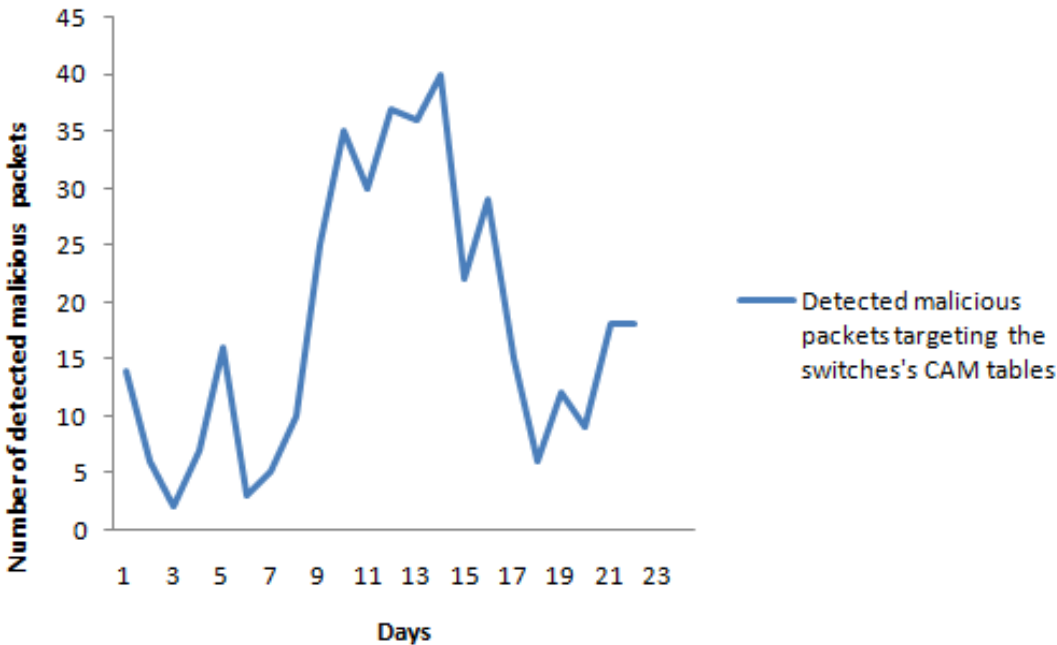


Offensive techniques
(Ethical hacking)

- **Better anatomize the concepts**
- **Hands-on skills**



Evolution of the number of DoS attacks detected by the university's IDS sensors



Evolution of the number of detected malicious IP and ARP packets targeting the switches' CAM tables

Paper:

Teaching Stateless and Stateful Firewall Packet Filtering: A Hands-on Approach

Information Security Program



Basic packet filtering

Stateless & Stateful firewall concept

Firewall technologies

Packet classification

Filtering mechanisms

...

Paper



Hands-on lab exercise:

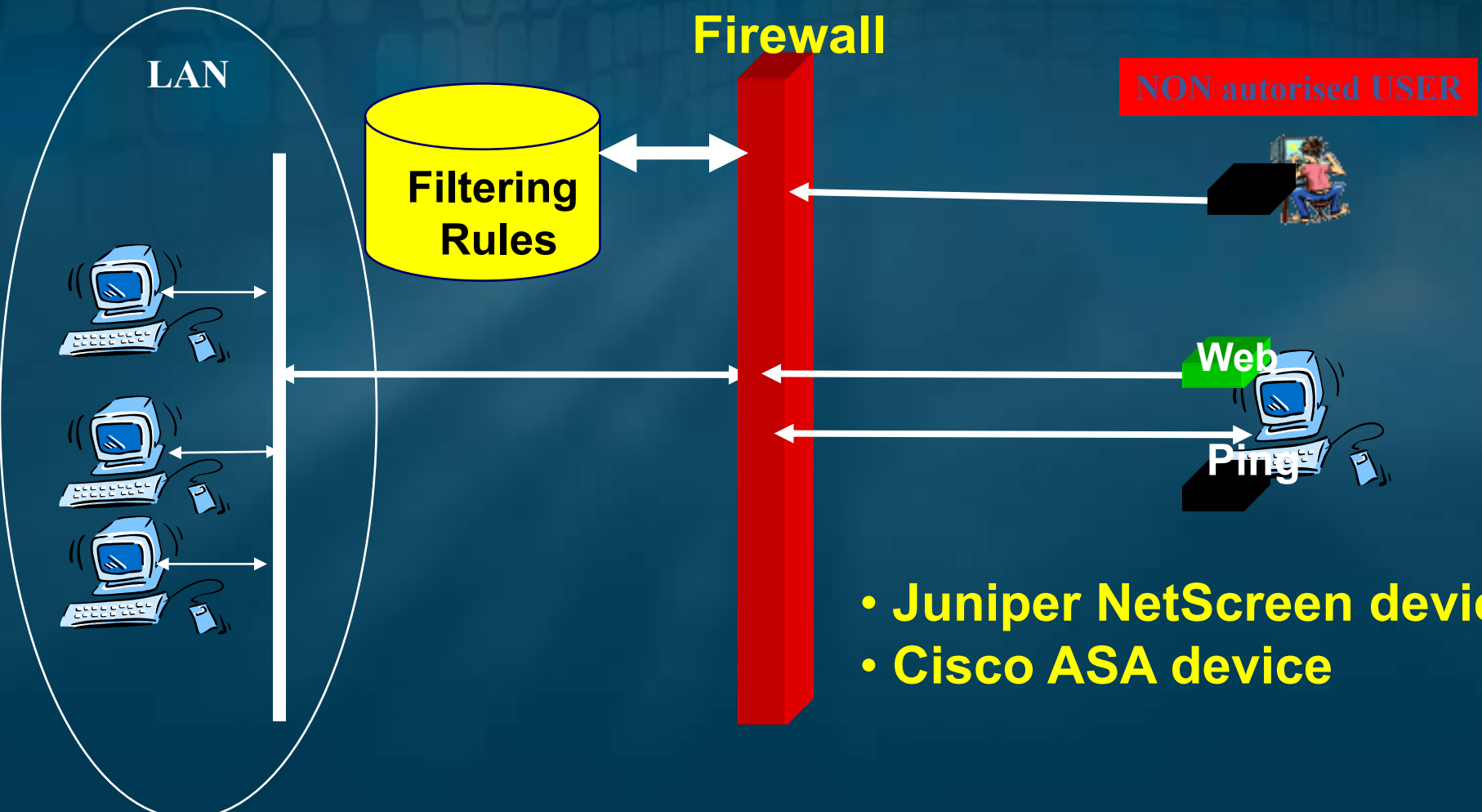
***How to identify whether a given
firewall performs
stateless or stateful packet filtering.***



The learning objective: better anatomize the concept of stateless and stateful firewall packet filtering through examples and experiments in an isolated network laboratory.



Incoming /outgoing Network Traffic Filtering



- Juniper NetScreen device
- Cisco ASA device

Security Policy



Filtering Rules

Example of security policy:

- I want to DENY all incoming Ping request

My host



Ping (ICMP, Type = 8, Code = 0)



Filtering rule:

Rule	Direction	Source IP	Destination IP	Protocol	Type	Code	Action
R1	Incoming	Any	My IP	ICMP	8	0	Deny

Stateless and Stateful Firewall Concepts

Concept: Stateless & Stateful Firewalls

Stateful firewall: is able to memorize and identify the status of:

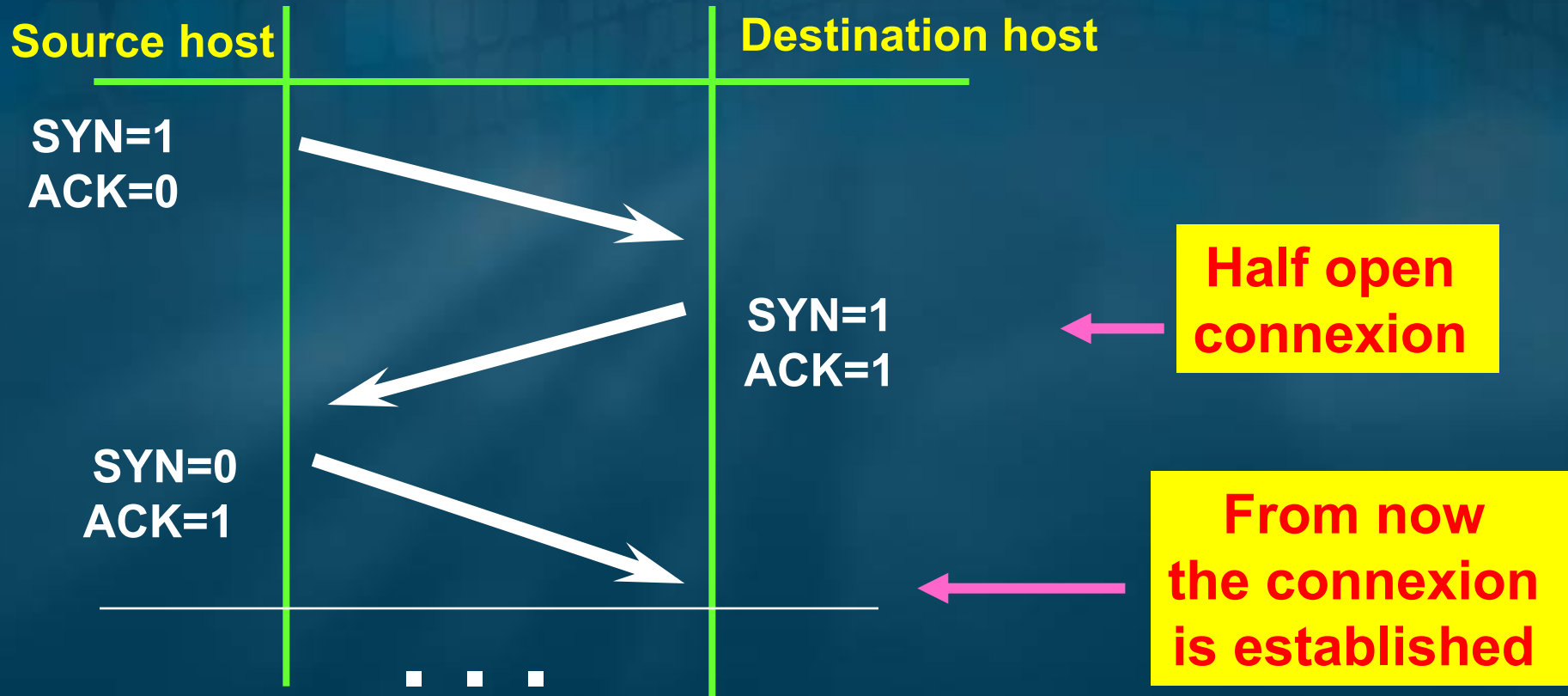
- **TCP sessions**
- **UDP sessions**
- **ICMP request/reply traffic**

A stateless firewall has:

No mechanism to identify packets that belong to established sessions

Opening a TCP session: Three-way handshake

TCP Connexion establishment :



