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INTRO TO NETWORKING

PART 1: Basic concepts

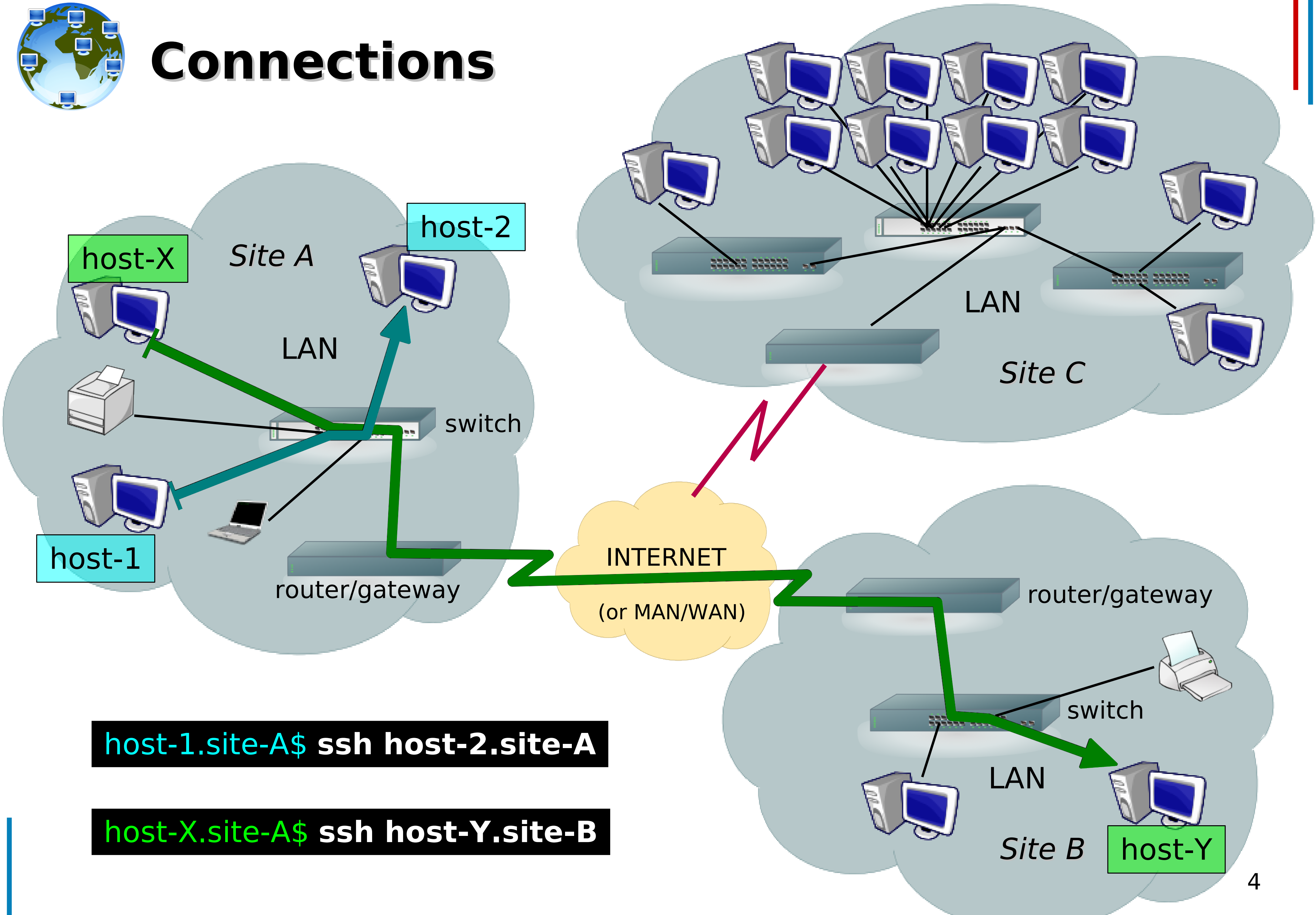
eLab
Joint DEMOCRITOS/SISSA
Laboratory for e-Science

Agenda

- Connections
- Concept of Packet
- Network Stack Models (TCP/IP - ISO/OSI)
- Internet Protocol and IP Address Space
- Ethernet and Physical Address
- Speed, Bandwidth, Latency, Throughput
- High Speed (and Low Latency) Networks
- LINUX commands (configuration and diagnostic)

Connections

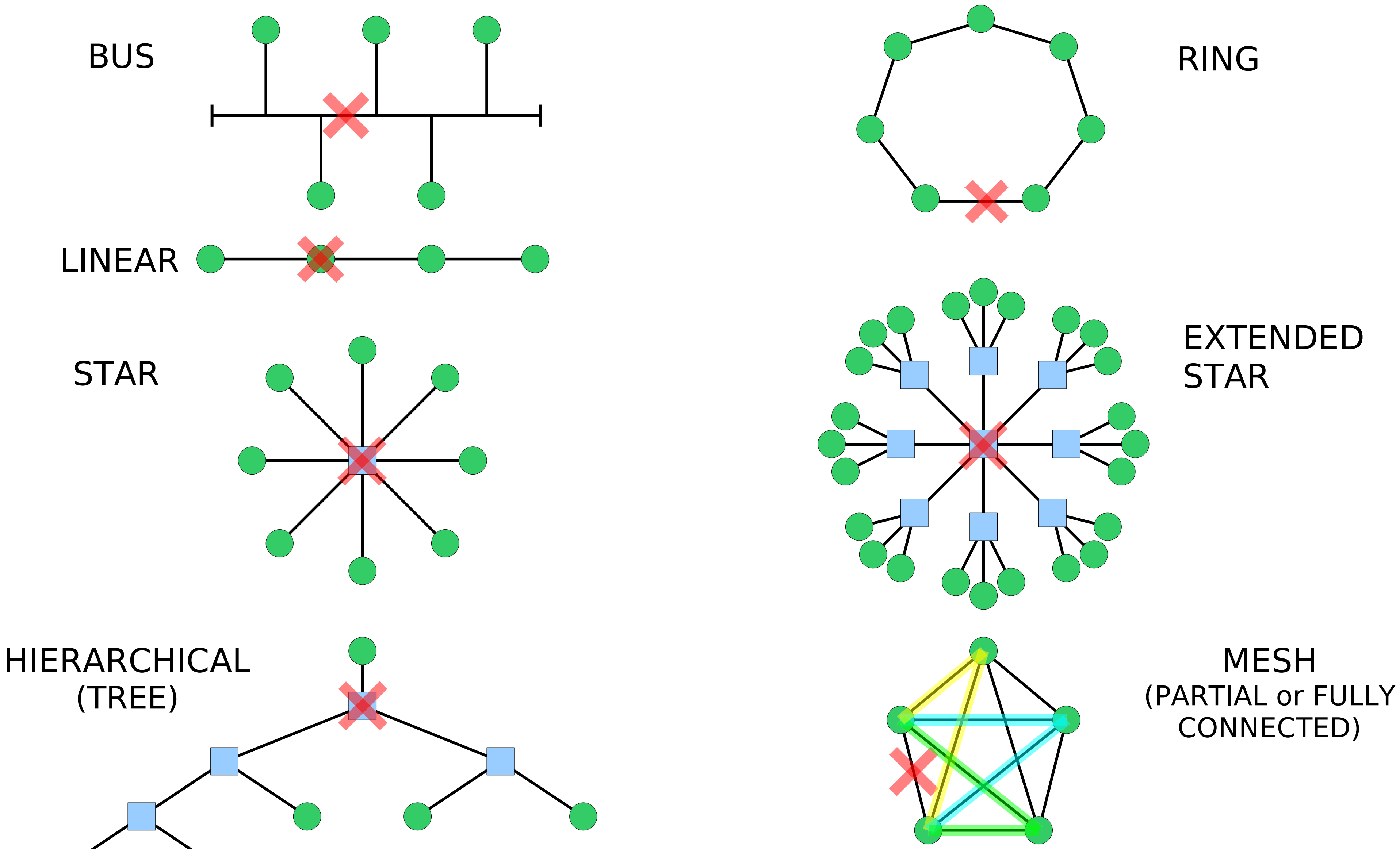
Connections



host-1.site-A$ ssh host-2.site-A

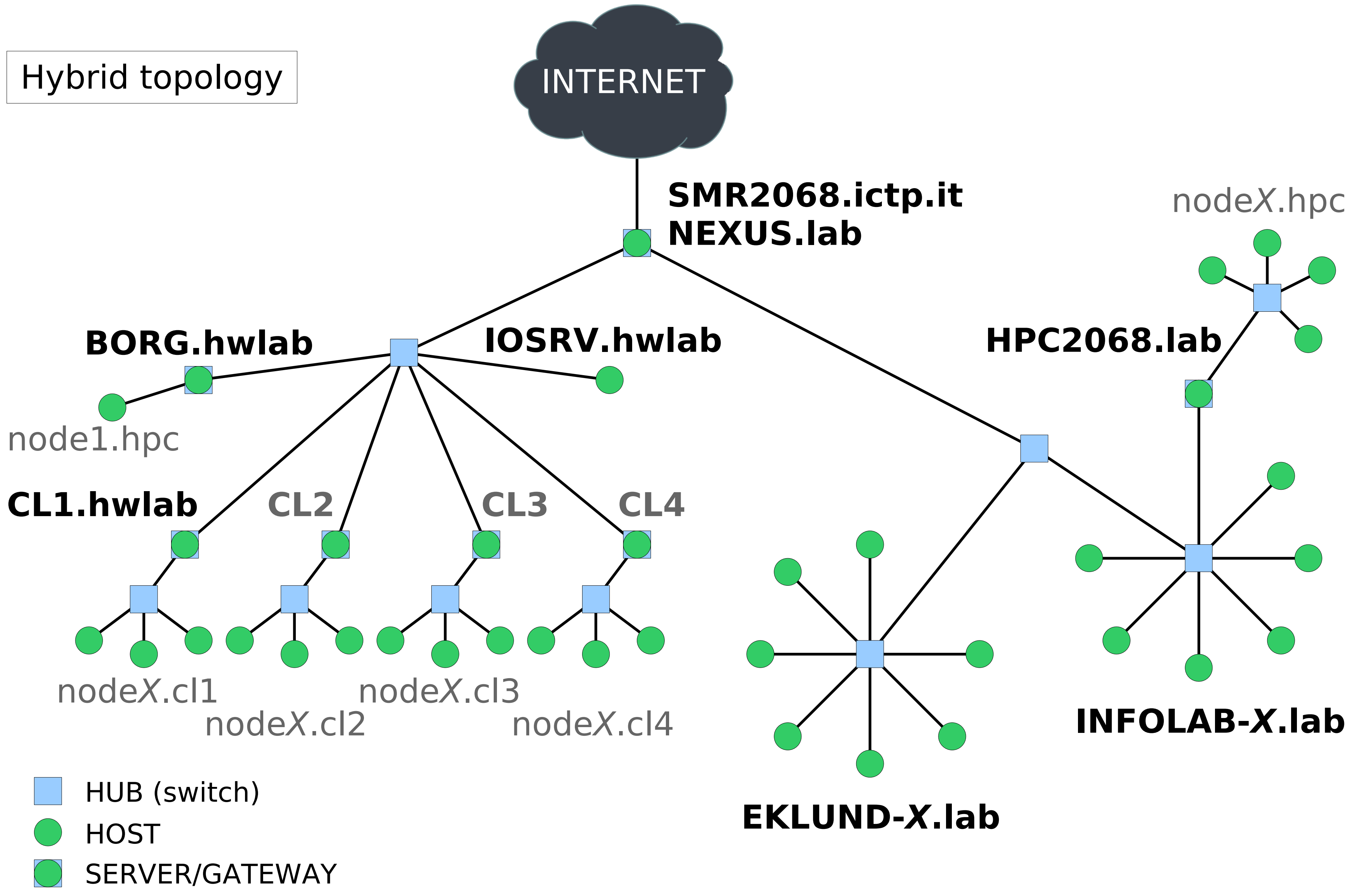
host-X.site-A$ ssh host-Y.site-B

Physical Network Topologies



Example: the lab network

Hybrid topology

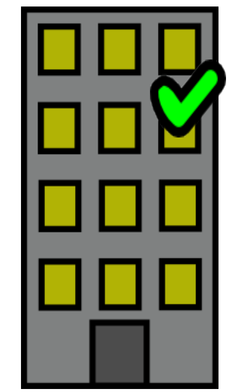


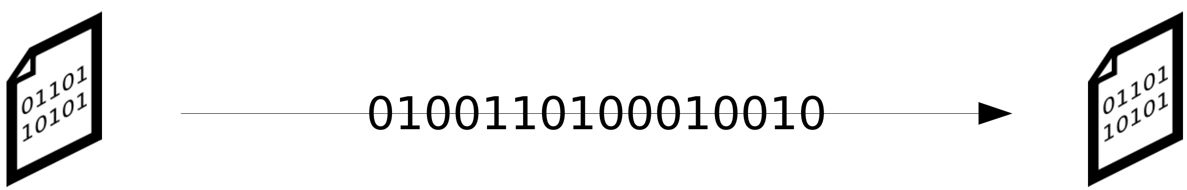
Concept of Packet

Addressing and Multiplexing

From Address:
Country
City
Street and Number
Name

To Address:
Country
City
Street and Number
Name/Apartment/Floor

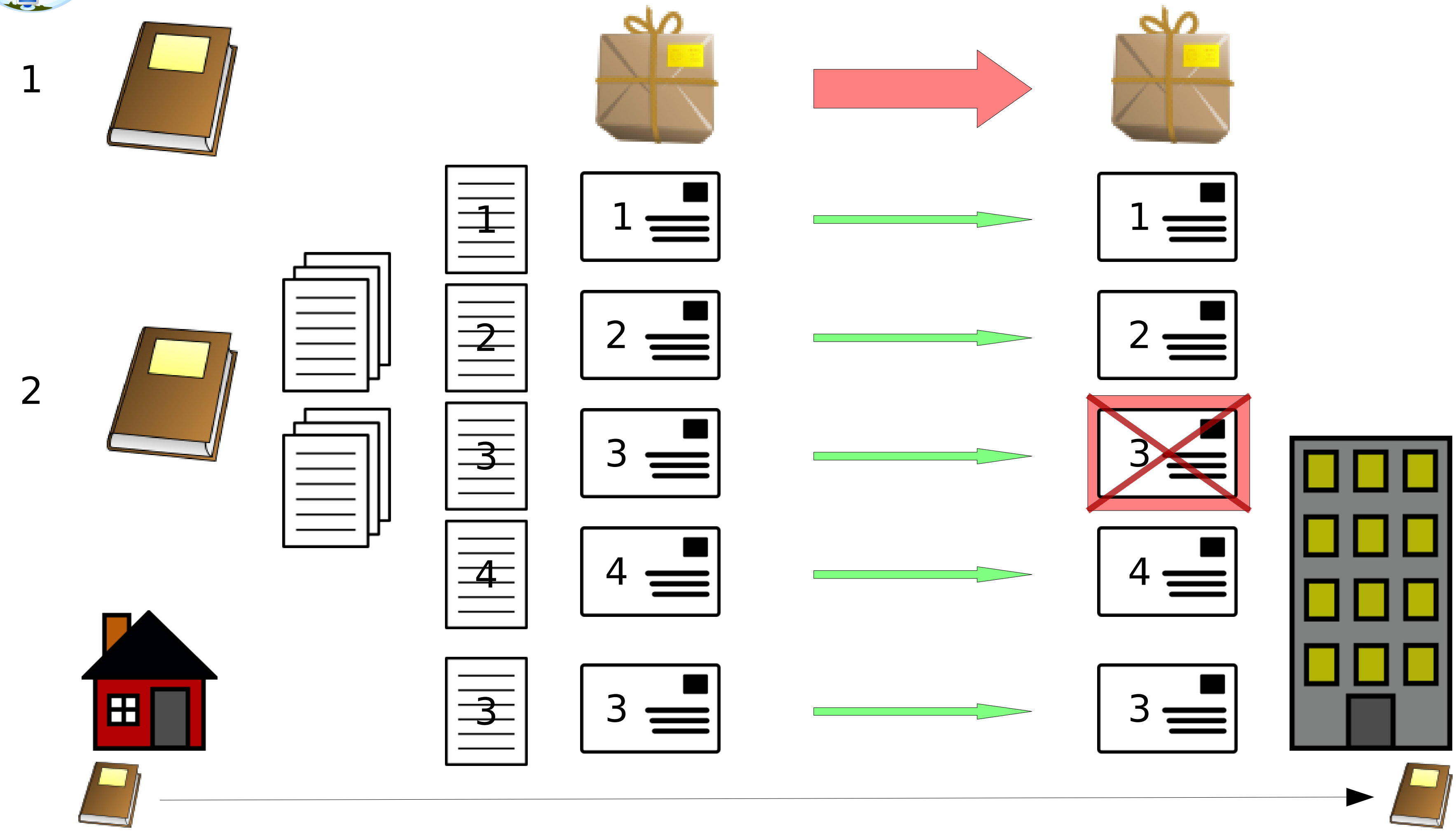




Source Address:
hostname: **host-a**
domain: **example.com**
IP address: **192.0.32.10**
protocol: **TCP**
port: **35432**

