SAPIENZA
UNIVERSITÀ DI ROMA

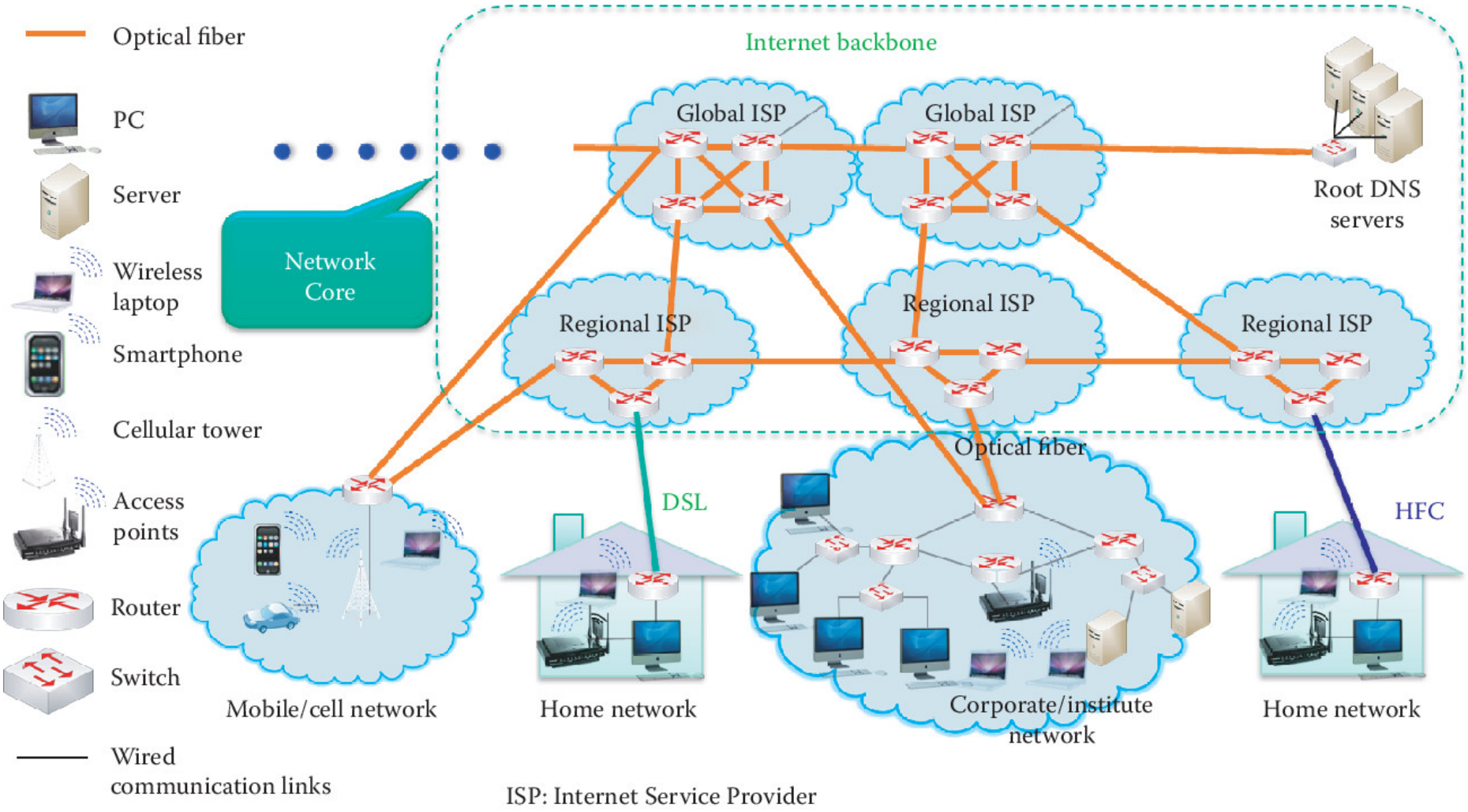
Practical Network Defense

Master's degree in Cybersecurity 2018-19

Network traffic monitoring

Angelo Spognardi
spognardi@di.uniroma1.it
Dipartimento di Informatica
Sapienza Università di Roma

Internet architecture



Internet hierarchy

- Network edge
  - Hosts: server, client, P2P
  - Applications: http, mail, Facebook, Twitter
- Network core
  - Edge router: connecting an organization/ISP to the Internet
  - Interconnection of routers using fiber
  - Naming services
- Access networks
  - Wired, or wireless communication links

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.

