IP: the Internet Protocol

Matteo Pomposini(matteo.pomposini@uniroma2.it)

Marco Sgorlon(marco.sgorlon@uniroma2.it)

Bruno Ricci (b.ricci@ing.uniroma2.it)

Fondamenti di telecomunicazioni

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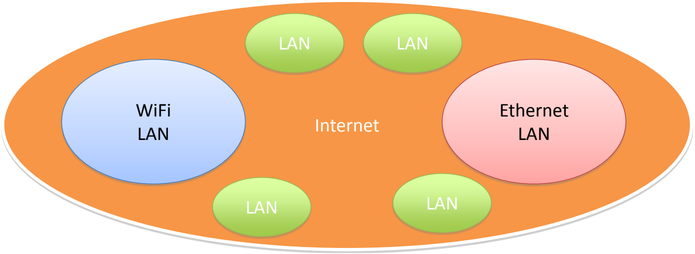
Why IP?

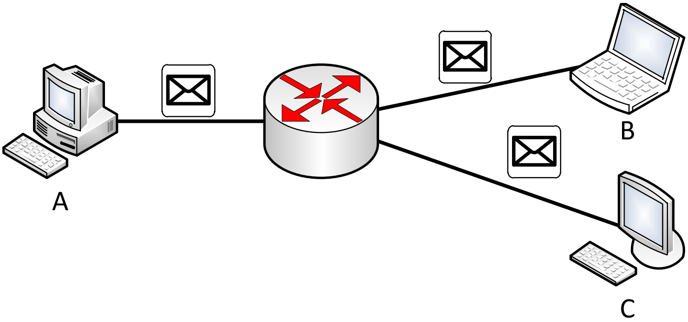
- Many different network access technologies, reflecting many different needs
  - Wireless technologies: 3G, Wi-Fi, Wi-Max, ...
  - High speed transfers with cable: copper, optical fibers, ...
  - Low energy consumption: Bluetooth, Zigbee, NFC, ...
- And what if all these technologies must talk to each other?
  - The Internet Protocol (IP) acts as a common language for data transfer between different *hosts*, independently from the network technology in us

Internet Protocol

- Internet Protocol mission: allow hosts on different network to interoperate, disregarding the specific network technology adopted on each network
- Standardized in 1981 on RFC 791 (`http://www.ietf.org/rfc/rfc791.txt`)

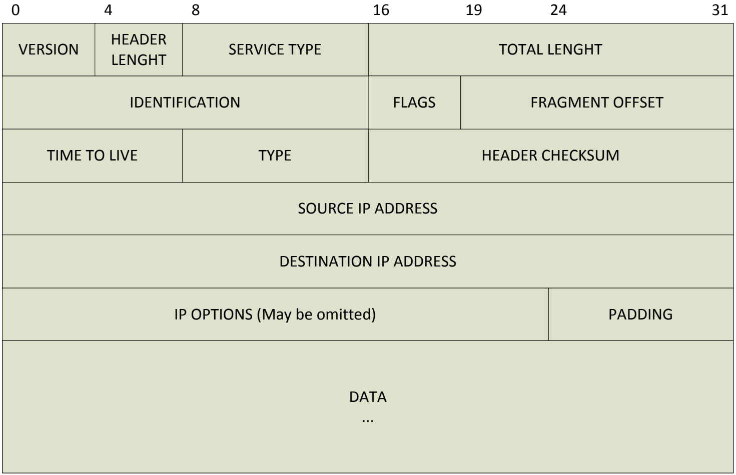


A simple IP architecture



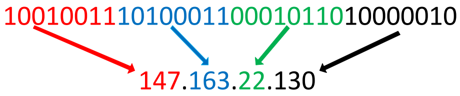
- All hosts use IP protocol to exchange data
- All data is exchanged using a specific PDU called IP datagram (packet)

IP datagram format



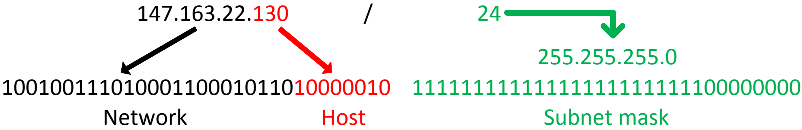
IP address

- Each host over the network has an IP address to identify itself
  - 32 bit long
  - Unique inside a single IP network
  - Identifies an interface (on a host, on a router)
- Often represented by dotted notation
  - 4 bytes separated by a point
  - Just for human convenience!