Destination Address:
hostname: **host-b**
domain: **example.org**
IP address: **192.0.2.44**
protocol: **TCP**
port: **25 (SMTP)**

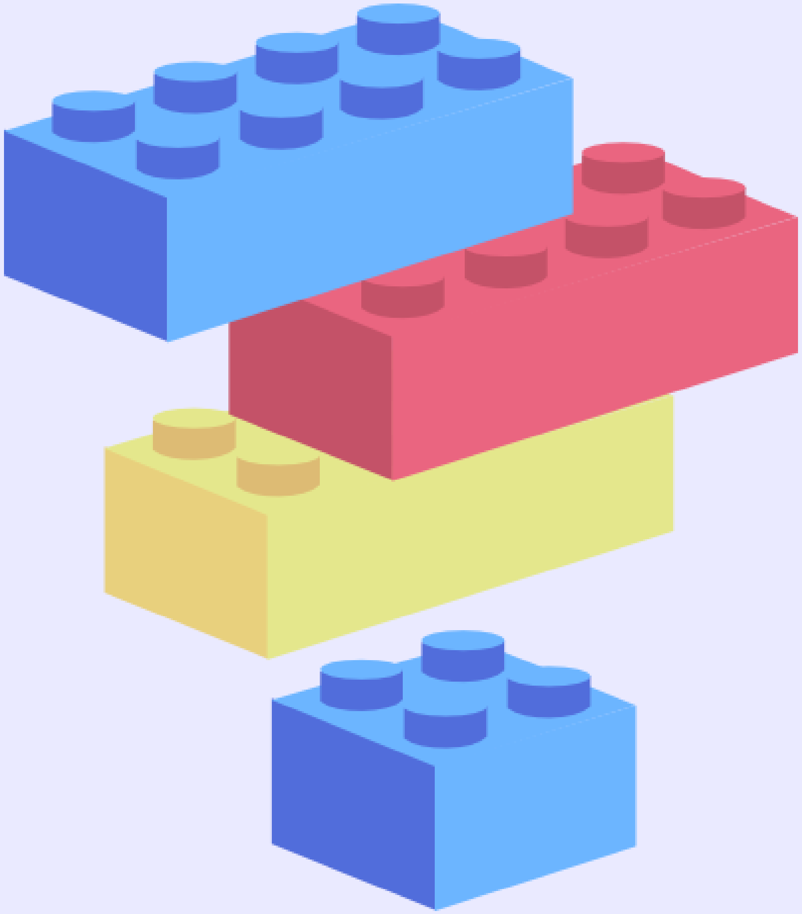
Fragmentation and Windowing



NETWORK CONNECTIONS ARE (OFTEN) NOT RELYABLE
BANDWIDTH IS NOT FREE AND IS NOT UNLIMITED

In case of failure, sending twice a large amount of data has a cost, both in terms of money and time. Network protocols splits and fragments the data stream, TCP uses sequence numbers to reassemble the data in case they reach the destination out of order (retransmission, timeout, different routes,...).

Network Stack



Network Stack Models

TCP/IP Model

	Layer	
SW	Application	Protocols
	Transport	Protocols
	Internet	Networks
HW	Network Access	Networks

ISO/OSI Model

Layer	
7. Application	Application Layers
6. Presentation	Application Layers
5. Session	Application Layers
4. Transport	Data Flow Layers
3. Network	Data Flow Layers
2. Data Link	Data Flow Layers
1. Physical	Data Flow Layers

SW	Logical Addressing	objects (e-mails, web pages, ...)
	Logical Addressing	streams (segments, packets, frames)
HW	Physical Addressing	bits (voltage levels, light impulses, ...)

TCP/IP Model

	Protocols
Application	E-Mail (SMTP), Web (HTTP), ...
Transport	TCP, UDP
Internet	IP, ICMP, ARP, RARP
Network Access	ARP, RARP ETHERNET (10/100/1G/10G), PPP, SLIP, ...

ISO/OSI Model

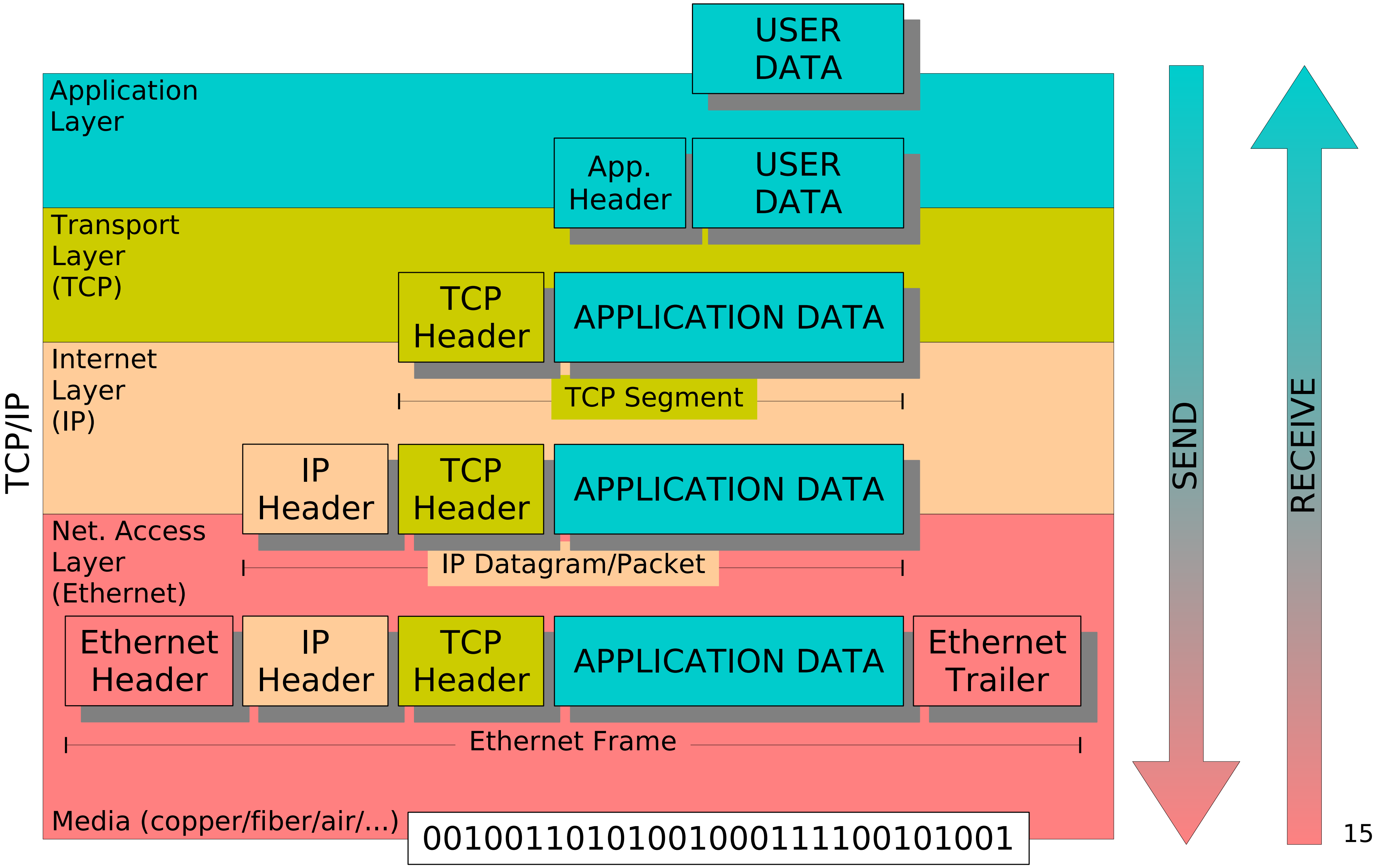
Layer	Function
7. Application	**Network Processes to Applications** • Provides network services to application processes, such as electronic mail, file transfer and terminal emulation
6. Presentation	**Data Representation** • Ensures data is readable by receiving system • Format of data • Data structures • Negotiates data transfer syntax for application layer
5. Session	**Interhost Communication** • Establishes, manages, and terminates sessions between applications
4. Transport	**End-to-end Connections** • Concerned with transportation issues between hosts • Data transport reliability • Establishes, maintains, terminates virtual circuits • Fault detection and recovery information flow control
3. Network	**Network Address and Best Path Determination** • Logical addressing • Best effort delivery
2. Data Link	**Direct Link Control, Access to Media** • Provides reliable transfer of data across media • Physical addressing, network topology, line discipline, error notification, ordered delivery of frames and flow control
1. Physical	**Binary Transmission** • Wires, connectors, voltages, data rates

Protocol Data Unit (PDU)

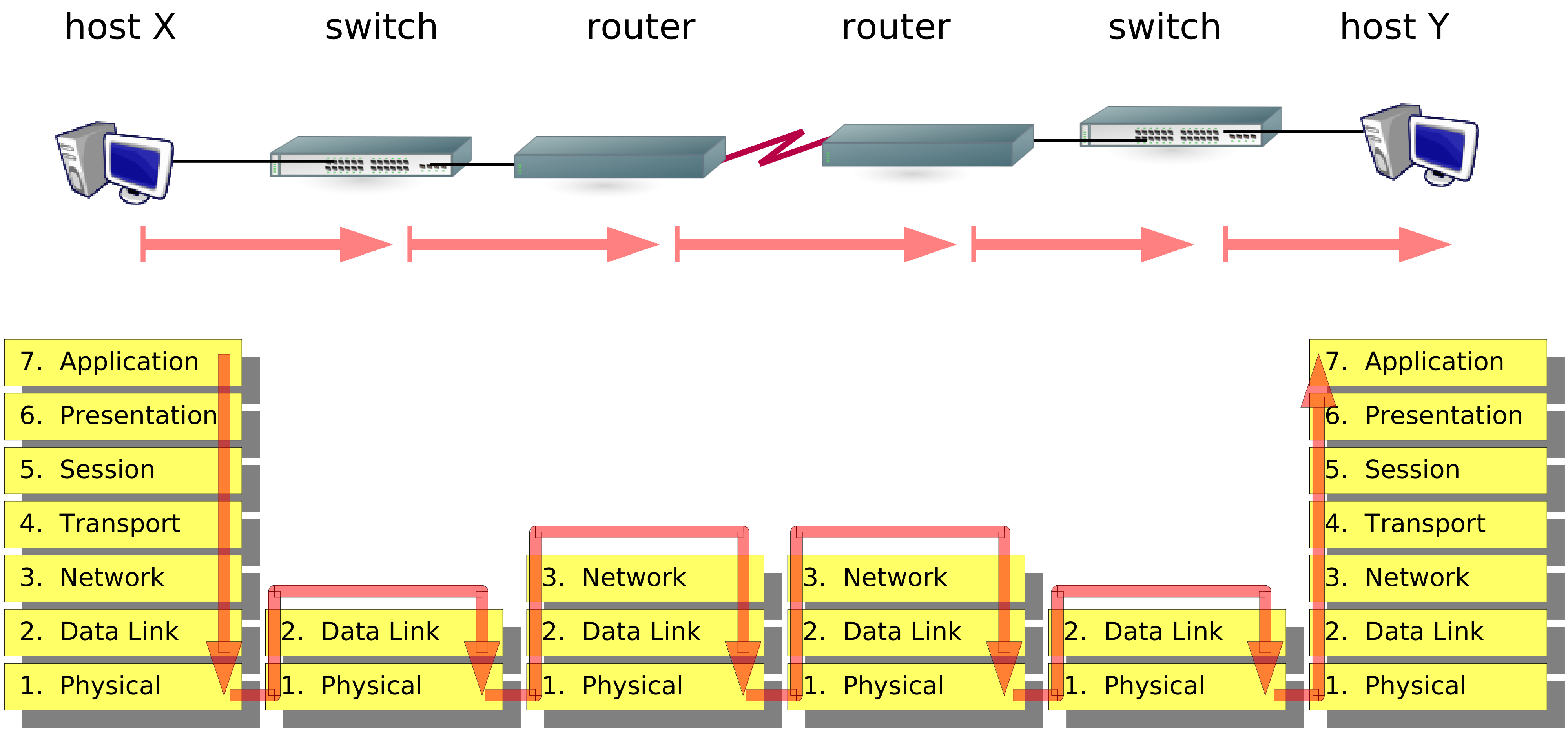
Host A		Host B
7. Application	Data	7. Application
6. Presentation	Data	6. Presentation
5. Session	Data	5. Session
4. Transport	Segments	4. Transport
3. Network	Packets	3. Network
2. Data Link	Frames	2. Data Link
1. Physical	Bits	1. Physical

