Practical Network Defense

Master's degree in Cybersecurity 2020-21

Network traffic monitoring

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Layering Concepts

- The communication between the hosts in the network is organized in tasks, each assigned to a **layer**
- Each layer:
  - offers a service (a host of facilities) to the "Users" in the layer above
  - exploits the services offered the layer below
- The task of a level involves the exchange of messages that follow a set of rules defined by a **protocol**.
- Example:
  - Layer (N - 1) provides an insecure service in which data can overheard by unauthorized persons.
  - Protocol of level N specifies that messages sent via (N - 1)-service are encrypted with symmetric encryption.
  - Layer N offers a secure, confidential service.

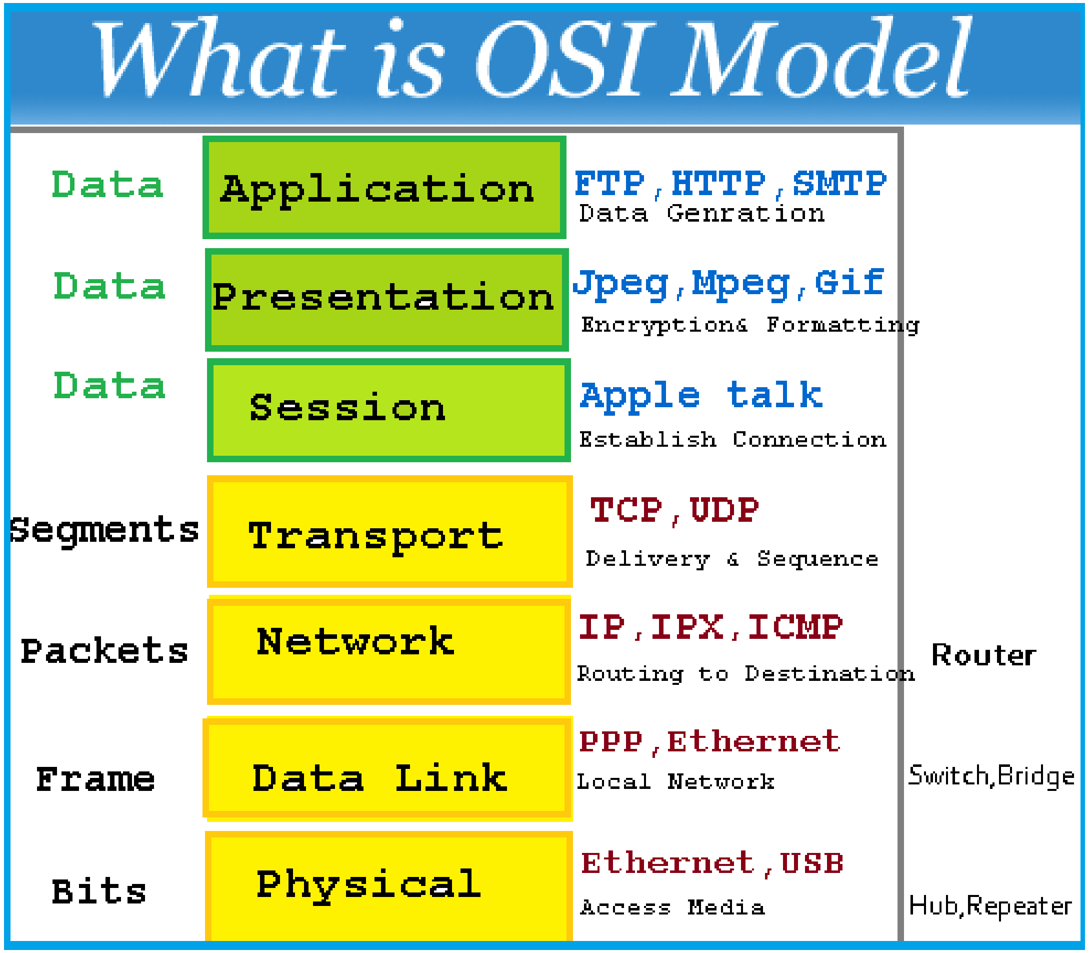
Encapsulation/decapsulation

- The data to be transferred from the application layer to application layer over a network.
- Each layer adds some protocol information and provides data to the layer below.
- The physical layer (bottom) sends data over the physical medium to the destination.
- The physical layer in the destination sends the data up the "stack".
- Each protocol in the destination reads the appropriate protocol information and forwards the data to the layer above.

2 layered architectures

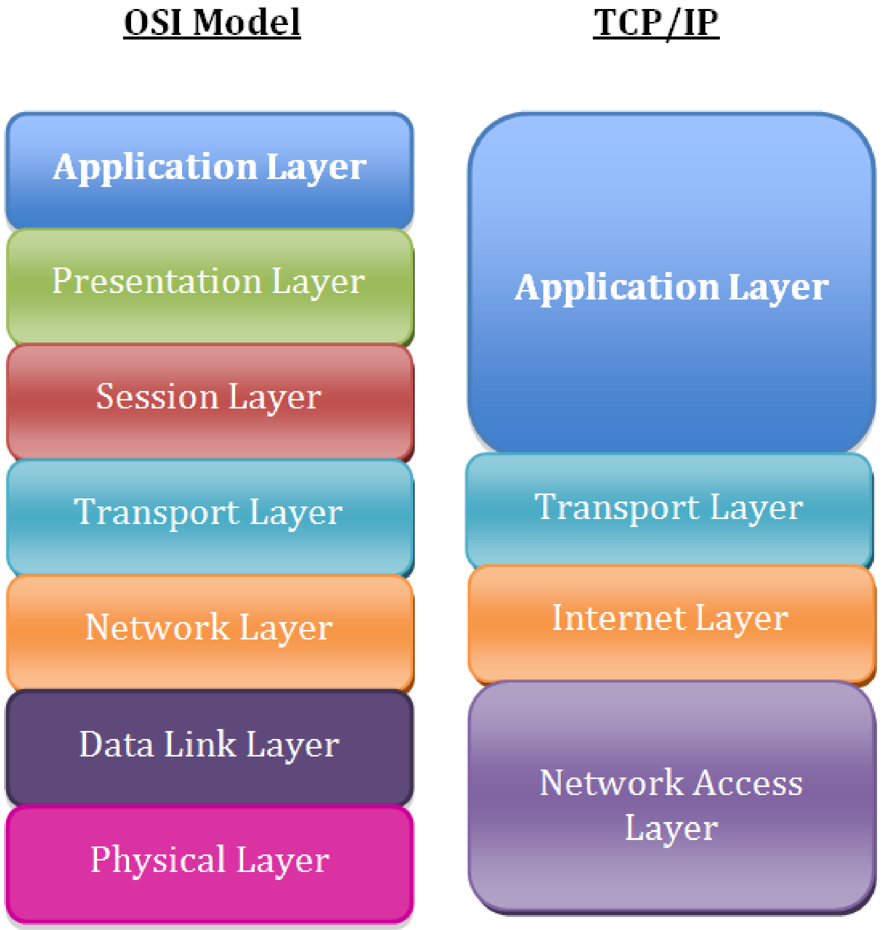
- ISO/OSI model: based on a reference model with 7 layer.
- TCP/IP model: created by the IETF, based on a reference model with 4 layers.
  - The lower TCP/IP layer is often split in 2 layers.
- Common idea: **packet switched network**

Architecture comparison



What is OSI Model

Data	Application	FTP, HTTP, SMTP Data Genration	
Data	Presentation	Jpeg, Mpeg, Gif Encryption& Formatting	
Data	Session	Apple talk Establish Connection	
Segments	Transport	TCP, UDP Delivery & Sequence	
Packets	Network	IP, IPX, ICMP Routing to Destination	Router
Frame	Data Link	PPP, Ethernet Local Network	Switch,Bridge
Bits	Physical	Ethernet, USB Access Media	Hub,Repeater