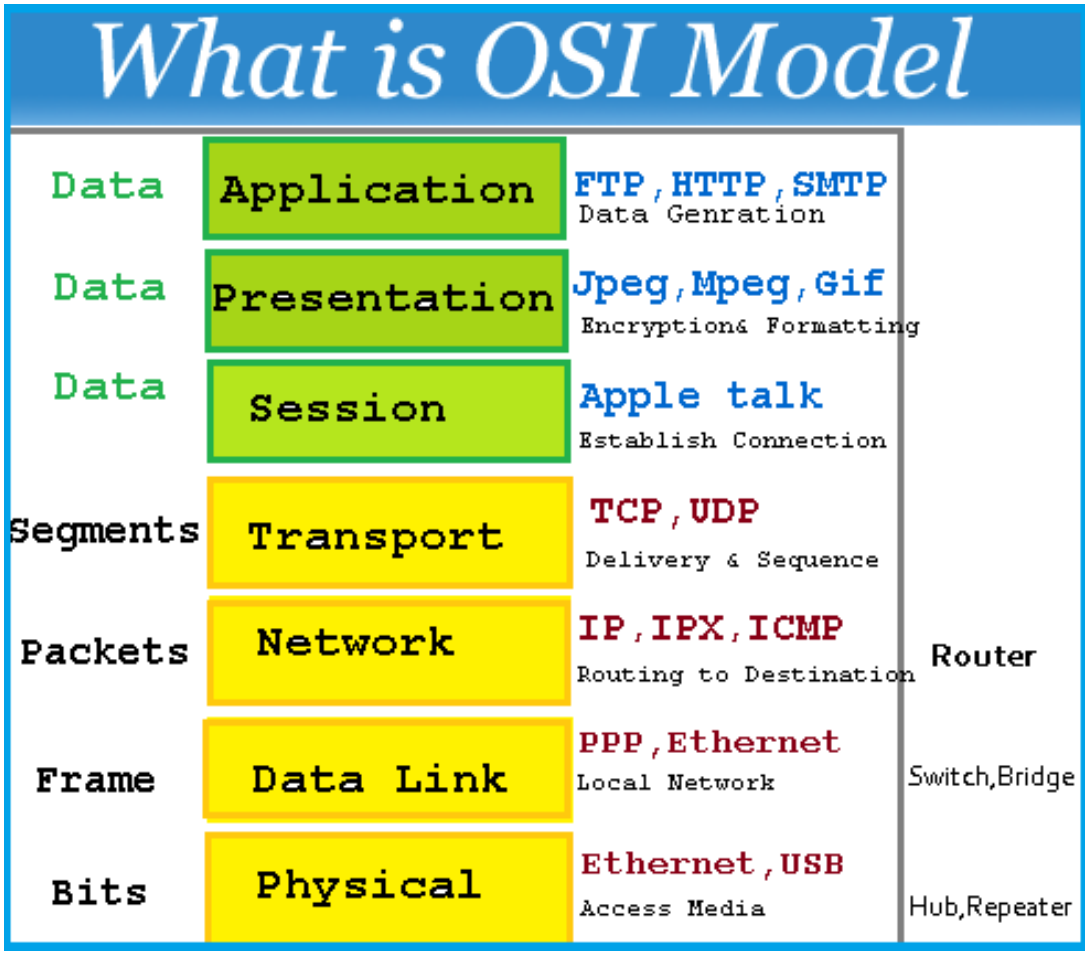
Encapsulation/decapsulation

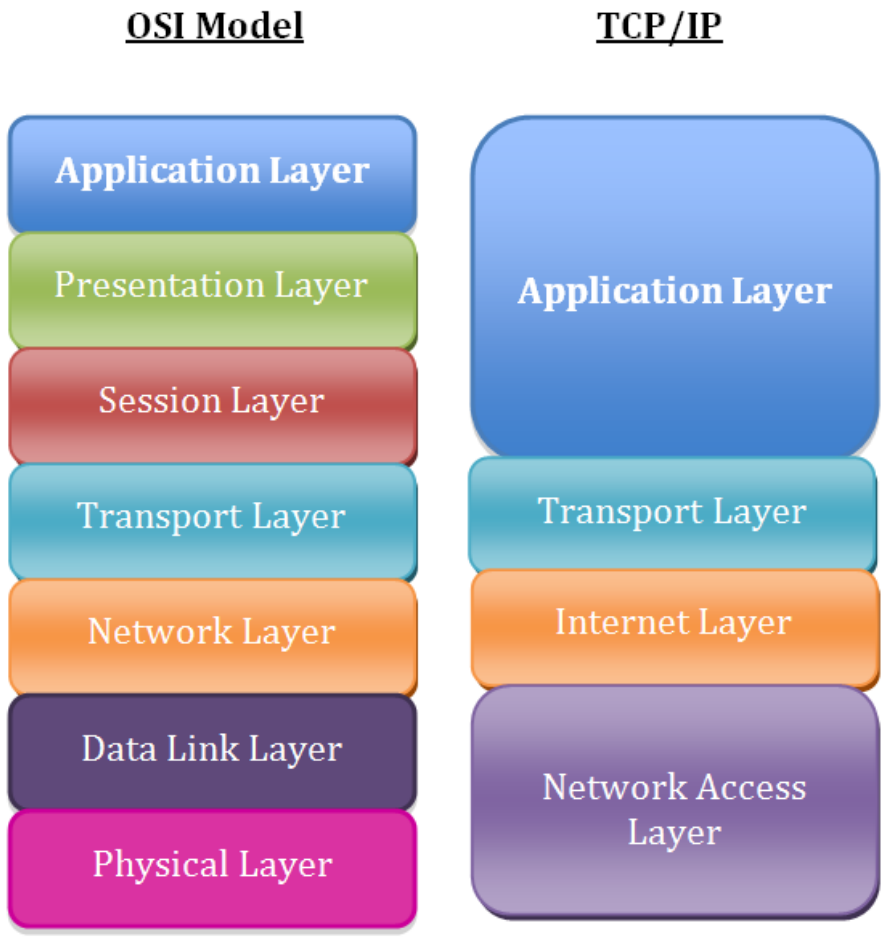
- The data to be transferred from the application layer to application layer over a network.
- Each layer adds some protocol information and provides data to the layer below.
- The physical layer (bottom) sends data over the physical medium to the destination.
- The physical layer in the destination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