SYN & ACK bits in the TCP Header

Source host

Destination host

SYN=1
ACK = 0

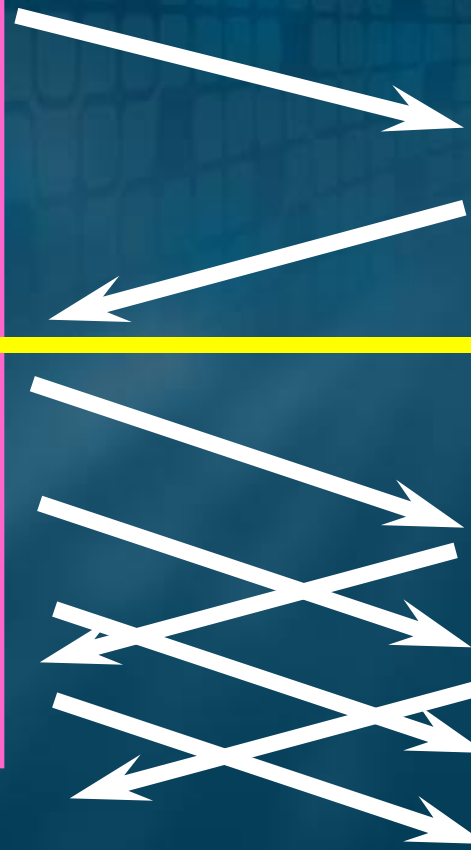
SYN=1
ACK = 1

SYN = 0
ACK = 1

SYN = 0
ACK = 1

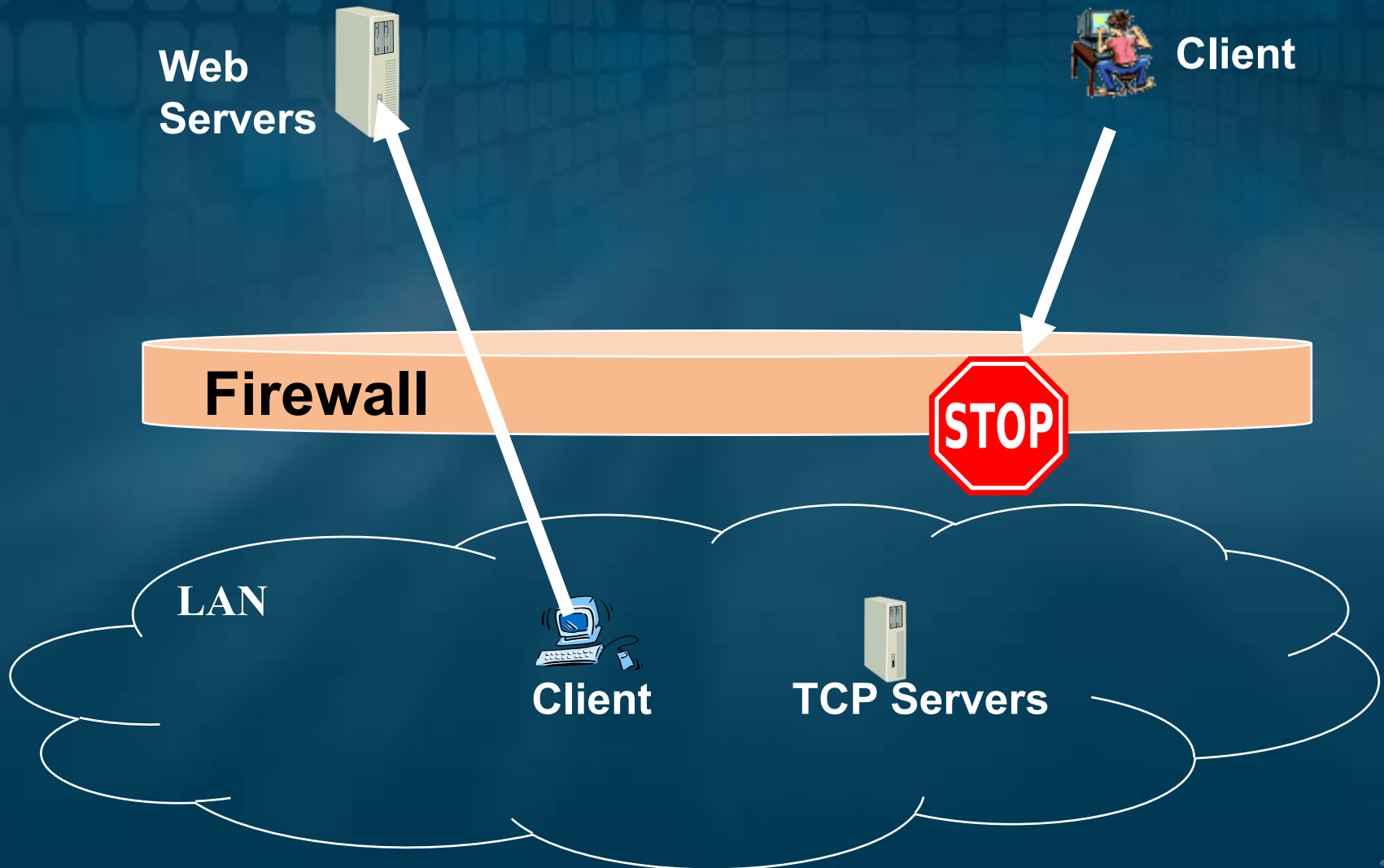
SYN = 0
ACK = 1

4 types of packets should be allowed



Stateless and Stateful Firewall Concept (TCP sessions)

Security Policy



Stateless and Stateful Firewall

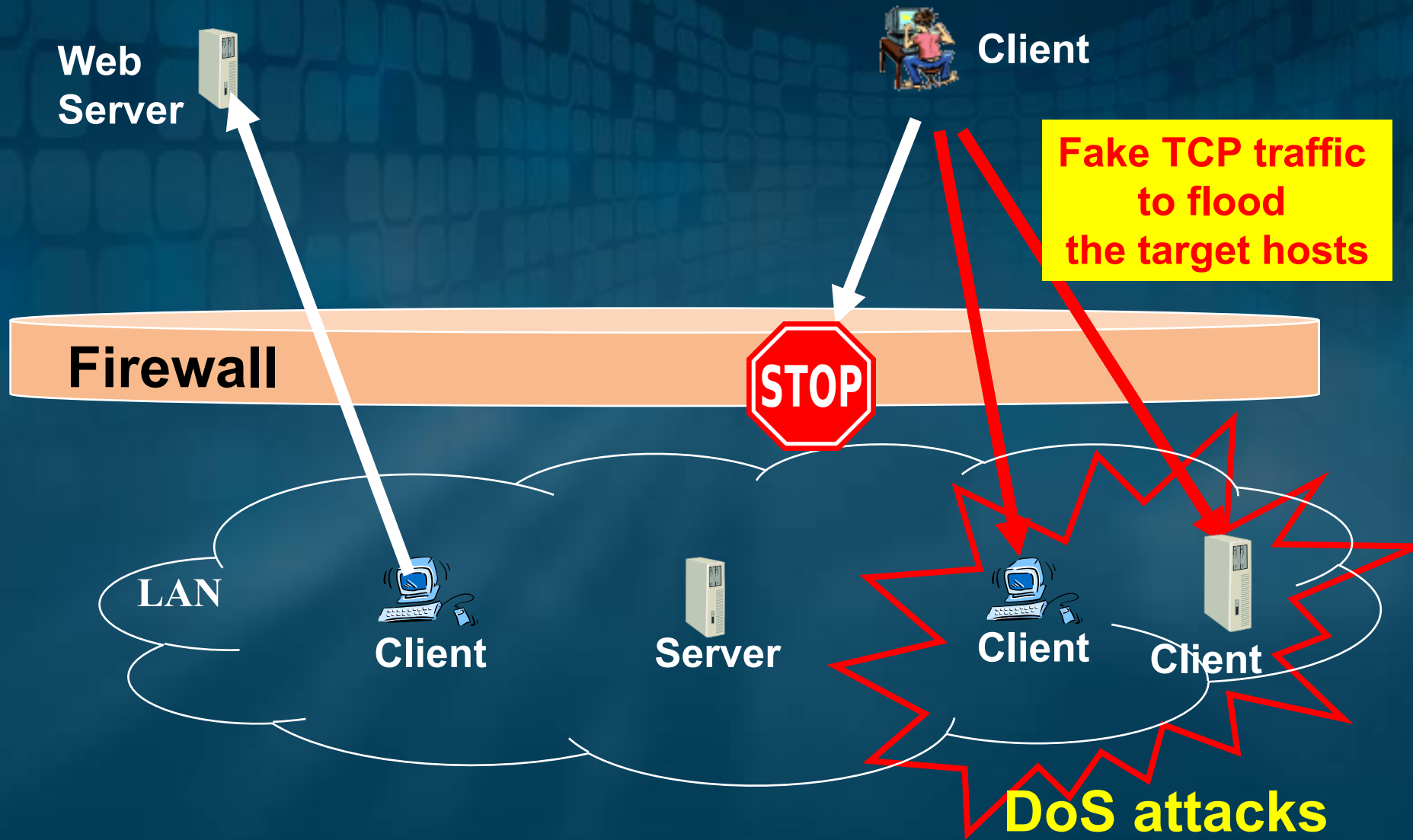
Security policy:

- Our hosts are **ALLOWED** to access any external web server (TCP/80)
- External hosts are **NOT ALLOWED** to access any TCP service in our LAN

Filtering rules :

Direction	Source IP	Dest. IP	Protocol	Sour. Port	Dest. Port	SYN bit	ACK bit	Action
Out	LAN	Externe	TCP	Any	80	1	0	Accept
In	Externe	LAN	TCP	80	Any	1	1	Accept
Out	LAN	Externe	TCP	Any	80	0	1	Accept
In	Externe	LAN	TCP	80	Any	0	1	Accept
In	Externe	LAN	TCP	Any	Any	1	0	Deny

Stateless and Stateful Firewall



Stateless and Stateful Firewall

Filtering rules :

Direction	Source IP	Dest. IP	Proto	Sour. Port	Dest. Port	SYN	ACK	Action
Out	LAN	Externe	TCP	Any	80	1	0	Accept
In	Externe	LAN	TCP	80	Any	1	1	Accept
Out	LAN	Externe	TCP	Any	80	0	1	Accept
In	Externe	LAN	TCP	80	Any	0	1	Accept
In	Externe	LAN	TCP	Any	Any	1	0	Deny

Packet:

Direction	Source IP	Dest. IP	Proto	Sour. Port	Dest. Port	SYN	ACK
In	Externe	LAN	TCP	Any	80	1	0

External hosts cannot establish a connection with our hosts

This packet will be rejected

Stateless and Stateful Firewall

Filtering rules :

Direction	Source IP	Dest. IP	Proto	Sour. Port	Dest. Port	SYN	ACK	Action
Out	LAN	Externe	TCP	Any	80	1	0	Accept
In	Externe	LAN	TCP	80	Any	1	1	Accept
Out	LAN	Externe	TCP	Any	80	0	1	Accept
In	Externe	LAN	TCP	80	Any	0	1	Accept
In	Externe	LAN	TCP	Any	Any	1	0	Deny

Packet:

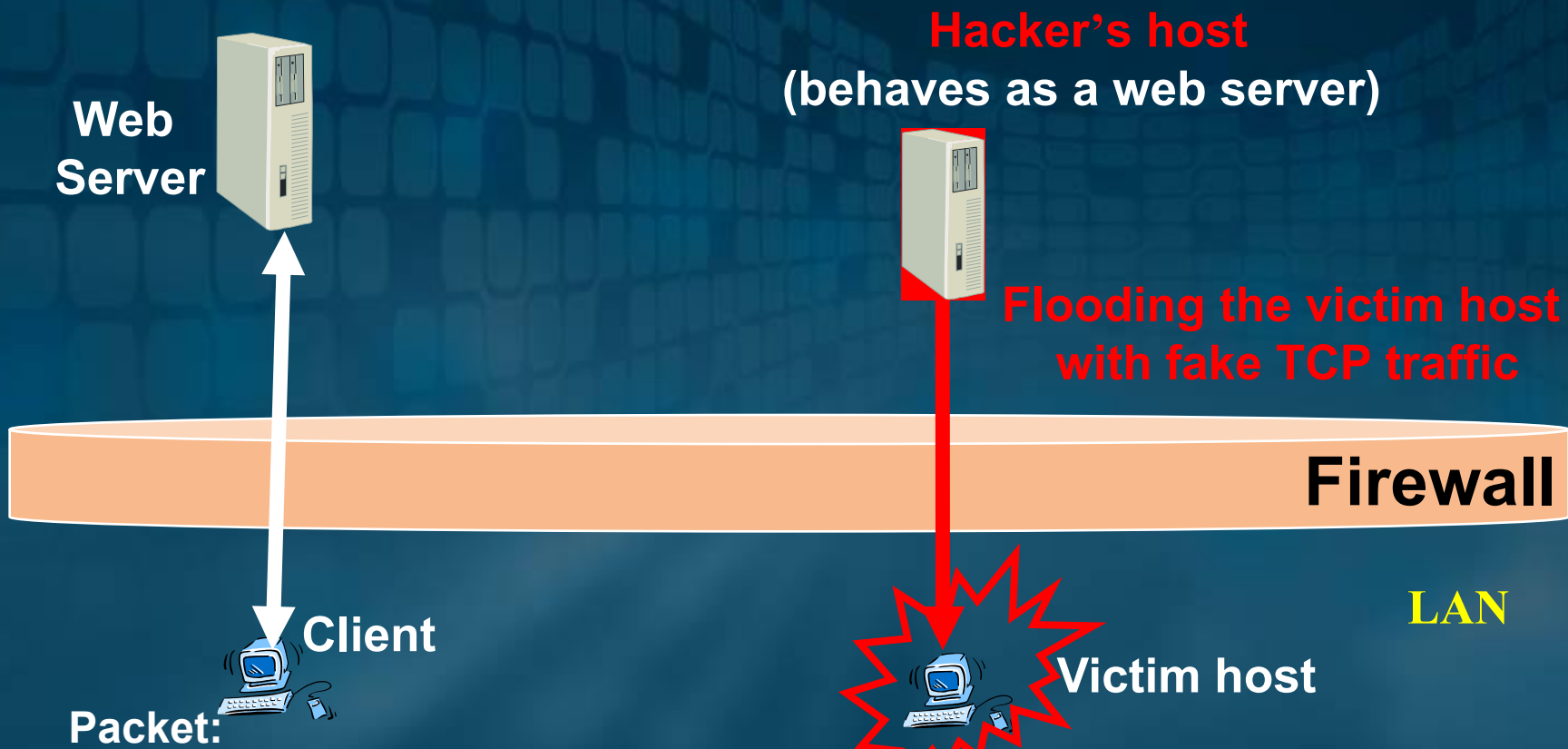
Direction	Source IP	Dest. IP	Proto	Sour. Port	Dest. Port	SYN	ACK
In	Externe	LAN	TCP	7000	80	1	0
In	Externe	LAN	TCP	80	9000	0	1

Our hosts are NOT protected from this malicious packet.

This packet will be accepted

This packet will be rejected

Stateless and Stateful Firewall



Packet:

Direction	Source IP	Dest. IP	Proto	Sour. Port	Dest. Port	SYN	ACK
In	Externe	LAN	TCP	7000	80	1	0
In	Externe	LAN	TCP	80	9000	0	1

This packet will be accepted

This packet will be rejected

Stateful Firewall



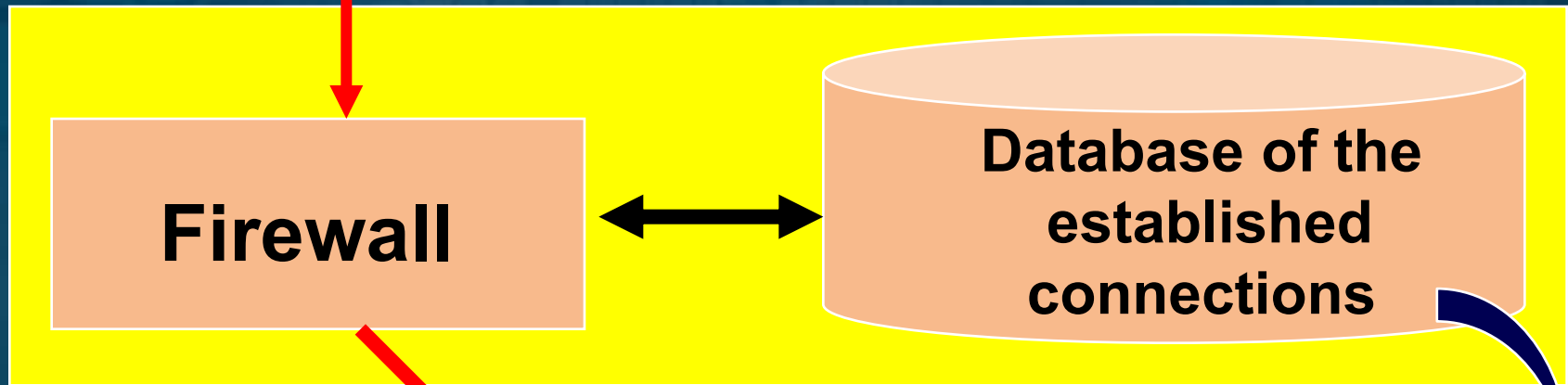
Database of the established connections

Source IP	Dest. IP	Protocole	Source Port	Destination Port	status
Client#1	Web server#1	TCP	4000 (for example)	80	established
Client #2	Web server #2	TCP	5000 (for example)	80	established

Stateful Firewall

Incoming TCP Packet:

Direction	Source IP	Dest. IP	Proto	Sour. Port	Dest. Port	SYN	ACK
In	Externe	LAN	TCP	80	3000	0	1



Rejected

Database of established connections:

Source IP	Dest. IP	Protocole	Source Port	Destination Port	status
Client	Web server	TCP	4000	80	Full established

Stateless and Stateful Firewalls

Malicious packet

Direction	Source IP	Dest. IP	Proto	Sour. Port	Dest. Port	SYN	ACK
In	Externe	LAN	TCP	80	Any	0	1

Stateless Firewall

Accepted

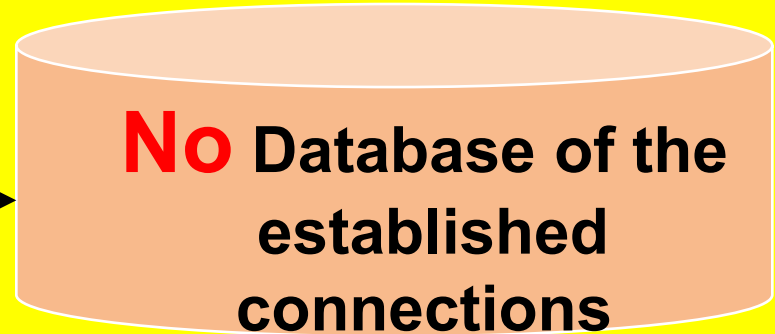
Stateful Firewall

Rejected

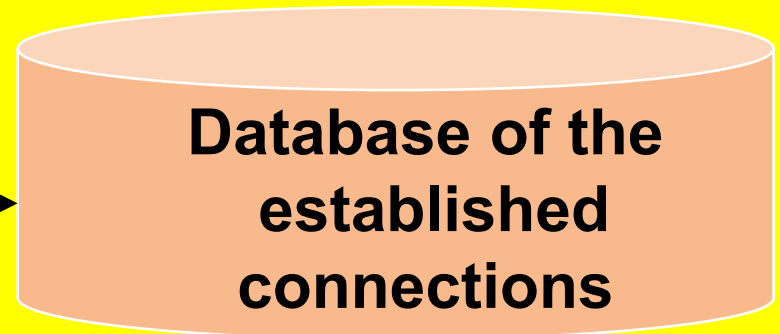
LAN's hosts are protected from malicious packets used to generate DoS attacks

