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CLASE 1: INTRODUCCIÓN

REDES DE COMPUTADORES

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DE LA TEMÁTICA

El curso permite a los alumnos conocer la teoría y las tecnologías que sustentan los tópicos avanzados de las redes de computadores. Asimismo, analiza la aplicación práctica de dicha teoría para el diseño de sistemas de información en red.

PROFESOR

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  Oficina D211

  nicolas.cenzano@uai.cl

Reserva tu horario de consultas

- Link disponible en webc

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¡CONOZCÁMONOS UN POCO!

Ingresemos a b.socrative.com/login/student/

- Room name: **TICS3132**
- Student ID: su RUT sin puntos ni guión ni dígito verificador. Ej: 18502012

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RESULTADO DE APRENDIZAJE

Al aprobar el curso, el alumno conocerá los principios teóricos que fundamentan el funcionamiento de las redes, pudiendo analizar y sintetizar soluciones en redes para variadas situaciones, apreciando el correcto uso de esta tecnología.

DE LOS CONTENIDOS DEL CURSO

Introducción a redes de computadores: arquitecturas, modelos de redes

Capa Física: medios, bases físicas

Introducción a Comunicaciones: señales, transmisión, conceptos cuantificables de ancho de banda y transmisión de datos y velocidad de transferencia

Arquitectura de Redes Móviles y Móviles, revisión de tecnologías. Redes WiFi. Redes Móviles (1G a 6G).

Capa enlace de datos: introducción, corrección, detección de errores y protocolos

Capa de red: introducción, enrutamiento, TCP/IP

Capa de red y transporte: subredes IPv4, IPv6 y protocolos de transporte

Subredes VLSM

Capa de aplicación: introducción, seguridad, dns, www, multimedia

Redes en Cloud Computing

Fibra y redes satelitales

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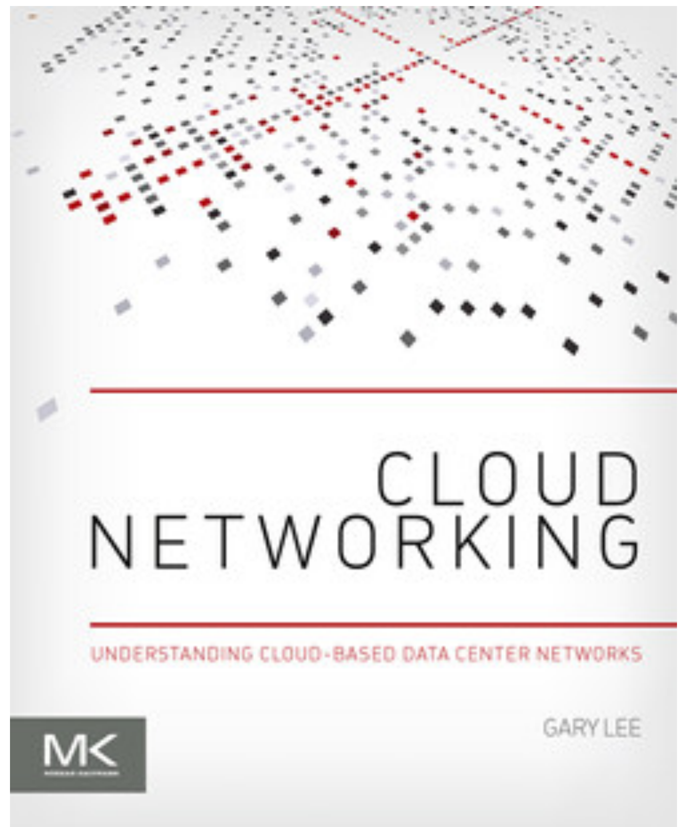
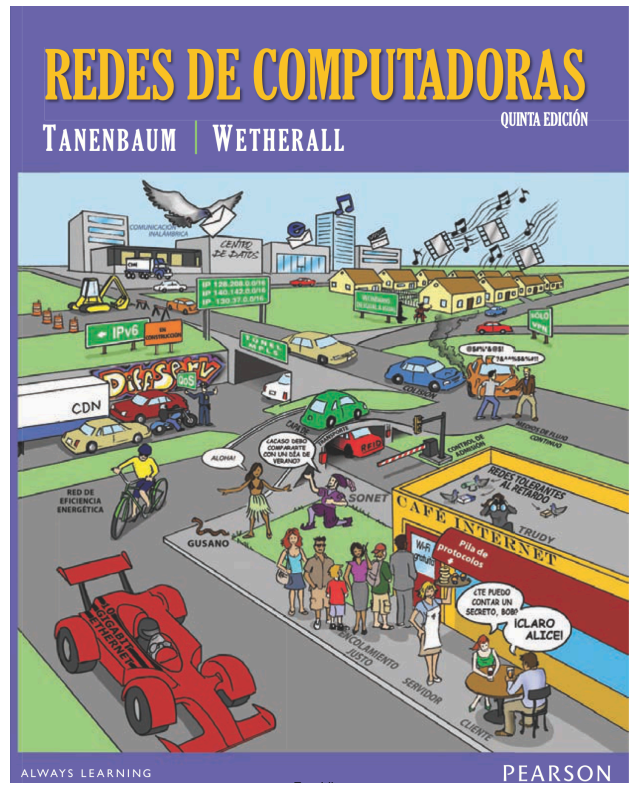
EVALUACIONES

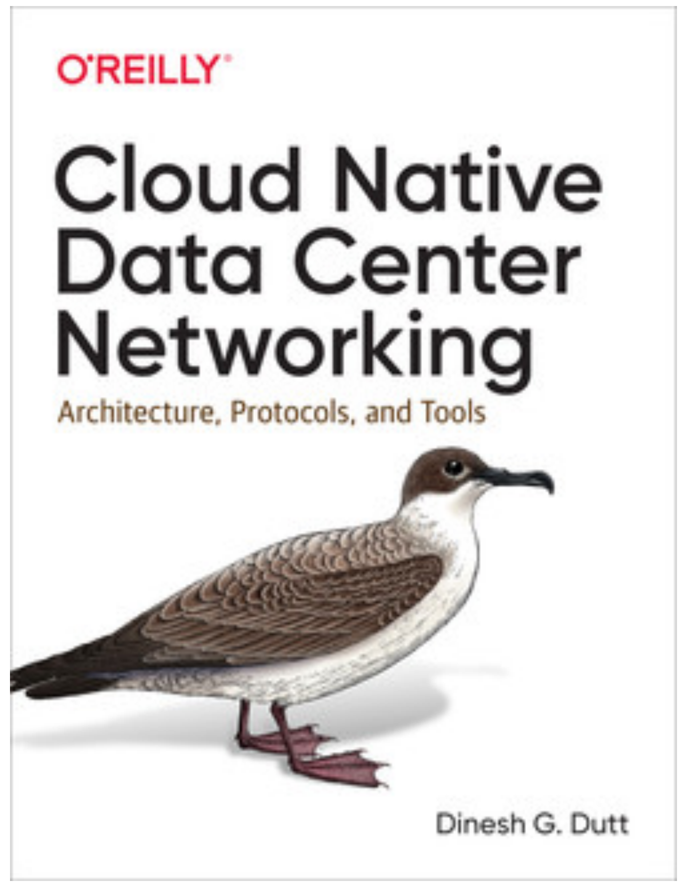
- Dos Pruebas con una ponderación de 35% cada una.
  - Prueba 1 - Semana del 25 de Septiembre
  - Prueba 2 - Semana del 13 de Noviembre
- Controles/Actividades/Tareas con una ponderación de 30%
- Nota de Presentación 70% de la nota final
- Examen 30% de la nota final

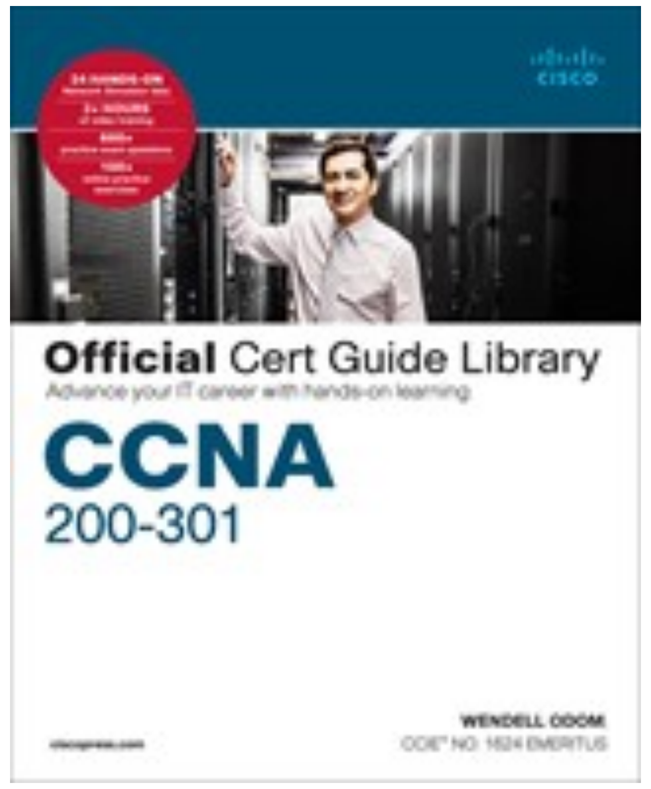
BIBLIOGRAFÍA

- Dinesh G. Dutt, “Cloud Native Data Center Networking”, O’Reilly, 2019
- Gary Lee, Cloud Networking, O’Reilly, 2014.
- Andrew S. Tanenbaum, “Redes de Computadores”, Pearson, 5ª edición, 2012.
- Wendell Odom, “CCNA 200-301 Official Cert Guide”, Volume 1, Cisco Press, 2019.









CLASE 1: BASES - FUNDAMENTOS EN REDES

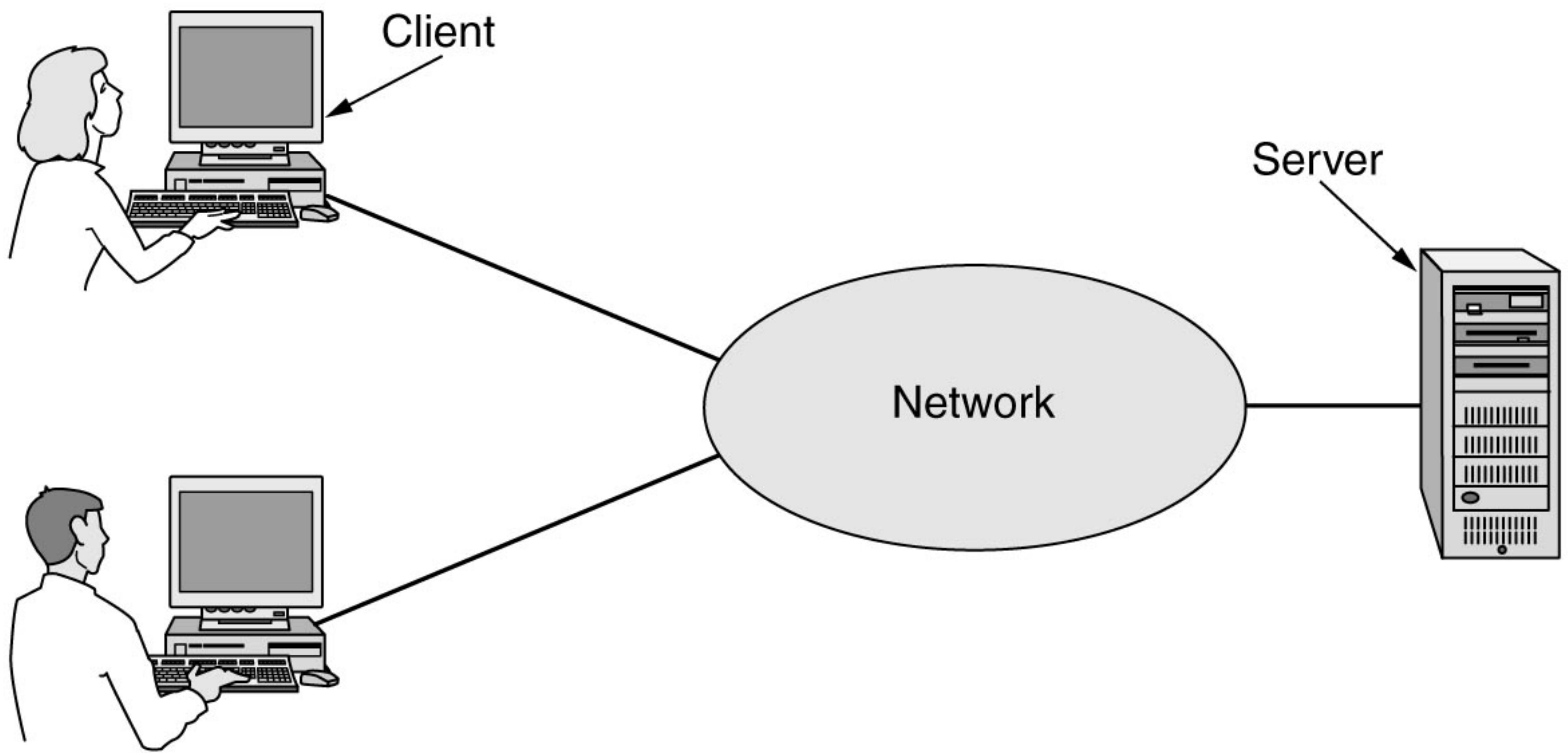
REDES DE COMPUTADORES

INTRODUCCIÓN A REDES

- Uso redes en organizaciones
  - Compartir recursos que son escasos y/o costosos
  - Alta confiabilidad: diversas fuentes de recursos
  - Ahorrar recursos: algunos computadores grandes (mainframes) conectados a muchos PC´s (arquitectura cliente-servidor)
  - Video de introducción a redes