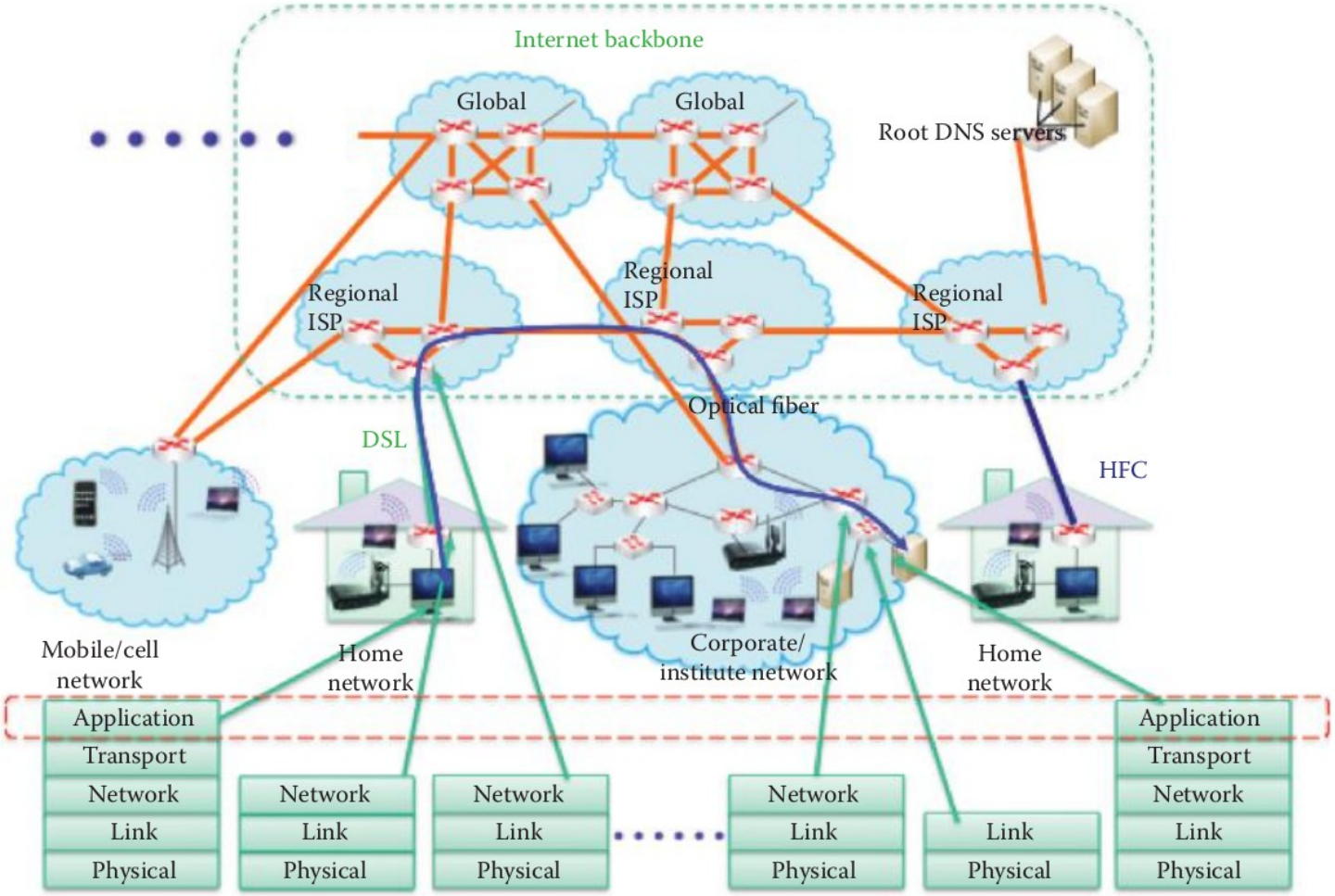




TCP / IP model

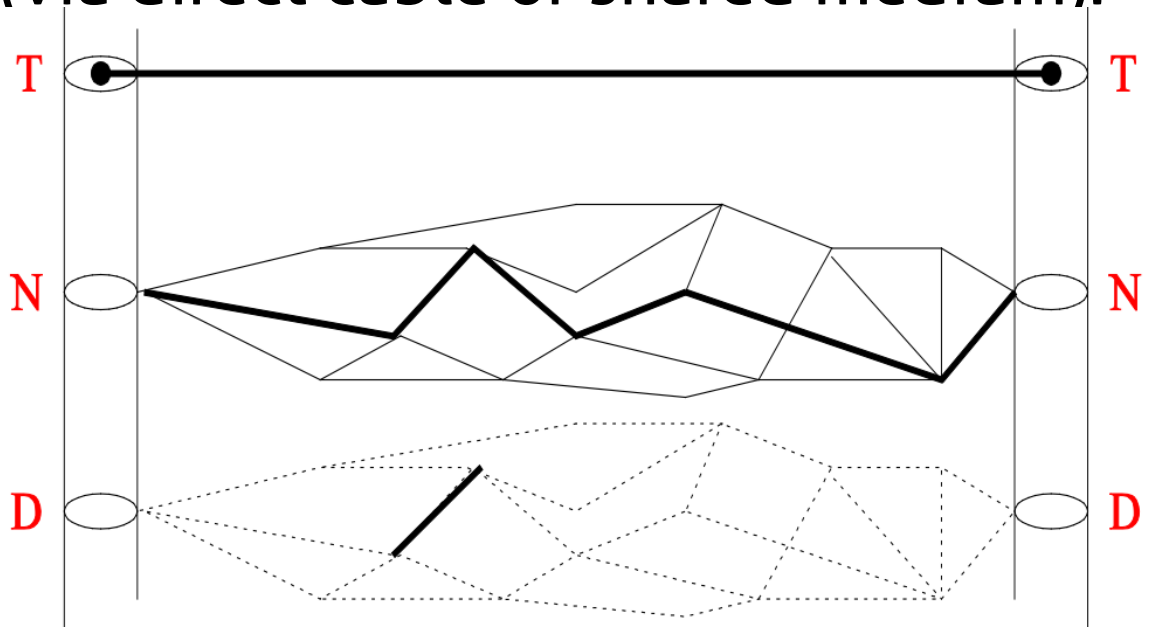
- Application layer: Corresponds to the top three layers of the OSI model.
  - Protocols: SMTP (sending e-mail), HTTP (web), FTP (file transfer), and others
- Transport layer: Equivalent to Layer 4 (Transport) of the OSI model
  - Protocols: TCP, UDP
- Internet: Equivalent to layer 3 (network) of the 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

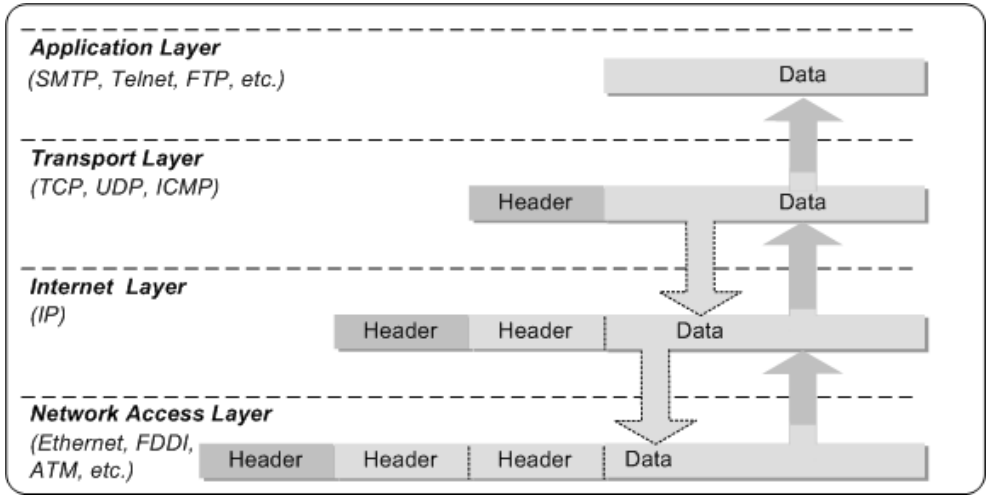
- **Transport**: the illusion of direct end-to-end connection between processes in arbitrary systems.
- **Network**: transferring data between arbitrary nodes.
- **Data Link**: transferring data between directly connected systems (via direct cable or shared medium).

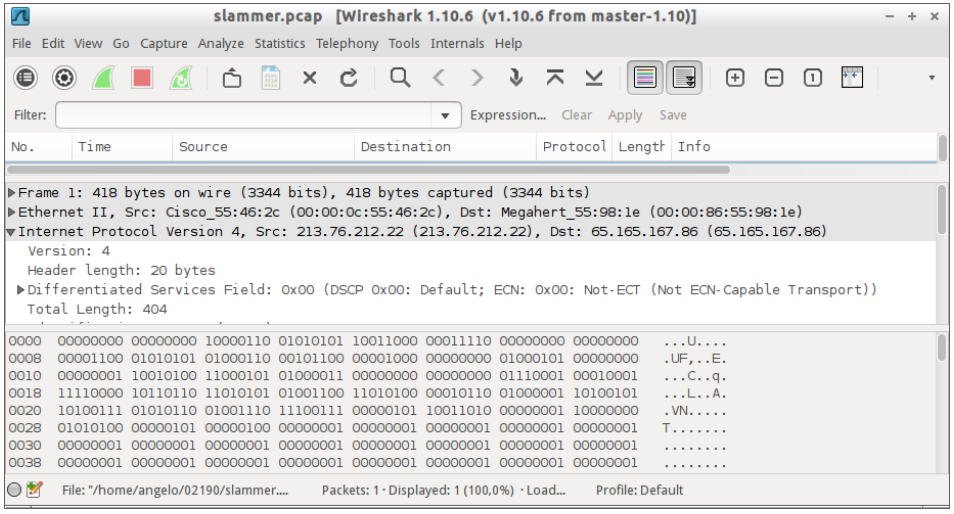


Addresses in the architectures

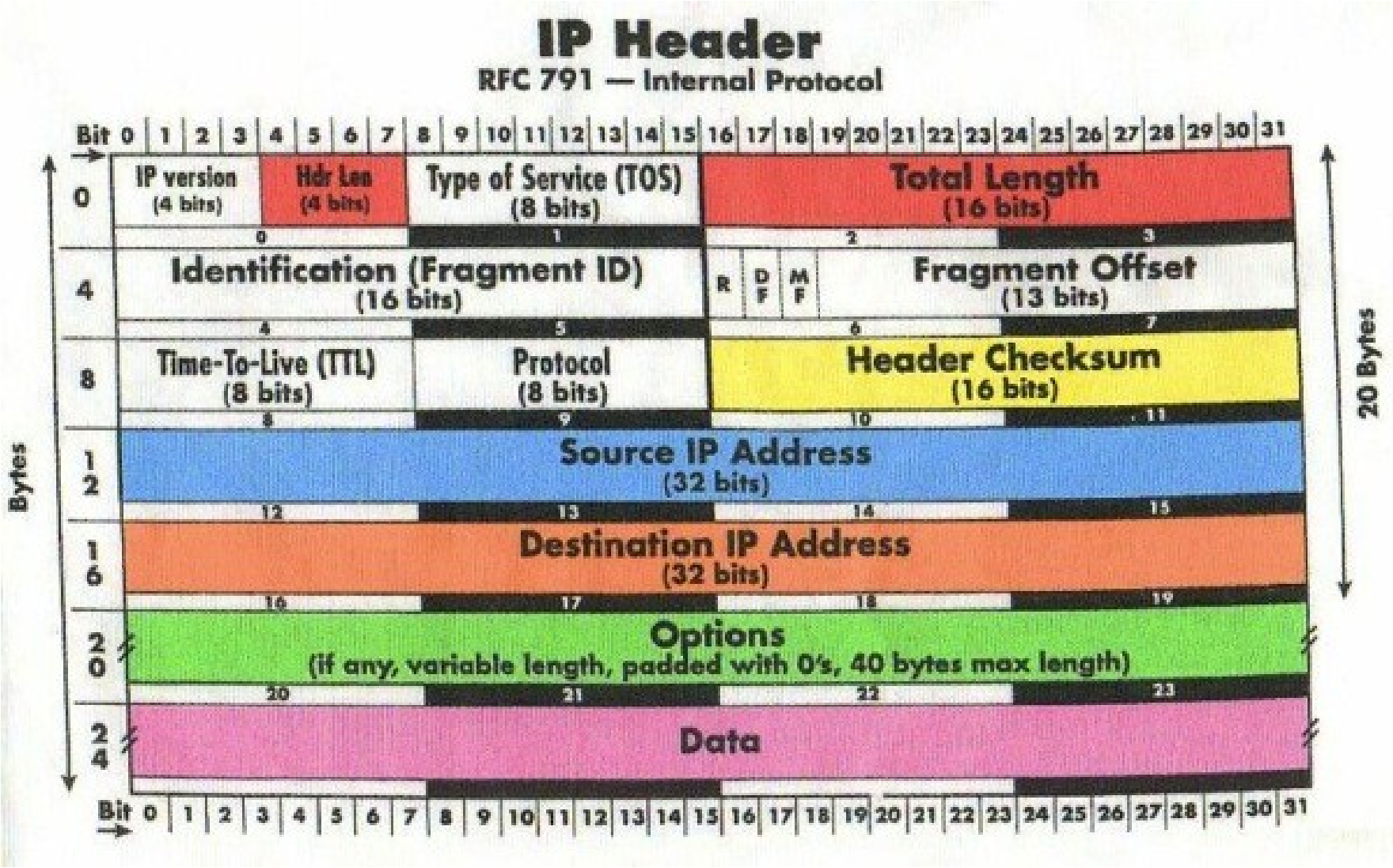
- Each layer has a type of address:
  - Application layer: Internet name, eg. www.*sapienza.it*
  - Transport layer: Port number, in the range [0..65535] that identifies the client or server. For example 80 for HTTP server.
  - Internet layer: IP address that identifies a network card, for example 151.100.17.4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