Stateless and Stateful Firewall

Stateless Firewall

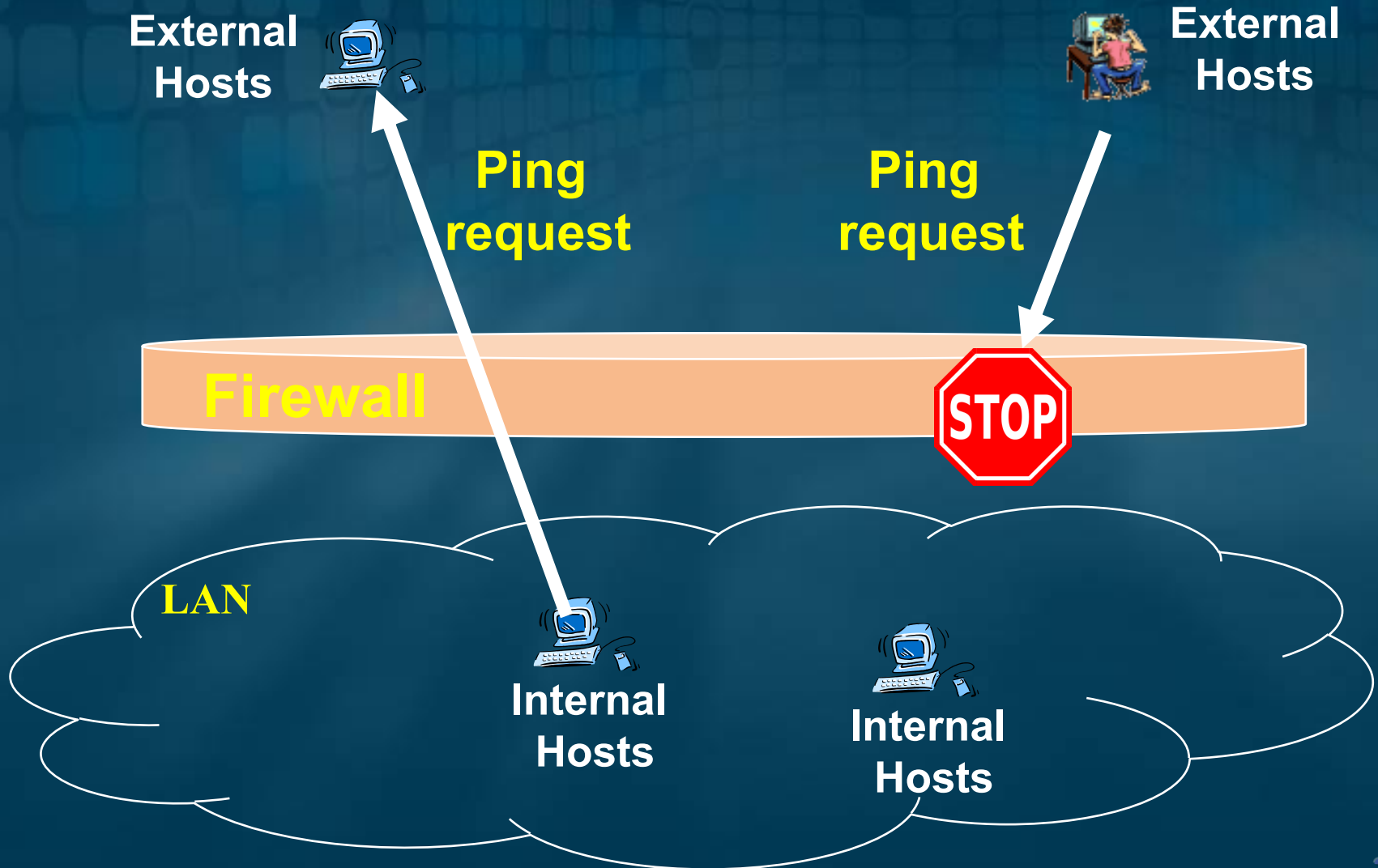


Stateful Firewall



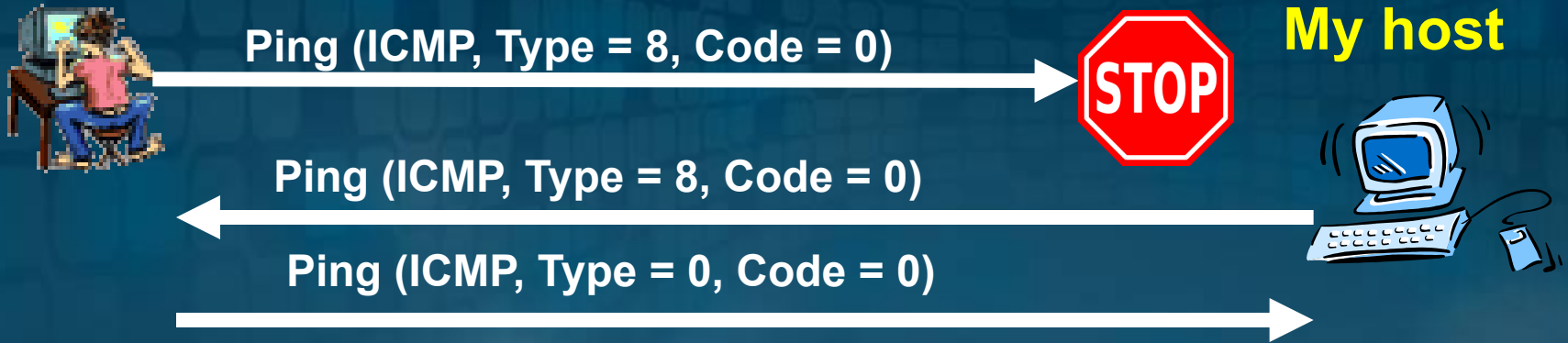
Stateless and Stateful Firewall Concept (ICMP traffic: Ping)

Security Policy



Example of security policy:

- Deny incoming Ping
- Allow outgoing Ping

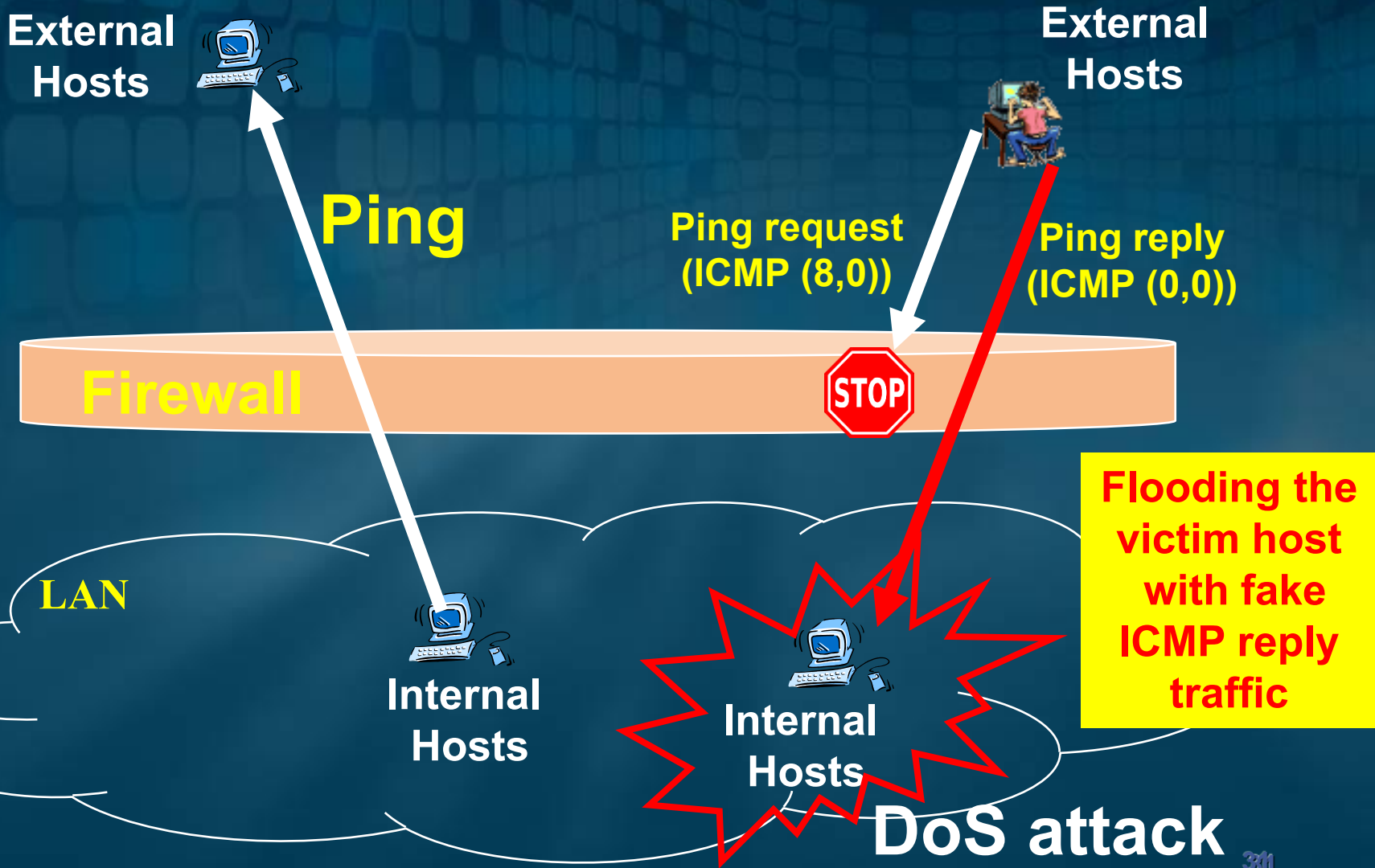


Rule	Direction	Source IP	Destination IP	Protocol	Type	Code	Action
R1	Incoming	Any	My IP	ICMP	8	0	Deny

Rule	Direction	Source IP	Destination IP	Protocol	Type	Code	Action
R2	Outgoing	My IP	Any	ICMP	8	0	Allow

Rule	Direction	Source IP	Destination IP	Protocol	Type	Code	Action
R3	Incoming	Any	My IP	ICMP	0	0	Allow

Stateless Firewall for ICMP traffic



To better anatomize the concepts of stateless and stateful firewall



Hands-on lab exercise:

describes steps to identify whether the **Cisco ASA 5520** Firewall offers stateful or stateless TCP and ICMP packet filtering.



The experiment's steps can be used to test any other firewall device or software

Cisco ASA 5520 : Stateless or Stateful Firewall?



The two experiments:

Exp. 1: Stateful **TCP** packet filtering testing

Exp. 2: Stateful **ICMP** packet filtering testing

Network Architecture

Cisco ASA 5520 device



GigabitEthernet0/1

GigabitEthernet0/0

**Host#1:
Web client**



(192.168.2.20)
(CommView sniffer)

**Host#2:
Web server**



(192.168.3.30)
(CommView sniffer)

Exp. 1:
**Stateful TCP packet
filtering testing**

Exp. 1: Stateful TCP packet filtering testing



Step 1: Host #1 accesses the Web site in host #2

Step 2: Sniff the Web session traffic

Step 3: Host #1 generates a FAKE TCP packet

Step 4: Analyze the results and identify the type of firewall

Exp. #1:

Security policy: Allow web traffic (TCP/80) between the Web client (Host#1) and the Web server (Host#2).

The screenshot shows the Cisco ASDM 5.0 for ASA configuration interface. The main window displays the 'Security Policy > Access Rules' configuration page. The interface includes a menu bar (File, Rules, Search, Options, Tools, Wizards, Help), a toolbar with icons for Home, Configuration, Monitoring, Back, Forward, Search, Refresh, Save, and Help, and a sidebar with navigation options like Features, Interfaces, Security Policy, NAT, VPN, IPS, Routing, Building Blocks, Device Administration, Properties, and Wizards.

The 'Access Rules' section is active, showing a table of rules. The table has columns for Rule #, Rule Enabled, Action, Source Host/Network, Destination Host/Network, Rule Applied To Traffic, Interface, and Service. Two rules are listed, both with 'Rule Enabled' and 'Action' checked. The second rule is highlighted, and its 'Service' column value 'http/tcp' is circled in red.

#	Rule Enabled	Action	Source Host/Network	Destination Host/Network	Rule Applied To Traffic	Interface	Service
-	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	any	any		Network_2 (outbound)	ip
1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	192.168.2.0/24	192.168.3.0/24	outgoing	Network_2	http/tcp
1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	192.168.2.0/24	192.168.3.0/24	incoming	Network_1	http/tcp

At the bottom of the window, there are buttons for 'Apply', 'Reset', and 'Advanced...', along with a status bar showing 'Device configuration loaded successfully.', user information '<admin> NA (15)', and a timestamp '12/01/11 11:20:59 PM UTC'.

From Host#1, a Web browser is used to connect to the Web server at Host#2

At Host#1, CommView sniffer is used to capture the three-way handshake TCP packets of the Web session.

The screenshot displays the CommView interface with the following details:

- Left Pane (Packet Details):**
 - Ethernet II**
 - IP version: 0x04 (4)
 - Header length: 0x05 (5) - 20 bytes
 - Differentiated Services Field: 0x00 (0)
 - Total length: 0x0030 (48)
 - ID: 0x003E (62)
 - Flags
 - Fragment offset: 0x0000 (0)
 - Time to live: 0x80 (128)
 - Protocol: 0x06 (6) - TCP
 - Checksum: 0x7407 (29703) - correct
 - Source IP: 192.168.2.20
 - Destination IP: 192.168.3.30
 - IP Options: None
 - TCP**
 - Source port: 1038
 - Destination port: 80
 - Sequence: 0x03739F10 (57909008)
 - Acknowledgement: 0x00000000 (0)
 - Header length: 0x07 (7) - 28 bytes
 - Flags: SYN
 - Window: 0xFFFF (65535)
 - Checksum: 0x55BB (21947) - correct
 - Urgent Pointer: 0x0000 (0)
 - TCP Options
 - Data length: 0x0 (0)
- Right Pane (Packet List):**

No	Protocol	Src IP	Dest IP	Src Port	Dest Port
1	IP/TCP	? 192.168.2.20	? 192.168.3.30	1038	http
2	IP/TCP	? 192.168.3.30	? 192.168.2.20	http	1038
3	IP/TCP	? 192.168.2.20	? 192.168.3.30	1038	http
4	IP/TCP	? 192.168.2.20	? 192.168.3.30	1038	http
5	IP/TCP	? 192.168.3.30	? 192.168.2.20	http	1038
6	IP/TCP	? 192.168.3.30	? 192.168.2.20	http	1038
7	IP/TCP	? 192.168.2.20	? 192.168.3.30	1038	http
8	IP/TCP	? 192.168.2.20	? 192.168.3.30	1038	http
9	IP/TCP	? 192.168.3.30	? 192.168.2.20	http	1038
- Bottom Pane (Hex Dump):**