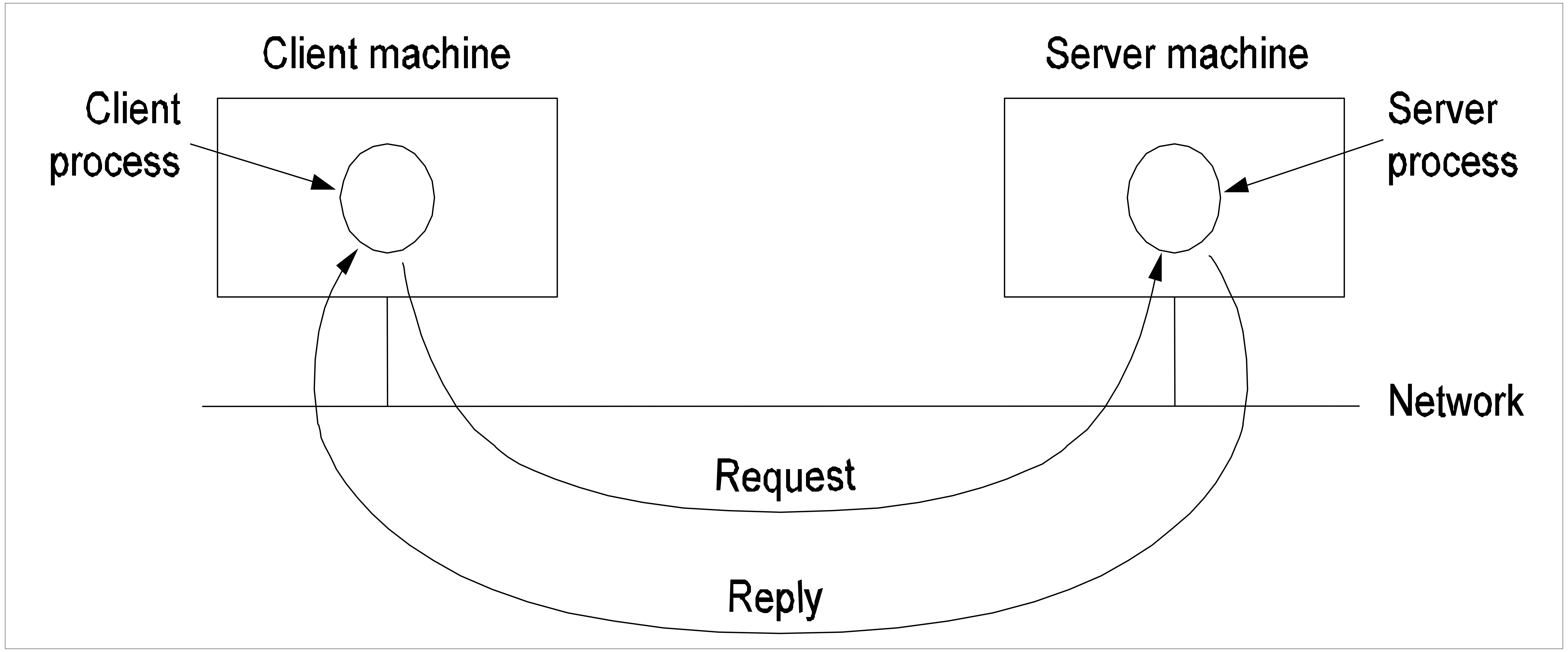
INTRODUCCIÓN A REDES

- Arquitectura cliente-servidor



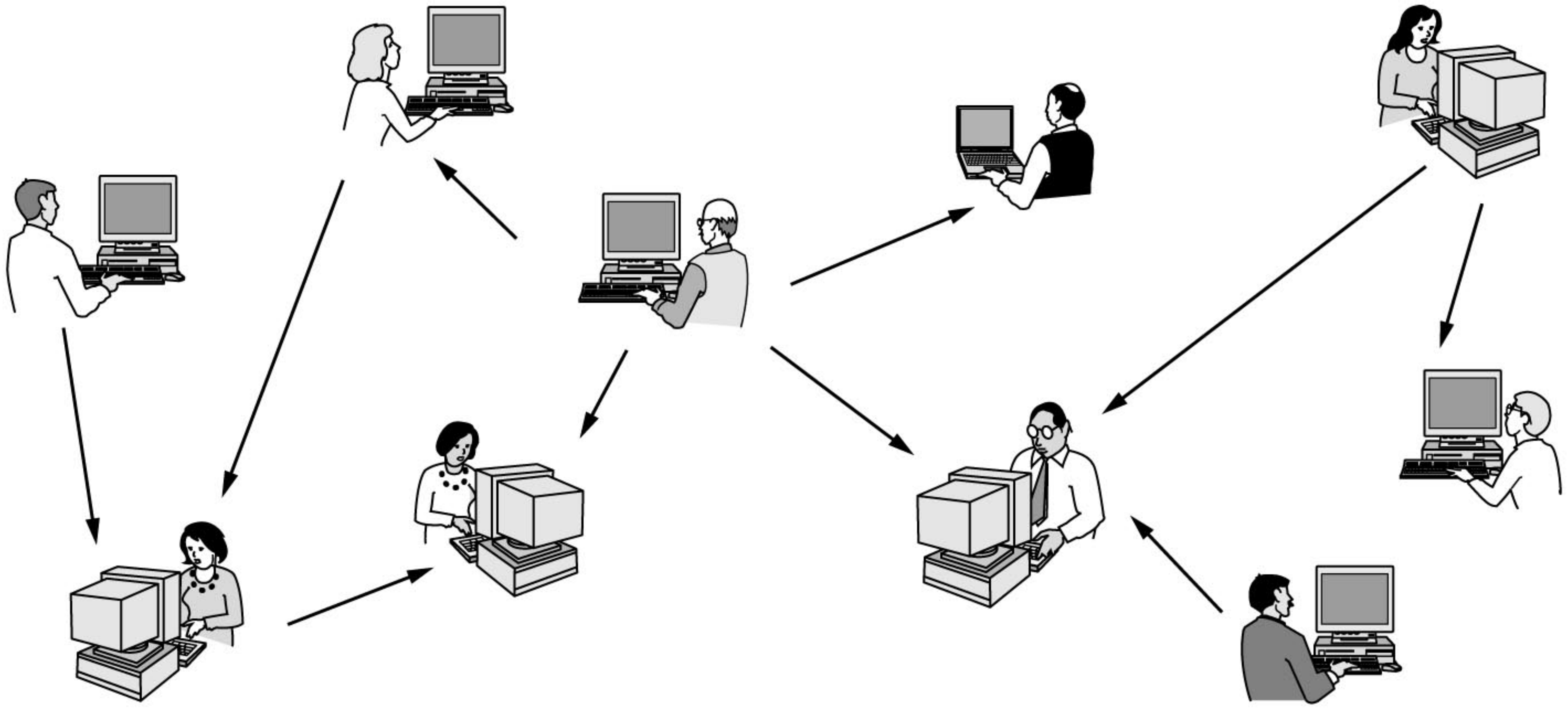
INTRODUCCIÓN A REDES

- Arquitectura cliente-servidor



INTRODUCCIÓN A REDES

- Arquitectura peer-to-peer



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INTRODUCCIÓN A REDES

- Uso redes para personas
  - Acceso a información remota
  - Comunicación persona a persona
  - Entretenimiento interactivo

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INTRODUCCIÓN A REDES

- Clasificación Redes de acuerdo distancia entre computadores

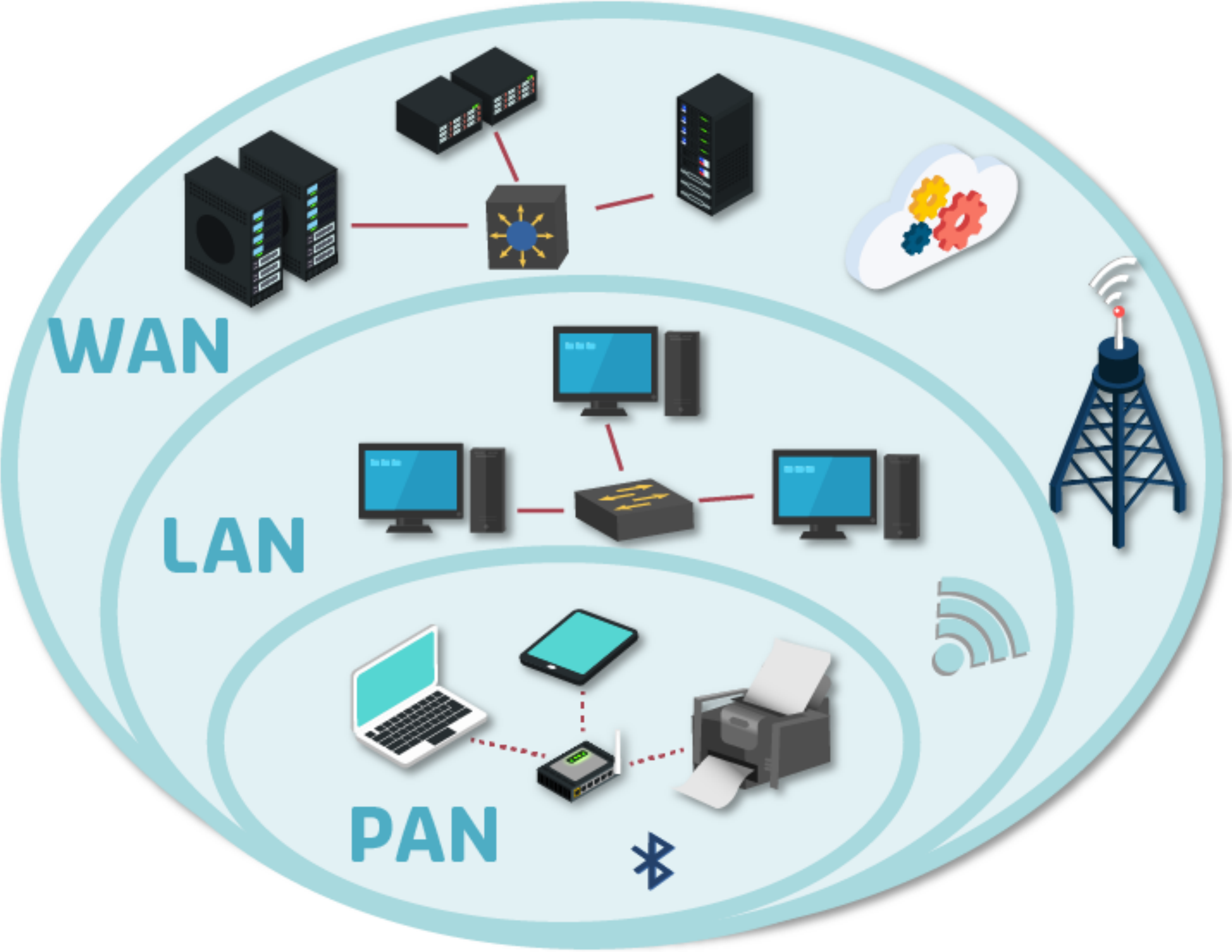
Distancia entre comps.	Ubicación
10 m	Pieza
100 m	Edificio
1 Km	Campus
10 Km	Ciudad
100 Km	País
1,000 Km	Continente
10,000 Km	Planeta