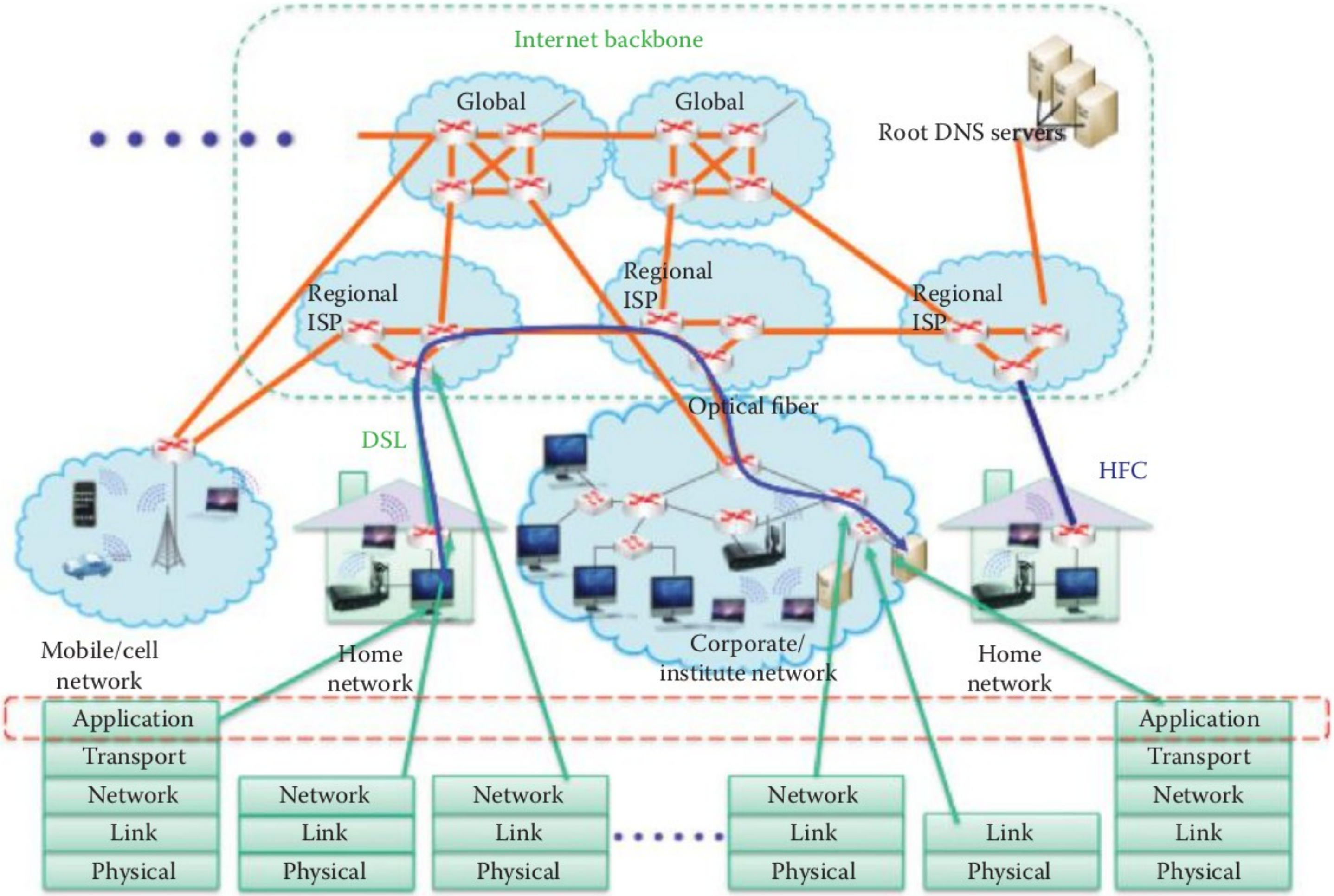


OSI Model	TCP/IP
Application Layer	Application Layer
Presentation Layer	
Session Layer	
Transport Layer	Transport Layer
Network Layer	Internet Layer
Data Link Layer	Network Access Layer
Physical Layer	

TCP / IP model

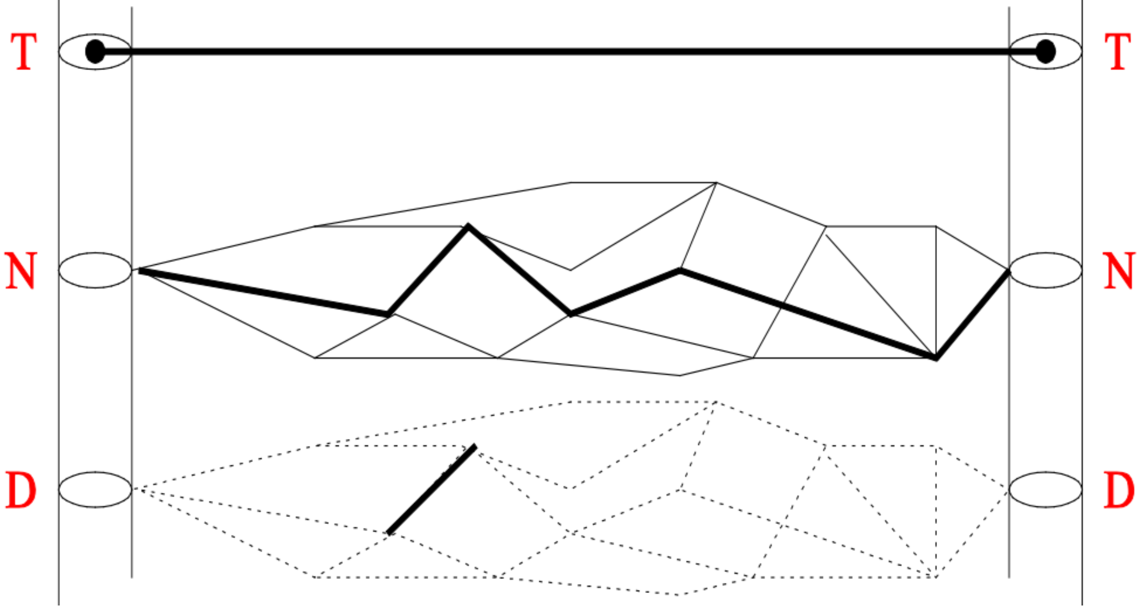
- Application layer: Corresponds to the top three layers of the OSI model.
  - Protocols: SMTP (sending e-mail), HTTP (web), FTP (file transfer), and others
- Transport layer: Equivalent to Layer 4 (Transport) of the OSI model
  - Protocols: TCP, UDP
- Internet: Equivalent to layer 3 (network) of the OSI model.
  - Protocols: IP, ICMP, IPSec
- Datalink: Equivalent to layer 2 (data link) of the OSI model.
  - Protocols: Ethernet, WiFi, ARP, etc.
- Physical layer: Equivalent to Layer 1 (Physical) of the OSI model.
  - NOTE: Datalink + physical layers are known as Network access layer.

Client-server communication example



Layer ideal representation

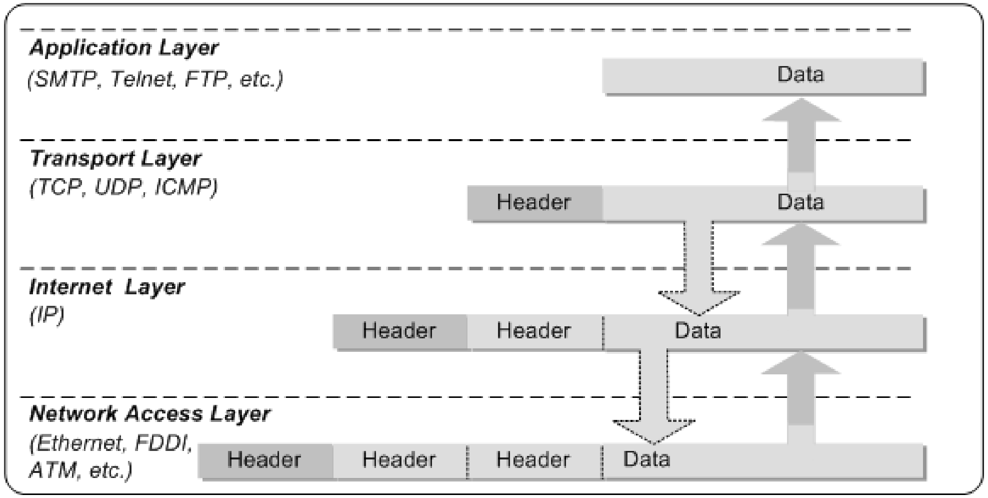
- **Transport**: the illusion of direct end-to-end connection between processes in arbitrary systems.
- **Network**: transferring data between arbitrary nodes.
- **Data Link**: transferring data between directly connected systems (via direct cable or shared medium).