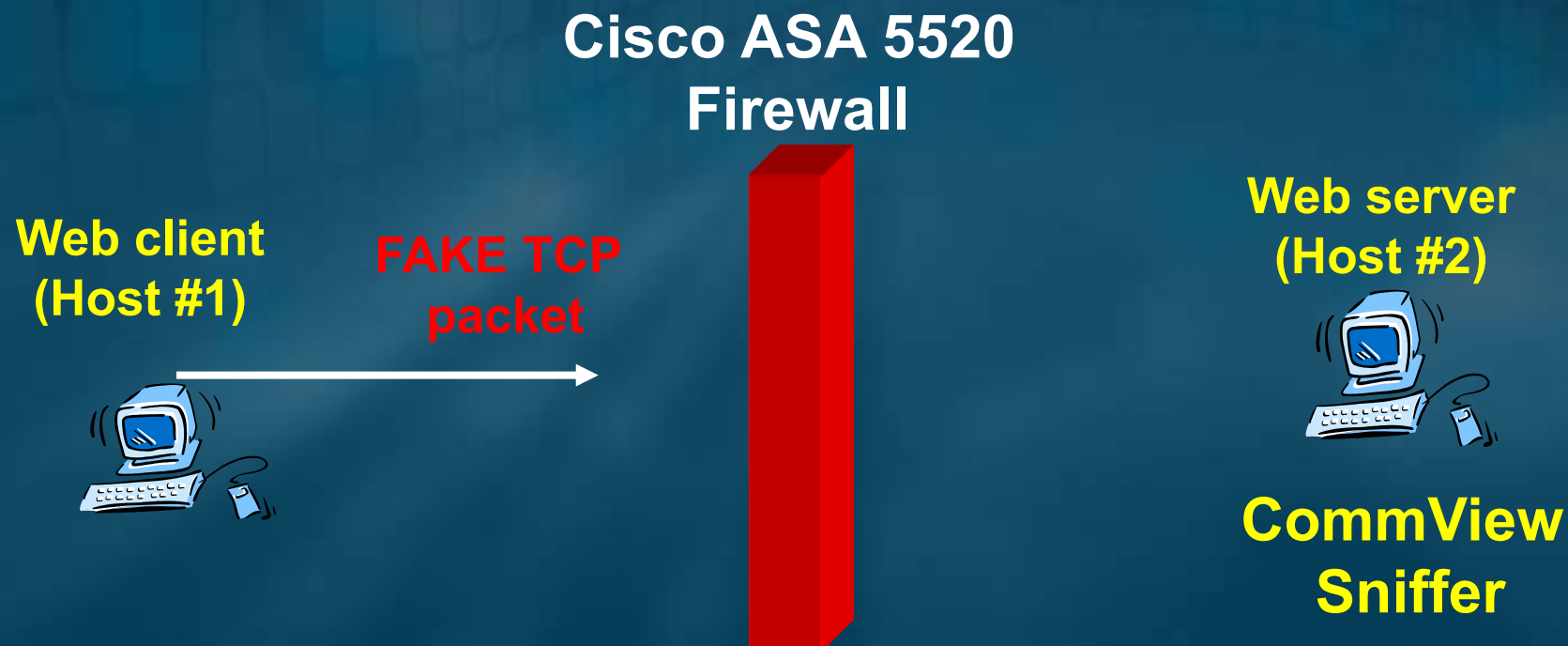
```
0x0000  00 1B D4 54 EF C2 00 1E-0B 2C 86 2E 08 00 45 00
0x0010  00 30 00 3E 40 00 80 06-74 07 C0 A8 02 14 C0 A8
0x0020  03 1E 04 0E 00 50 03 73-9F 10 00 00 00 00 70 02
0x0030  FF FF 55 BB 00 00 02 04-05 B4 01 01 04 02
```
- Status Bar:** Capture: Off | Pkts: 4 in / 5 out / 0 pass | Auto-saving: Off | Rules: 1 On | Alarms: Off | 11% CPU Us.

Collect the values of the main fields of the captured **three-way handshake** packets (characterizing the **Web** session):

Example:

Packet number as displayed in CommView sniffer	Source IP	Destination IP	Source port	Destination port	SYN	ACK
1	192.168.2.20	192.168.3.30	1038	80	1	0
2	192.168.3.30	192.168.2.20	80	1038	1	1
3	192.168.2.20	192.168.3.30	1038	80	0	1

Using a packet generator, a **FAKE** TCP packet **pretending** that a TCP connection on port 80 is already established (**SYN = 0 and ACK = 1**), is sent to Host #2:



Established TCP session:

Packet number as displayed in CommView sniffer	Source IP	Destination IP	Source port	Destination port	SYN	ACK
1	192.168.2.20	192.168.3.30	1038	80	1	0
2	192.168.3.30	192.168.2.20	80	1038	1	1
3	192.168.2.20	192.168.3.30	1038	80	0	1

The **FAKE** TCP packet includes a source port different from the source port of the current active Web session.

FAKE TCP packet:

Source IP	Destination IP	Source port	Destination port	SYN	ACK
192.168.2.20	192.168.3.30	7000	80	0	1

FAKE TCP packet:

Packet generator tool:

Send Packets via Local Area Connection

Ethernet II

- IP
 - IP version: 0x04 (4)
 - Header length: 0x05 (5) - 20 bytes
 - Differentiated Services Field: 0x00 (0)
 - Total length: 0x0028 (40)
 - ID: 0x0040 (64)
 - Flags
 - Fragment offset: 0x0000 (0)
 - Time to live: 0x80 (128)
 - Protocol: 0x06 (6) - TCP
 - Checksum: 0x740D (29709) - correct
 - Source IP: 192.168.2.20
 - Destination IP: 192.168.3.30
 - IP Options: None
- TCP
 - Source port: 7000
 - Destination port: 80
 - Sequence: 0x03739F11 (57909009)
 - Acknowledgement: 0x9855179F (2555713439)
 - Header length: 0x05 (5) - 20 bytes
 - Flags: ACK
 - Window: 0xFFFF (65535)
 - Checksum: 0xBB30 (47920) - correct
 - Urgent Pointer: 0x0000 (0)
 - TCP Options: None
 - Data length: 0x0 (0)

0x00: 00 1B D4 54 EF C2 00 1E 0B 2C 86 2E 08 00 45 00
0x10: 00 28 00 40 40 00 80 06 74 0D C0 A8 02 14 C0 A8
0x20: 03 1E 1B 58 00 50 03 73 9F 11 98 55 17 9F 50 10
0x30: FF FF BB 30 00 00

CommView Visual Packet Builder

Packet Generator

Packet size: 54

Packets per second: 10

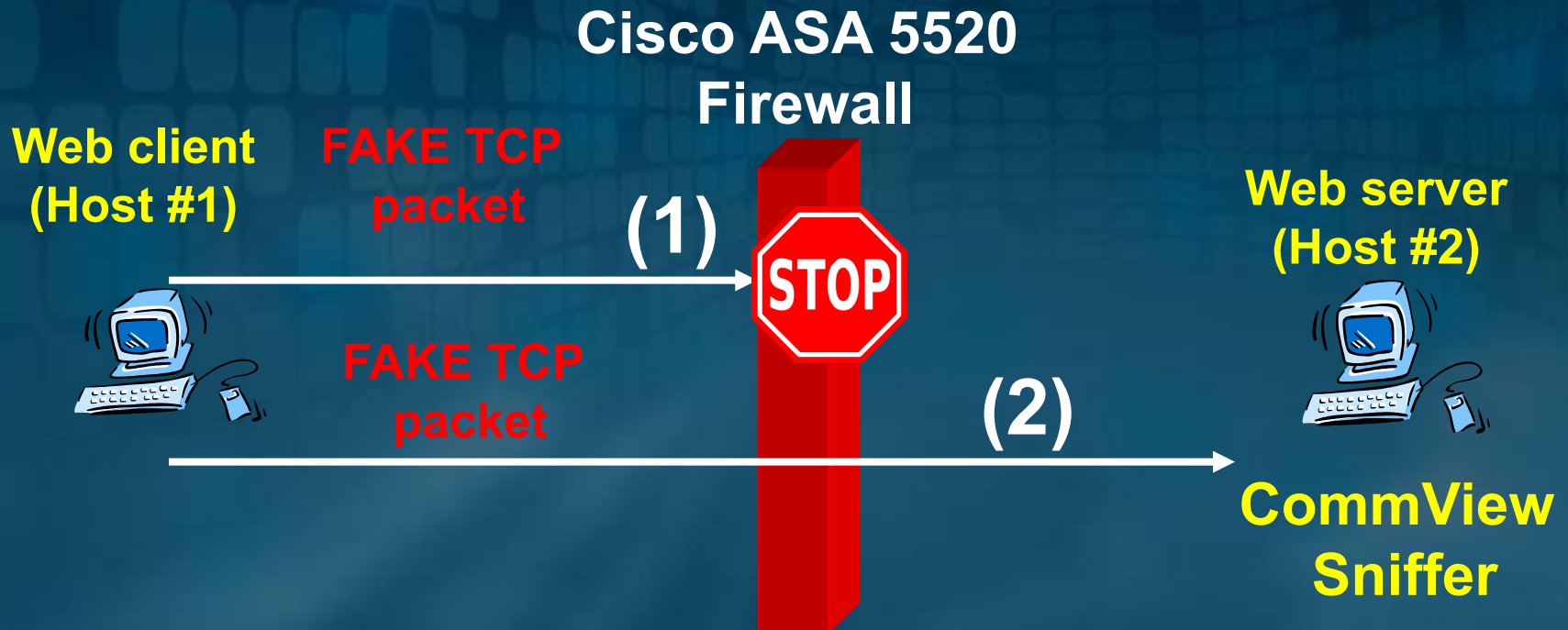
Continuously

1 time(s)

Send

16 packets sent

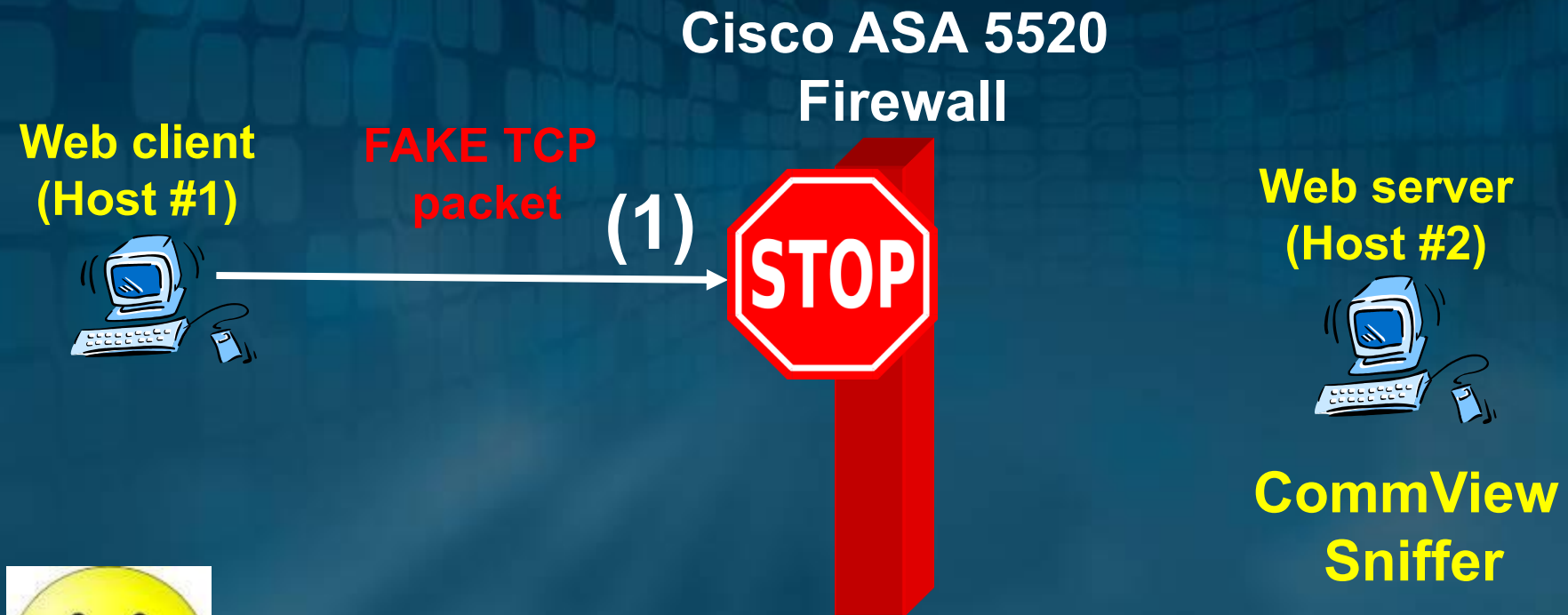
Two possible cases:



(1): Cisco ASA offers **stateful** TCP packet filtering

(2): Cisco ASA offers **stateless** TCP packet filtering

Experiment Result



Cisco ASA 5520 is a stateful firewall for TCP related traffic, since it denies TCP packets that do not belong to established TCP sessions

Exp. 2:
Stateful ICMP packet
filtering testing

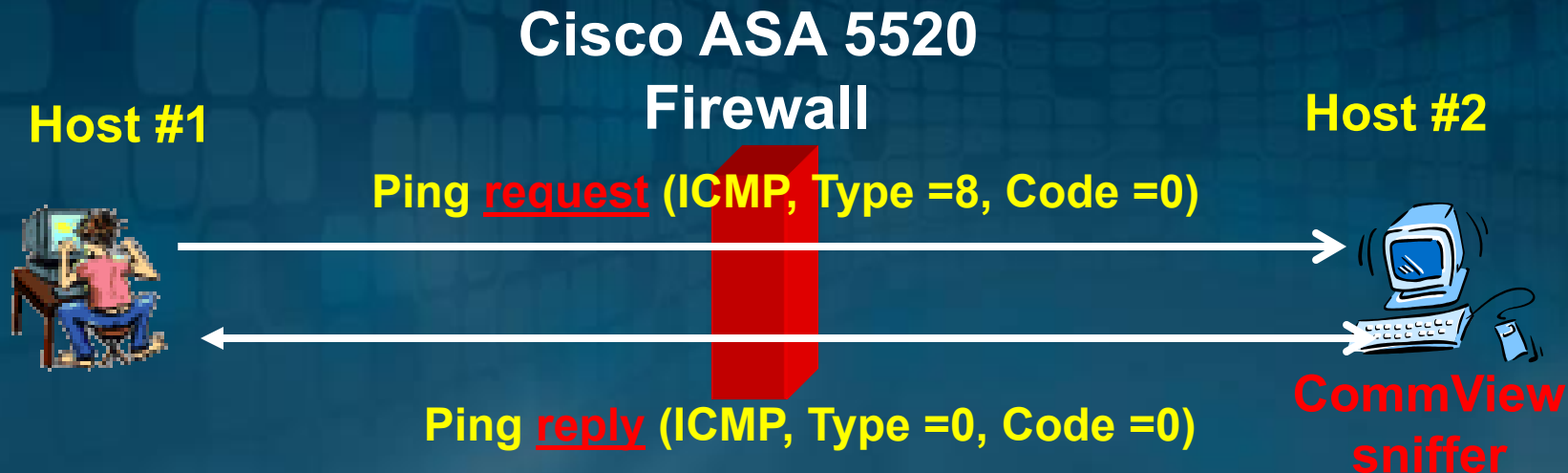
Exp. 2: Stateful ICMP packet filtering testing

Security policy:



Allow Host #1 to ping Host #2, but Host #2 is not allowed to ping Host #1.

Exp. 2: Stateful ICMP packet filtering testing



Host #1 pings Host #2

At Host #1, CommView sniffer is used to capture the exchanged ICMP packets.

The values of the main fields of the exchanged ICMP request and reply packets

Packet number as displayed in CommView	Source IP	Destination IP	Type	Code	Identifier	Sequence Number
1	192.168.2.20	192.168.3.30	8	0	512	9472
2	192.168.3.30	192.168.2.20	0	0	512	9472

Then, CommView Visual Packet Builder is used to send from Host #2 to Host #1 a fake ICMP echo **reply** packet, pretending that an ICMP echo request packet has been received before from Host#1.

Example of Fake ICMP echo reply packet:

Source IP	Destination IP	Type	Code	Identifier	Sequence Number
192.168.3.30	192.168.2.20	0	0	512	8000

Experiment Result:

Cisco ASA 5520
Firewall

Host #1

Host #2



Ping request (ICMP, Type =8, Code =0)



Ping reply (ICMP, Type =0, Code =0)

CommView
sniffer



Consequently, the Cisco ASA 5520 is a stateless firewall for ICMP related traffic, since it did not deny the fake ICMP echo reply packet.

Cisco ASA 5520 Firewall



Stateful TCP
packet filtering



Stateless ICMP
packet filtering



Hands-on Lab outcomes:

- **Better anatomize the concept of stateful and stateless packet filtering**
- **Test firewalls**
- **Generate fake packets**
- **Analyze network traffic using sniffer**

STUDENT'S PERFORMANCE AND SATISFACTION

Stateless and Stateful concepts: Network Border Control course (SECB358).

From **fall 2006 to spring 2008:** students enrolled in SECB358 course were not offered hands-on lab exercises on stateless and stateful packet filtering.

Only the conceptual part of the topic has been described in the class.

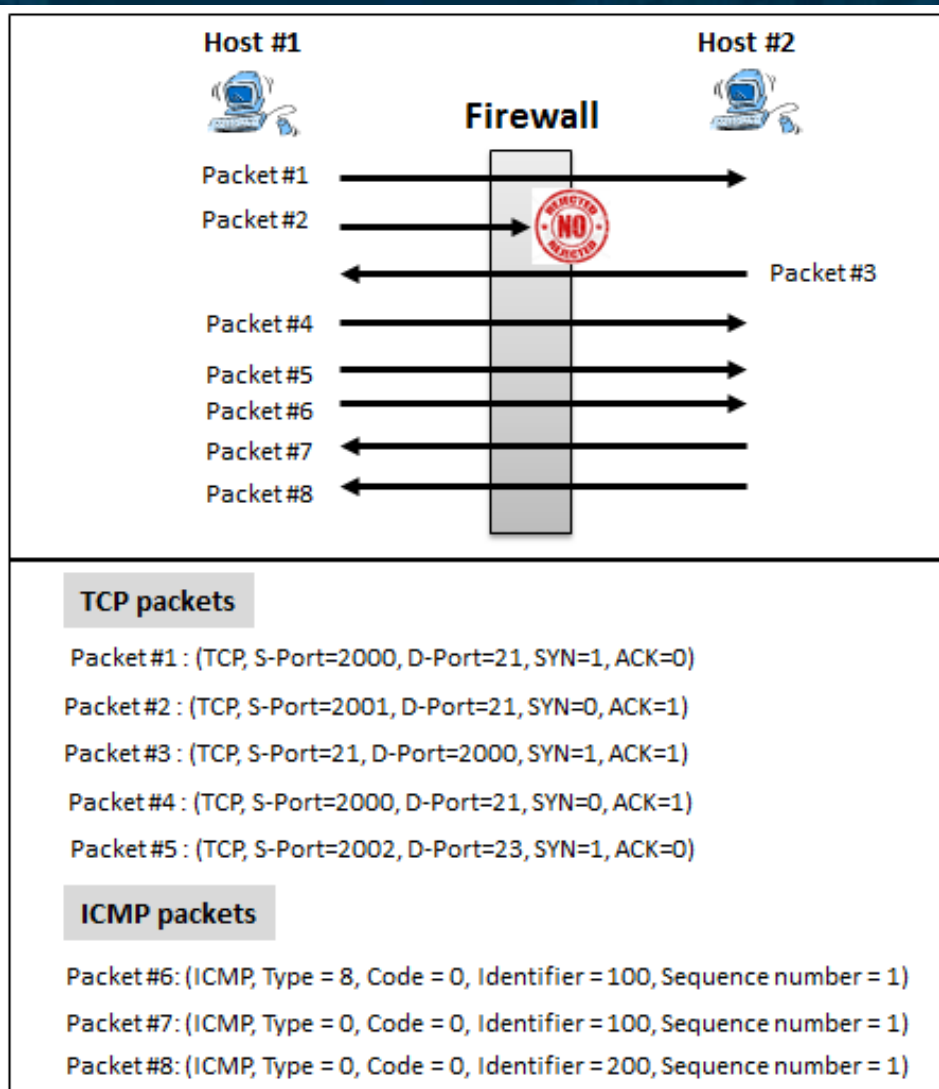
However, from **fall 2008 to spring 2011,** the students were offered the hands-on lab exercise described in this paper.

Over the **five year period,** each semester the students were given two quizzes and a Midterm exam exercise about stateless and stateful packet filtering

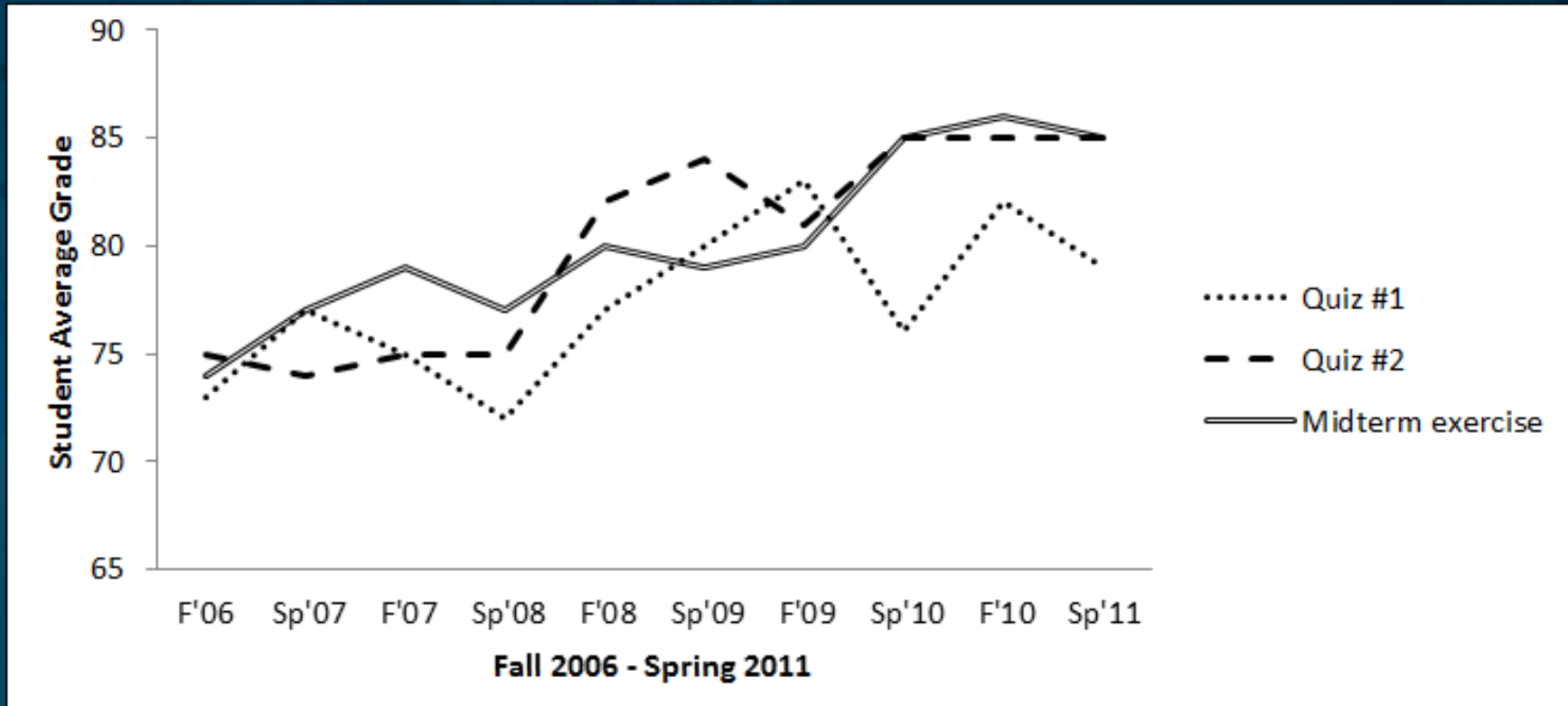
QUIZ EXAMPLE

*Tell if the firewall performs stateless or stateful packet inspection for **TCP** traffic,*