Red Area Local (LAN)

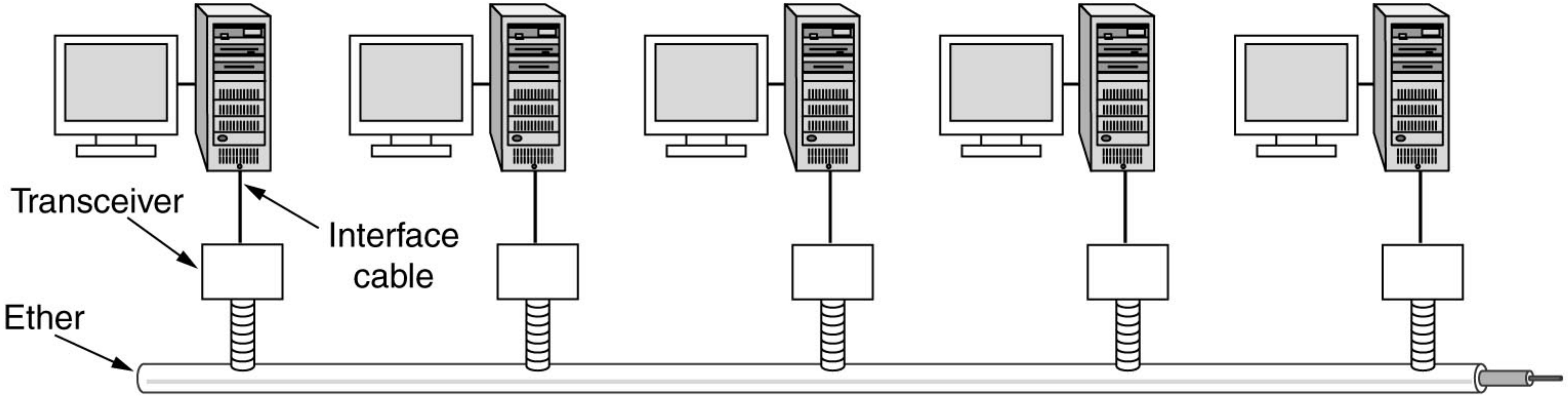
Red area metropolitana

Red área amplia (WAN)

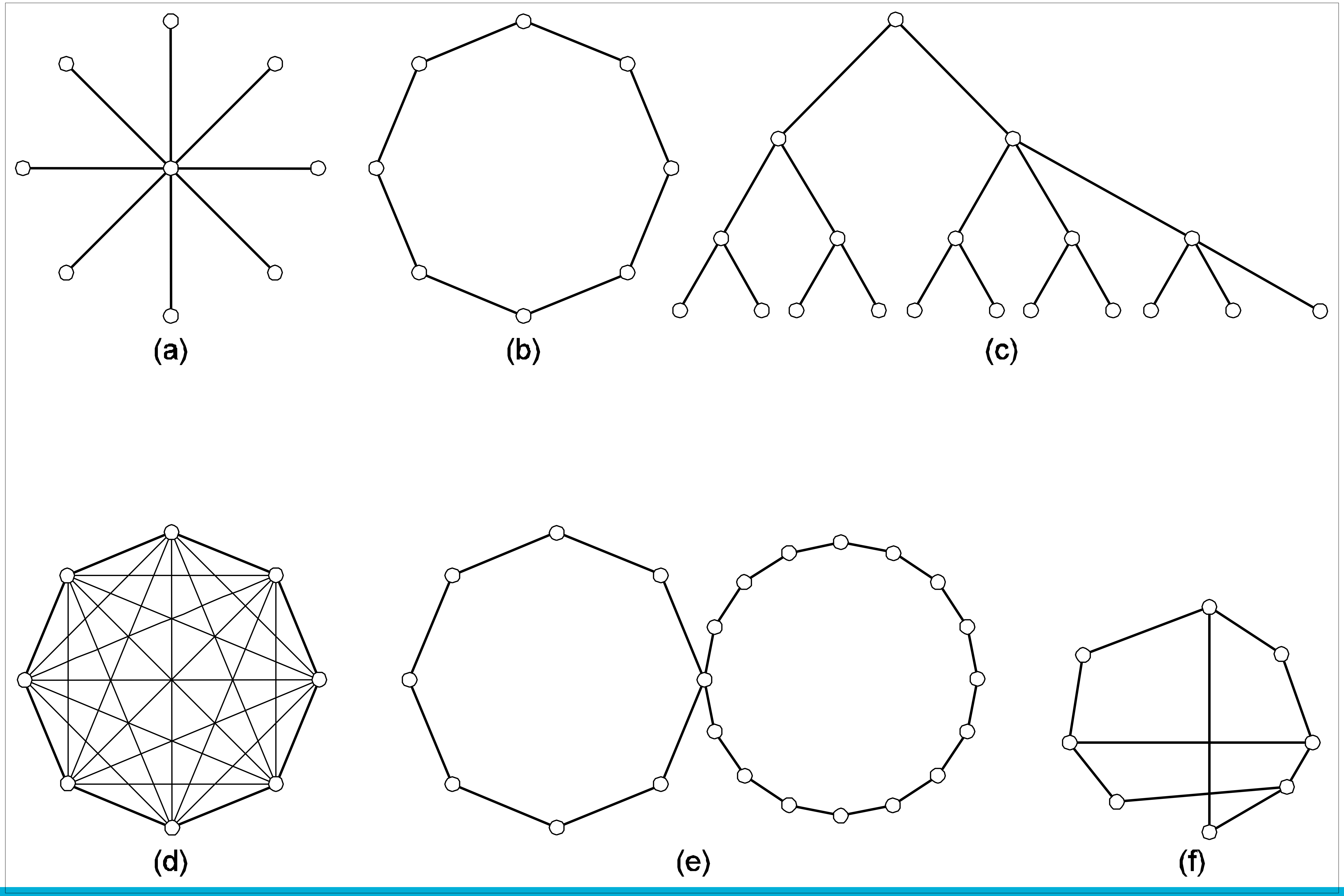
Internet


WAN
LAN
PAN

ETHERNET



REDES PUNTO A PUNTO



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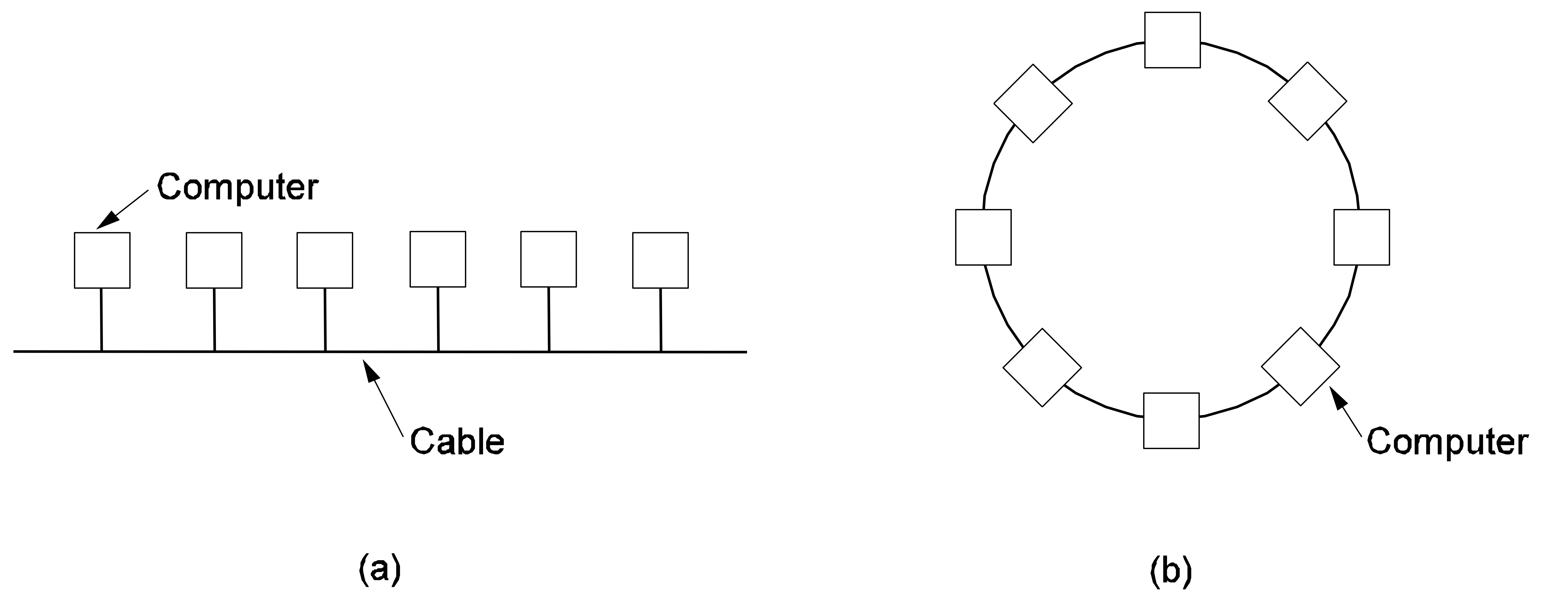
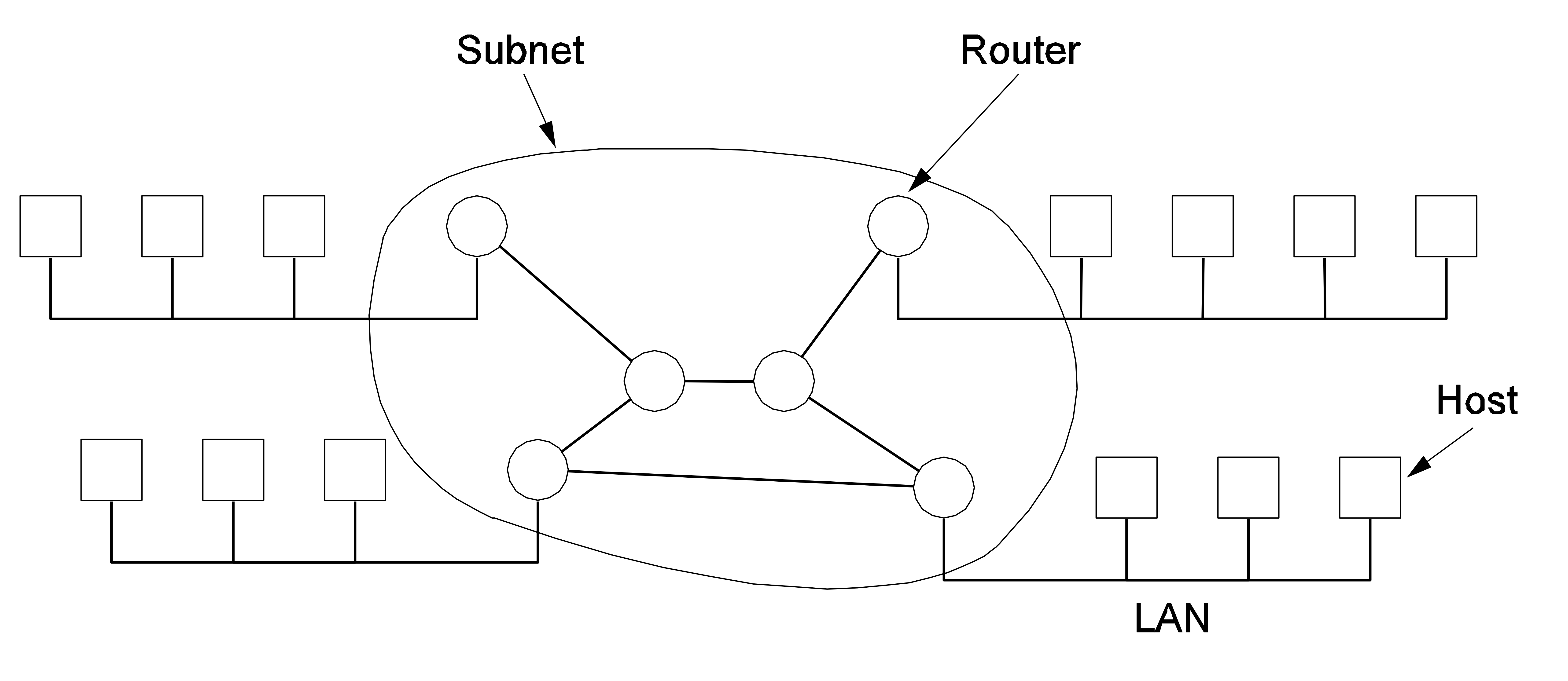
REDES DE DIFUSIÓN