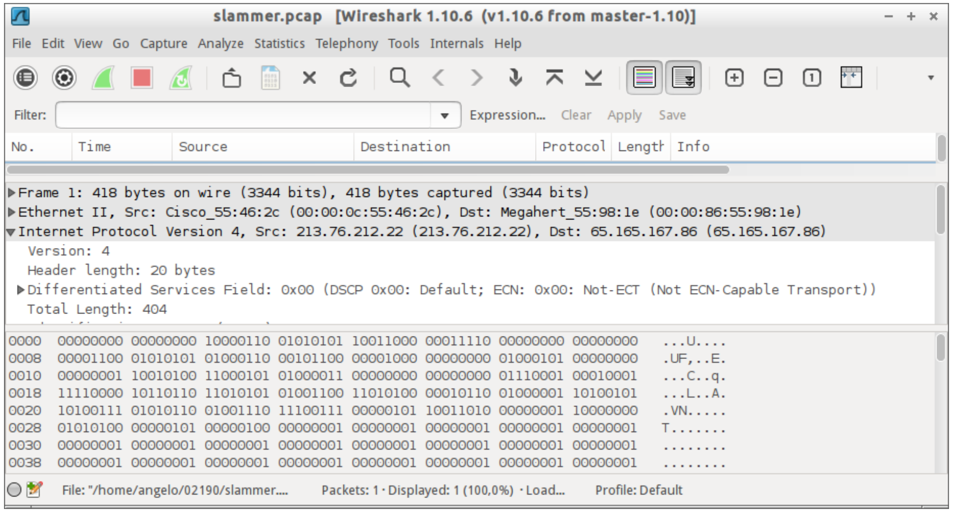


Addresses in the architectures

- Each layer has a type of address:
  - Application layer: Internet name, eg. www.*sapienza.it*
  - Transport layer: Port number, in the range [0..65535] that identifies the client or server. For example 80 for HTTP server.
  - Internet layer: IP address that identifies a network card, for example 151.100.17.4
  - Datalink layer: MAC address, also identifies a network cards, for example 49:bd:d2:c7:56:2a

Encapsulation in TCP/IP





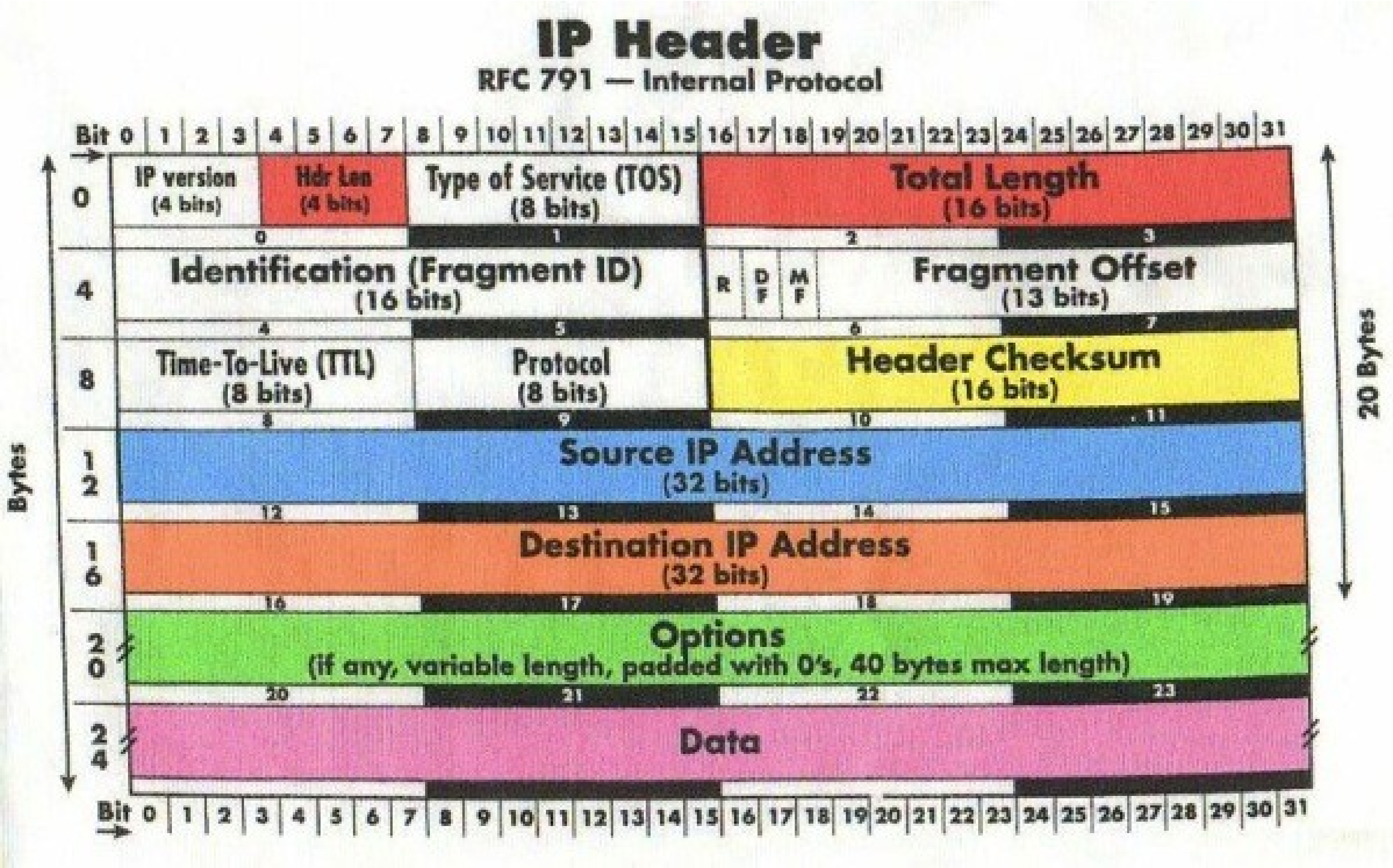
slammer.pcap [Wireshark 1.10.6 (v1.10.6 from master-1.10)]
File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help
Filter:
Expression... Clear Apply Save
No. Time Source Destination Protocol Length Info

```
▶Frame 1: 418 bytes on wire (3344 bits), 418 bytes captured (3344 bits)
▶Ethernet II, Src: Cisco_55:46:2c (00:00:0c:55:46:2c), Dst: Megahert_55:98:1e (00:00:86:55:98:1e)
▼Internet Protocol Version 4, Src: 213.76.212.22 (213.76.212.22), Dst: 65.165.167.86 (65.165.167.86)
   Version: 4
   Header length: 20 bytes
  ▶Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00: Not-ECT (Not ECN-Capable Transport))
   Total Length: 404
```

```
0000  00000000 00000000 10000110 01010101 10011000 00011110 00000000 00000000   ...U....
0008  00001100 01010101 01000110 00101100 00001000 00000000 01000101 00000000   .UF,..E.
0010  00000001 10010100 11000101 01000011 00000000 00000000 01110001 00010001   ...C..q.
0018  11110000 10110110 11010101 01001100 11010100 00010110 01000001 10100101   ...L..A.
0020  10100111 01010110 01001110 11100111 00000101 10011010 00000001 10000000   .VN.....
0028  01010100 00000101 00000100 00000001 00000001 00000001 00000001 00000001   T.......
0030  00000001 00000001 00000001 00000001 00000001 00000001 00000001 00000001   ........
0038  00000001 00000001 00000001 00000001 00000001 00000001 00000001 00000001   ........
```

File: "/home/angelo/02190/slammer.... Packets: 1 · Displayed: 1 (100,0%) · Load... Profile: Default

IP packets



IP Header

RFC 791 — Internal Protocol

Bit 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31

0 — IP version (4 bits) | Hdr Len (4 bits) | Type of Service (TOS) (8 bits) | Total Length (16 bits)

0 | 1 | 2 | 3

4 — Identification (Fragment ID) (16 bits) | R | DF | MF | Fragment Offset (13 bits)

4 | 5 | 6 | 7

8 — Time-To-Live (TTL) (8 bits) | Protocol (8 bits) | Header Checksum (16 bits)

8 | 9 | 10 | 11

12 — Source IP Address (32 bits)

12 | 13 | 14 | 15

16 — Destination IP Address (32 bits)

16 | 17 | 18 | 19

20 — Options (If any, variable length, padded with 0's, 40 bytes max length)