D-S-P-F-B

Encapsulation/De-encapsulation

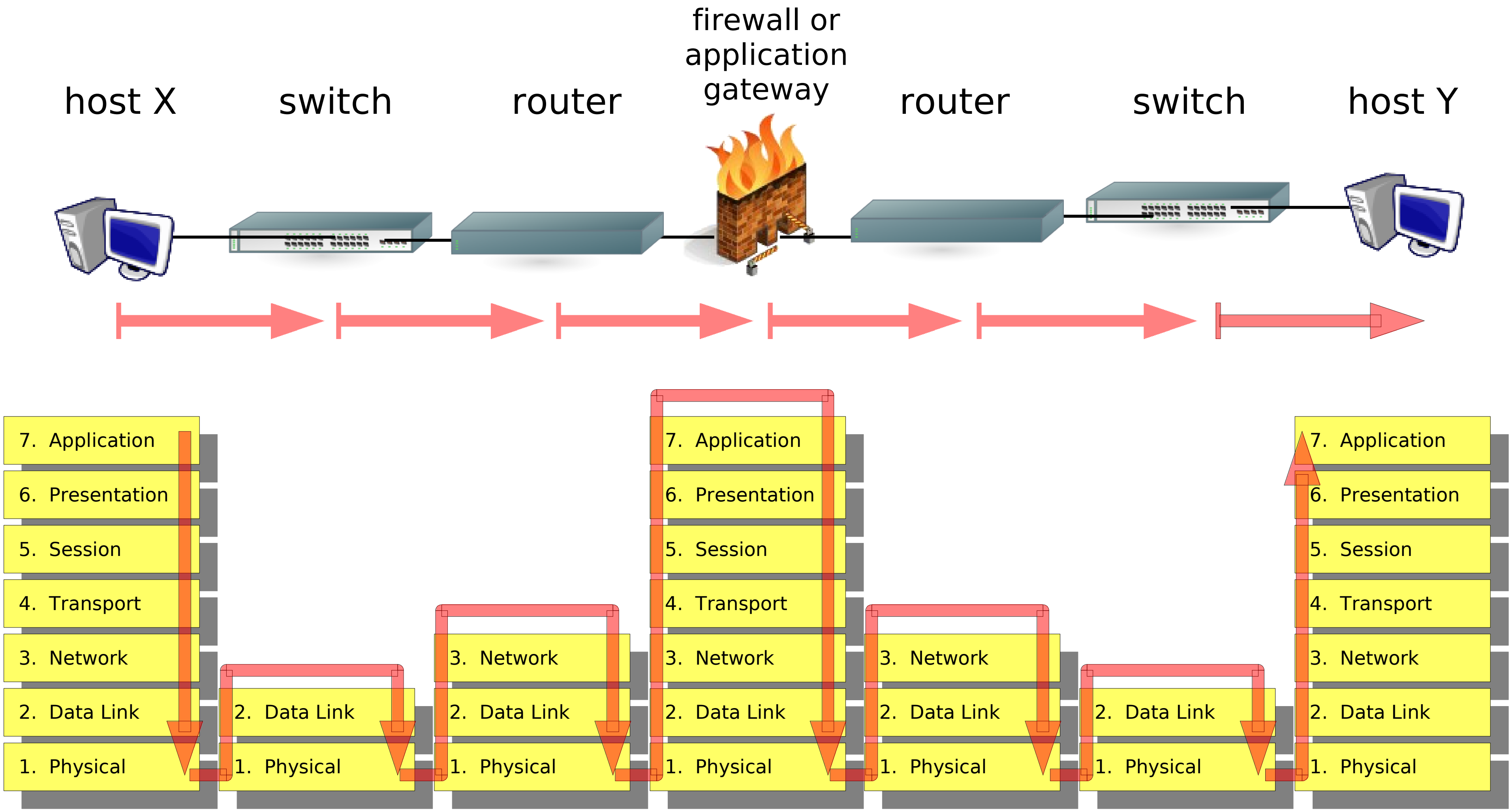


Data flow



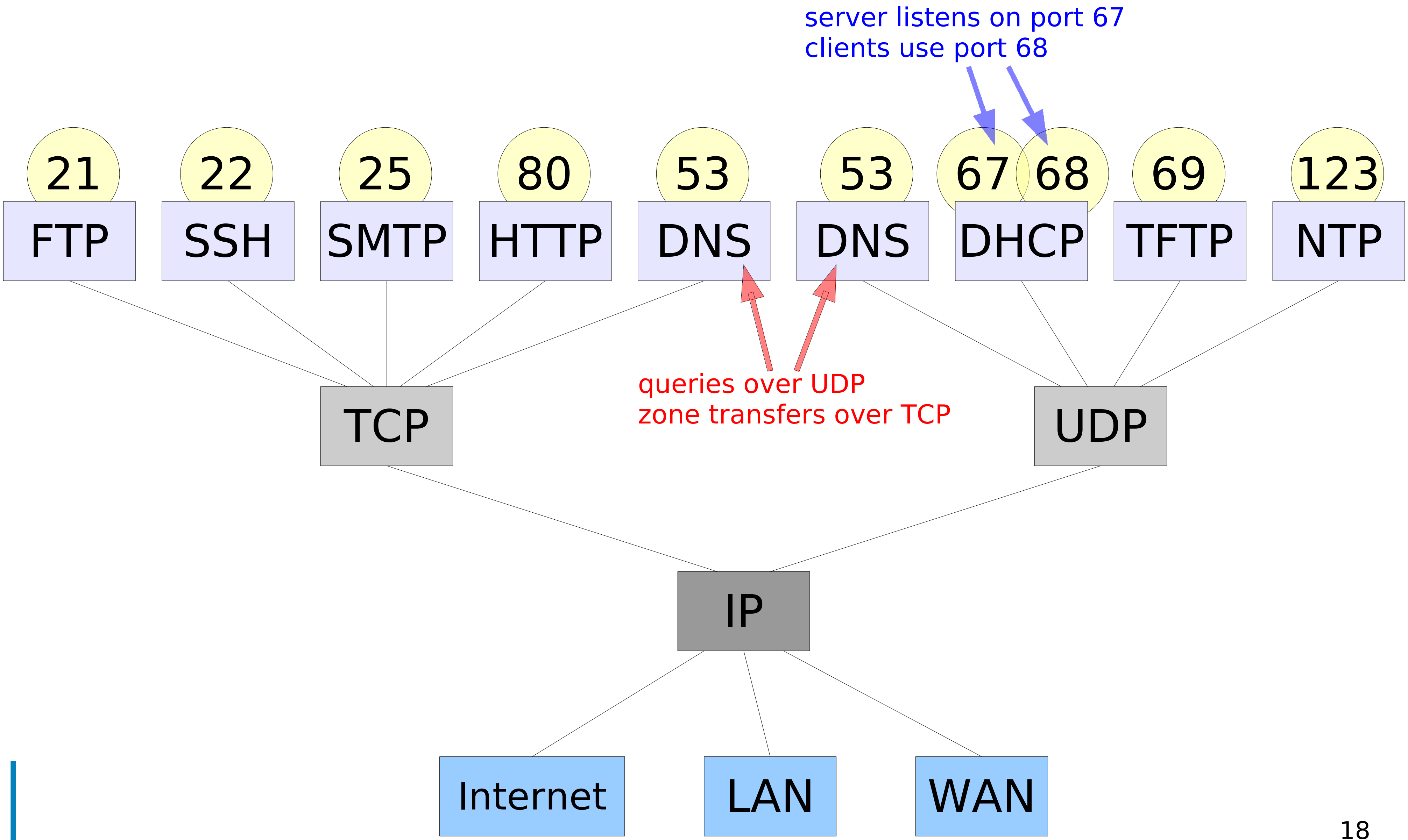
- Switches inspect the traffic for layer 2 info (MAC)
- Routers inspect the traffic for layer 3 info (IP)

Data flow



- Switches inspect the traffic for layer 2 info (MAC)
- Routers inspect the traffic for layer 3 info (IP)
- most Firewalls inspect the traffic for layers 2, 3 and 4 info
- Application Gateways (proxies) and layer-7 firewalls inspect the traffic up to layer 7

Protocols, Ports and Services

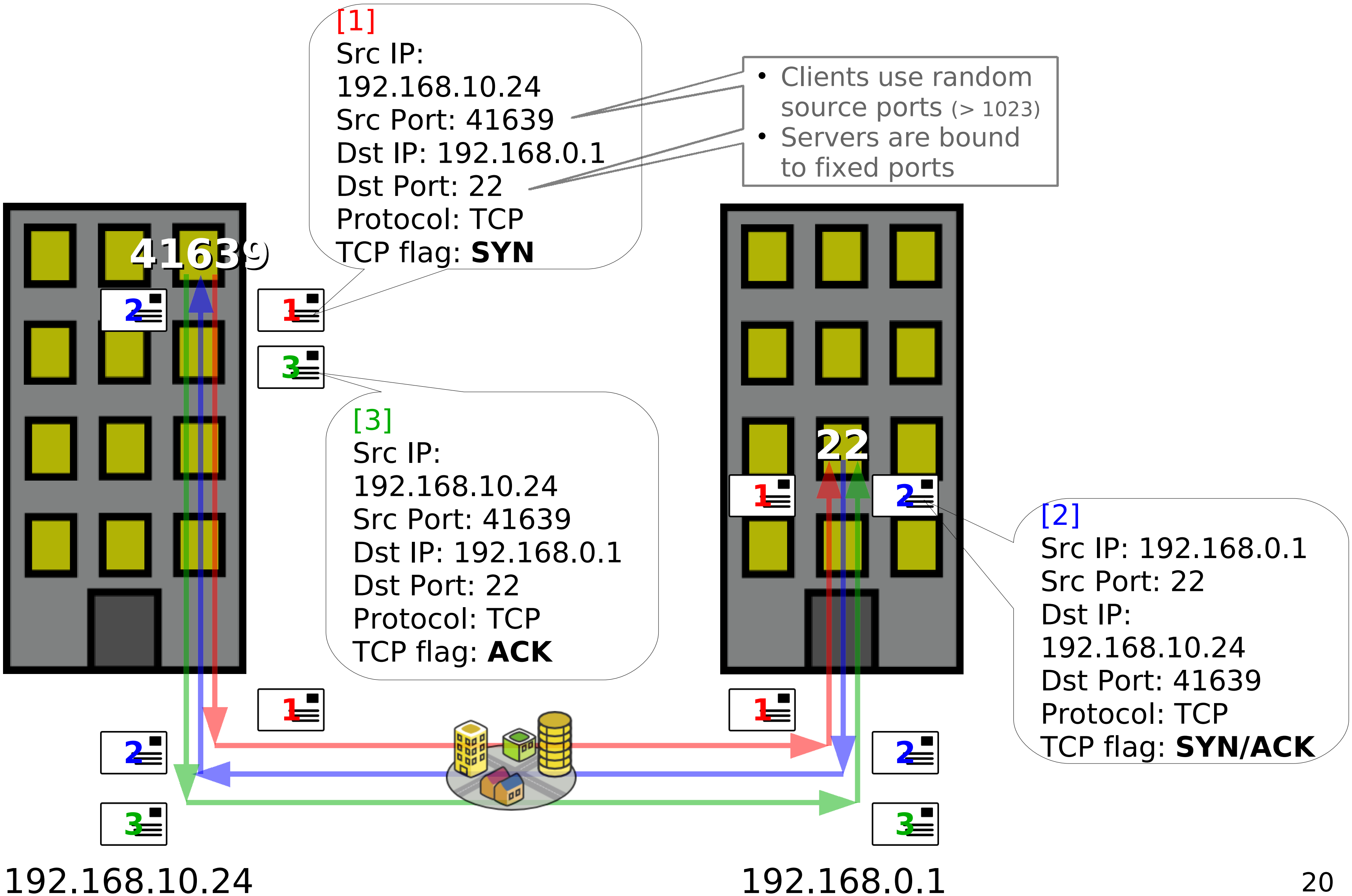


Ports

- Privileged Ports: 1-1023
  - main network services (SSH, SMTP, FTP, TFTP, DHCP, HTTP, HTTPS, ...)
  - need superuser's privileges

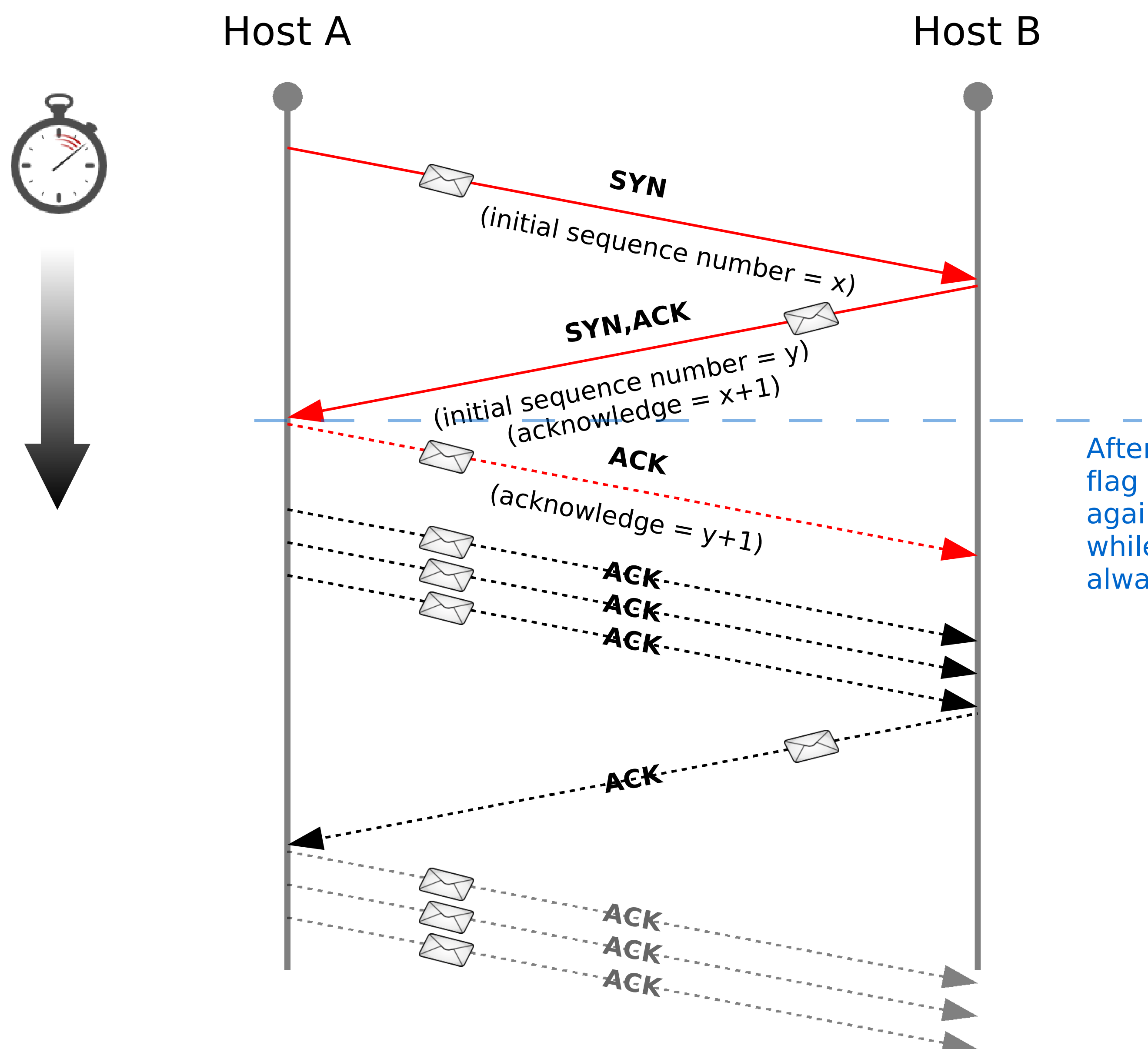
- Unprivileged Ports: 1024-65535
  - clients and unprivileged/no-suid services (Squid, NFS, X11, MySQL, ...)
  - any user can bind to any unprivileged port

Opening a connection
TCP 3-way Handshake



Opening a connection

TCP 3-way Handshake (TCP flags)



After this point, the SYN flag won't be ever set again for this connection, while the ACK will be always set.