REDES DE AREA ANCHA (WAN)



PROTOCOLOS DE REDES

- Configuración
  - Es el software de la red
  - Presente en diversas capas (niveles)

- Propósito
  - Manejar en forma ordenada la transferencia datos entre capas
  - Proporcionar confiabilidad a la red

MODELOS DE REDES

- Proveen una arquitectura (“plano”) de cómo debe implementarse una red
  - Especifican desde el más bajo al más alto nivel cómo debe implementarse una red
  - Proveen de independencia entre especificaciones de los componentes de una red
- Modelos de referencia
  - OSI
  - TCP/IP (Transmision Control Protocol/ Internet Protocol)

MODELO DE RED HÍBRIDO

5	Capa de aplicación
4	Capa de transporte
3	Capa de red
2	Capa de enlace de datos
1	Capa física

MODELO DE RED HÍBRIDO

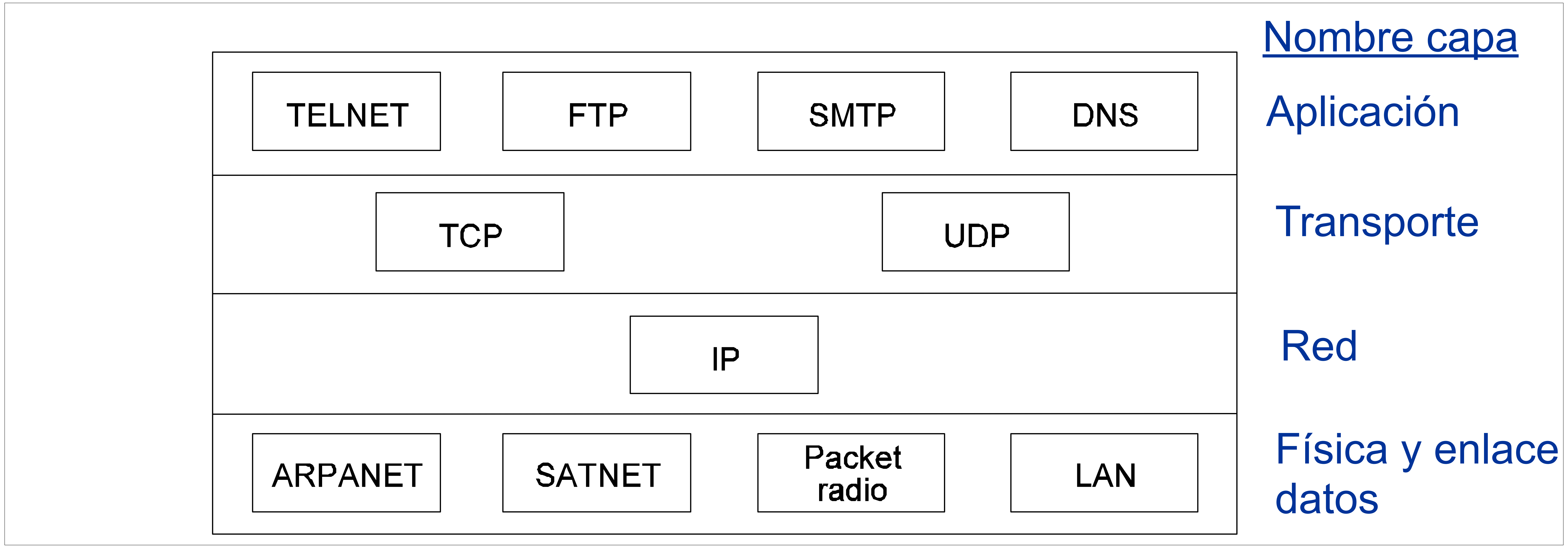
- Capa física
  - Entrega los medios para transmitir señales digitales (bits) desde un computador a otro
  - Se apoya en el hardware
- Capa de enlace de datos
  - Toma un medio de transmisión en bruto y entrega información (secuencia de bits) libre de errores
  - Evita que un receptor de poca capacidad sea saturado por un transmisor de alta capacidad
  - Enlaza dos nodos directos de una red
  - Agrupa bits en marcos o tramas

MODELO DE RED HÍBRIDO

- Capa de red
  - Se encarga de hacer llegar los paquetes (conjunto de bits) desde el origen al destino
  - Rutea paquetes a través de los componentes (computadores, enrutadores) que componen la red
  - Agrupa marcos en datagramas o paquetes

- Capa de transporte
  - Optimiza el servicio de transporte de data en su globalidad (usando posiblemente varias redes)
  - Agrupa paquetes en segmentos

EJEMPLO: MODELO TCP/IP



TCP = Transmission Control Protocol (servicio orientado a conexión)
UDP = User Datagram Protocol (protocolo de datagrama de usuario) (no orientado a conexión)
SMTP = Simple Mail Transfer Protocol (protocolo simple de transferencia de correo)
DNS = Domain Name Service (servicio de nombres de dominio)

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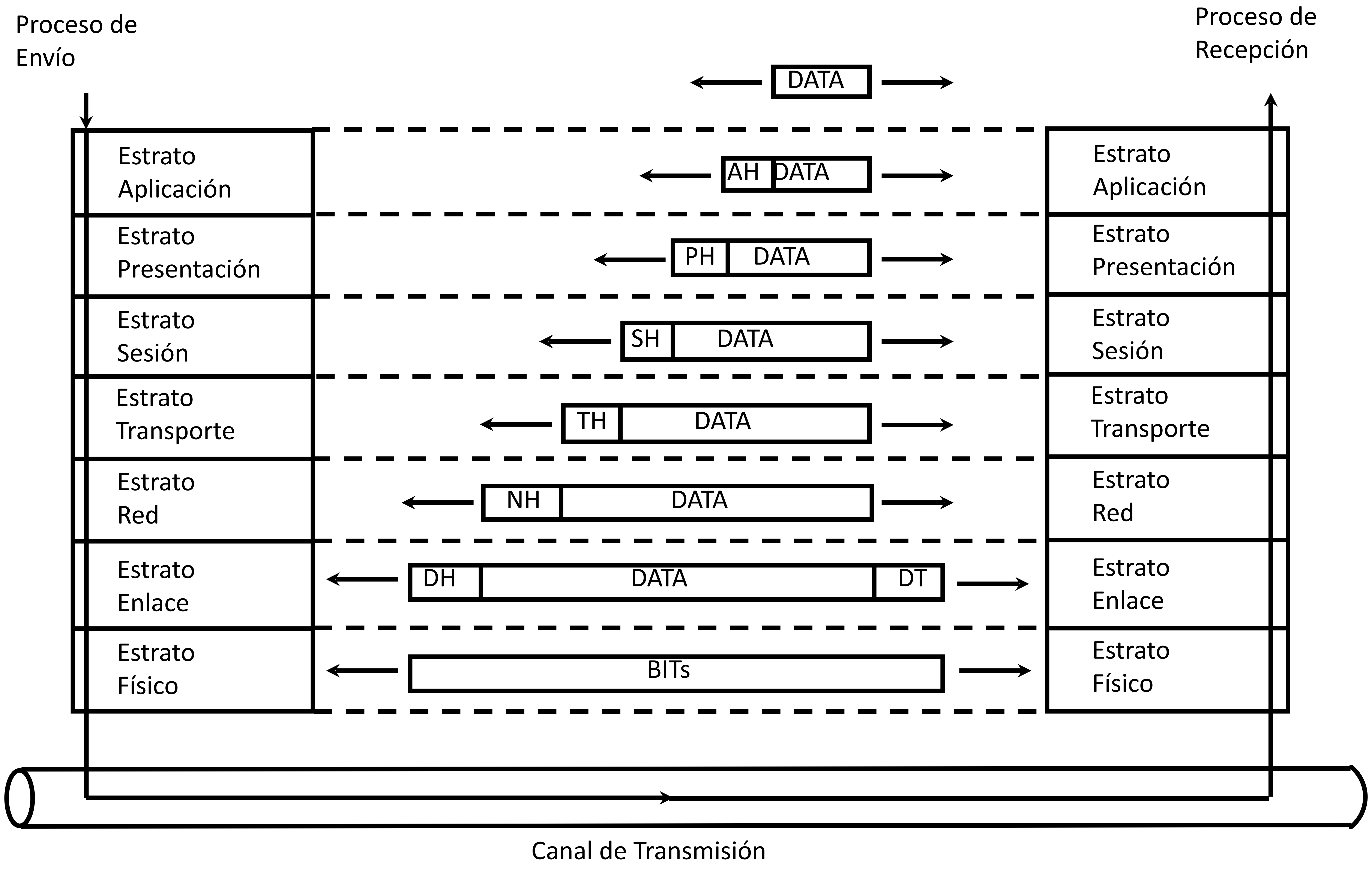
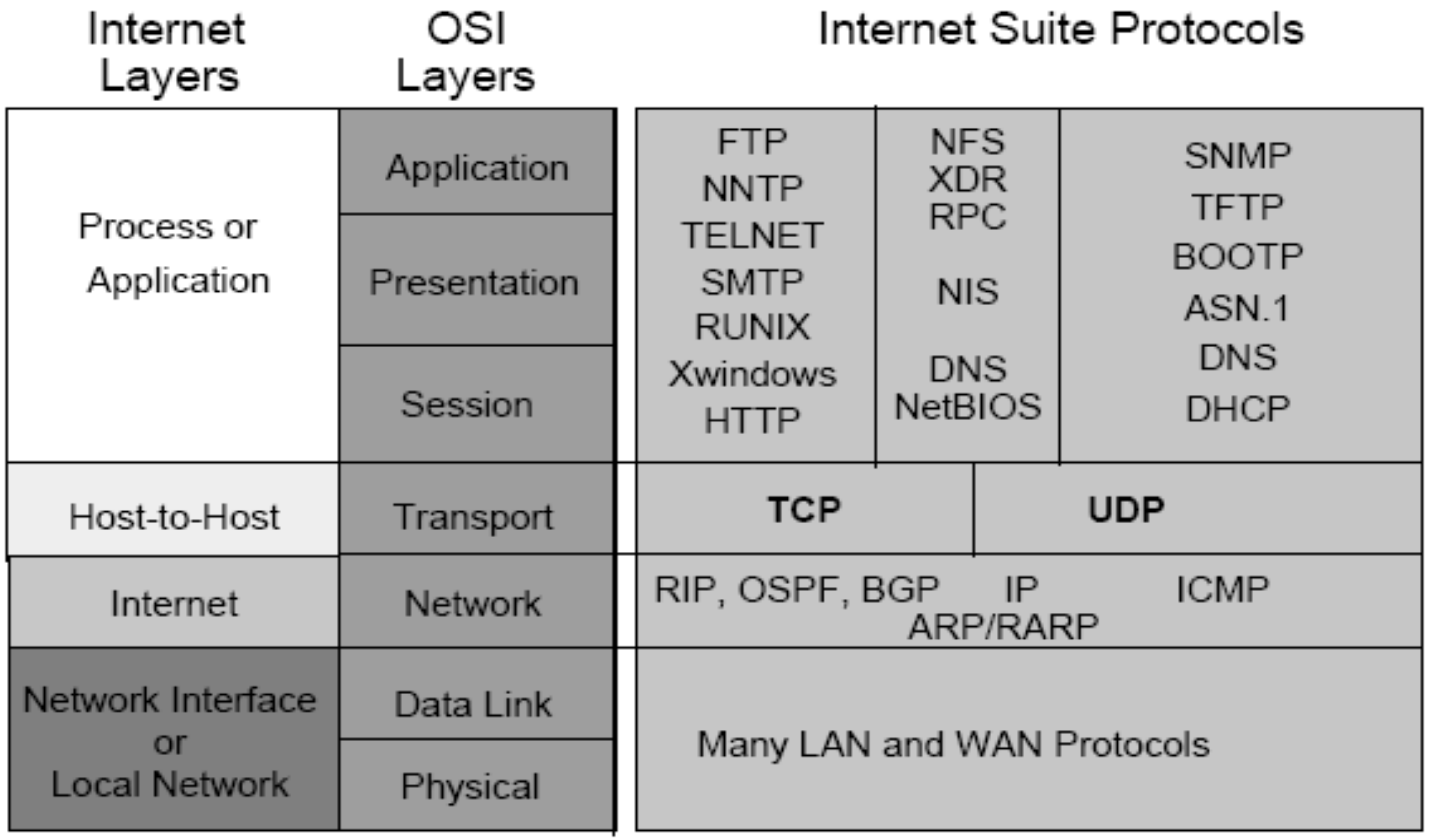
MODELO OSI, ENCAPSULAMIENTO



MAIN TCP/IP PROTOCOLS



RFC (REQUEST FOR COMMENTS)

- Standarization documents of TCP/IP Protocols
- More than 7300 RFCs up today
- Public domain
- Official repository
  - www.rfc-editor.org

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SOME OF THEM ARE VERY FORMAL…

RFC1700 - Assigned Numbers

Network Working Group — J. Reynolds
Request for Comments: 1700 — J. Postel
STD: 2 — ISI
Obsoletes RFCs: 1340, 1060, 1010, 990, 960, — October 1994
943, 923, 900, 870, 820, 790, 776, 770,
762, 758,755, 750, 739, 604, 503, 433, 349
Obsoletes IENs: 127, 117, 93
Category: Standards Track

ASSIGNED NUMBERS

Status of this Memo

This memo is a status report on the parameters (i.e., numbers and keywords) used in protocols in the Internet community. Distribution of this memo is unlimited.