*and (2) tell if the firewall performs stateless or stateful packet inspection for **ICMP** traffic*



Students' Grading Performance



The hands-on lab exercise allowed students to better anatomize the concept of stateless and stateful packet filtering learned from the lecture

Students' Satisfaction

To measure their satisfaction level and collect their feedback regarding the discussed hands-on lab exercise: An anonymous questionnaire was administered to 110 students, who participated in the lab exercise:

Questions	Responses
Did you enjoy the hands-on lab exercise?	<ul style="list-style-type: none">• 86% strongly agree• 11% agree• 2% neither agree or disagree• 1% disagree
Do you think the hands-on lab exercise is easy to follow and straightforward?	<ul style="list-style-type: none">• 85% strongly agree• 10% agree• 2% neither agree or disagree• 3% disagree
Do you feel you understand the theoretical concepts better after performing the hands-on lab exercise?	<ul style="list-style-type: none">• 87% strongly agree• 9% agree• 3% neither agree or disagree• 1% disagree
How likely are you to recommend the hands-on lab exercise to others?	<ul style="list-style-type: none">• 88% strongly agree• 9% agree• 2% neither agree or disagree• 1% disagree
Would you like to see similar hands-on lab exercises offered in your network security classes?	<ul style="list-style-type: none">• 90% strongly agree• 8% agree• 1% neither agree or disagree• 1% disagree

Conclusion:

Information Security Program (Undergraduate)



Security concepts



**Hands-on lab
exercises**



- **Better anatomize the concepts**
- **Hands-on skills**

Information Security Program (Undergraduate)



Hands-on lab
exercises about
defense techniques



Hands-on lab
exercises about
offensive techniques
(Ethical hacking)

Hands-on lab exercises about **defense** and **offensive** techniques

Textbook:



October 2012

Papers:

“Switch’s CAM Table Poisoning Attack: Hands-on Lab Exercises for Network Security Education,”
Proceedings of the 14th Australasian Computing Education Conference (ACE 2012), Australia.

“Hands-on Lab Exercises Implementation of DoS and MiM Attacks using ARP Cache Poisoning”, Proceedings of the Information Security Curriculum Development Conference 2011 (InfoSecCD 2011), USA.

“ARP Spoofing: A Comparative Study for Education Purposes”, Proceedings of the Information Security Curriculum Development Conference (InfoSecCD 2009), USA.

Thank You

What Students Learn

Protect networks and systems from attacks

Computer Forensics

Filter traffic

Implement biometrics solutions

Develop Virus and AntiVirus

Use and implement cryptography solutions

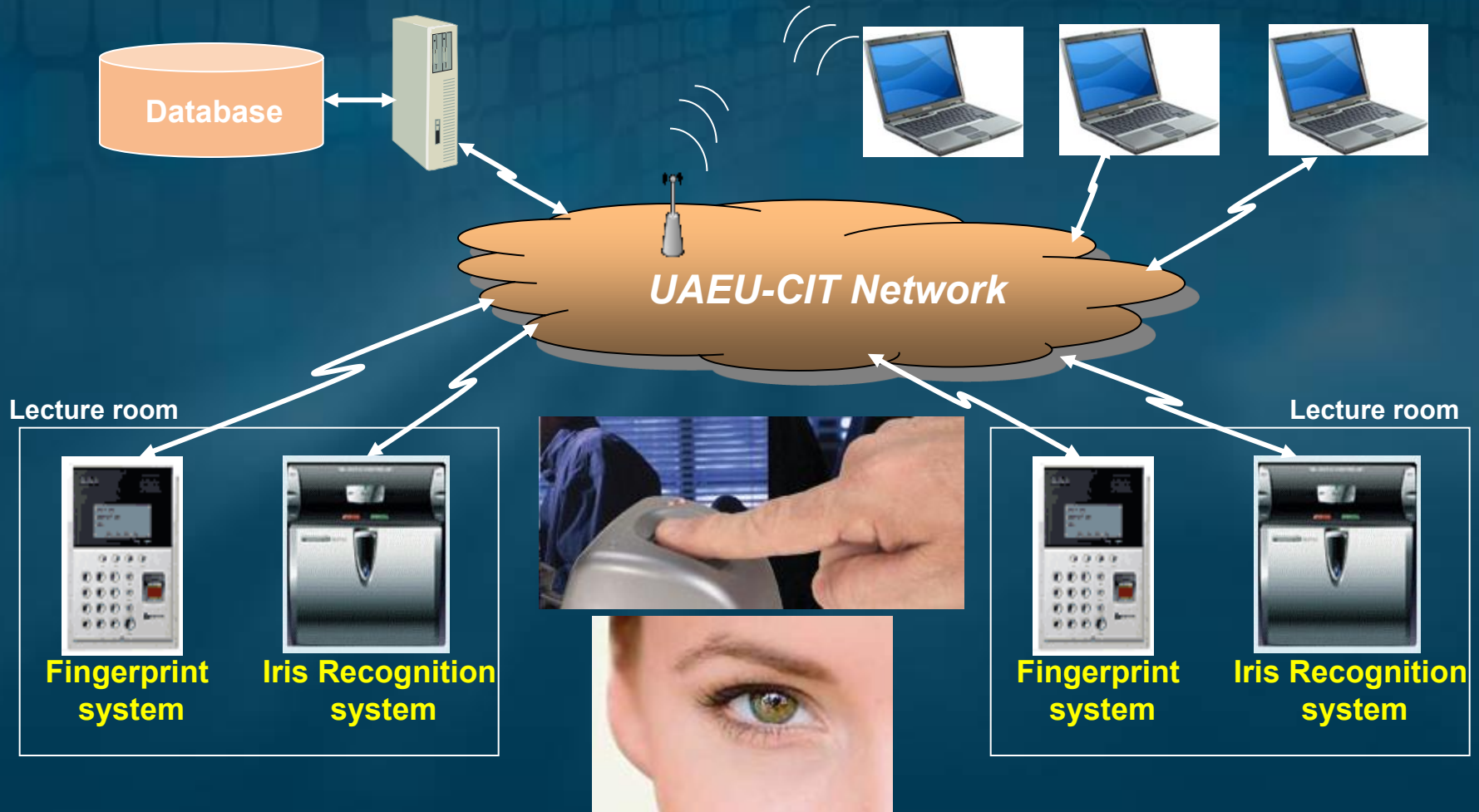
Security audit...



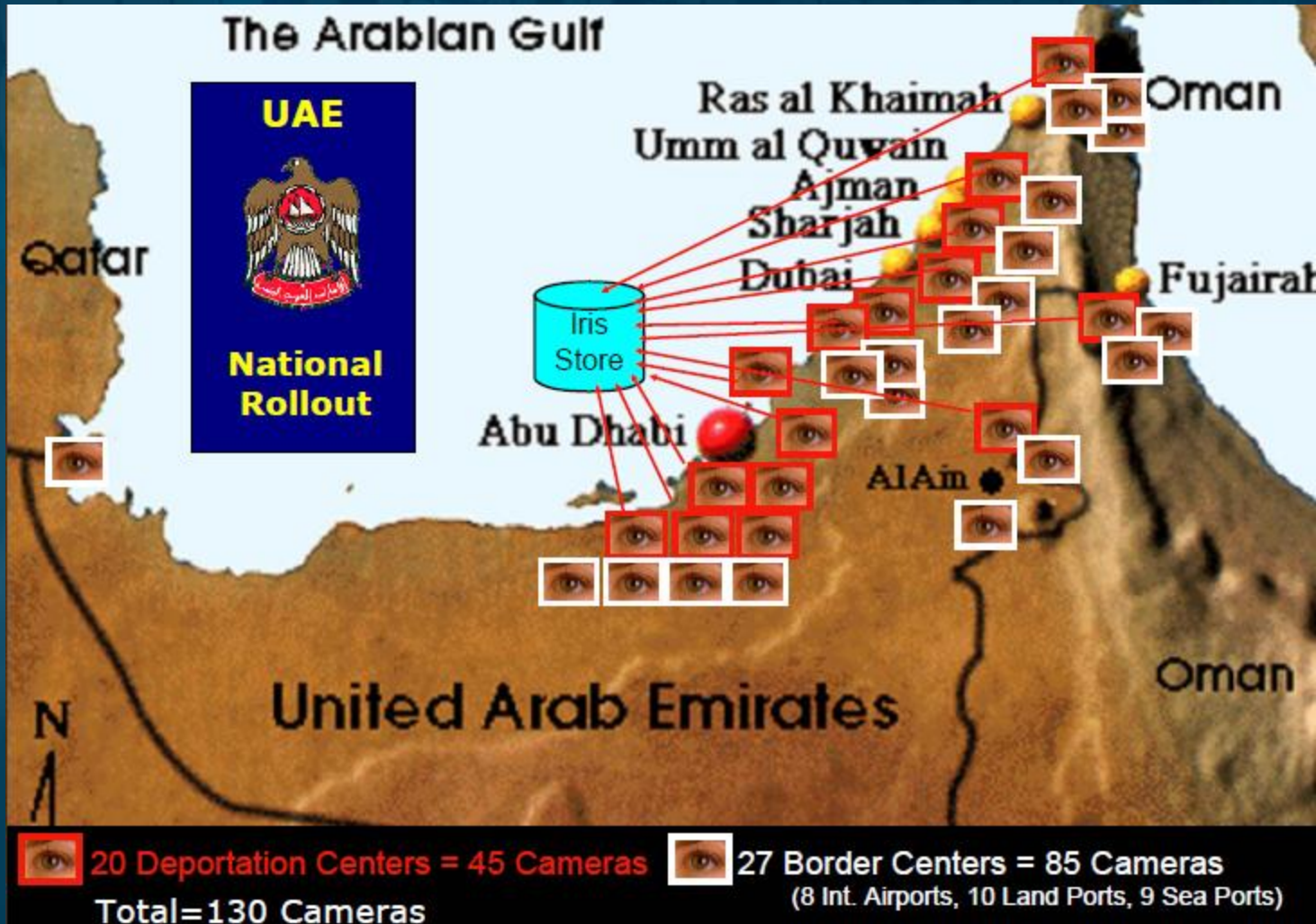
UAEU Biometrics e-Attendance System

Main Server

Teachers



The UAE Iris Expellees Tracking and Border Control System



Ethical Hacking, Penetration Testing, Computer Forensics Lab

Develop viruses

Cybercrime

Computer Forensics

Security auditing





Textbook:

The screenshot shows the Amazon product page for the textbook "Network Attacks and Defenses: A Hands-on Approach" by Zouheir Trabelsi. The book cover features three martial artists in white uniforms. The title is circled in red. The page includes the Amazon logo, navigation links, a search bar, and product details such as the list price of \$89.95, a current price of \$81.70, and a 9% discount. It also notes that the title has not yet been released and provides shipping information.