Opening a connection
Protocols and (some) operations involved

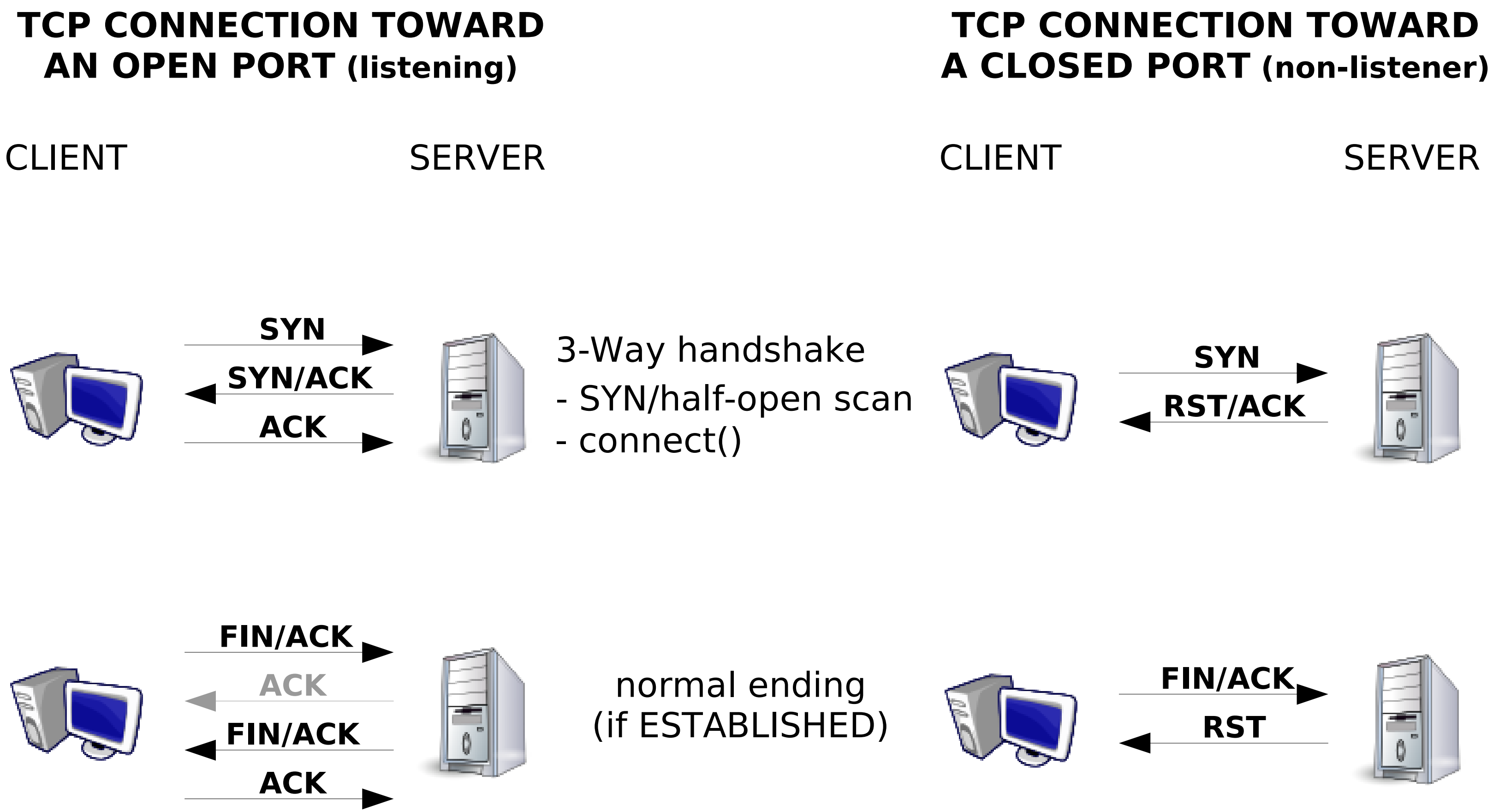
<u>Sending</u>

- layer 6/7: ssh someuser@host.somedomain.com
- layer 5: ssh/openssl session to host.somedomain.com, port 22, send **data**
- DNS: IP for host.somedomain.com
- layer 4: split the data into TCP **segments** and open a connection
- layer 3: obtain the route to the IP address for host.somedomain.com and send the **packets** to the next-hop
- layer 3/2: do we know the MAC address to next-hop? Check ARP table.
- layer 2: obtain MAC of next-hop, set frame header/trailer, send **frames**
- layer 1: check the link and transmit **bits** translated to a physical quantity (electric levels, light impulses, radio waves, ...)

<u>Receiving</u>

- layer 1: check whether there's a transmission on the media
- layer 2: check whether the destination MAC belong to the NIC
- layer 3: check whether the destination IP address is ours
- layer 4: check whether at port 22, protocol TCP, there's a server listening
- layer 5: ssh/openssl negotiation and data transmission
- layer 6/7: check whether the connection is allowed from the source-host and that the user is hosted at this domain (authentication and spawn of a shell/command or deny connection)

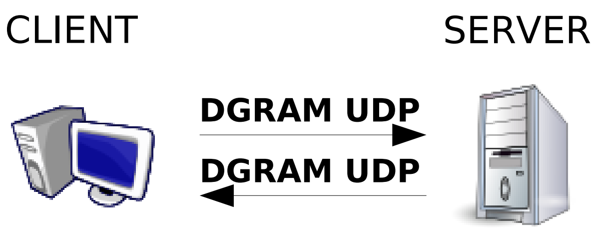
TCP Connection



RFC 793

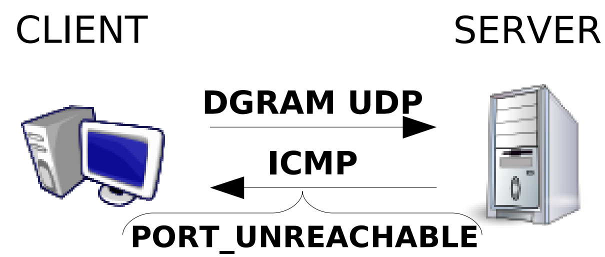
UDP & ICMP

UDP CONNECTION TOWARD AN OPEN PORT (listening)

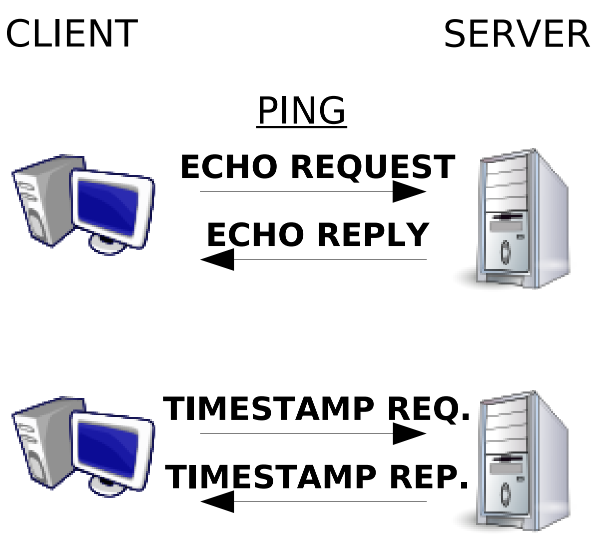


Depending on the application,
there could be a reply or not

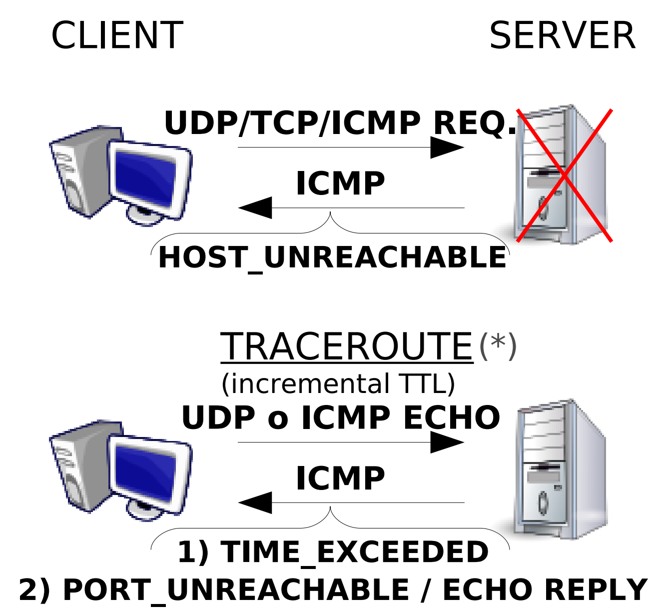
UDP CONNECTION TOWARD A CLOSED PORT (non-listener)



ICMP REQUEST/REPLY



ICMP NOTIFY



RFC 768
RFC 792

(*) TCPTRACEOUTE does the same but uses TCP SYN, SYN/ECN/CWR or ACK and expects a SYN/ACK or RST, RST/ACK

Internet Protocol and IP Address Space

Internet Protocol

The **Internet Protocol (IP)**:

- provides network connectivity at **layer 3**
- is the main **routed protocol** of the Internet
- is the most widely used implementation of a **hierarchical network-addressing scheme**
- **addresses are used to route packets** from a source to a destination through the **best available path**
- is a **connectionless, unreliable, best-effort delivery protocol** (verification handled by upper protocols)

IP(v4) addresses

The **IP address** is:

- a **numerical label** assigned to devices participating in a computing network, expected to **uniquely identify each host**
- obtained by the ISP (public IPs) or the system/network administrator (private IPs)
- **assigned** to a host **statically or dynamically** (BOOTP/DHCP)
- a 32 bits / 4 bytes unsigned integer number, usually **represented in a dotted-decimal notation**, as four 8bits/1byte numbers (0-255), called “octets”, separated by a dot '.' (0.0.0.0-255.255.255.255), sometimes in hexadecimal format (00000000-FFFFFFFF)
- divided in two parts, the *network* portion and the *host* portion
- something like this: 192.168.0.1 (C0A80001)

Netmask, Network and Broadcast

The **netmask address** is:

- **a bit-mask of contiguous 1s** (starting from the MSB) that **separates the host portion from the network portion** of an IP address (1s on the network portion, 0s on the host portion)
- often represented in the “slash format” as the total number of bits used for the network and subnetwork portion of the mask (/8, /16, /24, /32, ...)
- something like this: 255.255.255.0 (FFFFFF00)

The **network address** is:

- what **identifies the network itself** and **defines the group of IP addresses that belongs to the same broadcast domain**, hosts that can communicate with each other without the need of a layer 3 device
- an IP address with the **host portion filled by 0s** (192.168.0.0, C0A80000)

The **broadcast address** is:

- a network address that **allows information to be sent to all nodes on a network**, rather than to a specific network host (unicast)
- an IP address with the **host portion filled by 1s** (192.168.0.255, C0A800FF)

IP Address Notation

- *Dotted Quad Notation* (*four-octet dotted-decimal*, *numbers-and-dots*)
  - 10.240.27.73 / 255.255.255.0 (10.240.27.73/24)
- Hexadecimal Notation
  - 0AF01B49 / FFFFFF00
- Binary Notation
  - 00001010 11110000 00011011 01001001 / 11111111 11111111 11111111 00000000

11111111 11111111 11111111	00000000	FFFFFF	00	255.255.255.	0	Netmask
00001010 11110000 00011011	01001001	0AF01B	49	10.240. 27.	73	IP Addr.
00001010 11110000 00011011	00000000	0AF01B	00	10.240. 27.	0	Network Addr.
00001010 11110000 00011011	11111111	0AF01B	FF	10.240. 27.	255	Broadcast Addr.

NETWORK PORTION	HOST PORTION

IP Address Classes

Class A	Network	Host		
Octet	1	2	3	4

Class B	Network		Host	
Octet	1	2	3	4

Class C	Network			Host
Octet	1	2	3	4

Class D	Host			
Octet	1	2	3	4

Class	Network	Netmask	Broadcast	Host
A	x.0.0.0	255.0.0.0 (/8)	x.255.255.255	x.*.*.*
B	x.x.0.0	255.255.0.0 (/16)	x.x.255.255	x.x.*.*
C	x.x.x.0	255.255.255.0 (/24)	x.x.x.255	x.x.x.*

Class D addresses are used for *multicast* groups. There is no need to allocate octets or bits to separate network and host addresses.

Identifying Address Classes

IP Address Class	High Order Bits	First Octet Address Range	Number of Bits in the Network Address	Number of Bits in the Host Address
Class A	0xxx	0 - 127	8	24
Class B	10xx	128 - 191	16	16
Class C	110x	192 - 223	24	8
Class D (*multicast*)	1110	224 - 239	-	-
Class E (research)	1111	240 - 255	-	-

Address Class	Number of (usable) Networks	Number of (usable) Hosts per Network
A	$2^{8-1}-2 = 126$	$2^{24}-2 = 16{,}777{,}214$
B	$2^{16-2} = 16{,}384$	$2^{16}-2 = 65{,}534$
C	$2^{24-3} = 2{,}097{,}152$	$2^{8}-2 = 254$
D (multicast)	N/A	N/A

The first address is reserved for the network ID, the last one is the network broadcast.

The 127.x.x.x address range is reserved as a loopback address, used for testing and diagnostic purposes, 0.x.x.x is reserved as “this”-network.

Subnetting

- **prevented complete IP address exhaustion**
- a **method used to manage IP addresses dividing full network address classes into smaller pieces** (the network is not limited to the default Class A, B, or C network masks)
- subnetting a network means to **use the subnet mask to divide the network** and **break a large network up into smaller**, more efficient and manageable **segments, or subnets**, increasing the flexibility in the network design and providing also **broadcast containment and low-level security**
- **subnet addresses include the network portion plus a subnet field and a host field** (fields created from the original host portion of the major IP address by **re-assigning bits from the host portion to the network portion**)
- the number of bits “borrowed” depends on the number of hosts required per subnet

Subnetting

Class A, /8

2^8 networks
2^{24} hosts per network

11111111	00000000	00000000	00000000	255. 0. 0. 0	Netmask
00001010	11110000	00011011	01001001	10.240. 27. 73	IP Addr.
00001010	00000000	00000000	00000000	10. 0. 0. 0	Network Addr.
00001010	11111111	11111111	11111111	10.255.255.255	Broadcast Addr.