OVERVIEW

This RFC is a snapshot of the ongoing process of the assignment of protocol parameters for the Internet protocol suite. To make the

OTHERS NOT FORMAL AT ALL …

```
Network Working Group                                          V. Cerf
Request for Comments: 968                                          MCI
                                                         December 1985

                    'Twas the Night Before Start-up'


STATUS OF THIS MEMO

   This memo discusses problems that arise and debugging techniques used
   in bringing a new network into operation.  Distribution of this memo
   is unlimited.

DISCUSSION

   Twas the night before start-up and all through the net,
     not a packet was moving; no bit nor octet.
   The engineers rattled their cards in despair,
     hoping a bad chip would blow with a flare.
   The salesmen were nestled all snug in their beds,
     while visions of data nets danced in their heads.
   And I with my datascope tracings and dumps
     prepared for some pretty bad bruises and lumps.
   When out in the hall there arose such a clatter,
```

MOST RELEVANT ARE…

< STANDARDS Ordered by STD > Back to Top

Mnemonic	Title	RFC#	STD#
--------	**[Reserved for Assigned Numbers. See RFC 1700 and RFC 3232.]**	xxx	2
--------	Requirements for Internet Hosts - Communication Layers	1122	3
--------	Requirements for Internet Hosts - Application and Support	1123	3
--------	**[Reserved for Router Requirements. See RFC 1812.]**	xxx	4
IP	Internet Protocol	791	5
ICMP	Internet Control Message Protocol	792	5
--------	Broadcasting Internet Datagrams	919	5
--------	Broadcasting Internet datagrams in the presence of subnets	922	5
--------	Internet Standard Subnetting Procedure	950	5
IGMP	Host extensions for IP multicasting	1112	5
UDP	User Datagram Protocol	768	6
TCP	Transmission Control Protocol	793	7
TELNET	Telnet Protocol Specification	854	8
FTP	File Transfer Protocol	959	9
--------	**["Mail routing and the domain system". Was RFC 974 (STANDARD), Now HISTORIC.]**	xxx	10
SMTP	**["Simple Mail Transfer Protocol". Was RFC 821 (STANDARD), Obsoleted by RFC 2821 (PROPOSED STANDARD)]**	xxx	10
--------	**["SMTP Service Extensions". Was RFC 1869 (STANDARD), Obsoleted by RFC 2821 (PROPOSED STANDARD)]**	xxx	10
SMTP-SIZE	SMTP Service Extension for Message Size Declaration	1870	10
MAIL	**["STANDARD FOR THE FORMAT OF ARPA INTERNET TEXT MESSAGES". Was RFC 822 (STANDARD), Obsoleted by RFC 2822 (PROPOSED STANDARD)]**	xxx	11
--------	**[Reserved for Network Time Protocol (NTP). See RFC 1305.]**	xxx	12
DOMAIN	Domain names - concepts and facilities	1034	13