20 | 21 | 22 | 23

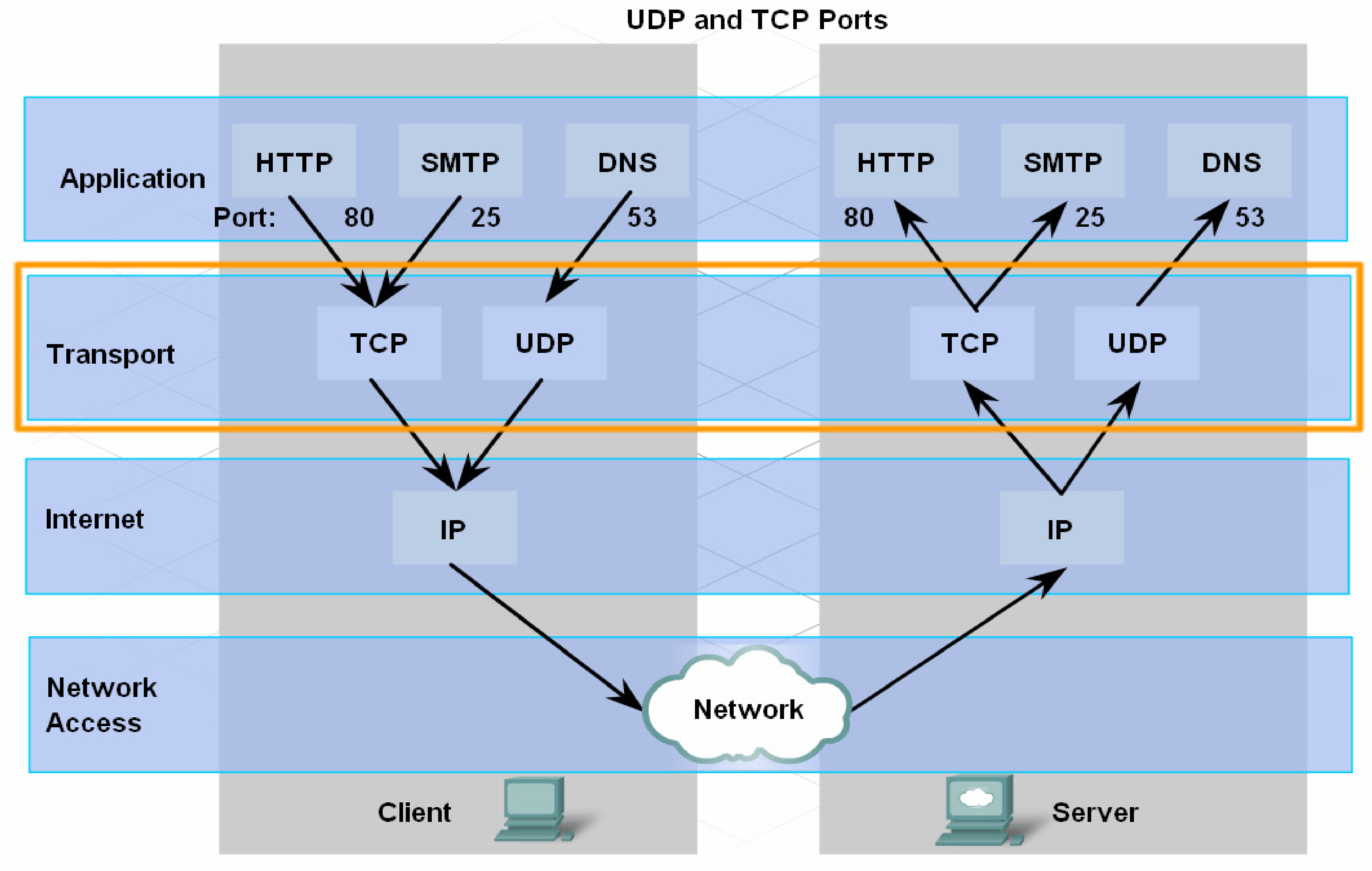
24 — Data

Bit 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31

Ports

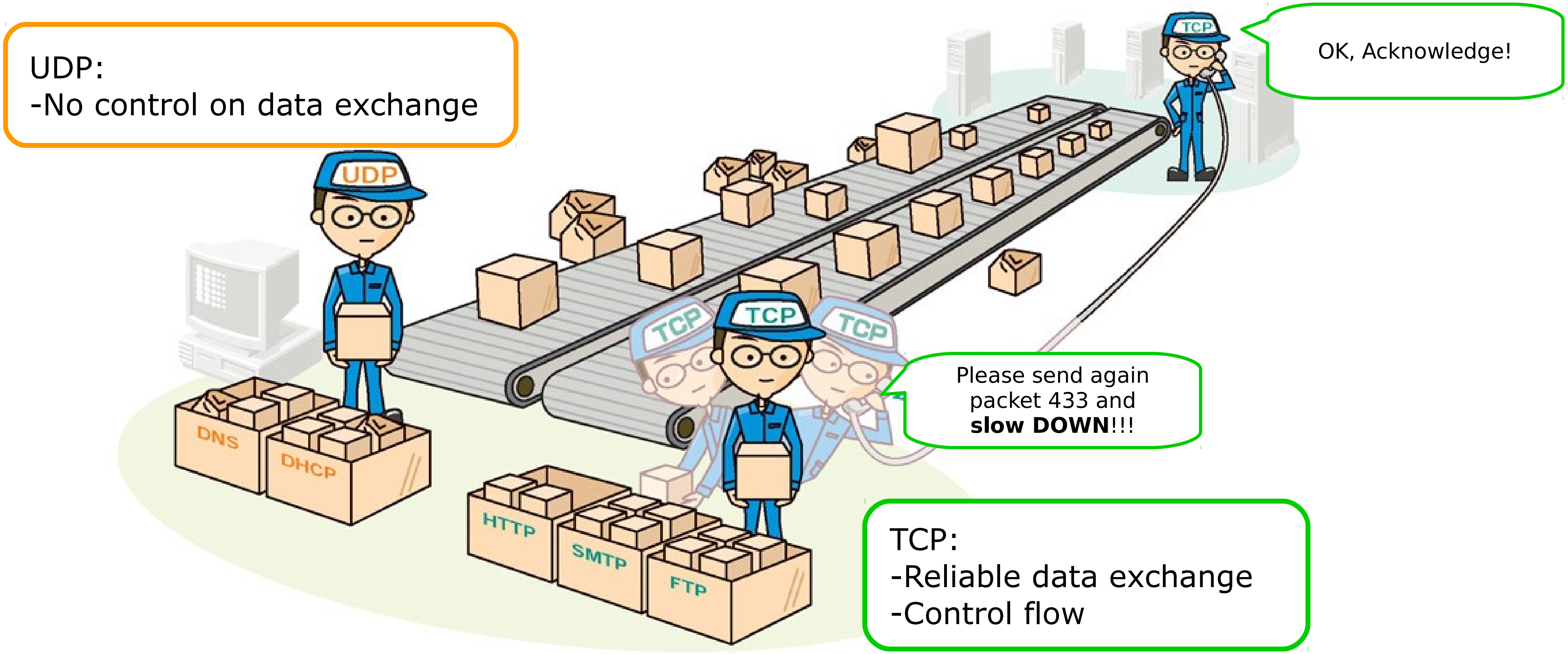
- Range [0..65535]
- Source port: randomly chosen by the OS
- Destination port determines the required service (application)
  - Assigned Ports [0..1023] are said “well-known ports” and used by servers for standard Internet applications:
    - 25: SMTP (sending mail)
    - 80: HTTP (web)
    - 143: IMAP (pick-up of mail)
  - Ports [1024..49151] can be registered with Internet Application Naming Authority (IANA)
  - Ports [49152..65535] ephemeral ports

Transport layer: TCP and UDP



TCP vs UDP

- Connection vs Connection-less



UDP:
-No control on data exchange

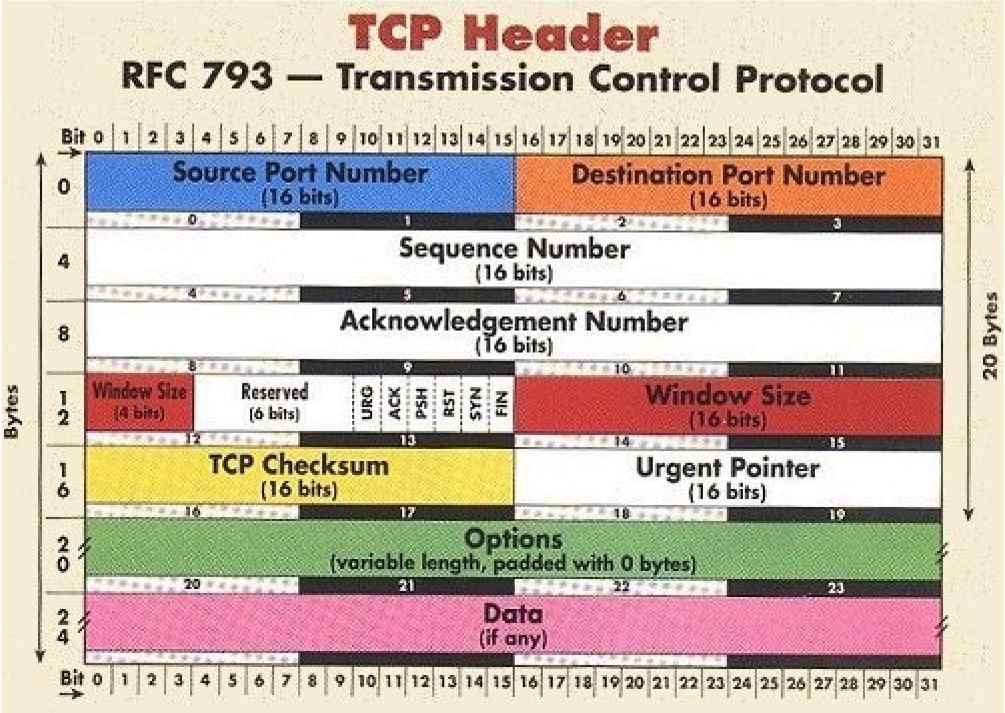
OK, Acknowledge!