NETWORK PORTION **HOST PORTION**

Classless, /20

2^{20} networks
2^{12} hosts per network

12 bits “borrowed” from hosts to networks

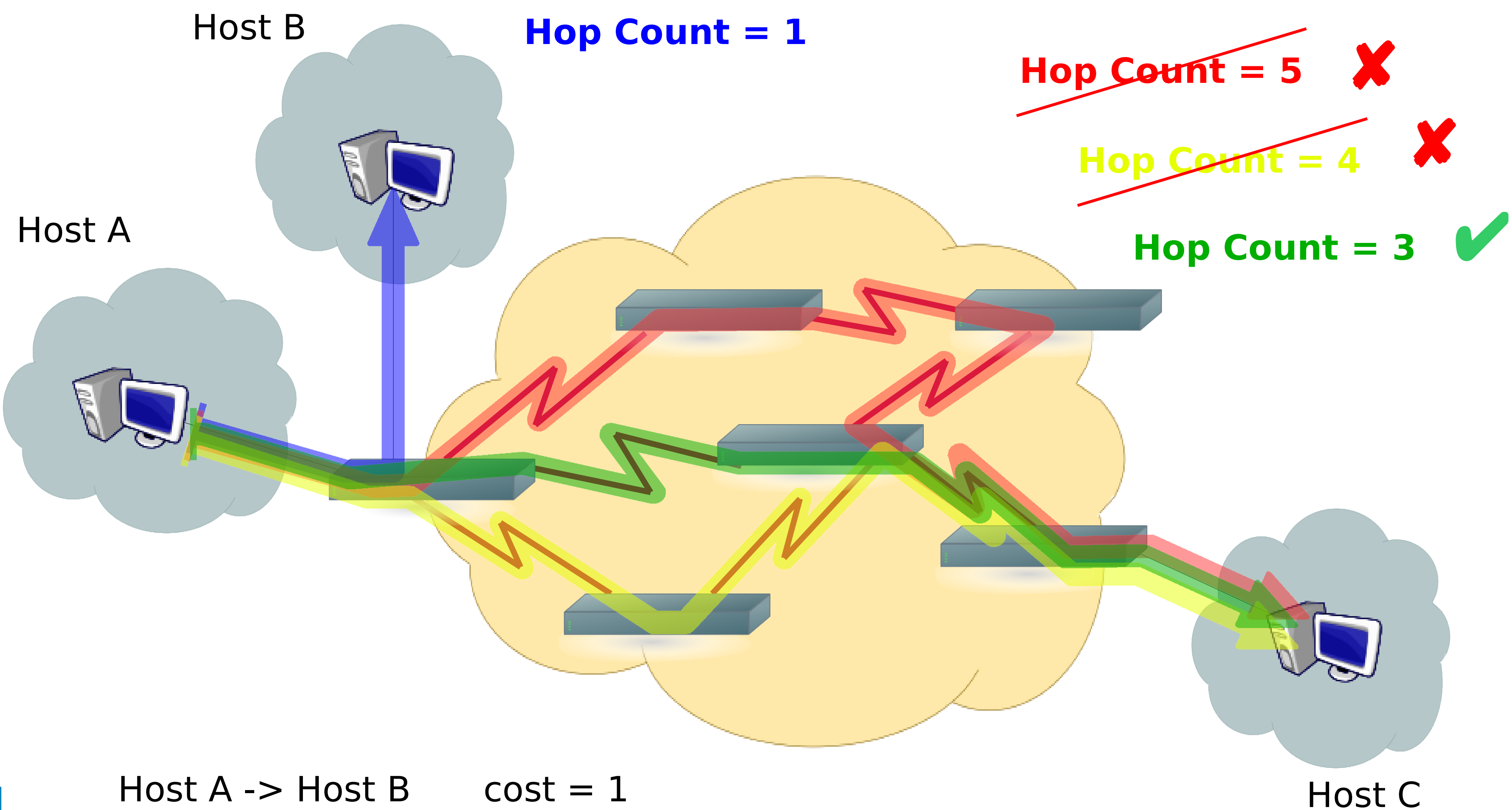
11111111	11111111	11110000	00000000	255.255.240. 0	Netmask
00001010	11110000	00011011	01001001	10.240. 27. 73	IP Addr.
00001010	11110000	00010000	00000000	10.240. 16. 0	Network Addr.
00001010	11110000	00011111	11111111	10.240. 31.255	Broadcast Addr.

NETWORK PORTION **SUBNET FIELD** **HOST FIELD**

Routing

- **routers are layer 3 devices that use the IP address to move data packets between networks** (when packets arrive at an interface, the **router uses the routing table** to determine where to send them)
- **each router that the packet encounters along the way is called a hop, the hop count is the distance traveled**
- **routing protocols use various combinations of metrics** (values that are used to determine the advantage of one route over another) **to determine the best path** along which network traffic should be forwarded (**hop count, load, bandwidth, delay, cost, and reliability of a network link**).
- **if a packet does not match any entries in the routing table, the router checks to see if a default route has been set**. If a default route has been set, the packet is forwarded to the associated port. **A default route is a route that is configured by the network administrator as the route to use if there are no matches in the routing table. If there is no default route, the packet is discarded**. A message is often sent back to the device that sent the data to indicate that the destination was unreachable.

Best path determination



Host A -> Host B cost = 1

Host A -> Host C cost = 3

Reserved IP Addresses

RFC 3330
RFC 1918
RFC 2606

- "This" network: 0.0.0.0/8
- Loopback: 127.0.0.0/8
- Private addresses: 10.0.0.0/8, 172.16.0.0/12, 192.168.0.0/16

  10.0.0.0 – 10.255.255.255
  172.16.0.0 – 172.31.255.255
  192.168.0.0 – 192.168.255.255
- "TEST-NET" (example.com, org, net): 192.0.2.0/24
- 6to4 Relay: 192.88.99.0/24
- "Link local" (zeroconf): 169.254.0.0/16
- Multicast: 224.0.0.0/4

IPv6 (in a nutshell)

- more extendible and scalable version of IP, **uses 128 bits** rather than the 32 bits
- **address assignment** can be **static** (manual configuration), **stateful** (DHCPv6) or **stateless auto-configuration** (SLAAC)
- **uses hexadecimal numbers** to represent the 128 bits, **8 groups of 4 hexadecimal digits** (16 bits) separated by ':'
  - 2001:0db8:0000:0000:00a9:0000:0000:0001
- initial 0s of each group can be removed
  - 2001:db8:0:0:a9:0:0:1
- a sequence of contiguous groups=0 can be replaced by a “::” (only once per address)
  - 2001:db8::a9**:0:0:**1 or 2001:db8**:0:0:**a9::1, NOT both (2001:db8::a9::1)
- netmask uses slash format "/N" (/64 is the default prefix)
  - 2001:db8::/32 (32 bits prefix)
    - addresses from 2001:db8:: to 2001:db8:ffff:ffff:ffff:ffff:ffff:ffff
  - 2001:db8::/64 (64 bits prefix):
    - addresses from 2001:db8:: to 2001:db8:0:0:ffff:ffff:ffff:ffff
- **::1/128 is the loopback address (“`ping6 ::1`” to test IPv6 stack)**

Host names, Domain names and DNS

- **hostname**
  - **cerbero**.hpc.sissa.it
- **first level domain**
  - cerbero.hpc.sissa.**it**
- **second level domain**
  - cerbero.hpc.**sissa**.it
- **third level domain**
  - cerbero.**hpc**.sissa.it
- ***Fully Qualified Domain Name* (FQDN)**
  - **cerbero.hpc.sissa.it**
- **DNS**
  - cerbero.hpc.sissa.it **-->** 147.122.17.62
  - 147.122.17.62 **-->** cerbero.hpc.sissa.it

Static vs. Dynamic IP assignment

- **static**: manual configuration (servers, network devices, workstations)

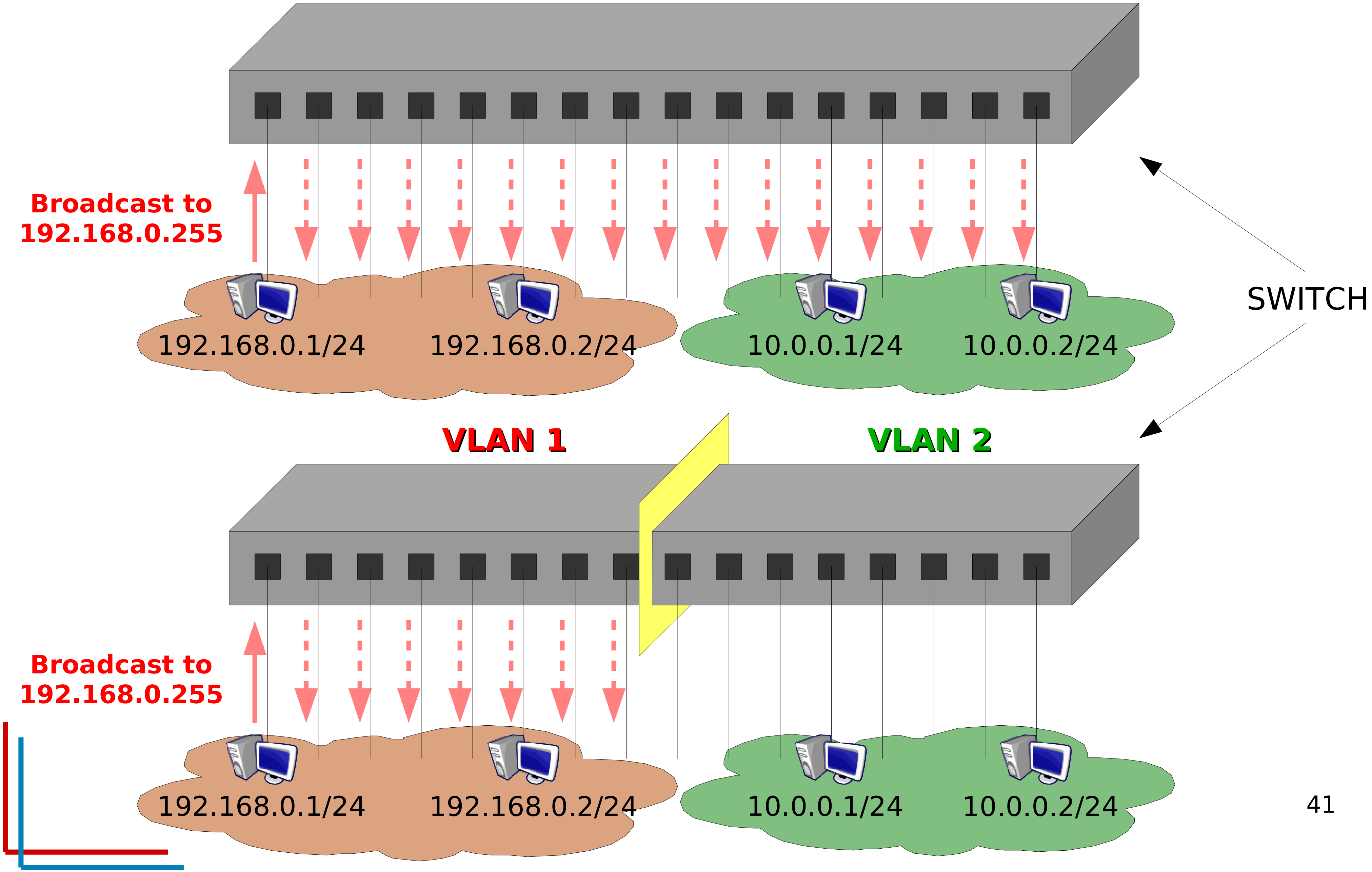
- **dynamic**: the DHCP server assigns an IP address to each DHCP client, associating the MAC address to an IP.
  The IP address can be:
  - **randomly assigned from a pool of IPs** (laptops on a wireless network or a LAN)
  - **sticky**, as above but the lease time is set to long periods (ISP)
  - **fixed** (workstations, network devices, cluster nodes, any device that must be always reachable at the same address), **requires individual profile for each device** (maps MAC-IP, providing Network Settings and, optionally, hostnames)

- **autoconfiguration (*link-local*)***:* communication between hosts on a single link (LAN segment) or a point-to-point connection

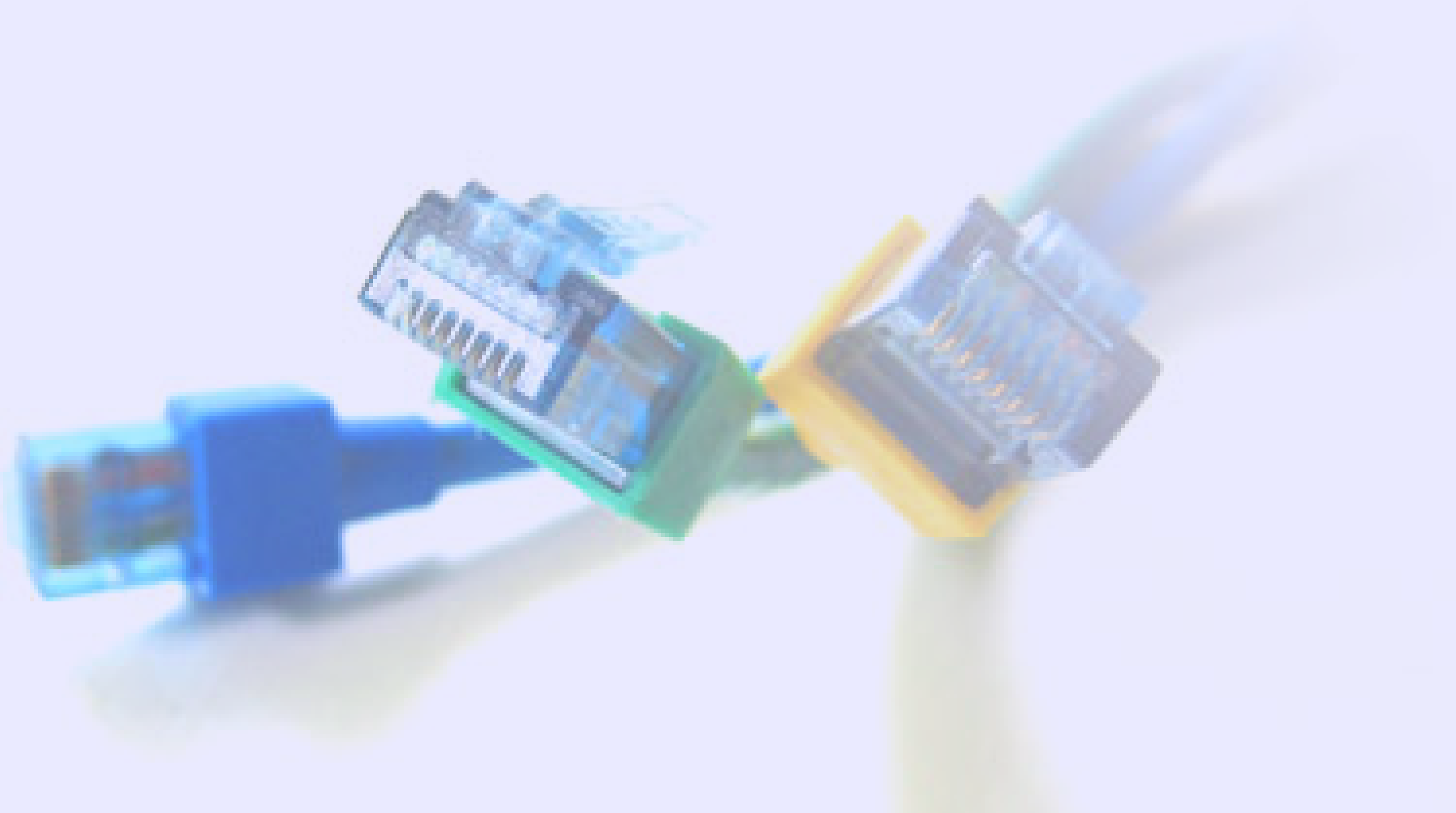
Virtual LANs (VLAN)