Encapsulation in TCP/IP





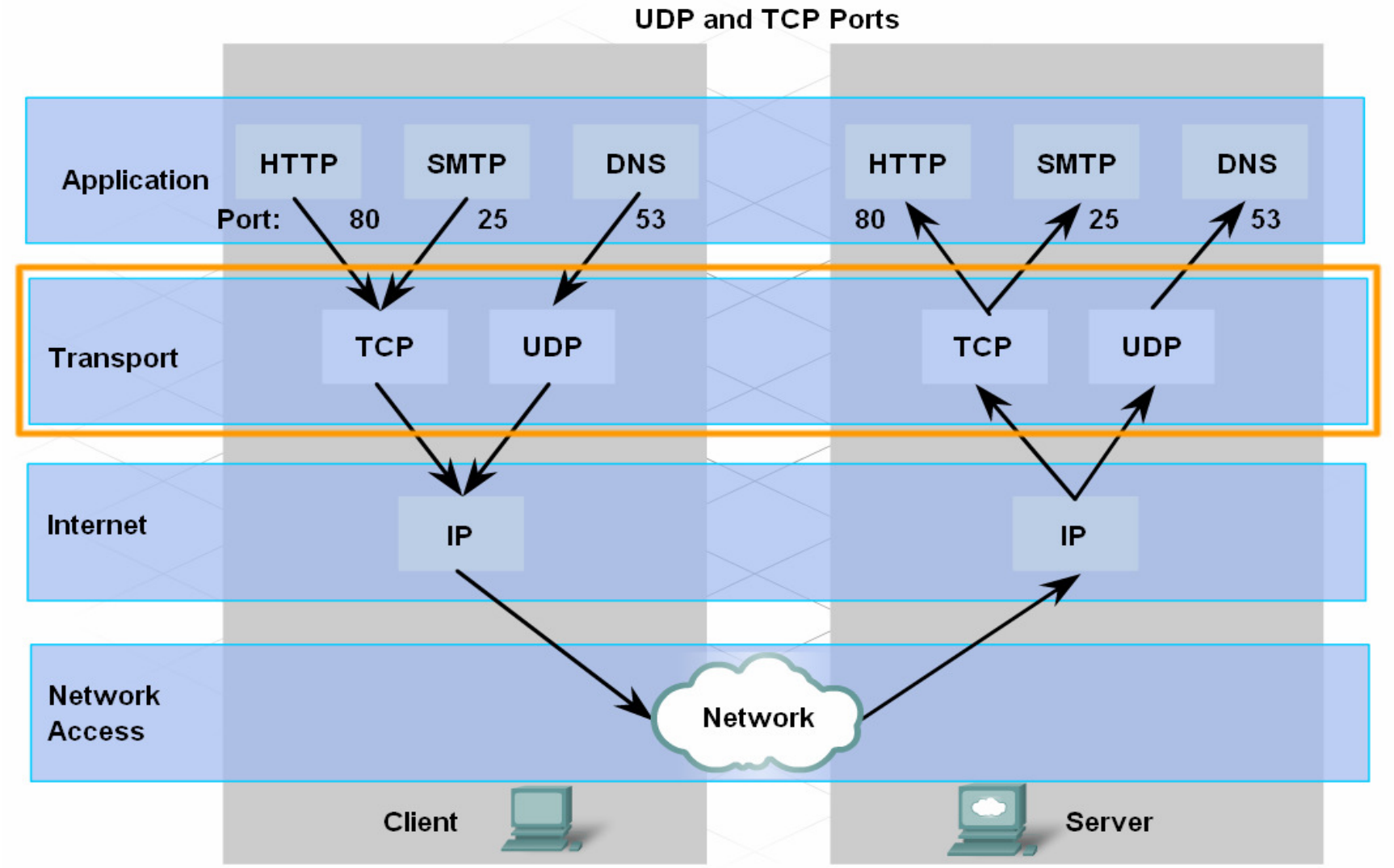
IP packets


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
D F
M F
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
Bytes
20 Bytes
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

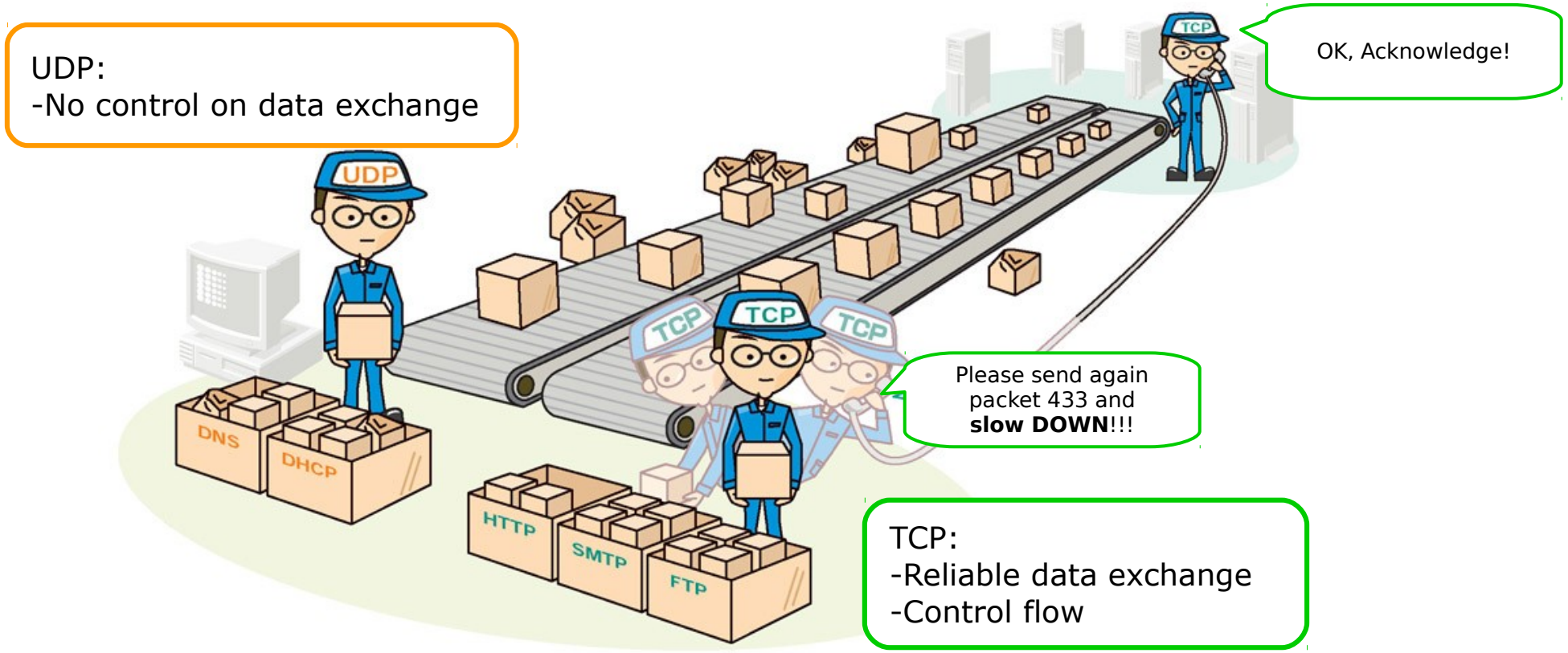
- Range [0..65535]
- Source port: randomly chosen by the OS
- Destination port determines the required service (application)
  - Assigned Ports [0..1023] are said "well-known ports" and used by servers for standard Internet applications:
    - 25: SMTP (sending mail)
    - 80: HTTP (web)
    - 143: IMAP (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