Please send again
packet 433 and
slow DOWN!!!

TCP:
-Reliable data exchange
-Control flow

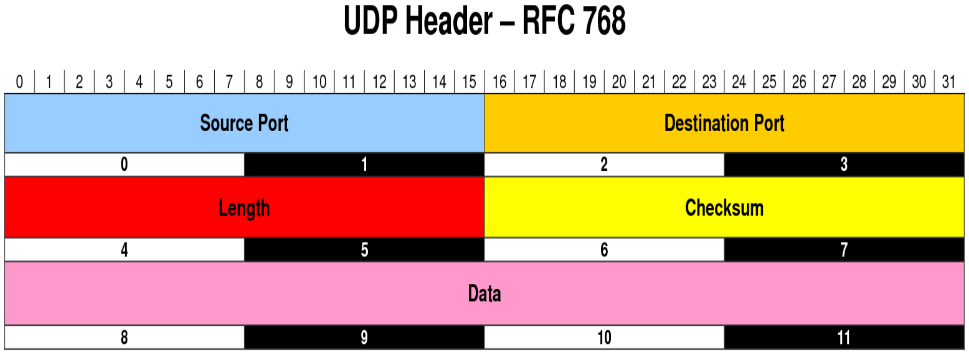
http://itpro.nikkeibp.co.jp/article/lecture/20070305/263897/

TCP header vs UDP header

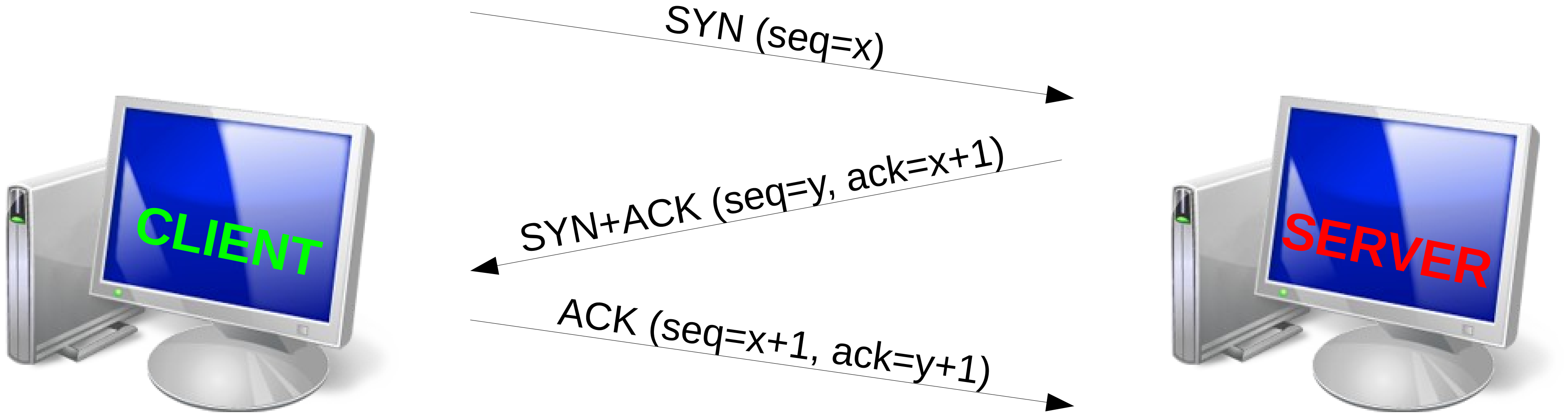

TCP Header

RFC 793 — Transmission Control Protocol

Bit 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Bytes
0
Source Port Number (16 bits)
Destination Port Number (16 bits)
0 1 2 3
4
Sequence Number (16 bits)
4 5 6 7
8
Acknowledgement Number (16 bits)
8 9 10 11
12
Window Size (4 bits)
Reserved (6 bits)
URG
ACK
PSH
RST
SYN
FIN
Window Size (16 bits)
12 13 14 15
16
TCP Checksum (16 bits)
Urgent Pointer (16 bits)
16 17 18 19
20
Options (variable length, padded with 0 bytes)
20 21 22 23
24
Data (if any)
20 Bytes


UDP Header – RFC 768

TCP connection handshake



Services relying on TCP

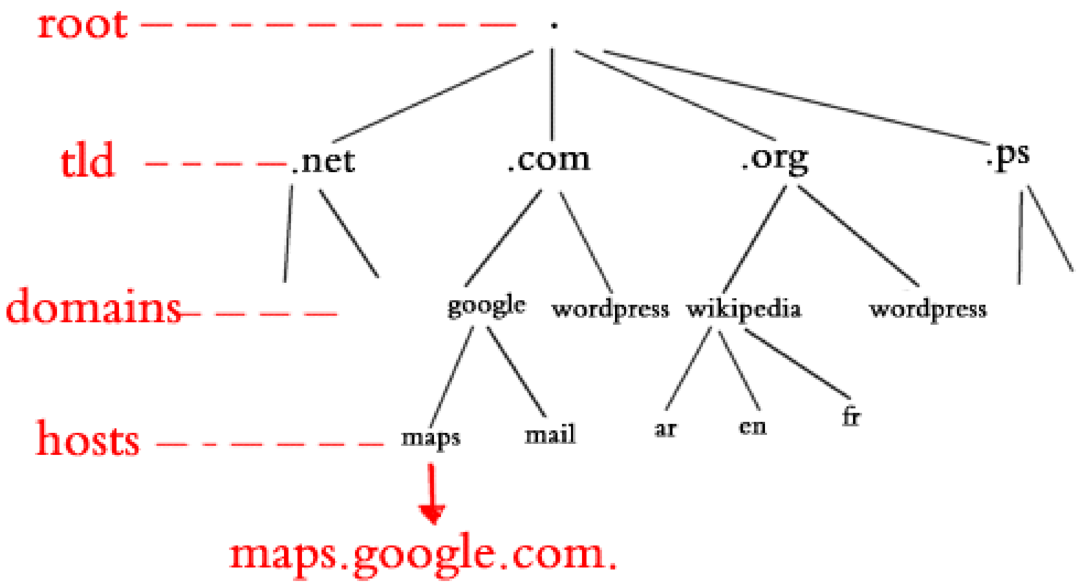
- FTP on port 20 and 21
- SSH on port 22
- Telnet on port 23
- SMTP on port 25
- HTTP on port 80
- IMAP on port 143
- SSL on port 443