- **logical group of hosts** with a common set of requirements that communicate as if they were attached to the Broadcast domain, **regardless of their physical location** (independent of physical topologies and distances – network location of users is no longer tightly coupled to their physical location)
- **provide segmentation services** traditionally provided by routers in LAN configurations, **addressing issues such as scalability, security, and network management**
- **a VLAN has the same attributes as a physical LAN**, but it allows for end stations to be grouped together even if they are not located on the same network switch (**network reconfiguration can be done through software instead of physically relocating devices**)
- **multiple Layer 3 networks on the same Layer 2 switch**
- in an environment employing VLANs, a one-to-one relationship often exists between VLANs and IP subnets (**Virtual LANs are Layer 2 constructs while IP subnets are Layer 3 constructs**)
- switches may not bridge IP traffic between VLANs as it would violate the integrity of the VLAN broadcast domain (routers in VLAN topologies provide broadcast filtering, security, address summarization, and traffic flow management)

VLAN – Segmentation



Ethernet and Physical Address

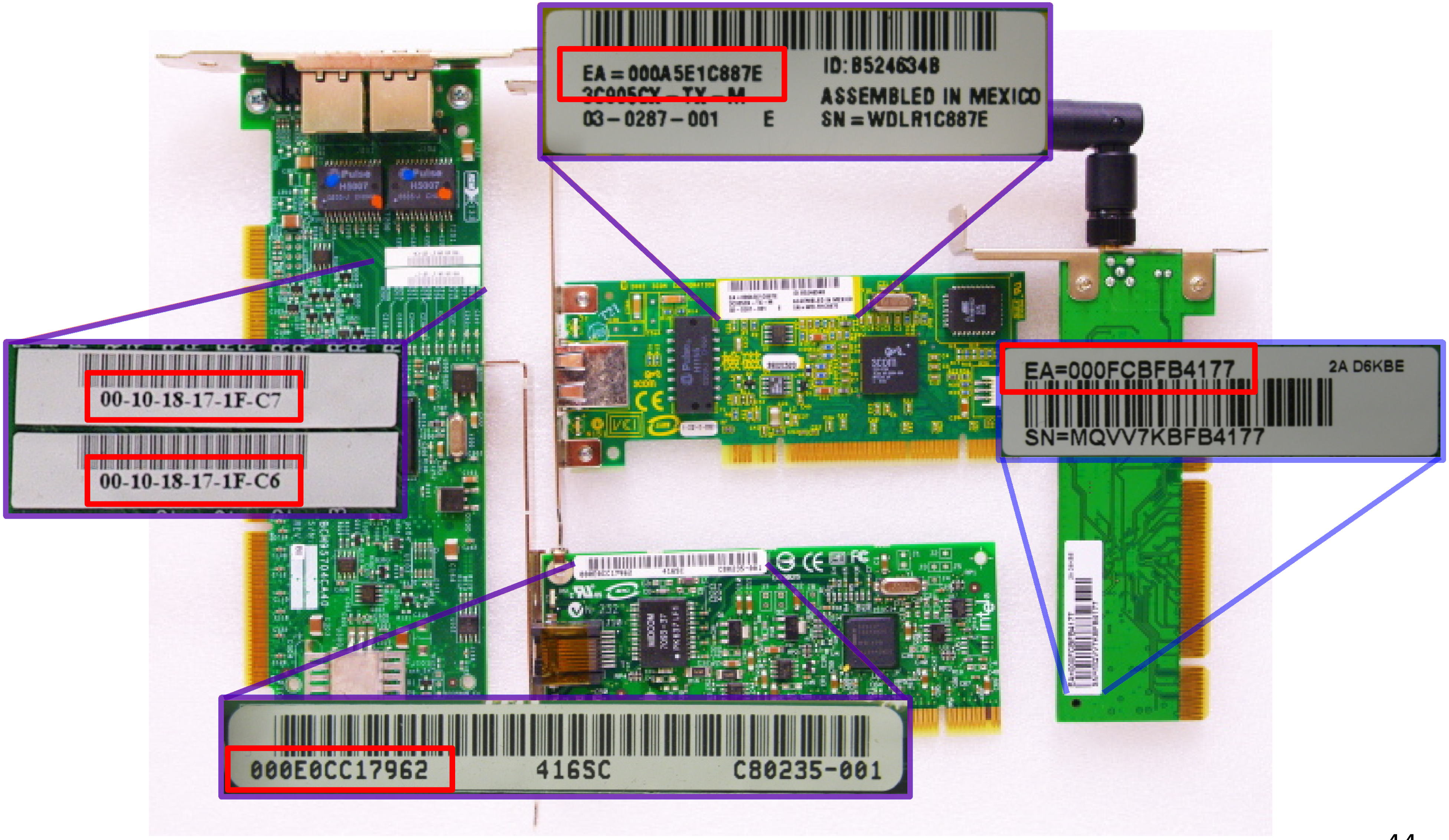


MAC Address

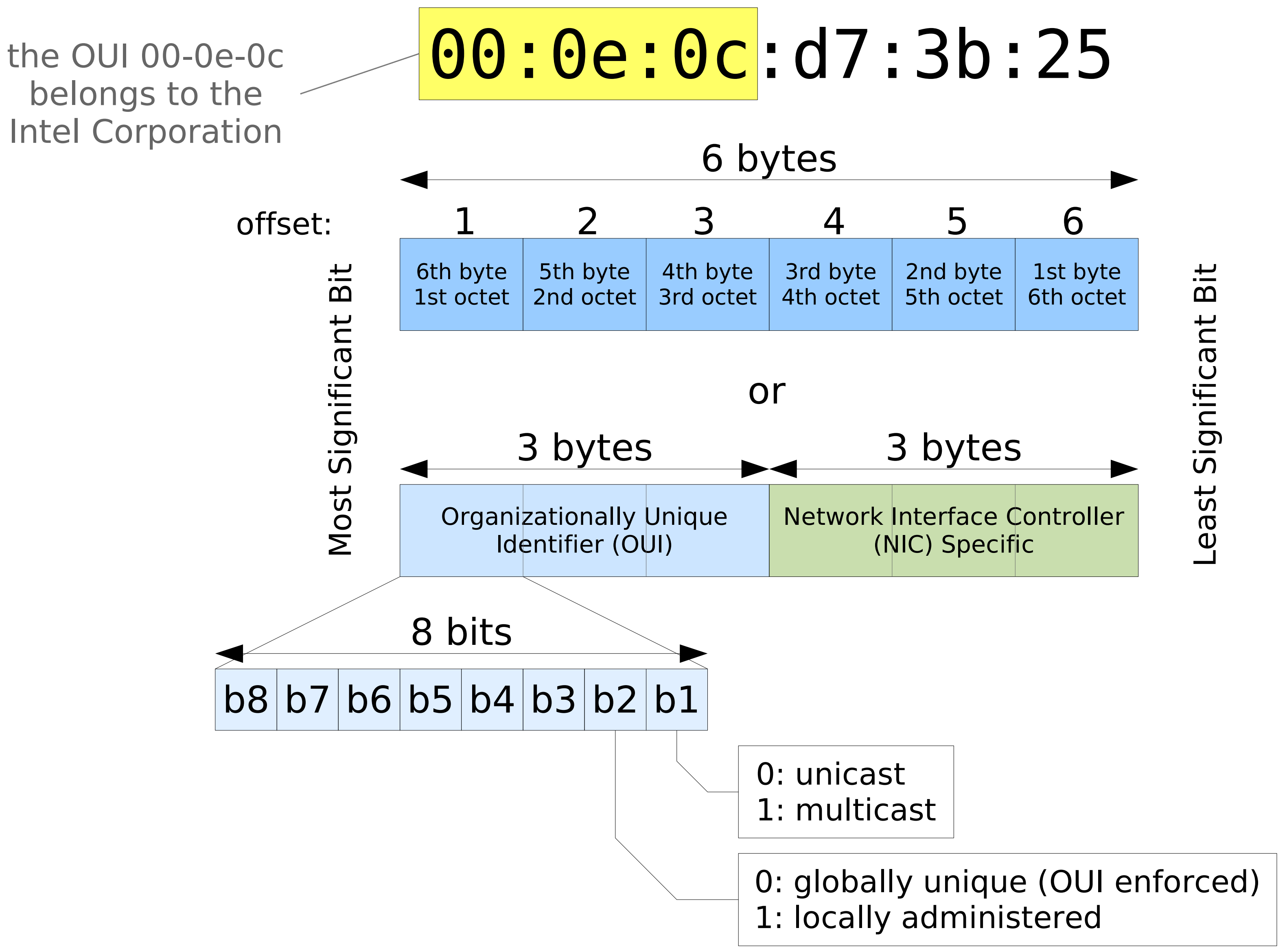
The ***Media Access Control*** **Address** is:

- a **physical address**, **globally unique**
- **assigned by the manufacturer** of the NIC and **burned-in into the PROM of the NIC** (in some cases, can be administratively assigned)
- part of the Ethernet protocol and **operates at Layer 2**
- sometimes called ***Ethernet Hardware Address*** (EHA)
- **used by DHCP to dynamically assign IP Addresses**
- a 48bits number represented as a 6 groups of two hexadecimal digits (6 bytes) separated by ':' (00:1d:09:d7:3b:25)
- made of two parts, 3 bytes each:
  - the OUI (Organizationally Unique Identifier)
  - the production number
- replaced in the frame header at each layer 3 device (router/gateway) during transmission

MAC Address


EA = 000A5E1C887E
ID: B524634B
ASSEMBLED IN MEXICO
03 – 0287 – 001 E
SN = WDLR1C887E
00-10-18-17-1F-C7
00-10-18-17-1F-C6
EA=000FCBFB4177
2A D6KBE
SN=MQVV7KBFB4177
000E0CC17962
416SC
C80235-001

MAC Address Notation



ARP: IP to MAC mapping

Address Resolution Protocol:

- layer 3 - layer 2 conversion, **maps IP addresses to physical hardware addresses** (MAC)

- used to **identify the next layer-2 hop/device** (NIC or switch) in order to reach the destination IP
  - ARP Who has 192.168.0.101? Tell 192.168.1.1
  - ARP 192.168.0.101 is at 00:04:76:9b:ec:46

- the OS keeps IP/MAC couples in the **ARP table** for a limited amount of time

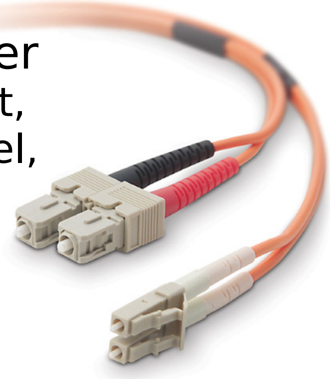
Cables and connectors

- **bandwidth varies depending upon the type of media as well as the technologies used,** the physics of the media account for some of the difference
- signals travel through twisted-pair copper wire, coaxial cable, optical fiber, and air
- **the physical differences in the ways signals travel result in fundamental limitations on the information-carrying capacity of a given medium**
- **actual bandwidth of a network is determined by a combination of the physical media and the technologies chosen for signaling and detecting network signals**.

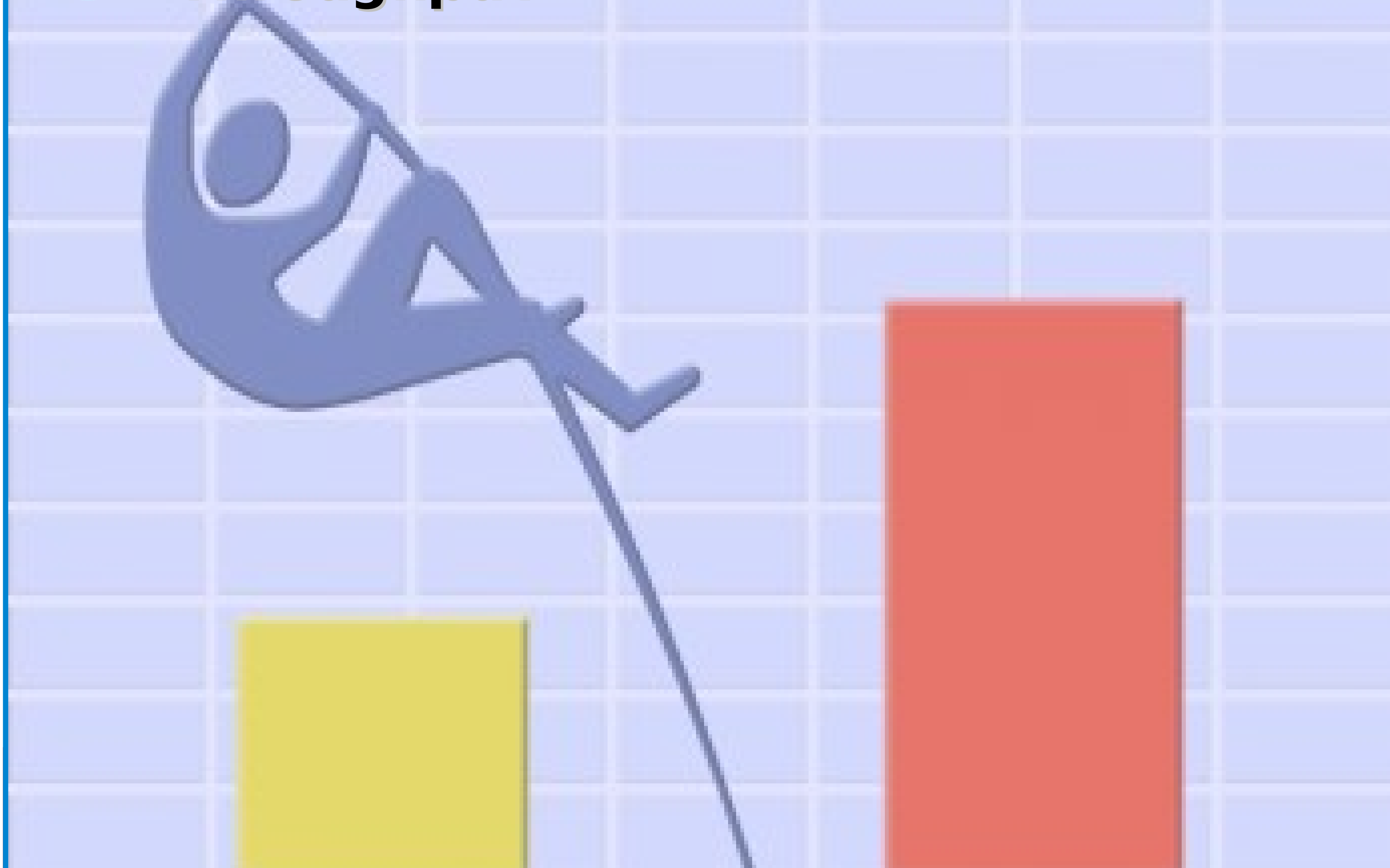
Ethernet RJ45
(10/100/1000)