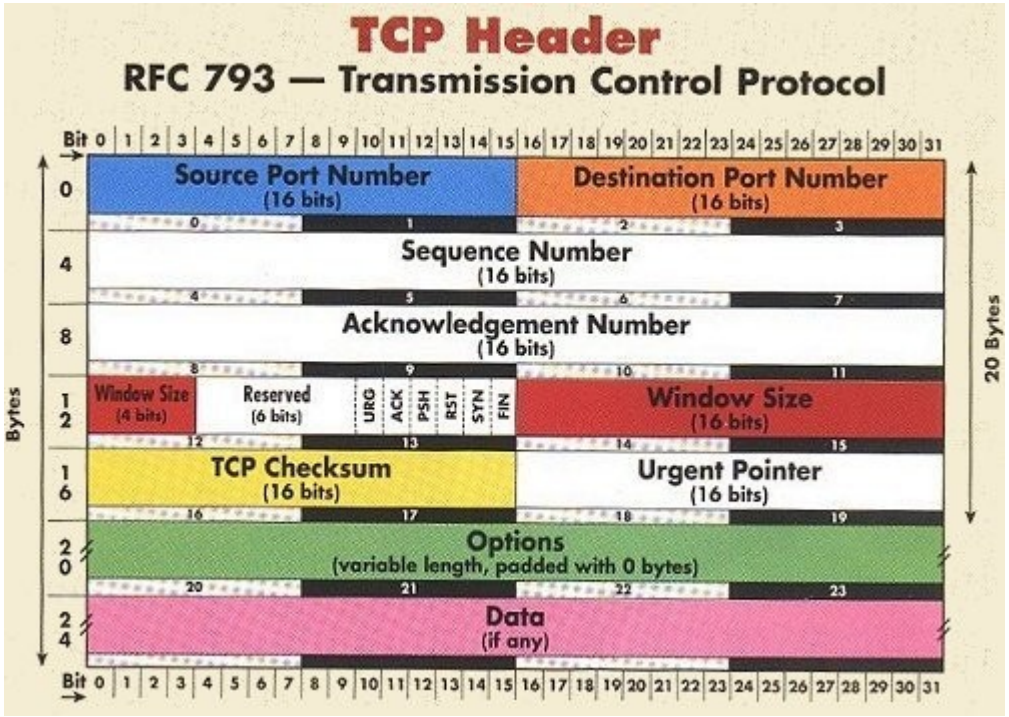
TCP vs UDP

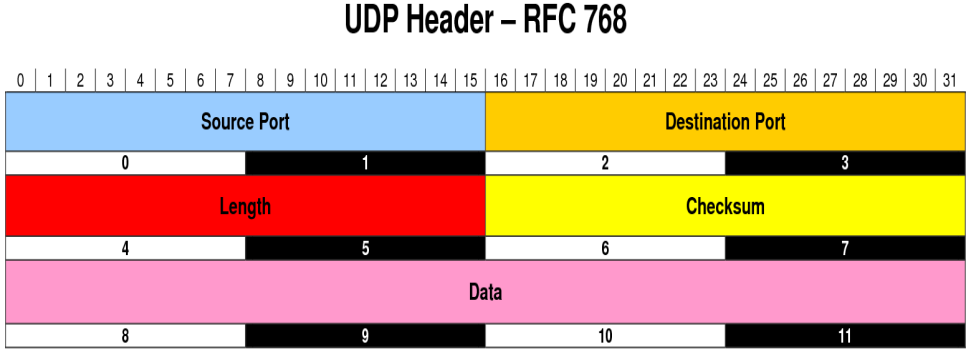
- Connection vs Connection-less



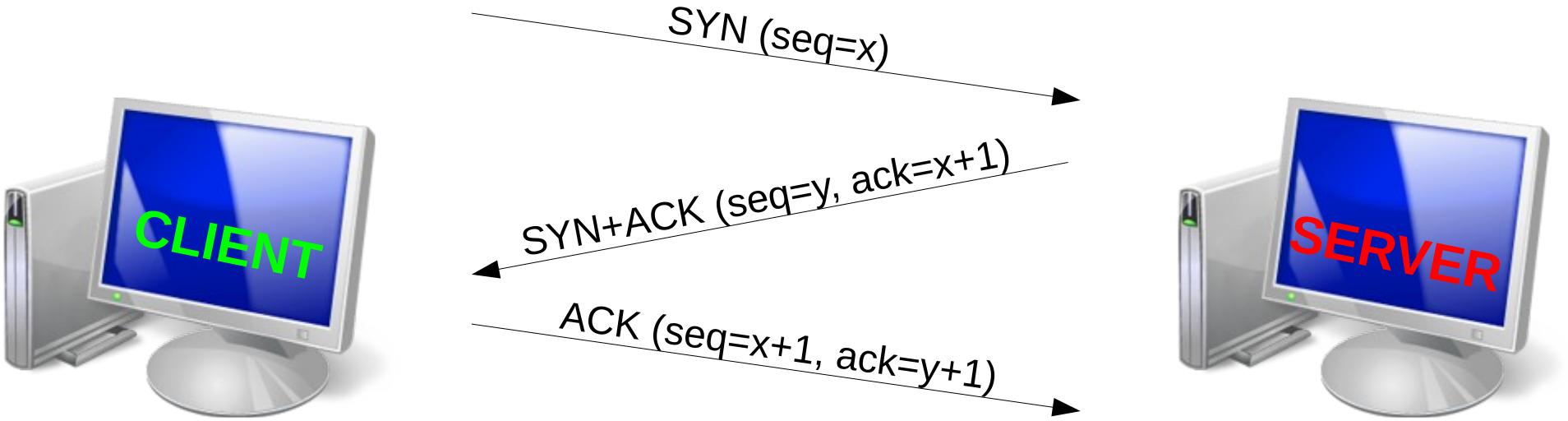
http://itpro.nikkeibp.co.jp/article/lecture/20070305/263897/

TCP header vs UDP header





TCP connection handshake



Services relying on TCP

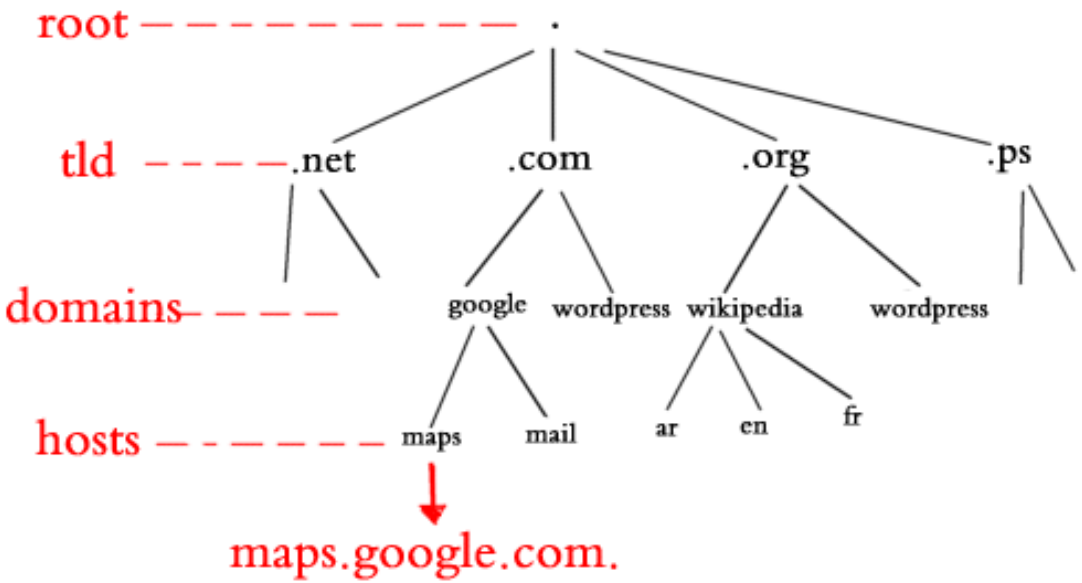
- FTP on port 20 and 21
- SSH on port 22
- Telnet on port 23
- SMTP on port 25
- HTTP on port 80
- IMAP on port 143
- SSL on port 443