Services relying on UDP

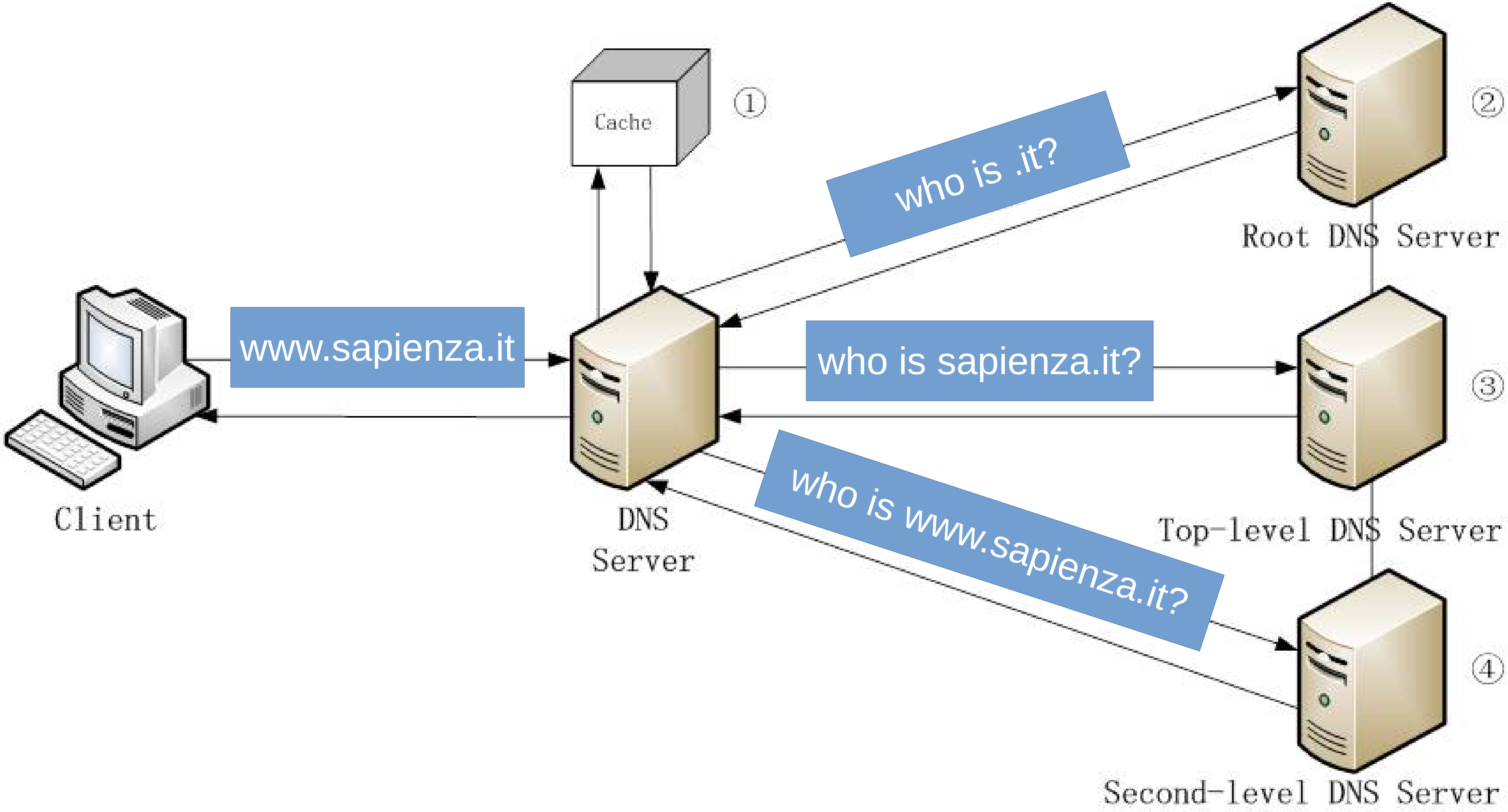
- DNS on port 53
- DHCP on ports 67 and 68
- TFTP on port 69
- SNMP on port 161
- RIP on port 520

DNS

- A service to get the IP address from an human-friendly domain name, like www.sapienza.it
- Hierarchy of entities responsible for domain names



DNS query example



Dive into packets

Capture packets

- Packets flow in the network, to capture them use a network traffic dump tool, like:
  - **dumpcap**
  - **wireshark/tshark** (https://www.wireshark.org/docs/)
  - **tcpdump**
- All based on the *pcap* (*winpcap* in Windows) library
- All of them can visualize and save the captured data
- Wireshark and tcpdump can also **analyze** *(decode)* the captured packets

Wireshark

- Data from a network interface are “dissected” in frames, segments, and packets, understanding where they begin and end
- Then, they are interpreted and visualized in the context of the recognized protocol
- **Promiscuous mode** (also called monitor mode) is required to capture packets not intended for the capturing host
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  - Looking for the root cause of a known problem
  - Searching for a certain protocol or stream between devices
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Using wireshark

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  - They allow to only focus on requested packets or certain activity by network devices
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Capture filters – wireshark/tcpdump

- Limit the traffic captured and, optionally, analyzed
  - Packets not captured are lost…
- Berkeley Packet Filter (BPF) syntax (man pcap-filter)

protocol direction type

  - Protocol: ether, tcp, udp, ip, ip6, arp
  - Direction: src, dst
  - Type: host, port, net, portrange
  - Other primitives: less, greater, gateway, broadcast
  - Combinations with operators: and (&&), or (||), not (!)

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Alternative way to capture traffic info

- Traffic represented as “connections”
- Netflow
  - For statistics and monitoring
  - Netflow v9 https://www.ietf.org/rfc/rfc3954.txt
- Zeek (formerly known as Bro)
  - Framework for traffic inspection and monitoring
  - Scripting engine to enable immediate processing

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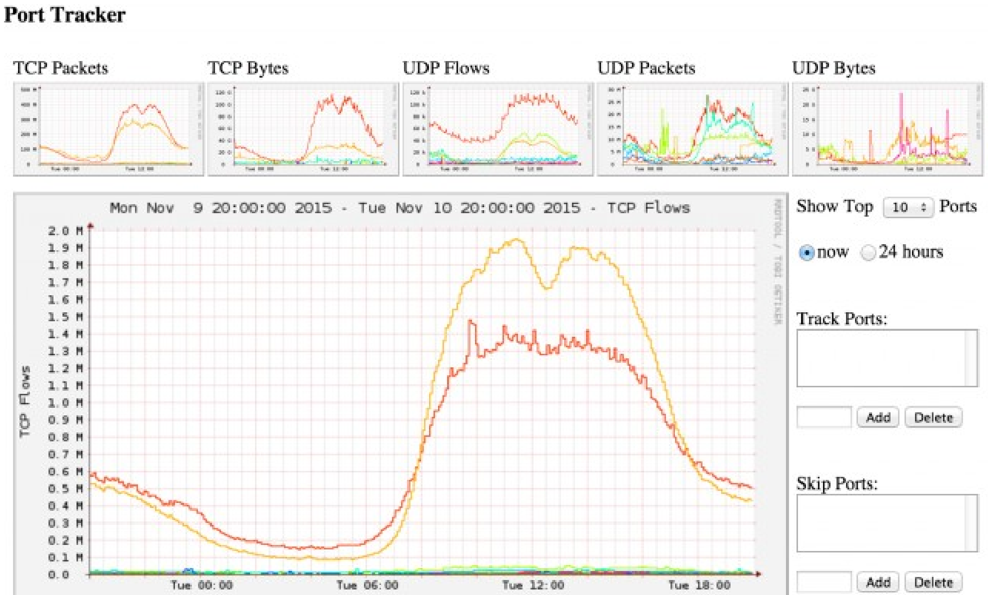
Netflow

- Suite of tools:
  - nfcapd
    - Capture and save netflows
  - nfdump
    - Analyze netflow files (tcpdump-stlye)
  - nfsen
    - Graphical tool to access captured netflows
      - It uses nfdump as back end

Nfsen



Port Tracker

Show Top 10 Ports

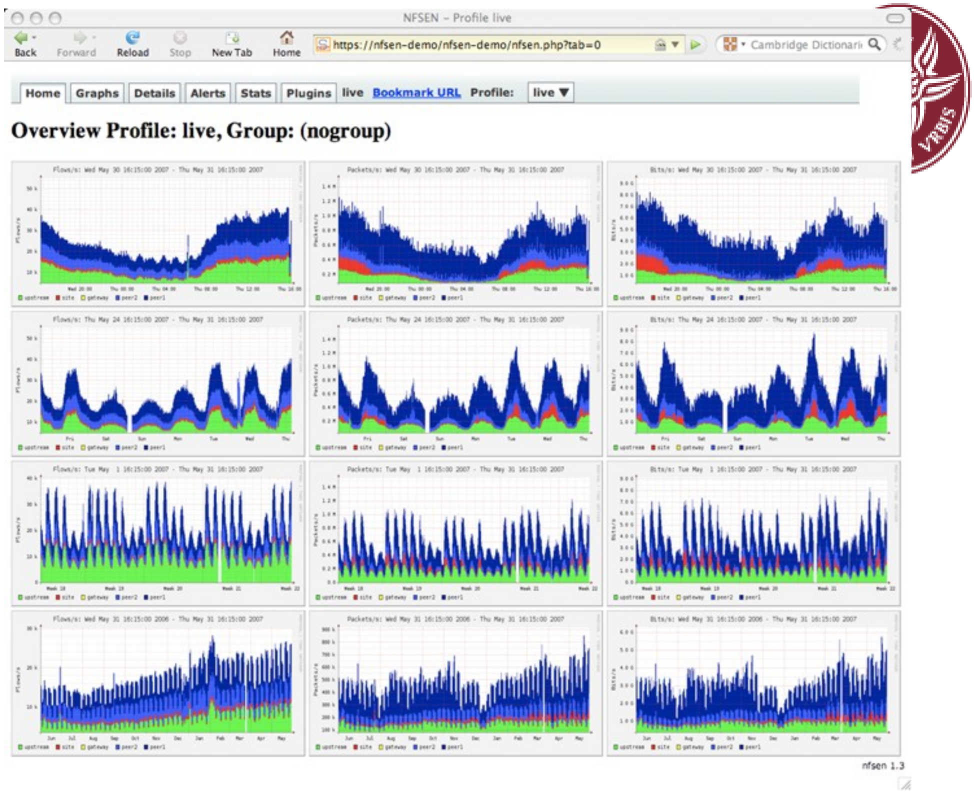
● now ○ 24 hours

Track Ports:

Add Delete

Skip Ports:

Add Delete

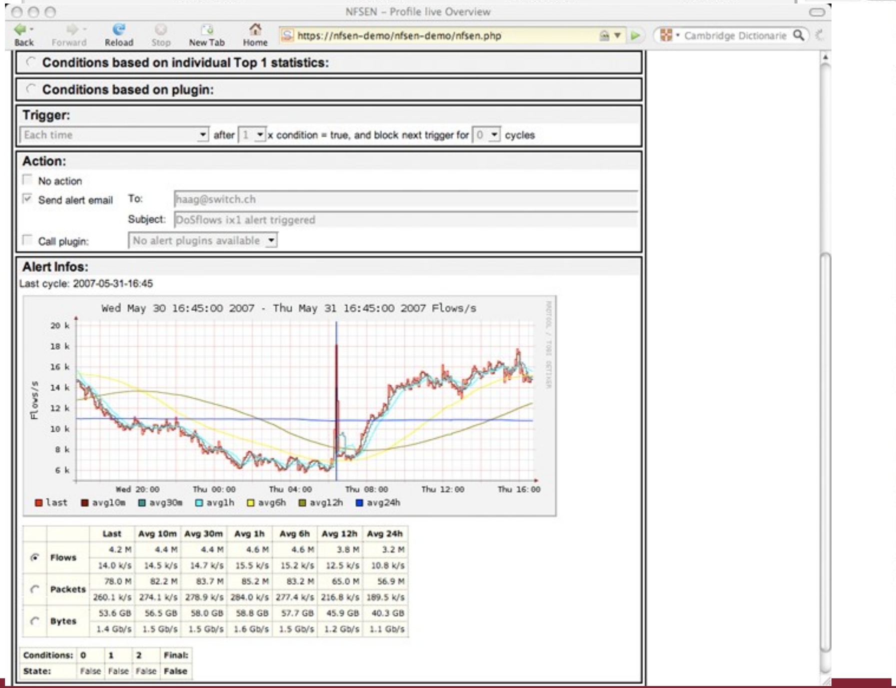


NFSEN – Profile live

https://nfsen-demo/nfsen-demo/nfsen.php?tab=0

Home | Graphs | Details | Alerts | Stats | Plugins | live | Bookmark URL | Profile: live

Overview Profile: live, Group: (nogroup)



NFSEN – Profile live Overview

https://nfsen-demo/nfsen-demo/nfsen.php

○ Conditions based on individual Top 1 statistics:

○ Conditions based on plugin:

Trigger:

Each time ▾ after 1 ▾ x condition = true, and block next trigger for 0 ▾ cycles

Action:

□ No action

☑ Send alert email To: haag@switch.ch

Subject: DoSflows ix1 alert triggered

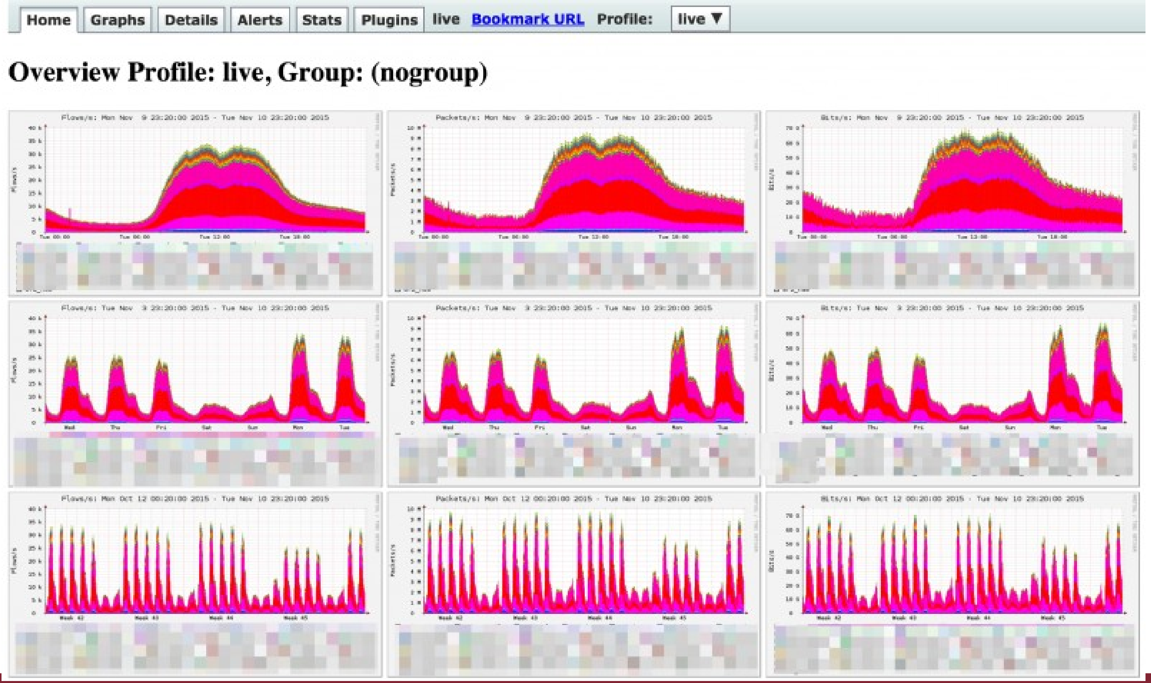
□ Call plugin: No alert plugins available ▾

Alert Infos:

Last cycle: 2007-05-31-16:45

		Last	Avg 10m	Avg 30m	Avg 1h	Avg 6h	Avg 12h	Avg 24h
●	Flows	4.2 M	4.4 M	4.4 M	4.6 M	4.6 M	3.8 M	3.2 M
		14.0 k/s	14.5 k/s	14.7 k/s	15.5 k/s	15.2 k/s	12.5 k/s	10.8 k/s
○	Packets	78.0 M	82.2 M	83.7 M	85.2 M	83.2 M	65.0 M	56.9 M
		260.1 k/s	274.1 k/s	278.9 k/s	284.0 k/s	277.4 k/s	216.8 k/s	189.5 k/s
○	Bytes	53.6 GB	56.5 GB	58.0 GB	58.8 GB	57.7 GB	45.9 GB	40.3 GB
		1.4 Gb/s	1.5 Gb/s	1.5 Gb/s	1.6 Gb/s	1.5 Gb/s	1.2 Gb/s	1.1 Gb/s

Conditions:	0	1	2	Final:
State:	False	False	False	False



Home | Graphs | Details | Alerts | Stats | Plugins | live | Bookmark URL | Profile: live ▼

Overview Profile: live, Group: (nogroup)

Flows/s: Mon Nov 9 23:20:00 2015 - Tue Nov 10 23:20:00 2015
Packets/s: Mon Nov 9 23:20:00 2015 - Tue Nov 10 23:20:00 2015
Bits/s: Mon Nov 9 23:20:00 2015 - Tue Nov 10 23:20:00 2015
Flows/s: Tue Nov 3 23:20:00 2015 - Tue Nov 10 23:20:00 2015
Packets/s: Tue Nov 3 23:20:00 2015 - Tue Nov 10 23:20:00 2015
Bits/s: Tue Nov 3 23:20:00 2015 - Tue Nov 10 23:20:00 2015
Flows/s: Mon Oct 12 00:20:00 2015 - Tue Nov 10 23:20:00 2015
Packets/s: Mon Oct 12 00:20:00 2015 - Tue Nov 10 23:20:00 2015
Bits/s: Mon Oct 12 00:20:00 2015 - Tue Nov 10 23:20:00 2015