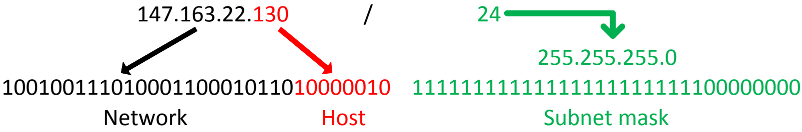


Grouping related hosts

- A single *network* is composed by *hosts*
- Internet is an inter-network
  - Used to connect *networks* together
  - Needs a way to address networks
- Solution: subnetting and IP prefixes



Subnetting and IP prefixes



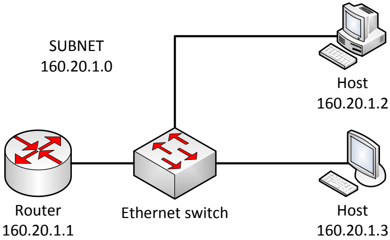
- A subnet mask divides a single network in *subnets*
  - More flexibility in huge network management
  - Hierarchical structure inside the same network
- Hosts inside a single subnet share the same network part
  - Division given by the subnet
  - Each IP has a different host part

IP addresses

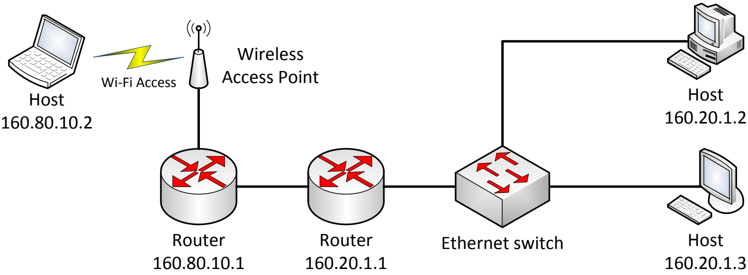
- In each subnet there are two reserved addresses
  - Host part with all 0 is the *network address*
  - Host part with all 1 is the *broadcast address*
- Example: 192.168.100.7/24
  - Network address: 192.168.100.0
  - Broadcast address: 192.168.100.255
- Routers must have an IP address and a netmask for each interface they have

Subnets

- Every host inside a LAN belongs to an **IP subnet**
- In each subnet, addresses belong to a specific range:
  - The first part of the address (network part) is the same for all the hosts
  - The second part (host part) must be different for all the host

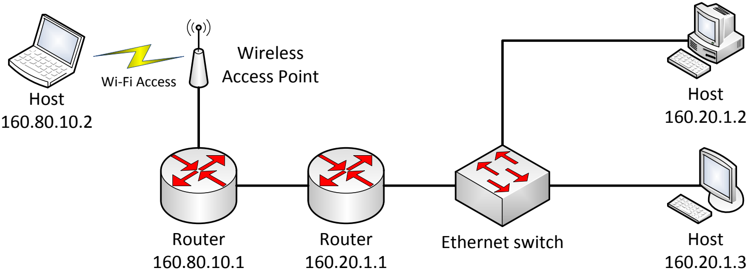


How IP? Architecture



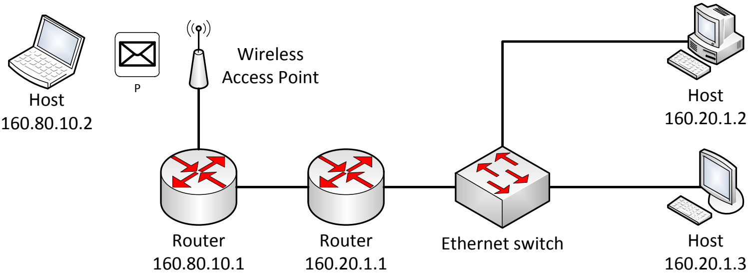
- Communication among IP hosts is carried using **IP packets**
  - IP packet is composed by an **IP header** and an **IP payload**
  - Source and destination IP addresses are specified inside the IP header
- Networks are connected using at least one **router**
  - Forwards packets depending on the packet destination address

How IP? Architecture - Example



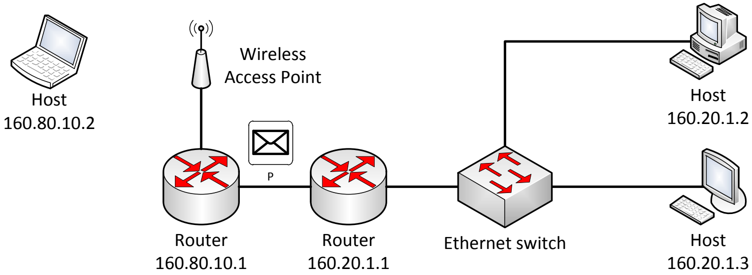
What happens if host 160.80.10.2 want to communicate with host 160.20.1.3?