Services relying on UDP

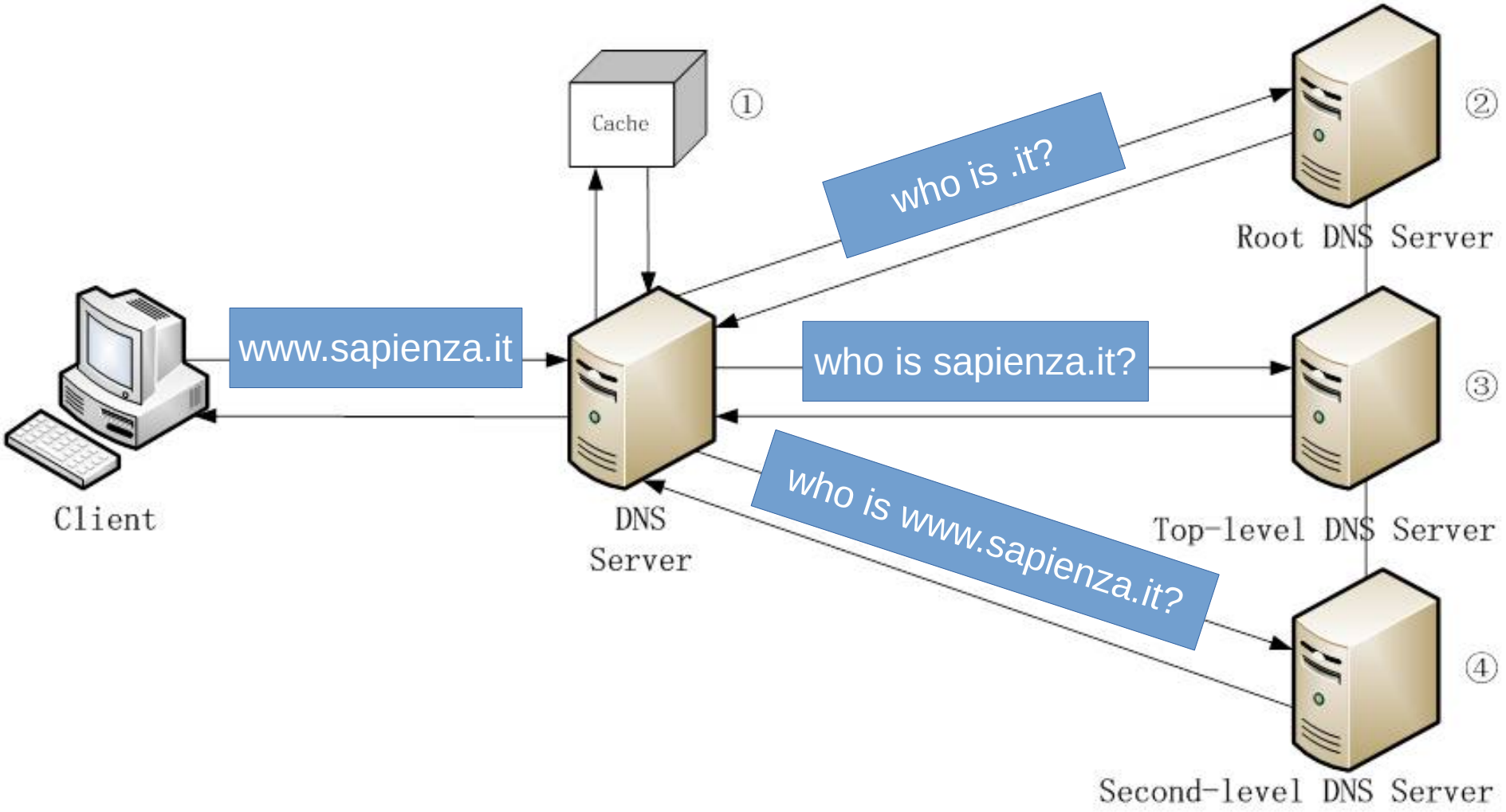
- DNS on port 53
- DHCP on ports 67 and 68
- TFTP on port 69
- SNMP on port 161
- RIP on port 520

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
- Best suited for
  - Looking for the root cause of a known problem
  - Searching for a certain protocol or stream between devices
  - Analyzing specific timing, protocol flags, or bits on the wire
  - Following a conversation between two devices
- It shouldn't be the first tool thought of early on in discovering a problem, but solving a problem...

Using wireshark

- Capturing is way too easy… Too many packets!
  - https://wiki.wireshark.org/CaptureSetup/CapturePrivileges
- To survive, use filters!
  - They allow to only focus on requested packets or certain activity by network devices
- Two kinds of filters: **display filters** and **capture filters**
  - Capture filters to limit the amount of network data that goes into processing and is getting saved
  - Display filters to inspect only the packets you want to analyze once the data has been processed

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 (!)

Display filters – wireshark

- Display only captured packets matching the filters
  - Packets are not discarded or lost
- Easy but refined syntax: only packets evaluating true are displayed
  - Comparison operators
  - Filters use types (strings where numbers are required return errors)
  - Common logical operators
- Filters can be built interacting with the packets

Logic of wireshark

- Frames are collected from the interface and passed to several, consecutive, "dissectors", one for each layer
- Frames pass from bottom layer to upper layer
- Protocols can be detected in two ways:
  - directly, if a frame (e.g. Ethernet) has the field that states which protocol it is encapsulating
  - indirectly, with tables of protocol/port combinations and heuristics
    - Usually working, troubles when protocols are used in nonstandard ports