10GBASE-CX4
(Infiniband &
10GB Ethernet)

SC / LC Fiber
(*G Ethernet,
Fiber Channel,
Myrinet
& more)



About Latency, Bandwidth, Speed and Throughput



Latency in Networking

Latency is the **delay** between the time a frame begins to leave the source device and when the first part of the frame reaches its destination. A variety of conditions can cause delays:

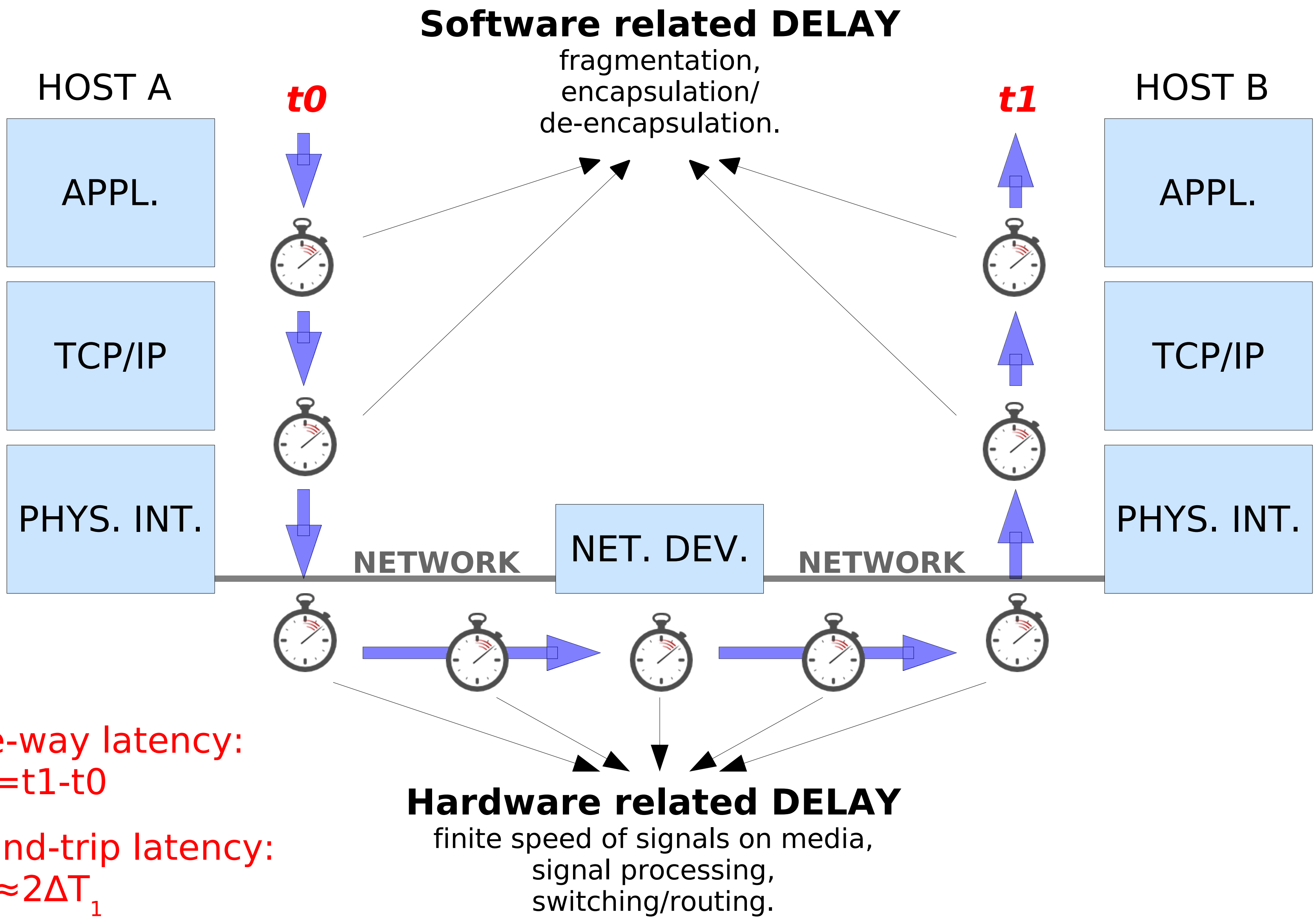
- <u>Media delays</u> may be caused by the **finite speed** that signals can travel through the physical media.
- <u>Circuit delays</u> may be caused by the **electronics that process the signal** along the path.
- <u>Software delays</u> may be caused by the **decisions that software must make** to implement switching and protocols.

Latency in HPC

The **one-way latency** may be also meant as **the period of time that a 0-sized message spends traveling from its source to its destination**, which involves the time necessary to encode, send the packet, receive the packet, and decode it to be made available to the higher level software stack. The **round-trip latency** includes also the travel back to the source of an **acknowledge message**.

- Protocol delays (TCP/IP fragmentation, TCP windowing and acknowledgments, encapsulation and de-encapsulation)
- Network delays (media, circuitry and signal processing, switching/routing)
- Application delays (message creation, acknowledgment)

Latency



One-way latency:
$\Delta T_1 = t1 - t0$

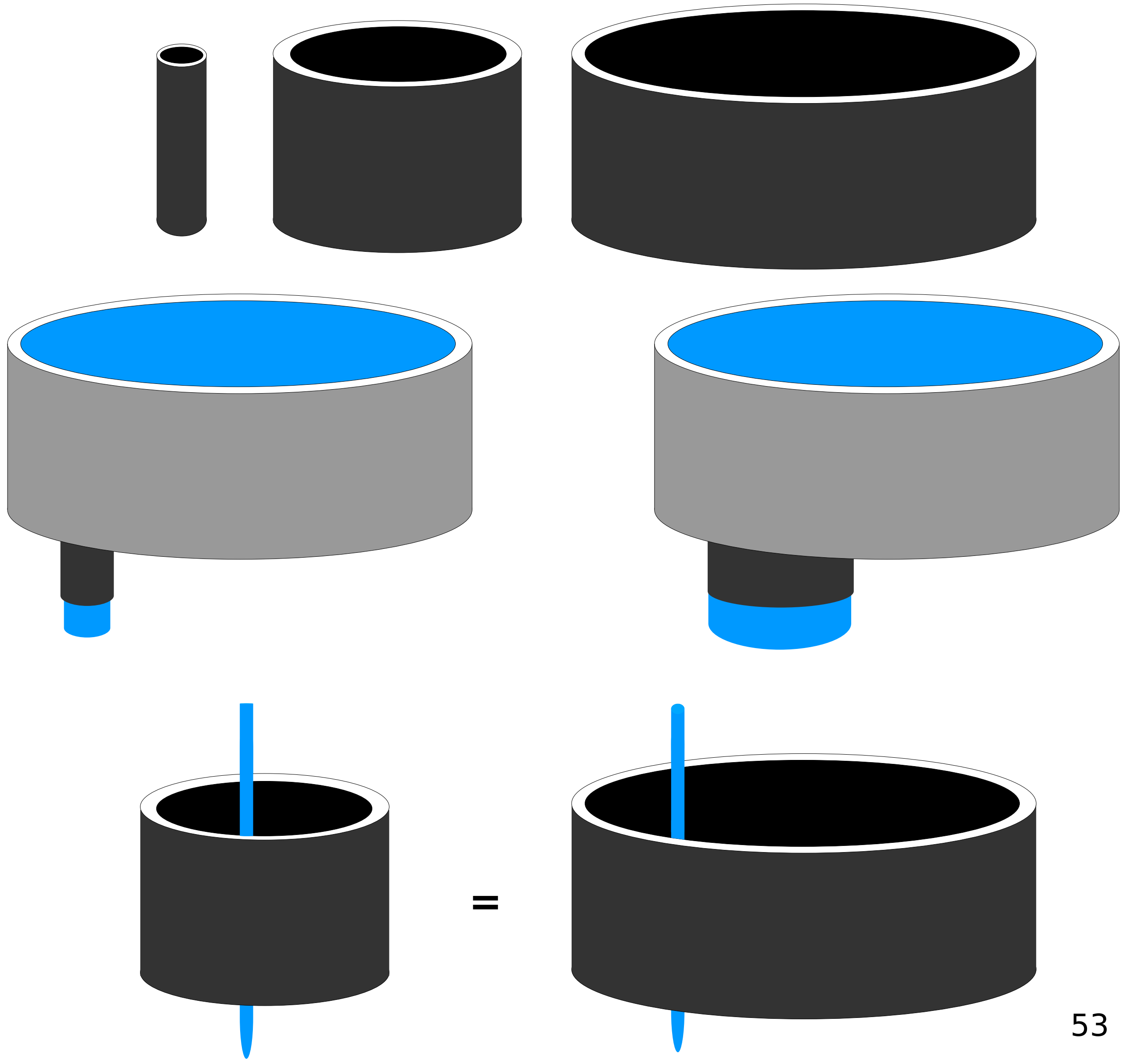
Round-trip latency:
$\Delta T_2 \approx 2\Delta T_1$

Bandwidth and Speed

Bandwidth is the measure of the **amount of information that can move through the network in a given period of time**. A typical LAN might be built to provide 100 Mbps to every desktop workstation, but this does not mean that each user is actually able to move 100 megabits of data through the network for every second of use. This would be true only under the most ideal circumstances.

Speed is often used interchangeably with bandwidth, but a large-bandwidth device will carry data at roughly the same speed of a small-bandwidth device if only a small amount of their data-carrying capacity is being used.

Bandwidth and Speed



The larger the bandwidth
the larger the amount of
data that can pass through

BUT

for amount of data significantly smaller than the actual capacity

<u>BANDWIDTH ≠ SPEED</u>

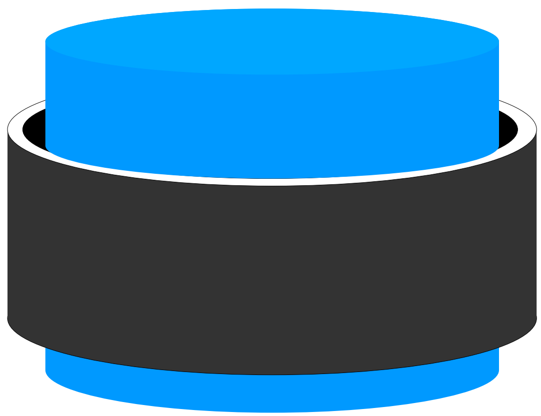
Throughput

Throughput refers to **actual measured bandwidth**, at a specific time of day, using specific Internet routes, and while a specific set of data is transmitted on the network. Unfortunately, for many reasons, throughput **is often far less than the maximum possible digital bandwidth** of the medium that is being used. The following are some of the factors that determine throughput:

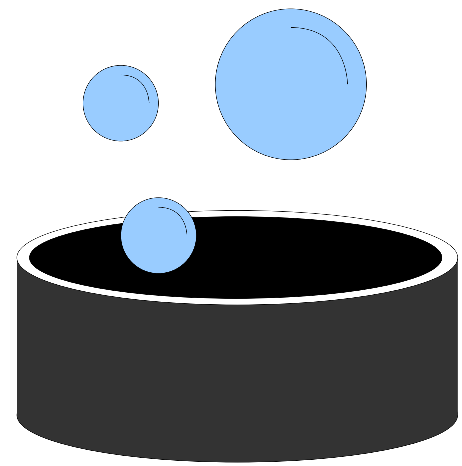
- **Internetworking devices**
- **Type of data being transferred**
- Network topology
- Number of users on the network
- User computer
- Server computer
- Power conditions

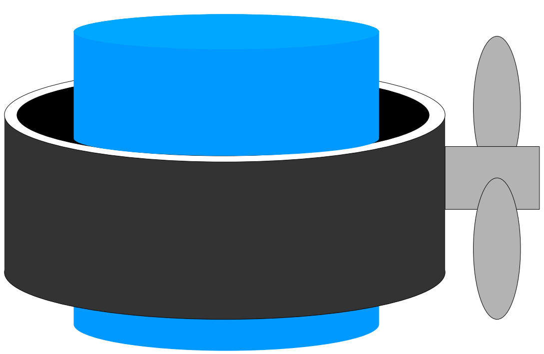
Throughput

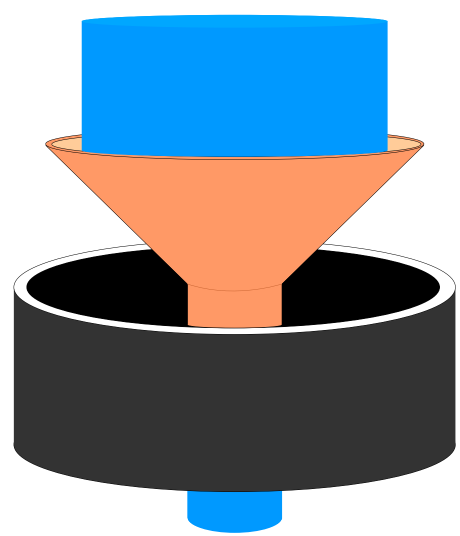
Best-case:
Throughput = Bandwidth

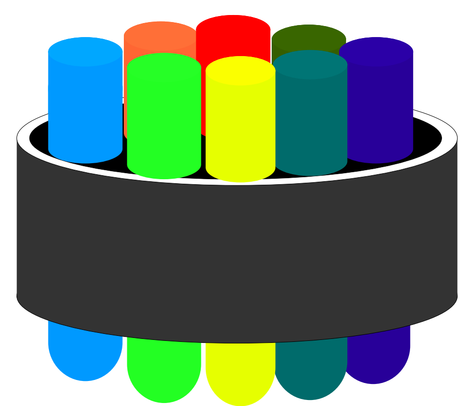


Real-case is often:
Throughput « Bandwidth









Network Performance Benchmarking and Low Latency Networks

Network performance

If the typical file size for a given application is known, dividing the file size by the network bandwidth yields an estimate of the fastest time that the file can be transferred:

$$T=S/BW$$

Two important points should be considered when doing this calculation:

- **the result is an estimate only, because the file size does not include any overhead added by encapsulation**
- **the result is likely to be a best-case transfer time, because available bandwidth is almost never at the theoretical maximum for the network type** (a more accurate estimate can be attained if throughput is substituted for bandwidth in the equation)

Best download	T=S/BW
Typical Download	T=S/P

BW = Maximum theoretical bandwidth of the "slowest link" between the source host and the destination host (measured in bits per second)
P = Actual throughput at the moment of transfer (measured in bits per second)
T = Time for file transfer to occur (measured in seconds)
S = File size in bits