How IP? Architecture - Example



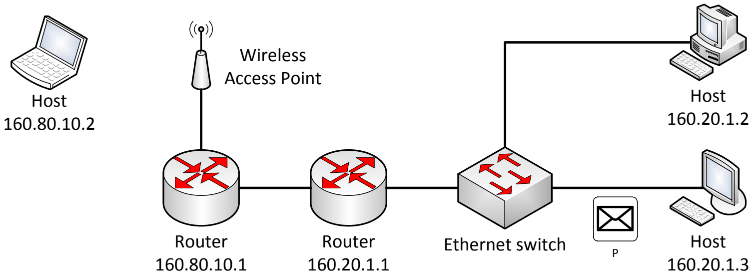
- Host 160.80.10.2 generates an IP packet
- The IP packet is sent to the router 160.80.10.1 using a specific LAN technology.

How IP? Architecture - Example



- The router 160.80.10.1 reads the IP header
- The packet is forwarded to the **next hop**, according to the internal **routing table**

How IP? Architecture - Example

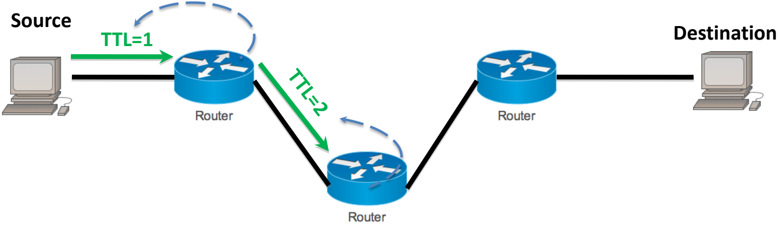


- The router 160.20.1.1 reads the IP header
- The packet is forwarded to the **next hop**, according to the internal **routing table**

Communication is independent from the underlying technology!

Some practice: traceroute

Exploiting time exceeded



Send packets with TTL = 1, 2, ... and record source of time excedeed message

- Linux & OSX: `traceroute <host>`
- Windows: `tracert <host>`

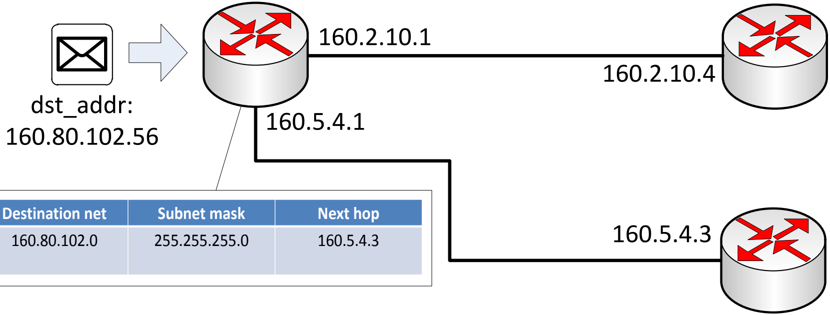
Routing

- All routers forward IP packets according to a **routing table**
- Each line has
  - A destination network...
  - ... its subnet mask...
  - ... and the next hop (where to send an incoming packet)

Destination network	Subnet mask	Next hop
160.80.102.0	255.255.255.0	160.5.4.3

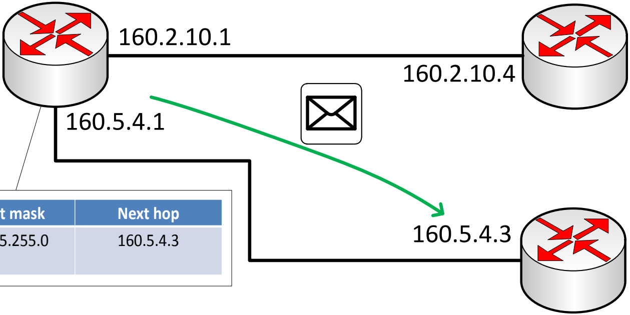
Routing rule: if the destination IP address of a packet matches a specific destination network, route the packet to the related next hop