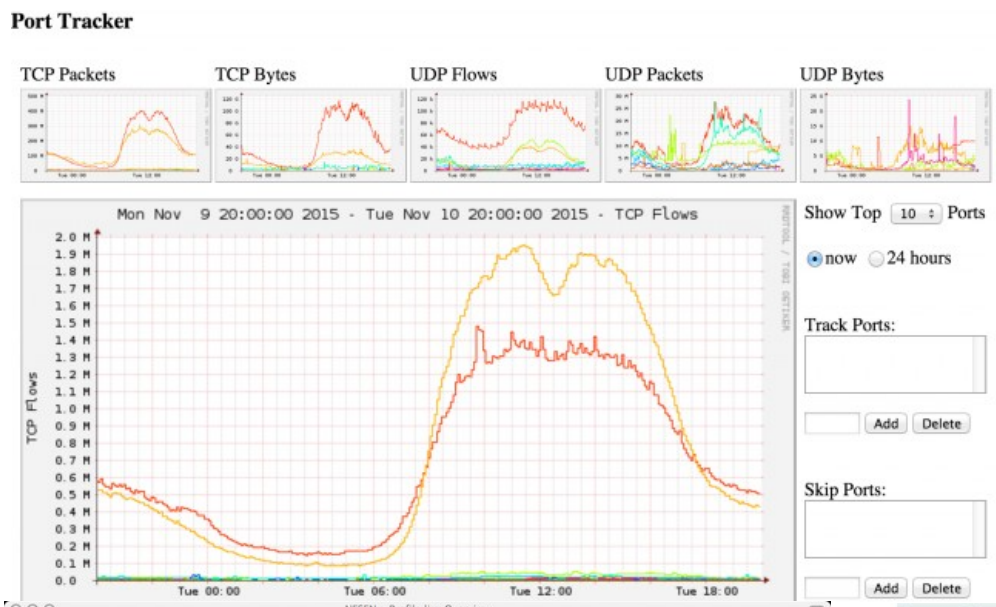
Alternative way to capture traffic info

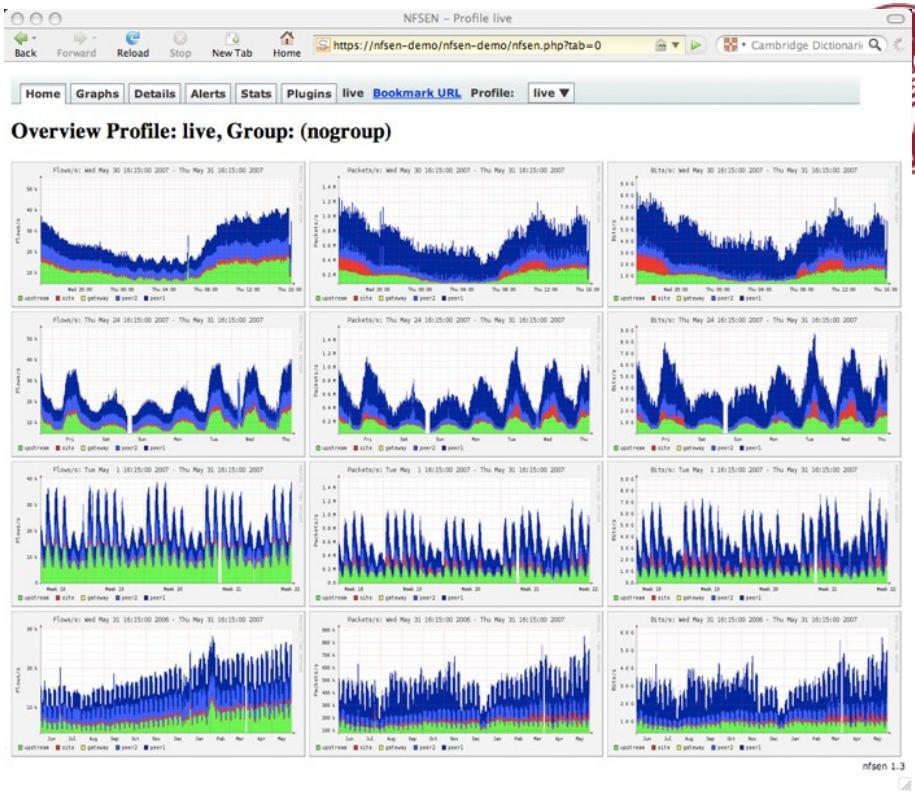
- Traffic represented as "connections"
- Netflow
  - For statistics and monitoring
  - Netflow v9 https://www.ietf.org/rfc/rfc3954.txt
- Zeek (formerly known as Bro)
  - Framework for traffic inspection and monitoring
  - Scripting engine to enable immediate processing

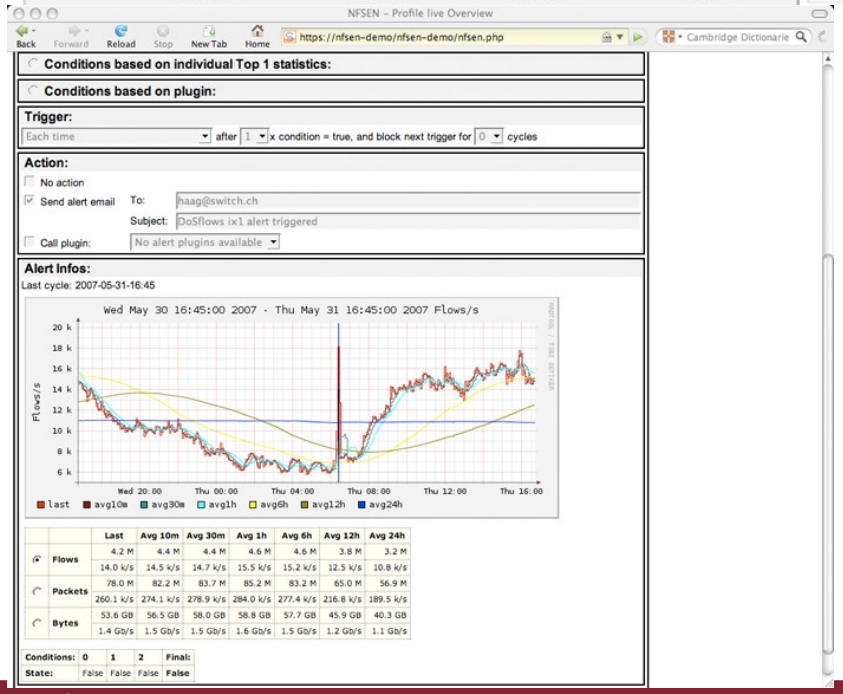
Netflow

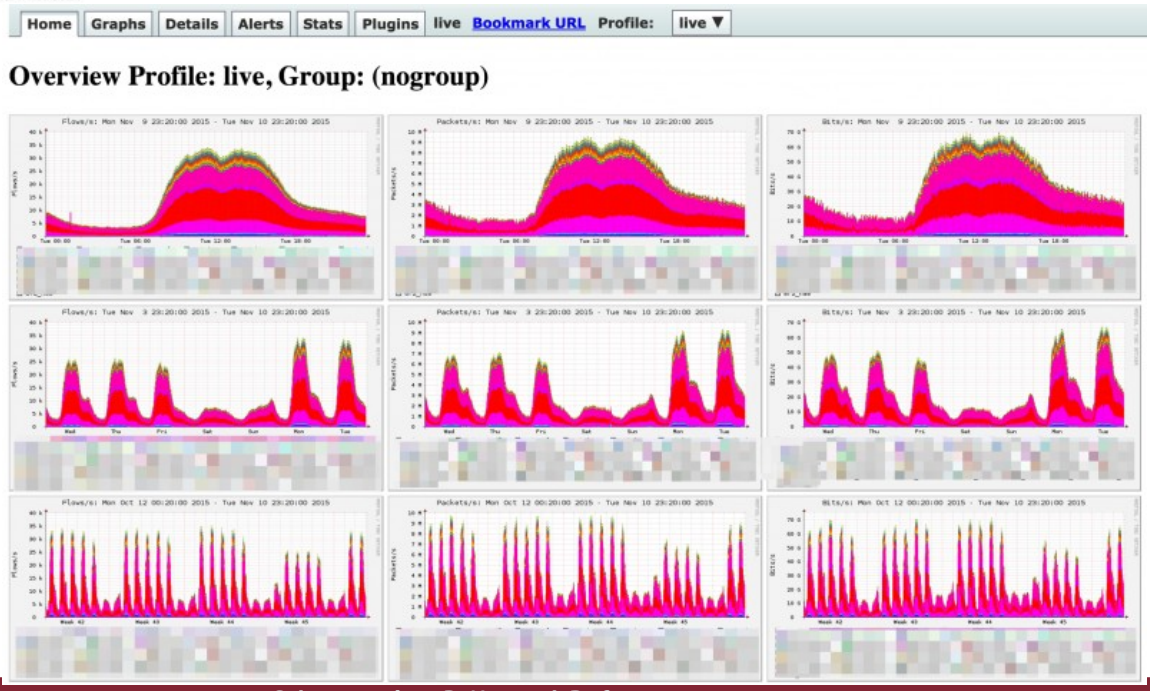
- Suite of tools:
  - nfcapd
    - Capture and save netflows
  - nfdump
    - Analyze netflow files (tcpdump-stlye)
  - nfsen
    - Graphical tool to access captured netflows
      - It uses nfdump as back end