Benchmarking

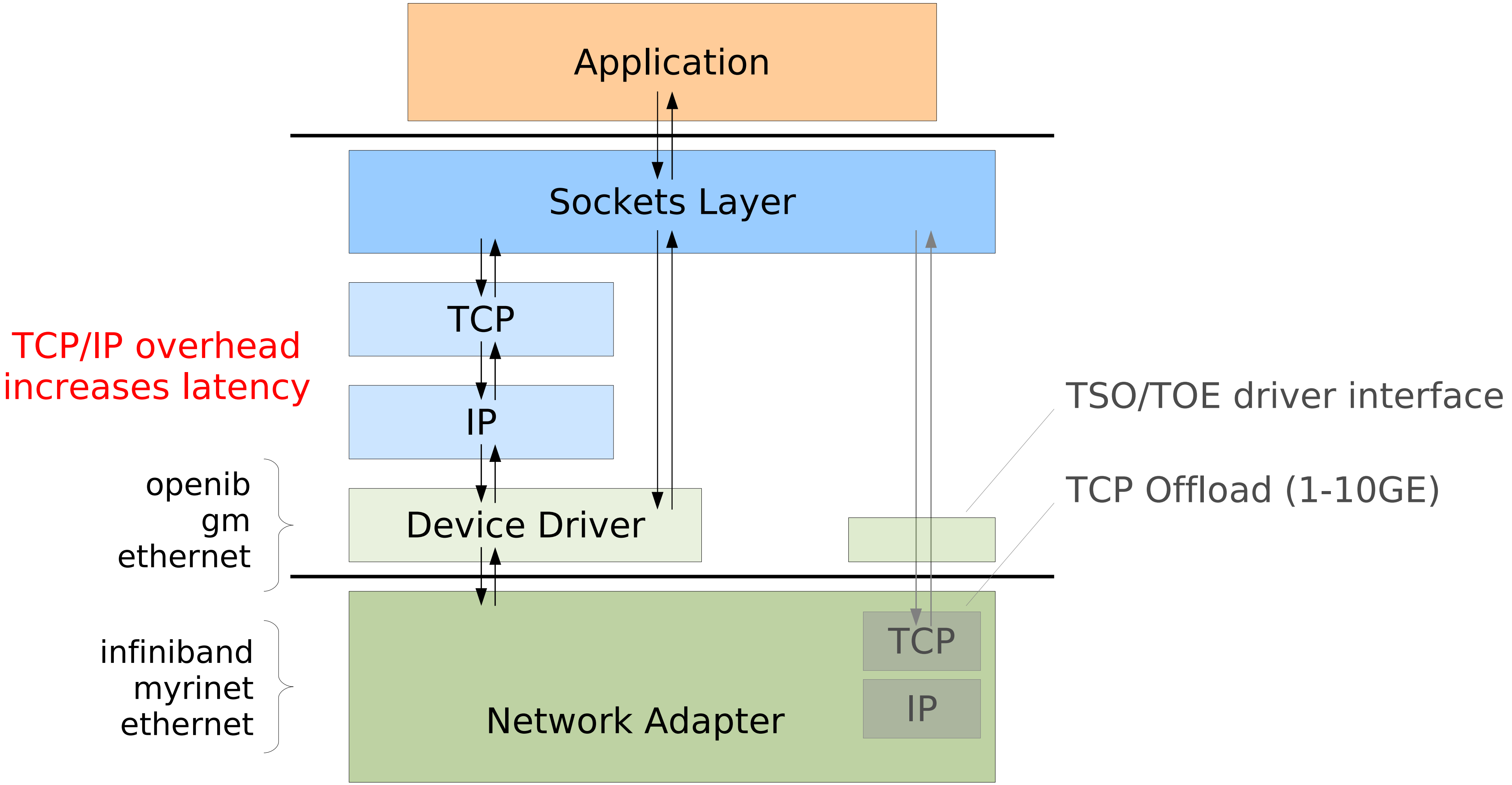
- **specifications** often “lie”, or at least **report best-case transfer rates and theoretical bandwidth** or aspects of benchmarks that show their products in the best light (*bench-marketing*)
- **direct comparison of different architectures becomes important**, especially in HPC
- **benchmarks are designed to mimic a particular type of workload**
  - ***synthetic benchmarks* use specially created programs** that impose the workload on the component
  - ***application benchmarks* run real-world programs on the system**
  - whilst *application benchmarks* usually give a much better measure of real-world performance on a given system, *synthetic benchmarks* are useful for testing individual components, like a networking device
- some **open source network benchmarking tools** are **IPERF, NETPERF, NETPIPE**

Why is (low) latency so important?

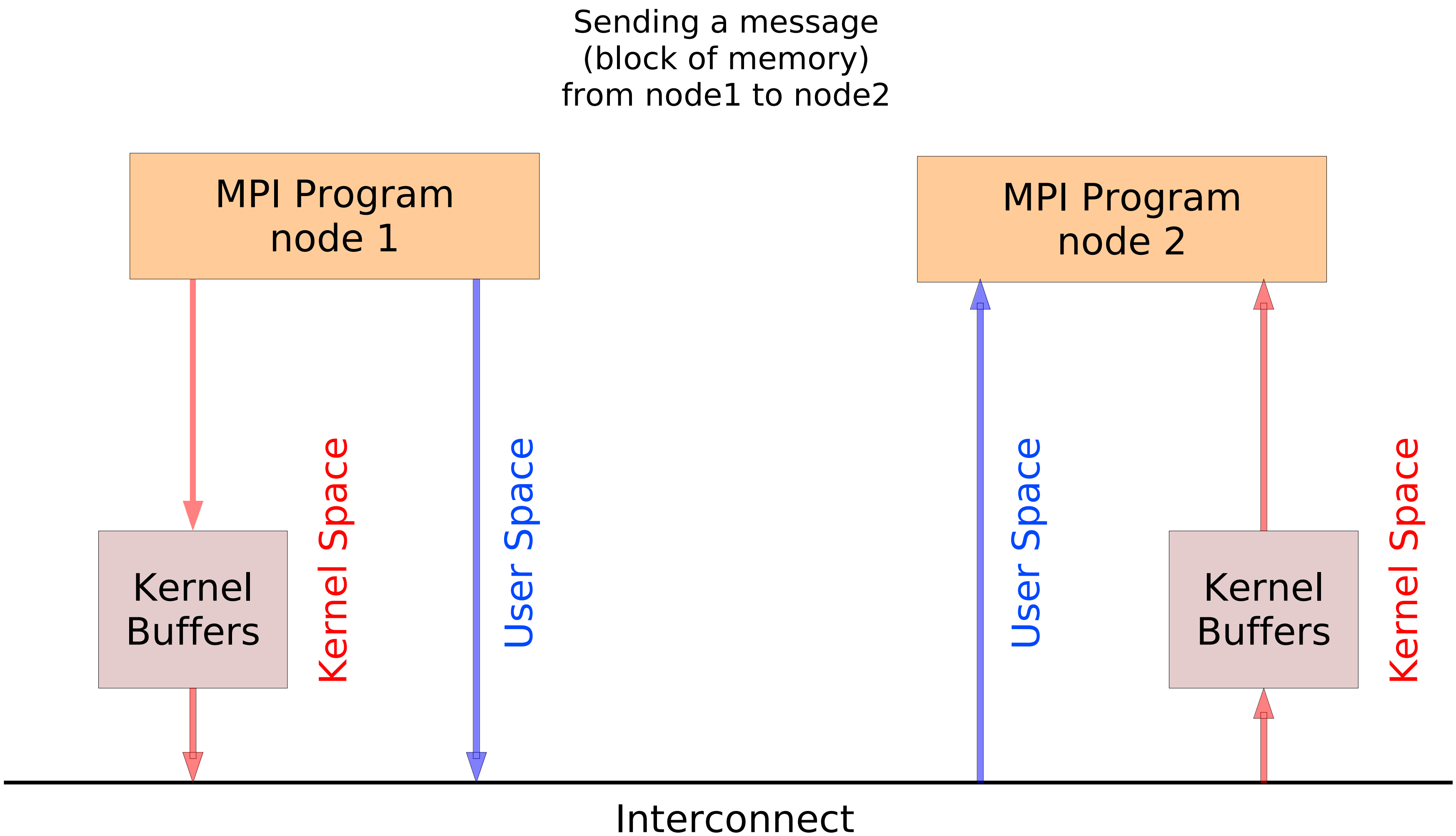
According to **Amdahl's law:**

- **a high-performance parallel system tends to be bottlenecked by its slowest sequential process**
- in all but the most embarrassingly parallel supercomputer workloads, **the slowest sequential process is often the latency of message transmission across the network**

Low Latency Networks
TCP/IP vs Native Protocols



Low Latency Networks
Kernel Space vs User Space



High-Speed Network Devices

DEVICE	BANDWIDTH	
	Gbit/s	MByte/s
Gigabit Ethernet (1000base-X)	1	116
Myrinet 2000	2	250
Infiniband SDR 1X	2	250
Quadrics QsNetI	3.6	450
Infiniband DDR 1X	4	500
Infiniband QDR 1X	8	1000
Infiniband SDR 4X	8	1000
Quadrics QsNetII	8	1000
10 Gigabit Ethernet (10Gbase-X)	10	1250
Myri 10G	10	1250
Infiniband DDR 4X	16	2000
Scalable Coherent Interface (SCI) Dual Channel SCI, x8 PCIe	20	2500
Infiniband SDR 12X	24	3000
Infiniband QDR 4X	32	4000
Infiniband DDR 12X	48	6000
Infiniband QDR 12X	96	12000
100 Gigabit Ethernet (100Gbase-X)	100	12500

http://en.wikipedia.org/wiki/List_of_device_bandwidths

Final remarks

- High speed networks should have:
  - high bandwidth
  - high throughput
  - low latency
- Things to keep in mind:
  - choose the right topology for your needs (both physical and logical)
  - figure out what will be your typical data patterns (small/large chunks, frequent access, ...)
  - bet on reliable hardware
  - consider the cost

That's All Folks!

"Network is down."

```
( questions ; comments ) | mail -s uheilaaa baro@democritos.it

( complaints ; insults ) &>/dev/null
```

REFERENCES AND USEFUL LINKS

SOFTWARE:

- Linux Kernel http://www.kernel.org
- Netfilter http://www.netfilter.org

- nmap http://www.insecure.org/nmap/
- hping http://www.hping.org/
- netcat http://netcat.sourceforge.net/
- iptstate http://www.phildev.net/iptstate/
- ss http://linux-net.osdl.org/index.php/Iproute2
- lsof ftp://lsof.itap.purdue.edu/pub/tools/unix/lsof/
- netstat http://www.tazenda.demon.co.uk/phil/net-tools/
- tcpdump http://www.tcpdump.org
- wireshark http://www.wireshark.org
- ethereal http://www.ethereal.com (see wireshark)
- iptraf http://iptraf.seul.org/
- ettercap http://ettercap.sourceforge.net
- dsniff http://www.monkey.org/~dugsong/dsniff/
- tcptraceroute http://michael.toren.net/code/tcptraceroute/
- (telnet, traceroute, ping, ...)

DOC:

- IPTables HOWTO http://www.netfilter.org/documentation/HOWTO/
- IPTables tutorial http://iptables-tutorial.frozentux.net/
- Having fun with IPTables
  http://www.ex-parrot.com/~pete/upside-down-ternet.html
- Denial of Service http://www.cert.org/tech_tips/denial_of_service.html
- IPv4 Address space
  - http://www.cymru.com/Documents/bogon-bn.html
  - http://www.iana.org/assignments/ipv4-address-space
  - http://www.oav.net/mirrors/cidr.html
  - http://en.wikipedia.org/wiki/IPv4
  - IANA http://www.iana.org
  - RIPE http://www.ripe.net
  - RFC 3330 http://www.rfc.net/rfc3330.html
- SANS: http://www.sans.org/reading_room/whitepapers/firewalls/
  http://www.sans.org/reading_room/

RFC: (http://www.rfc.net)

- RFC 791 – Internet Protocol (IPv4)
  http://www.rfc.net/rfc791.html
- RFC 793 – Transmission Control Protocol (TCP)
  http://www.rfc.net/rfc793.html
- RFC 768 – User Datagram Protocol (UDP)
  http://www.rfc.net/rfc768.html
- RFC 792 – Internet Control Message Protocol (ICMP)
  http://www.rfc.net/rfc792.html
- RFC 1180 – A TCP/IP Tutorial
  http://www.rfc.net/rfc1180.html
- RFC 1700 / IANA db – Assigned Numbers
  http://www.rfc.net/rfc1700.html
  http://www.iana.org/numbers.html
- RFC 3330 – Special-Use IPv4 Addresses
  http://www.rfc.net/rfc3330.html
- RFC 1918 – Address Allocation for Private Internets
  http://www.rfc.net/rfc1918.html
- RFC 2196 – Site Security Handbook
  http://www.rfc.net/rfc2196.html
- RFC 2827 – Network Ingress Filtering
  http://www.rfc.net/rfc2827.html
- RFC 2828 – Internet Security Glossary
  http://www.rfc.net/rfc2828.html
- RFC 1149 – Transmission of IP Datagrams on Avian Carriers
  http://www.rfc.net/rfc1149.html
- Unofficial CPIP WG
  http://www.blug.linux.no/rfc1149/
- RFC 2549 – IP over Avian Carriers with Quality of Service
  http://www.rfc.net/rfc2549.html
- Firewalling the CPIP
  http://www.tibonia.net/
  http://www.hotink.com/wacky/dastrdly/

Some acronyms...

ICTP – the Abdus Salam International Centre for Theoretical Physics
DEMOCRITOS – DEMOCRITOS Modeling Center for Research In aTOmistic Simulations
INFM – Istituto Nazionale per la Fisica della Materia (Italian National Institute for the Physics of Matter)
CNR – Consiglio Nazionale delle Ricerche (Italian National Research Council)

IP – Internet Protocol
TCP – Transmission Control Protocol
UDP – User Datagram Protocol
ICMP – Internet Control Message Protocol
ARP – Address Resolution Protocol
MAC – Media Access Control

OS – Operating System
NOS – Network Operating System
LINUX – LINUX is not UNIX

PING – Packet Internet Groper

FTP – File Transfer Protocol – (TCP/21,20)
SSH – Secure SHell – (TCP/22)
TELNET – Telnet – (TCP/23)
SMTP – Simple Mail Transfer Protocol – (TCP/25)
DNS – Domain Name System – (UDP/53)
NTP – Network Time Protocol – (UDP/123)
BOOTPS – Bootstrap Protocol Server (**DHCP**) – (UDP/67)
BOOTPC – Bootstrap Protocol Server (**DHCP**) – (UDP/68)
TFTP – Trivial File Transfer Protocol – (UDP/69)
HTTP – HyperText Transfer Protocol – (TCP/80)
NTP – Network Time Protocol – (UDP/123)
SNMP – Simple Network Management Protocol – (UDP/161)
HTTPS – HyperText Transfer Protocol over TLS/SSL – (TCP/443)
RSH – Remote Shell – (TCP/514,544)

ISO – International Organization for Standardization
OSI – Open System Interconnection

TLS – Transport Layer Security
SSL – Secure Sockets Layer

RFC – Request For Comments

ACL – Access Control List

PDU – Protocol Data Unit

TCP flags:
- **URG**: Urgent Pointer field significant
- **ACK**: Acknowledgment field significant
- **PSH**: Push Function
- **RST**: Reset the connection
- **SYN**: Synchronize sequence numbers
- **FIN**: No more data from sender

RFC 3168 TCP flags:
- **ECN**: Explicit Congestion Notification
- (**ECE**: ECN Echo)
- **CWR**: Congestion Window Reduced

ISN – Initial Sequence Number