Routing example



Destination net	Subnet mask	Next hop
160.80.102.0	255.255.255.0	160.5.4.3

Routing example



Destination net	Subnet mask	Next hop
160.80.102.0	255.255.255.0	160.5.4.3

Routers

- Routing tables can be filled
  - Manually
  - Automatically, by routing protocol (e.g. RIP, BGP, OSPF, ...)
  - Mixed
- IP addressing/routing depends on the place

Longest prefix match and default gateways

Destination network	Subnet mask	Next hop
160.80.102.0	255.255.255.0	160.1.2.1
160.80.0.0	255.255.0.0	160.1.2.10

Where to send a packet with destination address 160.80.102.3?

- **Longest prefix match**: if more entries are matched, apply the rule with the greater subnet mask

Destination network	Subnet mask	Next hop
0.0.0.0	0.0.0.0	1.2.3.4

All those 0s???

- **Default gateway**: always matched, but not always used!

Some practice: viewing the routing table

- Windows: `netstat -rn`
- Linux & OSX: `route -n`

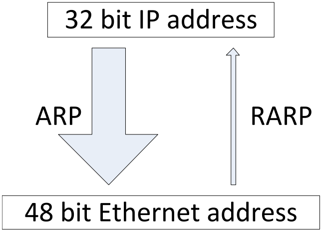
The bond between LAN and IP

IP packets are sent to the physical network interface by encapsulating them in a datalink frame using datalink addresses (operation performed hop-by-hop)

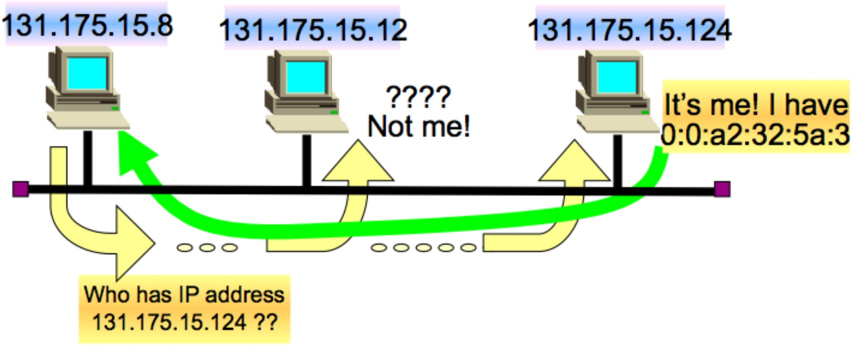
- Datalink addresses (MAC): local on a specific subnet
- IP addresses: globally assigned on the Internet
- How to dynamically map IP addresses to datalink addresses without any a-priori knowledge?
  - Solution: ARP (Address Resolution Protocol)

The solution: ARP

- Dynamic mapping
  - not a concern for application, user and system administrator
- Not layer 2 nor layer 3 protocol
- Need datalink with broadcasting capability
- ARP NOT strictly necessary
  - There may be IP-MAC mapping



The ARP idea


131.175.15.8
131.175.15.12
131.175.15.124
????
Not me!
It's me! I have
0:0:a2:32:5a:3
Who has IP address
131.175.15.124 ??

ARP features and practice

- Some ARP features
  - Stateless protocol: request-response
  - Send broadcast request
  - Receive unicast response
  - *Soft-state entries*: storage of IP datalink entries in a cache (the **ARP cache**) for a fixed amount of time
- Some practice
  - Windows, Linux and OSX: `arp -a`

Getting an IP address

How can an interface be configured?

- Manual configuration
- Automatically assigned, permanent random IP address
- Dynamically assigned
- Auto-assigned

DHCP

Autoconfiguration can be achieved via DHCP

(Dynamic Host Configuration Protocol)

- Goal of DHCP: **full** configuration of a host:
  - IP address, subnet mask, gateway IP address
  - DNS server
  - SMTP server
  - xyz server (extensible protocol!)
- Client/Server model (via UDP datagrams)

When IP? DHCP (3)