RFC 791, IPV4

```
                            3.  SPECIFICATION

3.1.  Internet Header Format

  A summary of the contents of the internet header follows:

    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Version|  IHL  |Type of Service|          Total Length         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |         Identification        |Flags|      Fragment Offset    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |  Time to Live |    Protocol   |         Header Checksum       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                       Source Address                          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Destination Address                        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Options                    |    Padding    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

IP

- Operates at OSI Layer 3
- Not Connection Oriented
- Use Hierarchical Addressing
- Best Effort
- Not Reliable

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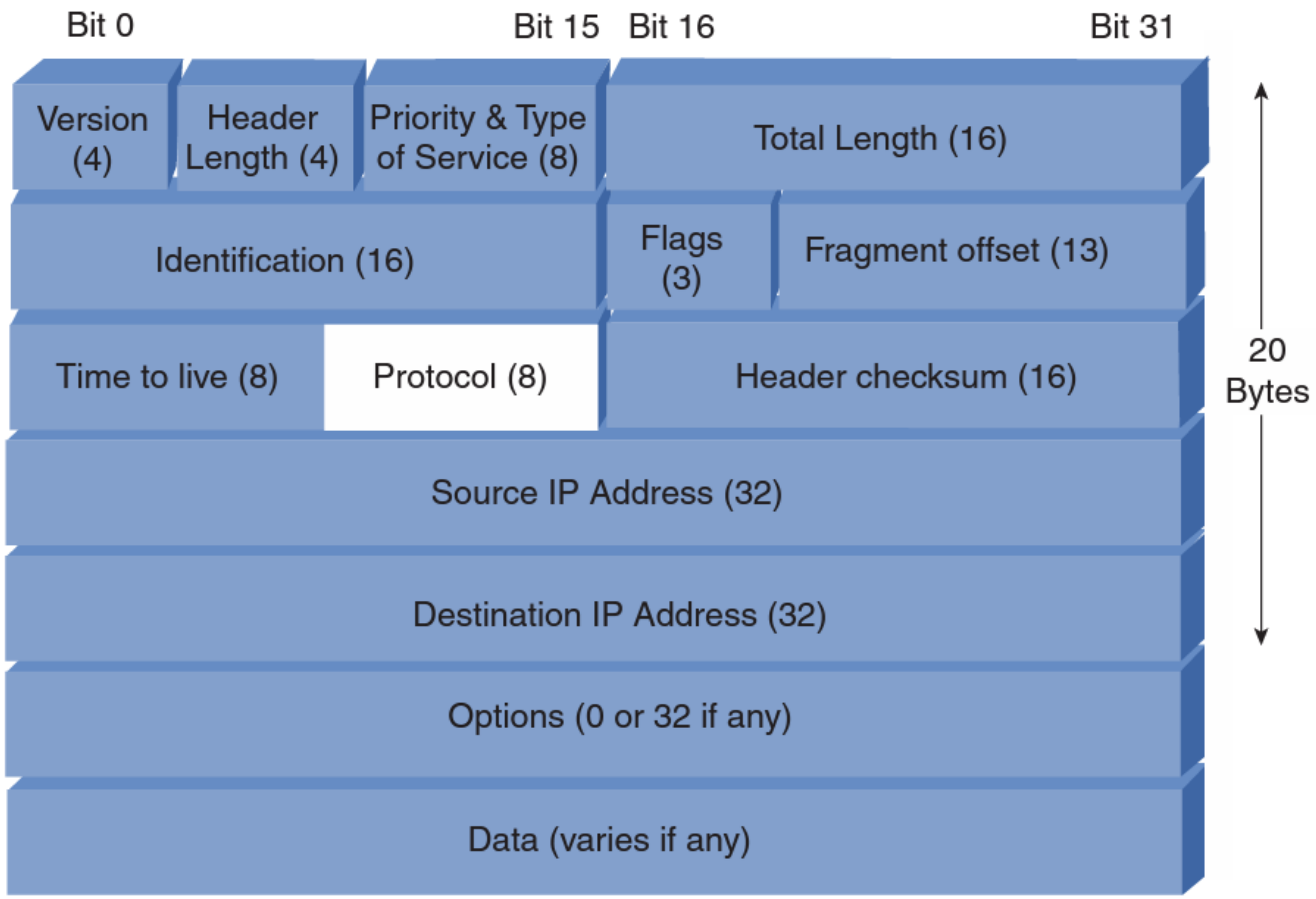
IPV4 HEADER



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IPV4 HEADER

Field	Meaning
Version	Version of the IP protocol. Most networks use version 4 today.
IHL	IP Header Length. Defines the length of the IP header, including optional fields.
DS Field	Differentiated Services Field. It is used for marking packets for the purpose of applying different quality-of-service (QoS) levels to different packets.
Packet length	Identifies the entire length of the IP packet, including the data.
Identification	Used by the IP packet fragmentation process; all fragments of the original packet contain the same identifier.
Flags	3 bits used by the IP packet fragmentation process.
Fragment offset	A number used to help hosts reassemble fragmented packets into the original larger packet.
TTL	Time to live. A value used to prevent routing loops.
Protocol	A field that identifies the contents of the data portion of the IP packet. For example, protocol 6 implies that a TCP header is the first thing in the IP packet data field.
Header Checksum	A value used to store an FCS value, whose purpose is to determine if any bit errors occurred in the IP header.
Source IP address	The 32-bit IP address of the sender of the packet.
Destination IP address	The 32-bit IP address of the intended recipient of the packet.

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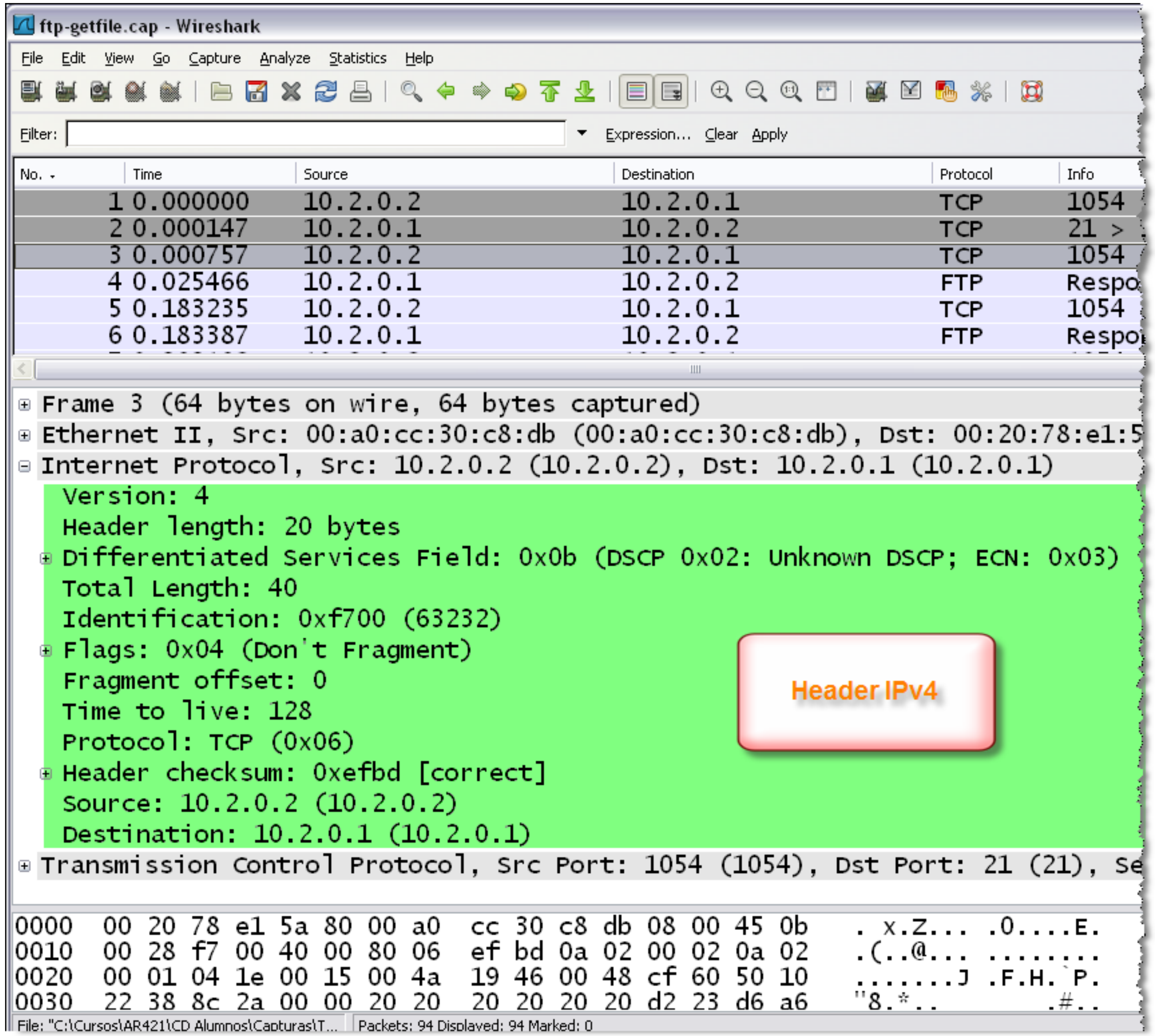
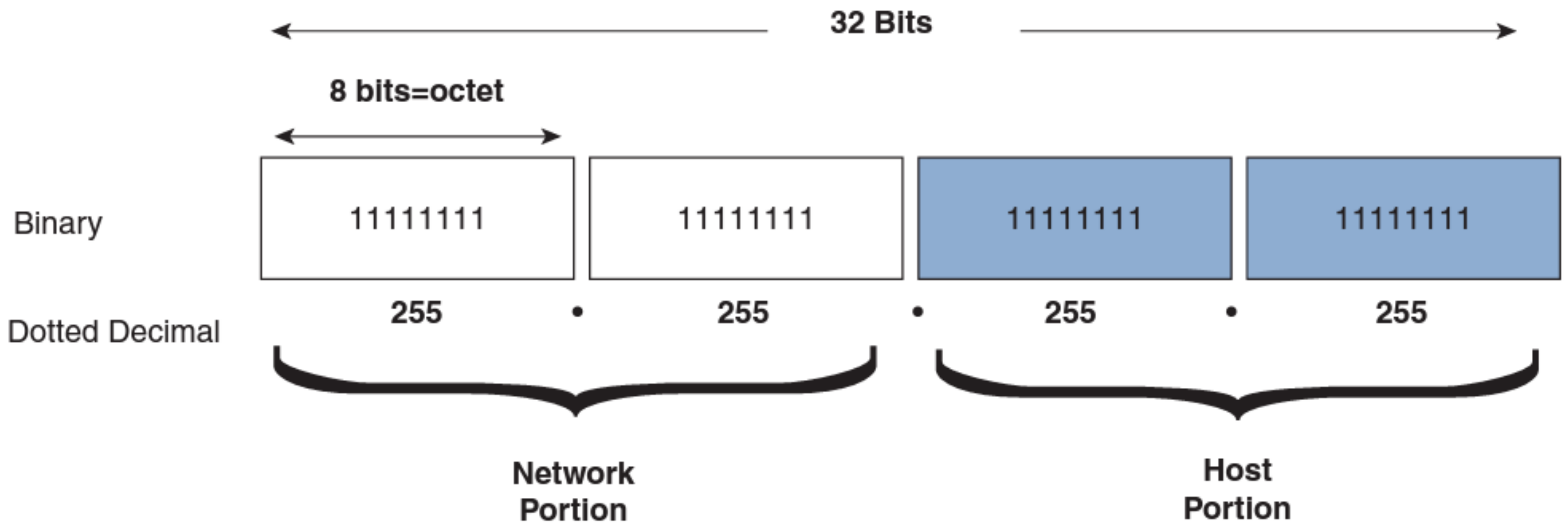
IPV4 HEADER, WIRESHARK VIEW



IPV4 ADDRESSING



IPV4 RESERVED ADDRESS

- Network Address
  - Ex: 172.16.0.0/16
- Directed Broadcast
  - Ex:172.16.255.255/16
- Local Broadcast
  - Ex:255.255.255.255
- Loopback
  - Ex:127.0.0.1

IPV4 ADDRESS CLASSES

Bits:	1 8	9 16	17 24	25 32
Class A:	**0**NNNNNNN	Host	Host	Host
	Range (1-126)			

Bits:	1 8	9 16	17 24	25 32
Class B:	**10**NNNNNN	Network	Host	Host
	Range (128-191)			

Bits:	1 8	9 16	17 24	25 32
Class C:	**110**NNNNN	Network	Network	Host
	Range (192-223)			

Bits:	1 8	9 16	17 24	25 32
Class D:	**1110**MMMM	Multicast Group	Multicast Group	Multicast Group
	Range (224-239)			

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IPV4 ADDRESS CLASSES

Any Network of This Class	Number of Network Bytes (Bits)	Number of Host Bytes (Bits)	Number of Addresses Per Network*
A	1 (8)	3 (24)	$2^{24} - 2$
B	2 (16)	2 (16)	$2^{16} - 2$
C	3 (24)	1 (8)	$2^{8} - 2$

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IPV4 ADDRESS CLASSES

Class	First Octet Range	Valid Network Numbers*	Total Number for This Class of Network	Number of Hosts Per Network
A	1 to 126	1.0.0.0 to 126.0.0.0	$2^7 - 2$ (126)	$2^{24} - 2$ (16,777,214)
B	128 to 191	128.0.0.0 to 191.255.0.0	2^{14} (16,384)	$2^{16} - 2$ (65,534)
C	192 to 223	192.0.0.0 to 223.255.255.0	2^{21} (2,097,152)	$2^8 - 2$ (254)

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BINARY REPRESENTATION SYSTEM

Base 2 Numbering System								
Number of Symbols	2							
Symbols	0, 1							
Base Exponent	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Place Value	128	64	32	16	8	4	2	1
Example: Convert 47 to Binary	0	0	1	0	1	1	1	1

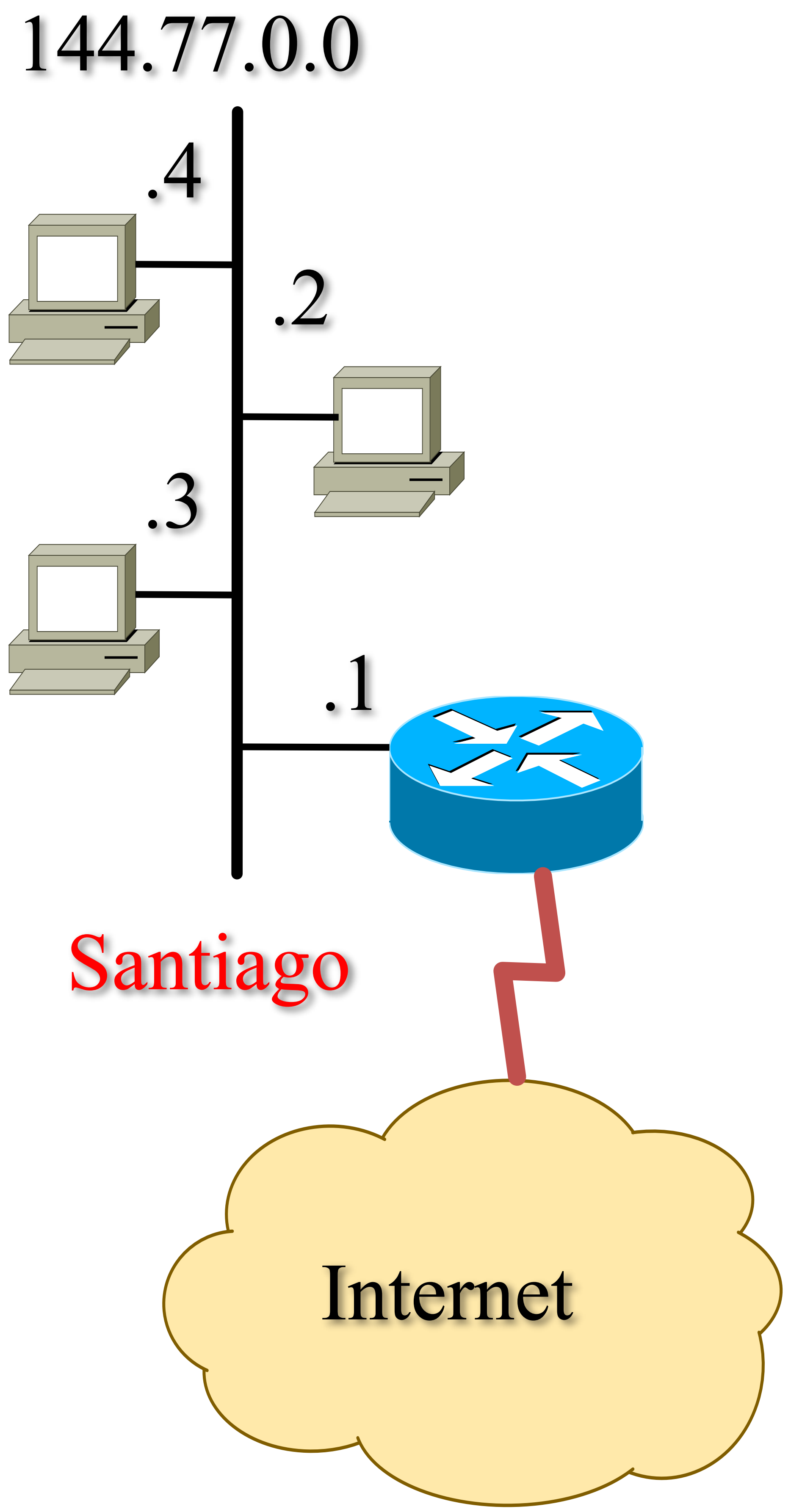
NETWORK NUMBERS

Network Number	Binary Representation, with the Host Part in Bold
8.0.0.0	00001000 **00000000 00000000 00000000**
130.4.0.0	10000010 00000100 **00000000 00000000**
199.1.1.0	11000111 00000001 00000001 **00000000**

IPV4 PRIVATE ADDRESS

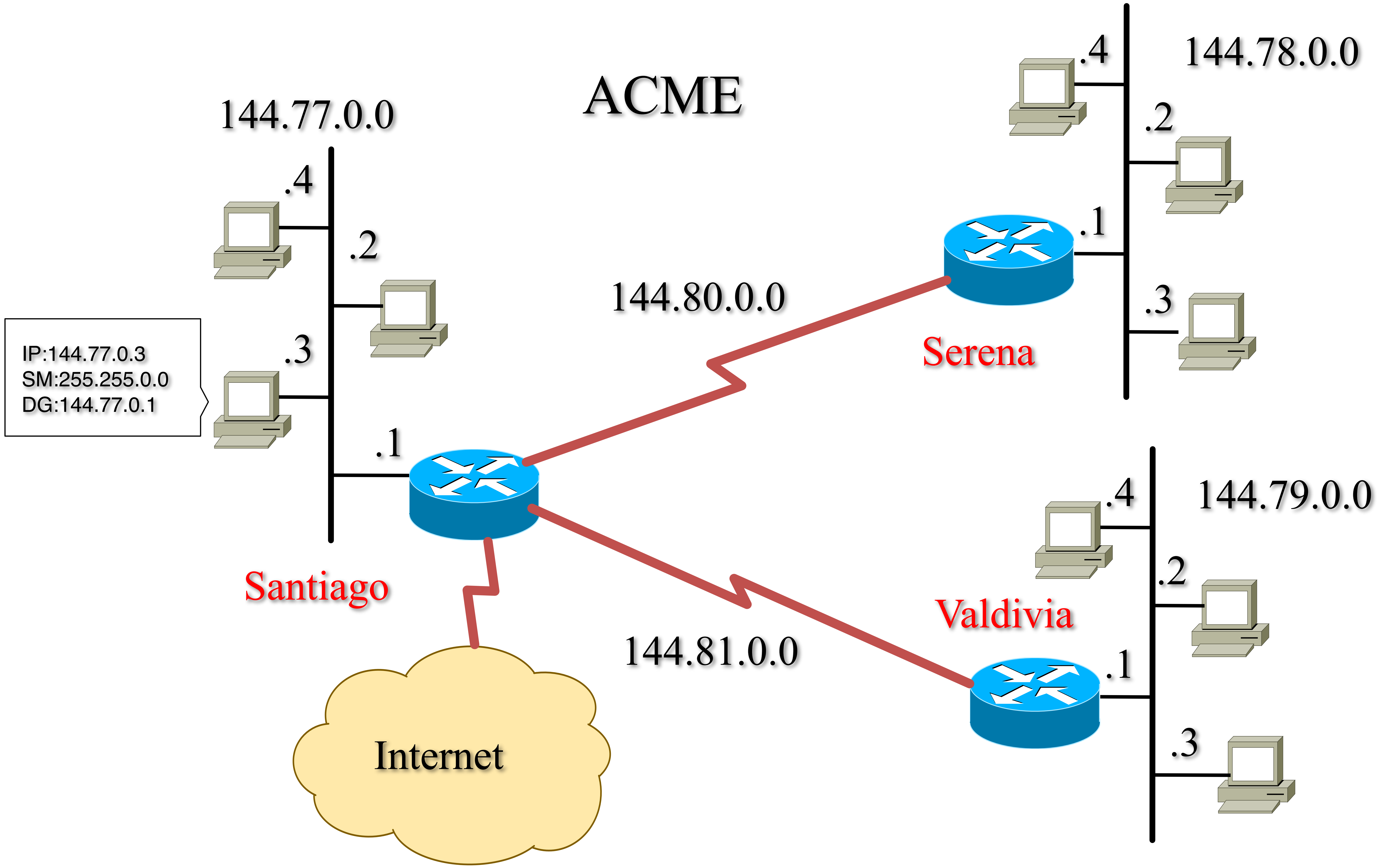
- Defined by RFC 1918
- Ranges:
  - 10.0.0.0 a 10.255.255.255
  - 172.16.0.0 a 172.31.255.255
  - 192.168.0.0 a 192.168.255.255
- Need a NAT/PAT to be used

IPV4 ADDRESSING EXAMPLE

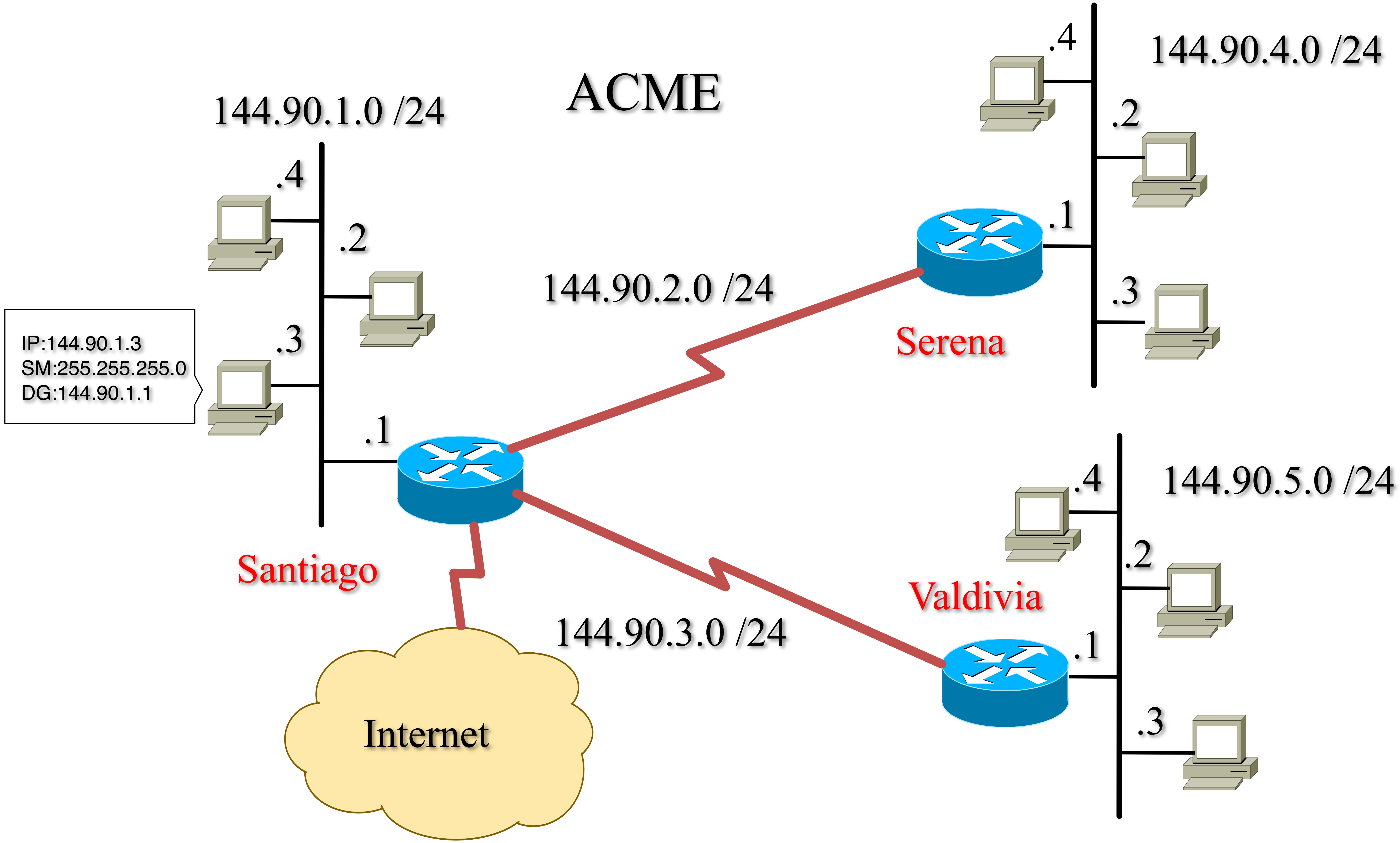


ACME

IPV4 ADDRESSING WITHOUT SUBNETS

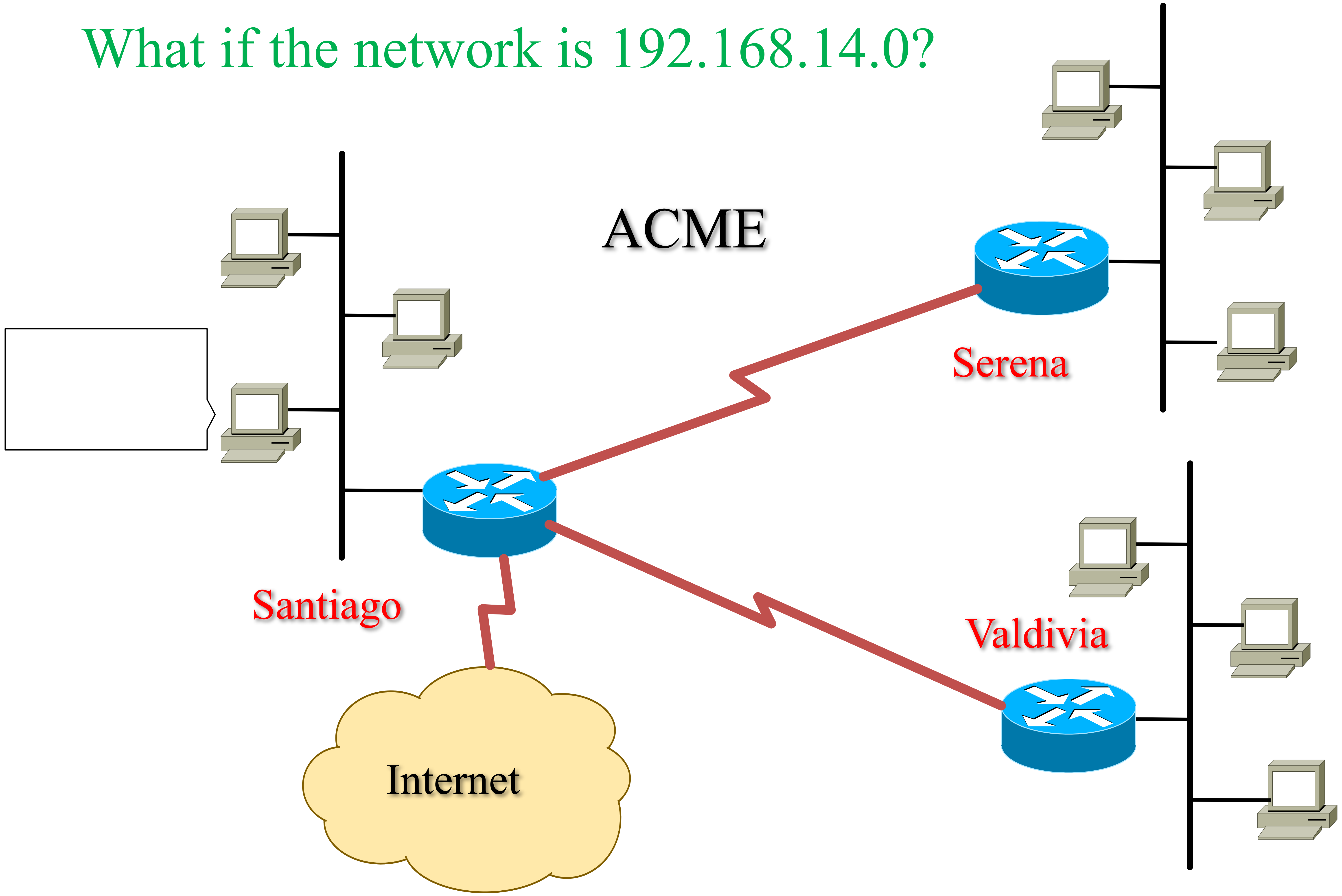


IPV4 ADDRESSING WITH SUBNETS

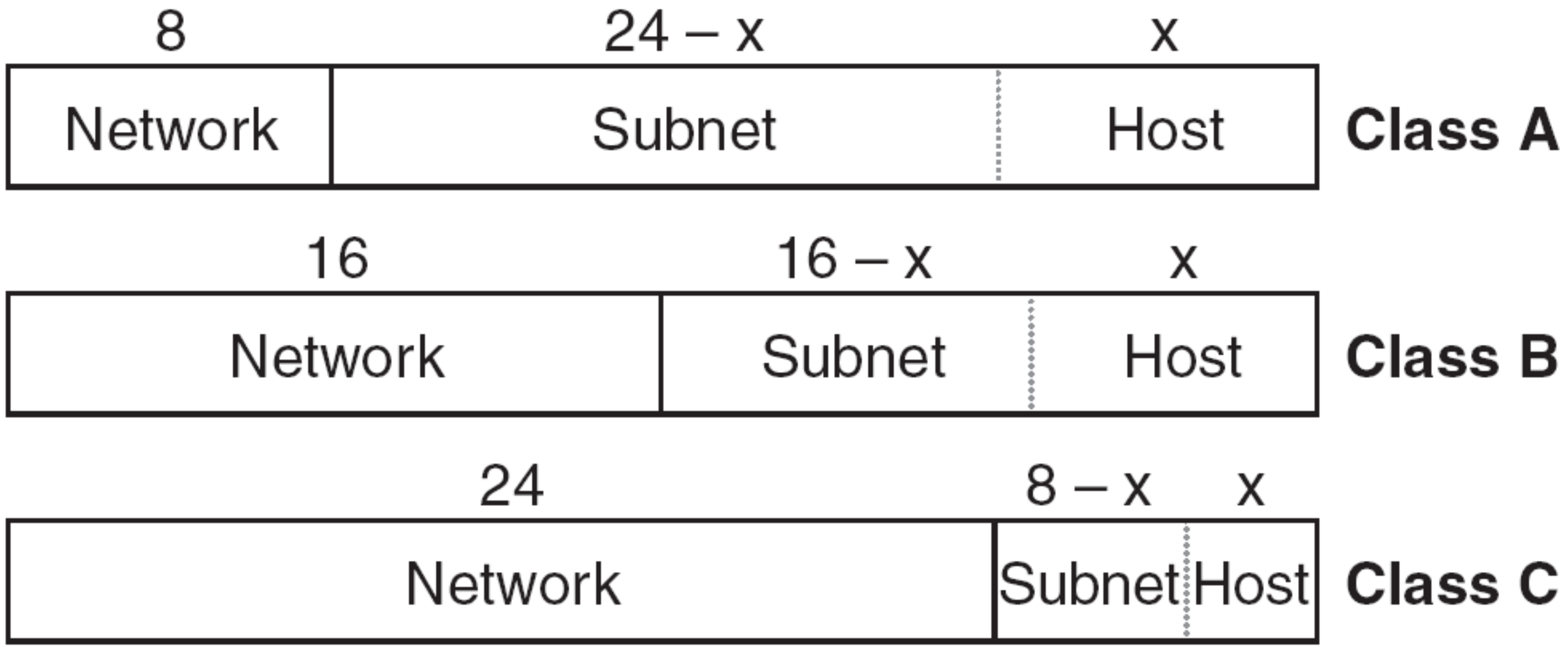


IPV4 ADDRESSING WITH SUBNETS

What if the network is 192.168.14.0?



CLASSFUL SUBNETS FORMAT



CLASSLESS SUBNETS FORMAT

LOGICAL AND OPERATION

	Decimal	Binary
Address	150.150.2.1	1001 0110 1001 0110 0000 0010 **0000 0001**