Nfsen


Port Tracker
TCP Packets
TCP Bytes
UDP Flows
UDP Packets
UDP Bytes
Mon Nov 9 20:00:00 2015 - Tue Nov 10 20:00:00 2015 - TCP Flows
TCP Flows
Tue 00:00
Tue 06:00
Tue 12:00
Tue 18:00
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 1.3


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
Wed May 30 16:45:00 2007 - Thu May 31 16:45:00 2007 Flows/s
Flows/s
Wed 20:00
Thu 00:00
Thu 04:00
Thu 08:00
Thu 12:00
Thu 16:00
last
avg10m
avg30m
avg1h
avg6h
avg12h
avg24h
Flows
Packets
Bytes
Conditions:
State:
Final:
False


Home
Graphs
Details
Alerts
Stats
Plugins
live
Bookmark URL
Profile:
live
Overview Profile: live, Group: (nogroup)

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

That’s all for today

- **Questions?**
- See you next lecture!
- Next Thursday we start at 12.40

SAPIENZA
UNIVERSITÀ DI ROMA

Practical Network Defense

Master's degree in Cybersecurity 2018-19

Network traffic monitoring 2

Angelo Spognardi
spognardi@di.uniroma1.it
Dipartimento di Informatica
Sapienza Università di Roma

Peer assessment??

Peer assessment!!

Where we were...

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
- Best suited for
  - Looking for the root cause of a known problem
  - Searching for a certain protocol or stream between devices
  - Analyzing specific timing, protocol flags, or bits on the wire
  - Following a conversation between two devices
- It shouldn't be the first tool thought of early on in discovering a problem, but solving a problem...

Using wireshark

- Capturing is way too easy… Too many packets!
  - https://wiki.wireshark.org/CaptureSetup/CapturePrivileges
- To survive, use filters!
  - They allow to only focus on requested packets or certain activity by network devices
- Two kinds of filters: **display filters** and **capture filters**
  - Capture filters to limit the amount of network data that goes into processing and is getting saved
  - Display filters to inspect only the packets you want to analyze once the data has been processed

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 (!)

Display filters – wireshark

- Display only captured packets matching the filters
  - Packets are not discarded or lost
- Easy but refined syntax: only packets evaluating true are displayed
  - Comparison operators
  - Filters use types (strings where numbers are required return errors)
  - Common logical operators
- Filters can be built interacting with the packets

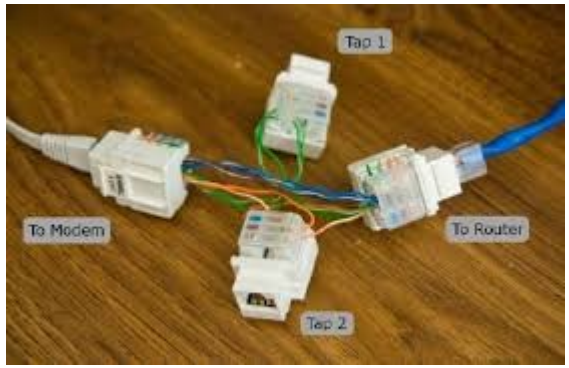
Logic of wireshark

- Frames are collected from the interface and passed to several, consecutive, "dissectors", one for each layer
- Frames pass from bottom layer to upper layer
- Protocols can be detected in two ways:
  - directly, if a frame (e.g. Ethernet) has the field that states which protocol it is encapsulating
  - indirectly, with tables of protocol/port combinations and heuristics
    - Usually working, troubles when protocols are used in nonstandard ports

Wireshark activity

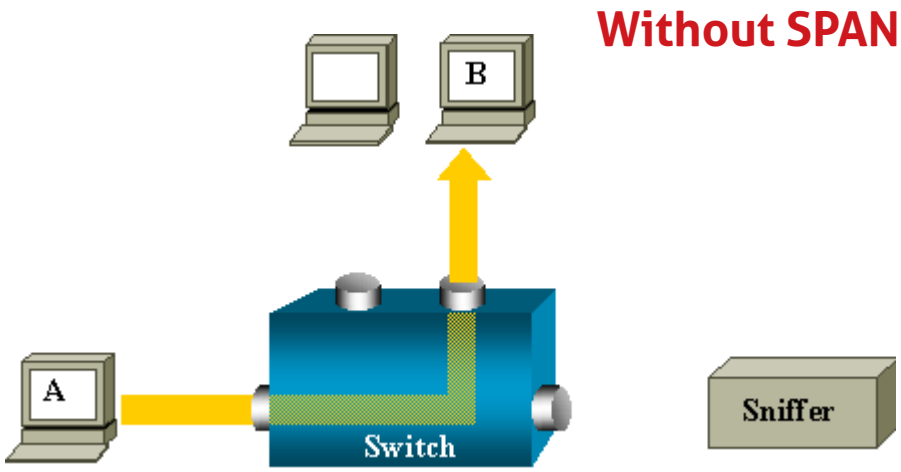
How to capture network traffic

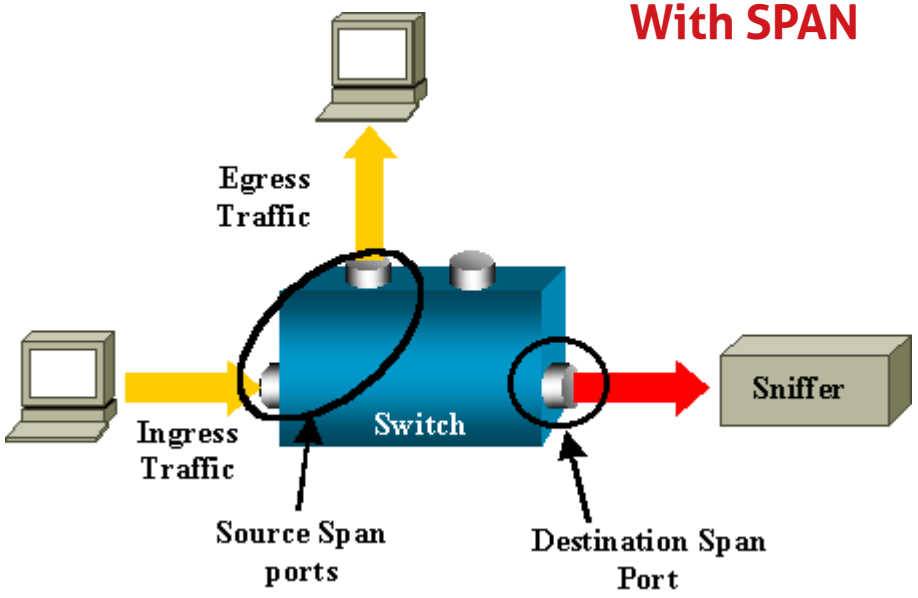
- Promiscuous mode
  - Limitations?
  - Remember the difference between hubs and switches!
- Physical tap
- Port mirroring on a managed switch
- More "aggressive" approaches:
  - ARP cache poisoning
  - MAC flooding
  - DHCP redirection
  - Redirection and interception with ICMP
- NOTICE: on virtualized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



Port mirroring

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





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

- Run tcpdump and save the captured traffic in an output file
- Use the browser for connecting to:
  - http://people.compute.dtu.dk/angsp/ba.php

    user=angelo psw=angsp
- Stop tcpdump
- Repeat the procedure with another outfile, connecting to:
  - http://people.compute.dtu.dk/angsp/da.php

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

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

- ARP poisoning in your Lab1 netkit
- Idea: connect a Kali machine to the same internal network and use it to attack the two pcs
  - Use Ettercap for ARP spoofing
    - Use arp command (or ip neigh) to verify the effects
    - Use wireshark to see the effects in the network
      - On which interface do you have to capture?
    - You can use the arp.duplicate-address-frame filter
  - Repeat the attack with a MAC flooding
  - Repeat the attack with Ettercap ICMP redirection

Activity 4

- 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!
- Please try harder to make your assignments!!
  - Peer-assessment becomes impossible without your commitment…