Summary

- Packets: made of stacked layers
  - Each layer has its own role in the communication
- Encapsulation is the rule
  - Protocol encapsulates other protocols as their data
- How to capture packets?
  - It depends on the final goal: monitoring, statistics, debugging, security
- Wireshark: dissecting packets
  - Very powerful tool to explore and dive into packets

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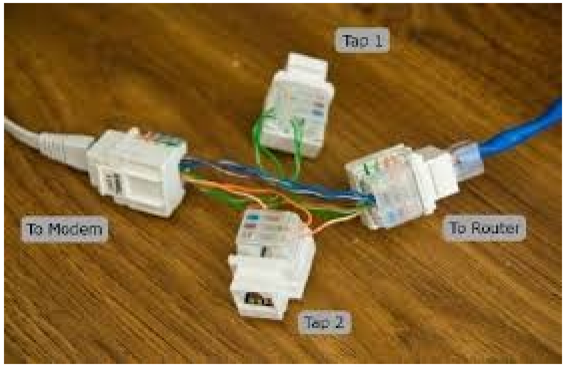
Wireshark activity

How to capture network traffic

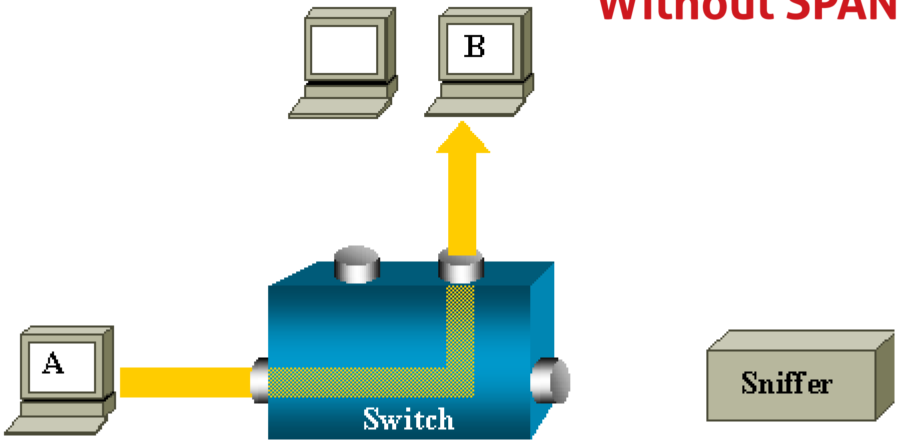
- Promiscuous mode
  - Limitations?
  - Remember the difference between hubs and switches!
- Physical tap
- Port mirroring on a managed switch
- More “aggressive“ approaches:
  - ARP cache poisoning
  - MAC flooding
  - DHCP redirection
  - Redirection and interception with ICMP
- NOTICE: on virtualized environments and SDN, this can be easier or harder



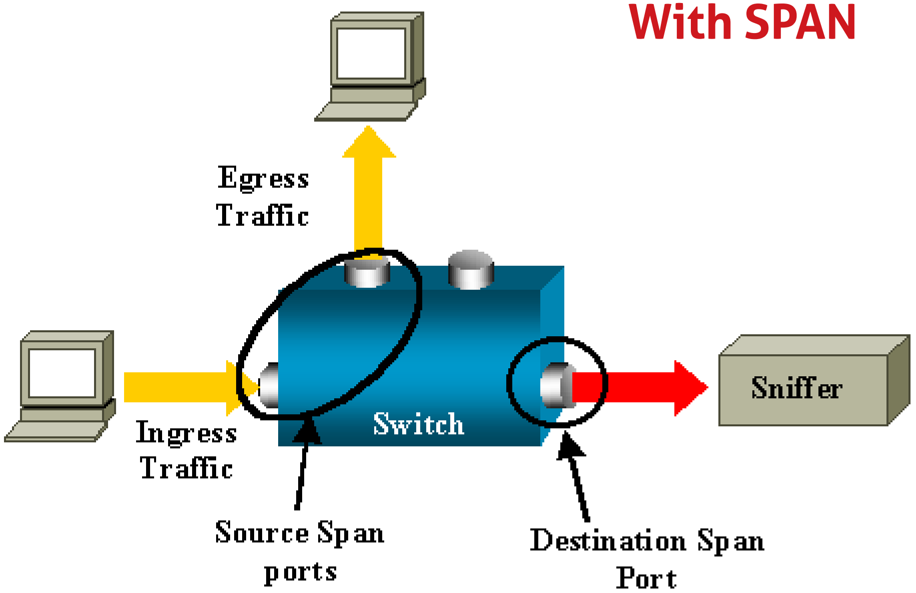
Port mirroring

- Switched Port Analyzer (SPAN) or Roving Analysis Port (RAP)

Without SPAN



With SPAN



Less conventional approaches for sniffing

- ARP cache poisoning (or spoofing)
  - Unsolicited ARP replies to steal IP addresses (ettercap, cain&abel)
- MAC flooding
  - Fill the CAM of the switch to make it acting as a hub (macof)
- DHCP redirection
  - Rogue DHCP server: it exhausts the IP addresses of the pool
  - Then pretends to be the default gateway of the network with the new DHCP requests (Gobbler, DHCPstarv, Yersinia)
- Redirection and interception with ICMP
  - ICMP type 5 (redirect) used to indicate a better route (ettercap)

How to prevent packet capture

- Dynamic address inspection
  - Implemented in switches: Dynamic Address Resolution Inspection (DAI) validates ARP packets
  - IP-to-MAC address binding inspection, drop invalid packets
- DHCP snooping
  - Implemented in switches: distinguishes between trusted and untrusted ports and uses a database of IP-to-MAC
  - Ports that show rogue activity can also be automatically placed in a disabled state

Additional setup

- Configure the GeoIP resolver
  - https://wiki.wireshark.org/HowToUseGeoIP
  - Download the GeoLight database
  - Unzip the files in a directory
- In wireshark:
  - Edit→Preferences→Name Resolution
  - Select MaxMind database directories
- Now you can use filters like

```
ip.geoip.country eq “China”
```

Activity 1: pnd-labs/lab1/ex4

- Download the package https://github.com/vitome/pnd-labs.git
- Run tcpdump and save the captured traffic in an output file
  - Best option: into the **`/hosthome/`** directory
- Use the browser for connecting to the webserver in pnd-labs/lab1/ex4/pc1
  - Browse page **`ba.php`**

    user=angelo psw=angsp
- Stop tcpdump
- Repeat the procedure with another outfile
  - Browse page **`da.php`**

    user=angelo psw=angsp
- Use wireshark to analyze and compare the captured files

Try to use also virtual interfaces

- add (or del) a virtual interface (pair veth0@veth1):
  - ip link add dev veth0 type veth peer name veth1
- connect one veth end to the virtual bridge:
  - ip link set master br0 dev veth1
- assign an IP address to the other end (not enslaved):
  - ip addr add x.x.x.x/y dev veth0
- enable both the ends of the virtual interface
  - ip link set veth0 up
  - ip link set veth1 up
- A script can be found in the pnd-labs folder

Activity 2

- Run tcpdump and save the captured traffic in an output file
- Connect via ftp to an open ftp server
  - e.g.: test.rebex.net (demo:password)
- Stop tcpdump
- Repeat the procedure with another outfile, connecting with sftp to:
  - test.rebex.net (demo:password)
- Use wireshark to analyze and compare the captured files
- Use wireshark FILTERS of ftp to look for user/password

Activity 3: pnd-labs/lab1/ex2

- Capture the DHCP exchange of pnd-labs/lab1/ex2
- Run tcpdump and save the captured traffic in an output file
- Then use wireshark from the host machine to explore the captured traffic

Activity 4: pnd-labs/lab1/ex3

- Capture the traffic exchange of pnd-labs/lab1/ex3 between the hosts of the two different lans from different positions
  - lan1, lan2 and internal (between r1 and r2)
- Use tcpdump to save the captured traffic in an output files into the /hosthome/ directory
- Then use wireshark from the host machine to explore the captured traffic
- Pay attention to the layering approach and how packets change when moving from one network to the other

Activity 5

- Try to solve with wireshark the CTF of Hack3rCon 3 conference (2012)
- http://sickbits.net/other/hc3.pcap-04.cap

References

- Wireshark for Security Professionals: Using Wireshark and the Metasploit Framework
    - Bullok, Parker, Wiley ed.
- The Network Security Test Lab: A Step-by-Step Guide
    - Gregg, Wiley e.

That’s all for today

- **Questions?**
- See you next lecture!