Mask	255.255.255.0	1111 1111 1111 1111 1111 1111 **0000 0000**
Result of AND	150.150.2.0	1001 0110 1001 0110 0000 0010 **0000 0000**

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MASK REPRESENTATIONS

- **Dotted-decimal:** 172.16.0.0 255.255.0.0
- **Bit count:** 172.16.0.0/16
- **Hexadecimal:** 172.16.0.0 0xFFFF0000

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MASK POSSIBLE VALUES

Subnet Mask's Decimal Octet	Binary Equivalent	Number of Binary 1s	Number of Binary 0s
0	00000000	0	8
128	10000000	1	7
192	11000000	2	6
224	11100000	3	5
240	11110000	4	4
248	11111000	5	3
252	11111100	6	2
254	11111110	7	1
255	11111111	8	0

EXERCISE

Convert the following masks:

1. 255.240.0.0
2. 255.255.192.0
3. 255.255.255.224
4. 255.254.0.0
5. 255.255.248.0
6. /30
7. /25
8. /11
9. /22
10. /24

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SUBNET EXAMPLE

Step	Example	Rules to Remember
Address	8.1.4.5	
Mask	255.255.0.0	
Number of Network Bits	8	Always defined by Class A, B, C
Number of Host Bits	16	Always defined as the number of binary 0s in the mask
Number of Subnet Bits	8	32 – (network size + host size)

SUBNET CALCULATION EQUATIONS

$$\# \text{ Subnets} = 2^{s}$$

$$\# \text{ Hosts per Subnet} = 2^{h} - 2$$

SAMPLE CASES

Address	8.1.4.5/16	130.4.102.1/24	199.1.1.100/24	130.4.102.1/22	199.1.1.100/27
Mask	255.255.0.0	255.255.255.0	255.255.255.0	255.255.252.0	255.255.255.224
Number of Network Bits	8	16	24	16	24
Number of Host Bits	16	8	8	10	5
Number of Subnet Bits	8	8	0	6	3 27-24
Number of Hosts Per Subnet	$2^{16}-2$, or 65,534	2^8-2, or 254	2^8-2, or 254	$2^{10}-2$, or 1022	2^5-2, or 30
Number of Subnets	2^8, or 256	2^8, or 256	0	2^6, or 64	2^3, or 8

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EXERCISE

Complete the following table:

Problem Number	Problem	Network Bits	Subnet Bits	Host Bits	Number of Subnets in Network	Number of Hosts per Subnet
1	10.66.5.99, 255.255.254.0					
2	172.16.203.42, 255.255.252.0					
3	192.168.55.55, 255.255.255.224					
4	10.22.55.87/30					
5	172.30.40.166/26					
6	192.168.203.18/29					

Note: Assume subnets Zero and Broadcast are allowed

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LOOKING FOR THE RIGHT MASK

Number of Bits in the Host or Subnet Field	Maximum Number of Hosts ($2^h - 2$)	Maximum Number of Subnets (2^s)
1	0	2
2	2	4
3	6	8
4	14	16
5	30	32
6	62	64
7	126	128
8	254	256
9	510	512
10	1022	1024
11	2046	2048
12	4094	4096
13	8190	8192
14	16,382	16,384

EXCERCISES

- Find the minimum number of subnet and host bits, all masks satisfying the requirements, the best mask for maximum subnets and the best mask to maximize number of hosts
  - Network 10.0.0.0 , 50 Subnets and 200 host/subnet
  - Network 172.32.0.0, 125 Subnets and 125 hosts/subnet
  - Network 192.168.44.0, 15 Subnets and 6 hosts/subnet
  - Network 10.0.0.0, 300 Subnets and 500 host/subnet
  - Network 172.32.0.0, 500 Subnets and 15 hosts/subnet
  - Network 172.16.0.0, 2000 Subnets and 2 hosts/subnet

ANALYZING EXISTING SUBNETS

- For a given IP Address and a given prefix, we can determine:
  - Subnet Address
  - Subnet Broadcast Address
  - Subnet valid IP range

NEMOTECHNIC DECIMAL METHOD

Octet	1	2	3	4
Mask				
Address				
Subnet Number				
First Address				
Last Address				
Broadcast Address				

NEMOTECHNIC DECIMAL METHOD

- Step 1 Write down the subnet mask in the first empty row of the subnet chart, and the IP address in the second empty row.
- Step 2 Find the octet for which the *subnet mask's value is not 255 or 0. This* octet is called the *interesting octet. Draw a dark rectangle around the* interesting octet's column of the table, top to bottom.
- Step 3 Record the subnet number's value for the uninteresting octets, as follows:
  - a) For each octet to the left of the rectangle drawn in Step 2: copy the *IP address's* value in that same octet.
  - b) For each octet to the right of the rectangle: write down a decimal 0.

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EXAMPLE USING 130.4.102.1/255.255.252.0

Octet	1	2	3	4
Mask	255	255	252	0
Address	130	4	102	1
Subnet Number	130	4		0
First Address				
Last Address				
Broadcast Address				

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NEMOTECHNIC DECIMAL METHOD

Step 4 To find the subnet number's value for this interesting octet:

a) Calculate the magic number by subtracting the *subnet mask's interesting octet value from 256.*

b) Write down the interesting octet's value, calculated as follows: find the multiple of the magic number that is *closest to, but not greater than, the IP address's* interesting octet value

Step 5 To find the first IP address, copy the decimal subnet number, but add 1 to the fourth octet.

EXAMPLE USING 130.4.102.1/255.255.252.0

Octet	1	2	3	4	Comments
Mask	255	255	252	0	
Address	130	4	102	1	
Subnet Number	130	4	**100**	**0**	Magic number = 256 – 252 = 4; 100 is the multiple of 4 closest to, but not higher than, 102.
First Address	130	4	**100**	**1**	Add 1 to the subnet's last octet.
Last Address					
Broadcast Address					

NEMOTECHNIC DECIMAL METHOD