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Product Details

Hardcover: 472 pages

Publisher: Auerbach Publications; 1 edition (October 22, 2012)

Language: English

ISBN-10: 1466517948

ISBN-13: 978-1466517943

Shipping Information: [View shipping rates and policies](#)

The UAE Iris Expellees Tracking and Border Control System



Dubai Airport

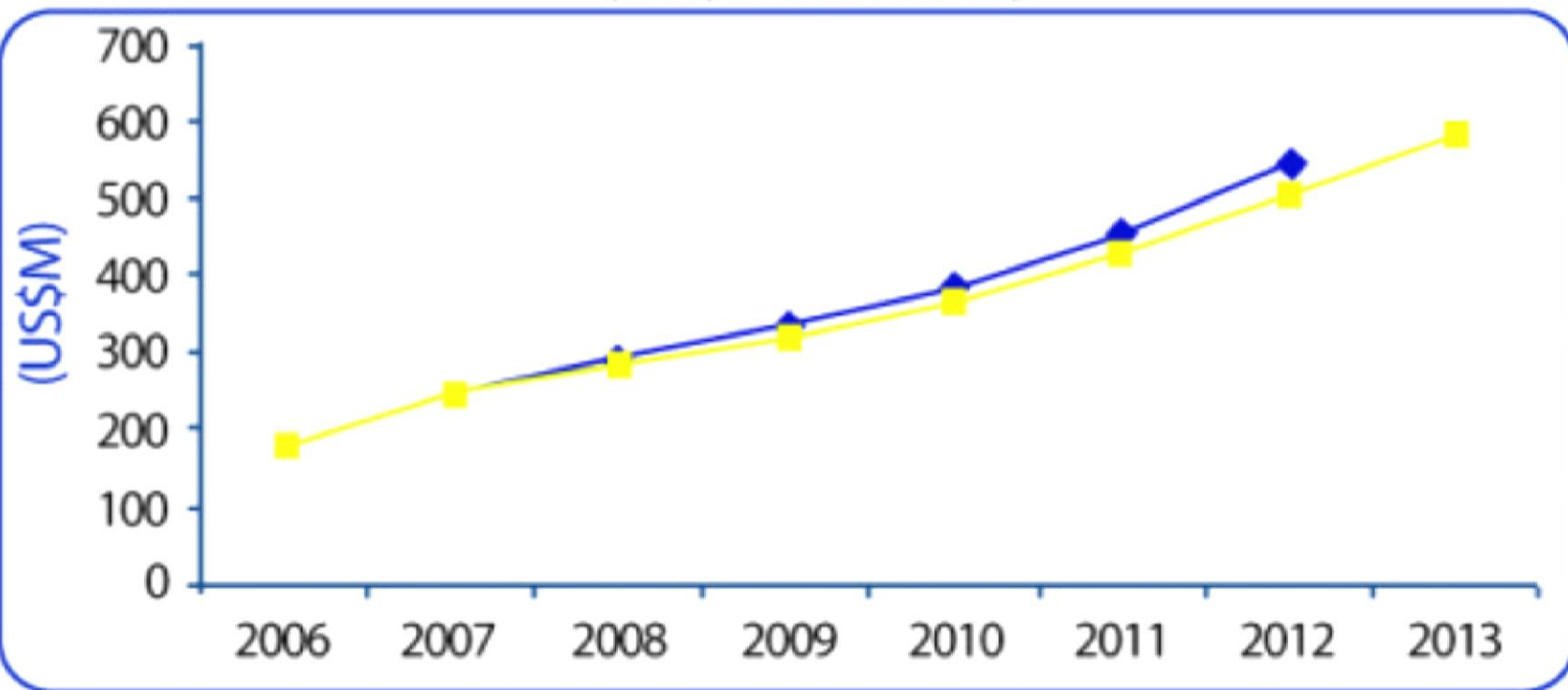




Abu Dhabi Int'l Airport T1



Forecasts of the Security Market in Gulf States (KSA, UAE & OGCC)

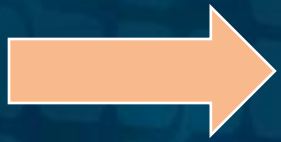


Source - IDC

■ New Forecast (2009 - 2013)
 ◆ New Forecast (2008 - 2012)

Source - IDC

■ New Forecast (2009 - 2013)
 ◆ New Forecast (2008 - 2012)



Huge investment in IT security by GCC countries



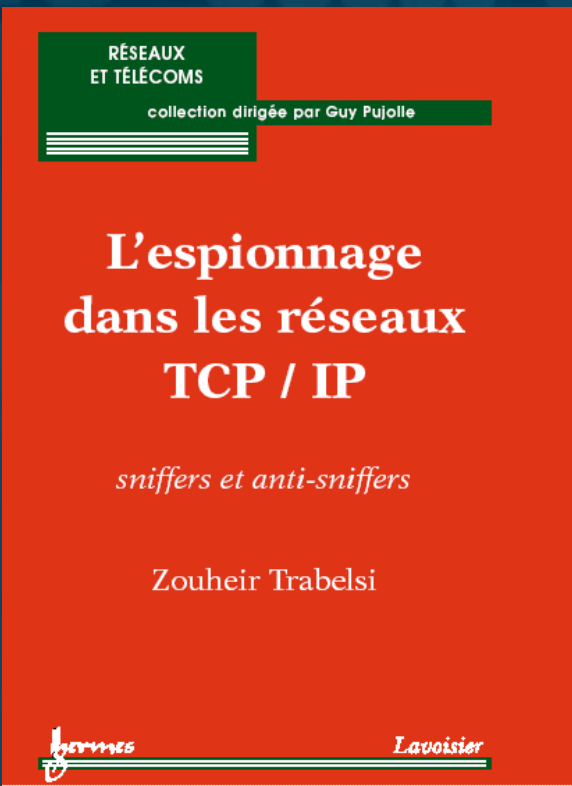
“IDC project that over the next five years, the IT security market in the Persian Gulf region will grow at an average annual rate of 23%.”

“UAE was the second largest source of security expenditure in the region last year, with 31.2% share.”

Security Experimental Facilities

Research Activities

Students Senior Projects
Students Security Course Project
Faculty Research Projects



Espionage in IP Networks:
Sniffers and AnitiSniffers

www.amazon.fr



Information Security Program

Security Labs





State-of-the-Art Security Labs

1 million US\$

**Intrusion Detection & Prevention
Lab**

Firewall & VPN Lab



Wireless Security Lab

Cryptography Lab

Biometrics



Information Security Program at UAEU

Cryptography

Firewall & VPN

**Intrusion Detection
and Prevention
(IDS/IPS)**

Database security

OS security

Biometrics

**Virus &
Malicious Code**



**Web application
security**

**Network Traffic
Analysis**

Ethical Hacking

**Secure
e-transactions**

**Wireless
Security**

**Security Auditing,
Penetration testing**

Intrusion Detection & Prevention Lab

Cisco Switch 3560 Series



Dynamic ARP Inspection:

- ARP cache poisoning attack
- MiM attack
- DoS attack
- Switch CAM table poisoning

Routers



Information Security Program (Undergraduate)



Security concepts

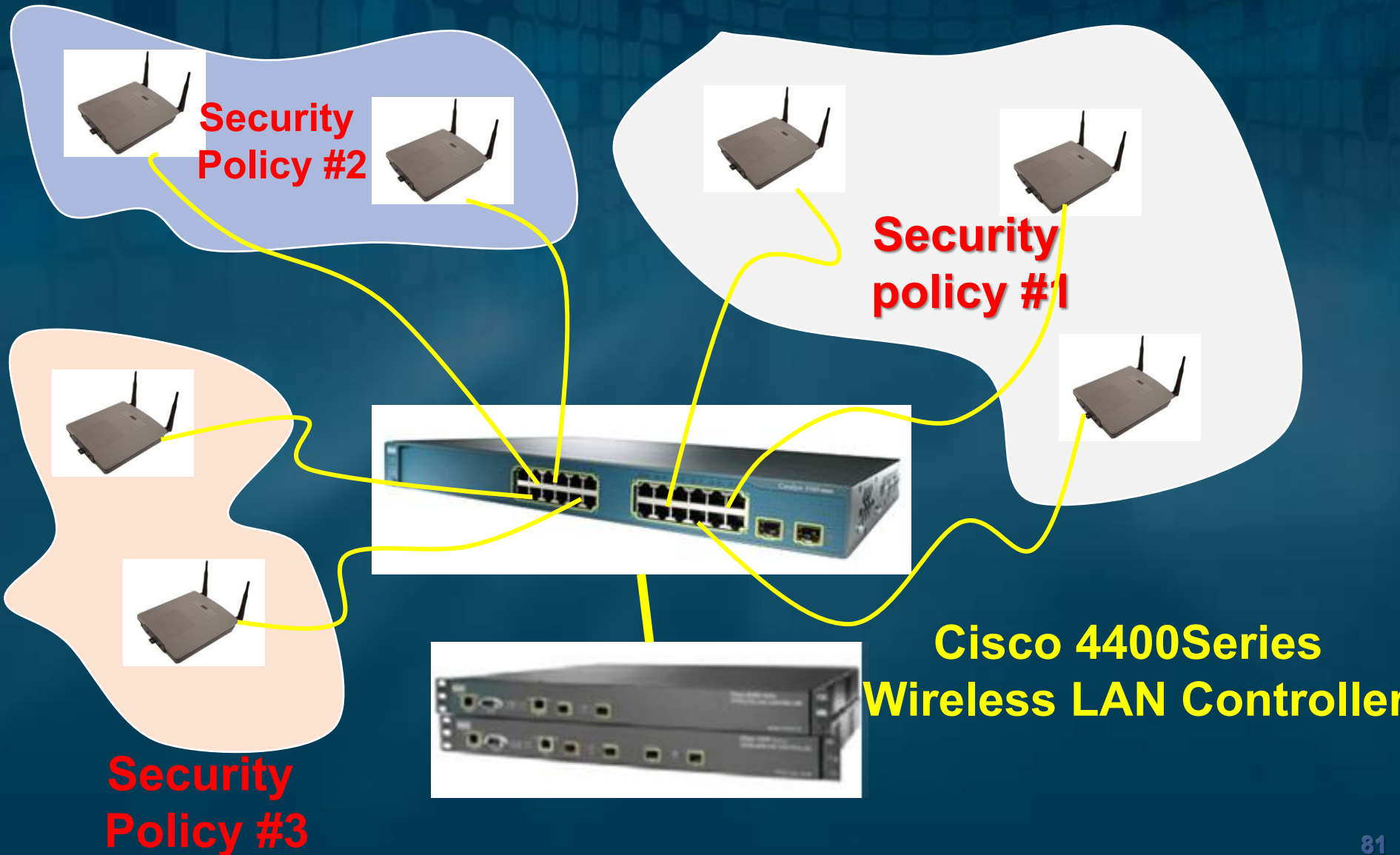


**Hands-on lab
exercises**



- **Better anatomize the concepts**
- **Hands-on skills**

Wireless Security Lab



Stateless and Stateful Firewall

A **stateless** firewall has:



No mechanism to identify packets that belong to established sessions