- **Step 6** Find the subnet broadcast address, as follows:
  - a) For each *subnet mask octet to the left of the rectangle: copy the IP address octet* value.
  - b) For each *subnet mask octet to the right of the rectangle: write down 255.*
  - c) Find the value for the interesting octet by adding the *subnet number's value in* the interesting octet to the *magic number, and subtract 1.*
- **Step 7** To find the last IP address, copy the decimal subnet broadcast address, but subtract 1 from the fourth octet.

EXAMPLE USING 130.4.102.1/255.255.252.0

Octet	1	2	3	4	Comments
Mask	255	255	252	0	
Address	130	4	102	1	
Subnet Number	130	4	100	0	Magic number = 256 – 252 = 4. 4 × 25 = 100, the closest multiple <= 102.
First Address	130	4	100	1	Add 1 to the subnet's last octet.
Last Address	130	4	103	254	Subtract 1 from the broadcast address's fourth octet.
Broadcast	130	4	103	255	Subnet's interesting octet, plus the magic number, minus 1 (100 + 4 – 1).

EXERCISES

1. 10.180.10.18, mask 255.192.0.0
2. 10.200.10.18, mask 255.224.0.0
3. 10.100.18.18, mask 255.240.0.0
4. 10.100.18.18, mask 255.248.0.0
5. 10.150.200.200, mask 255.252.0.0
6. 10.150.200.200, mask 255.254.0.0
7. 10.220.100.18, mask 255.255.0.0
8. 10.220.100.18, mask 255.255.128.0
9. 172.31.100.100, mask 255.255.192.0

10.172.31.100.100, mask 255.255.224.0

FINDING ALL SUBNETS

Octet	1	2	3	4
Mask				
Magic Number				
Network Number/Zero Subnet				
Next Subnet				
Next Subnet				
Last Subnet				
Broadcast Subnet				
Out of Range (Used by Process)				

LESS THAN 8 SUBNET BITS PROCESS

- **Step 1** Write down the subnet mask, in decimal, in the first row of Table
- **Step 2** Identify the interesting octet, which is the one octet of the mask with a value other than 255 or 0. Draw a rectangle around the column of the interesting octet.
- **Step 3** Calculate the magic number by subtracting the *subnet mask's interesting octet from 256. Record this value in the second row of the table.*
- **Step 4** Write down the classful network number, which is the same number as the zero subnet, in the third row of the table.
- **Step 5** To find each successive subnet number:
  - a) For the three uninteresting octets, copy the previous subnet number's values.
  - b) For the interesting octet, add the magic number to the previous subnet number's interesting octet.
- **Step 6** Once the sum calculated in Step 5b reaches 256, stop the process. The number with the 256 in it is out of range, and the previous subnet number is the broadcast subnet.

EXAMPLE USING 130.4.0.0/22

Octet	1	2	3	4
Mask	255	255	252	0
Magic Number			4	
Classful Network/Subnet Zero	130	4	0	0
First Nonzero Subnet	130	4	4	0
Next Subnet	130	4	8	0
Next Subnet	130	4	12	0
Next Subnet	130	4	16	0
Next Subnet	130	4	20	0
Next Subnet	130	4	24	0
(Skipping many subnets—shorthand)	130	4	X	0
Largest Numbered Nonbroadcast Subnet	130	4	248	0
Broadcast Subnet	130	4	252	0
Invalid—Used by Process	130	4	256	0

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EXAMPLE USING130.4.0.0/24

Octet	1	2	3	4
Mask	255	255	255	0
Magic Number			1	
Classful Network/Subnet Zero	130	4	0	0
First Nonzero Subnet	130	4	1	0
Next Subnet	130	4	2	0
Next Subnet	130	4	3	0
(Skipping many subnets—shorthand)	130	4	X	0
Largest Numbered Nonbroadcast Subnet	130	4	254	0
Broadcast Subnet	130	4	255	0
Invalid—Used by Process	130	4	256	0

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MORE THAN 8 SUBNET BITS PROCCESS

- **First 5 steps are the same**
- **Step 6** Beginning with the network number and mask, use same process until one of the steps results in a sum of 256. At that point, use the substeps listed here to find and record the next subnet number:
  - a) For the octet whose sum would have been 256, write down a 0.
  - b) For the octet to the left, add 1 to the previous subnet's value in that octet.
  - c) For the other two octets, copy the values of the same octets in the previous subnet number.
  - d) Start again Step 5
- **Step 7** Each time process results in a sum of 256, repeat Step 6 of this process.
- **Step 8** Repeat until Step 6b would actually change the value of the network portion of the subnet number. The previously created subnet is the broadcast subnet.

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EXAMPLE, FIRST STEP 6

Octet	1	2	3	4
Mask	255	255	255	192
Magic Number (256 – 192 = 64)				64
Classful Network/Subnet Zero	130	4	0	0
First Nonzero Subnet	130	4	0	64
Next Subnet	130	4	0	128
Next Subnet	130	4	0	192
A 256 in the Fourth Octet…	130	4	0	256

EXAMPLE, FIRST STEP 7

Octet	1	2	3	4
Mask	255	255	255	192
Magic Number				64
Classful Network/Subnet Zero	130	4	0	0
First Nonzero Subnet	130	4	0	64
Next Subnet	130	4	0	128
Next Subnet	130	4	0	192
Correct Next Subnet (found by writing 0 in the fourth octet, and adding 1 to the third octet)	130	4	1	0
Next Subnet	130	4	1	64
Next Subnet	130	4	1	128
Next Subnet	130	4	1	192

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EXERCISES

- List all subnets for:
  - 172.32.0.0/22
  - 200.1.2.0/28
  - 10.0.0.0/15
  - 172.32.0.0/25
  - 10.0.0.0/21
  - 172.20.0.0/24