

Ethernet / IEEE 802.3 / IEEE 802.1q Frame and Ethertypes

Ethertype	Keyword	Protocol
0x0800	IPv4	Internet Protocol, Version 4
0x0806	ARP	Address Resolution Protocol
0x0842	WoL	Wake-on-LAN Magic Packet
0x0835	RARP	Reverse Address Resolution Protocol
0x814c	SNMP	Simple Network Management Protocol
0x86dd	IPv6	Internet Protocol, Version 6

ARP

IPv4/6 Headers and IP Protocol Numbers/Next Header

No / NH	Protocol	No / NH	Protocol
0x01	ICMPv4 (Internet Control Management)	0x2f	GRE (General Routing Encapsulation)
0x06	TCP (Transmission Control)	0x3a	ICMPv6 (ICMP for IPv6)
0x11	UDP (User Datagram)	0x3b	No Next Header
0x2c	Fragment Header	0x84	SCTP (Stream Control Transmission)

ICMPv4

Type	Code	Description
0 - Echo Reply	0	Echo reply
1 and 2		Reserved
3 - Destination Unreachable	0	Destination network unreachable
	1	Destination host unreachable
	2	Destination protocol unreachable
	3	Destination port unreachable
	4	Fragmentation required, and DF flag set
	5	Source route failed
	6	Destination network unknown
	7	Destination host unknown
	8	Source host isolated
	9	Network administratively prohibited
	10	Host administratively prohibited
	11	Network unreachable for TOS
	12	Host unreachable for TOS
	13	Communication administratively prohibited
	14	Host Precedence Violation
	15	Precedence cutoff in effect
4 - Source Quench	0	Source quench (congestion control)
5 - Redirect Message	0	Redirect Datagram for the Network
	1	Redirect Datagram for the Host
	2	Redirect Datagram for the TOS & network
	3	Redirect Datagram for the TOS & host
8 - Echo Request	0	Echo request
11 - Time Exceeded	0	TTL expired in transit
	1	Fragment Reassembly Time Exceeded

TCP/UDP Header and well-known Ports

Port	Service Name	Port	Service Name	Port	Service Name
20	ftp (data)	53	domain (dns)	115	sftp
21	ftp (command)	67	bootps/dhcp server	143	imap
22	ssh	68	bootpc/dhcp client	443	https
23	telnet	69	tftp	514	syslog
25	smtp	80	http	546	dhcpv6-client
43	whois	110	pop3	547	dhcpv6-server

ICMPv6

Note: The following ICMPv6 messages are identical to their ICMPv4 counterparts:

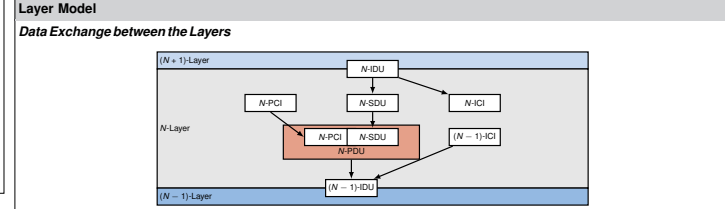
- Echo Request / Reply
- Destination Unreachable
- Time Exceeded

Restrictions for minimal length and alignment (padding) apply to the ICMPv6 types / codes (see below).

Type	Code	Description
0		Reserved
1 - Destination Unreachable	0	No route to destination
	1	Communication administratively prohibited
	3	Address unreachable
	4	Port unreachable
2 - Packet too big	0	Packet too big
3 - Time Exceeded	0	Hop limit exceeded in transit
	1	Fragment reassembly time exceeded
128 - Echo Request	0	Echo Request
129 - Echo Reply	0	Echo Reply
133 - Router Solicitation	0	Neighbor Discovery Protocol (NDP)
134 - Router Advertisement	0	Neighbor Discovery Protocol (NDP)
135 - Neighbor Solicitation	0	Neighbor Discovery Protocol (NDP)
136 - Neighbor Advertisement	0	Neighbor Discovery Protocol (NDP)
137 - Redirect Message	0	Neighbor Discovery Protocol (NDP)

QUIC

Disclaimer: QUIC allows several different header formats, depending on the used version and the given flags some fields can be omitted. However, for the exam you only need this header format.



Congestion Control

Metrics for Measuring Fairness: Consider n flows with x_i being the bandwidth for flow i .

Product Measure: $\prod_{i \in \{1, \dots, n\}} x_i$

Epsilon Fairness: $\frac{\min_i x_i}{\max_i x_i} \geq 1 - \epsilon$

Jain's Fairness Index: $\frac{(\sum_{i=1}^n x_i)^2}{n \sum_{i=1}^n x_i^2} \in [\frac{1}{n}, 1]$

Exponential Weighted Moving Average (EWMA): SampleRTT measures the time from segment transmission until ACK receipt (ignoring retransmissions). α is typically 0.125.

$EstimatedRTT = (1 - \alpha) \cdot EstimatedRTT + \alpha \cdot SampleRTT$

TCP Cubic

- W_{cubic} : Congestion Window according to TCP Cubic
- W_{max} : window size at which last packet loss occurred
- t : time since the last packet loss
- β : window decrease constant for multiplicative decrease of window
- C : Cubic parameter

$$W_{cubic}(t) = C \cdot (t - K)^3 + W_{max}$$

$$K = \sqrt[3]{W_{max} \cdot (1 - \beta_{cubic}) / C}$$

$$C = 0.4$$

$$\beta = 0.7$$

TCP Vegas

Formula: $\Delta = CWND \cdot \frac{RTT - RTT_{min}}{RTT}$

Each RTT:

- If $\Delta > \beta$ (Linux: 4): window size is decreased by 1 MSS
- If $\Delta < \alpha$ (Linux: 2): window size is increased by 1 MSS
- If $\alpha < \Delta < \beta$: Steady state \rightarrow no modifications

Numbering Systems and ASCII 1/2

Dec	Hex	Binary	Ascii	Dec	Hex	Binary	Ascii	Dec	Hex	Binary	Ascii	Dec	Hex	Binary	Ascii
0	00	00000000	NUL	32	20	00100000	SPACE	64	40	01000000	@	96	60	01100000	'
1	01	00000001	SOH	33	21	00100001		65	41	01000001	A	97	61	01100001	a
2	02	00000010	STX	34	22	00100010	"	66	42	01000010	B	98	62	01100010	b
3	03	00000011	ETX	35	23	00100011	#	67	43	01000011	C	99	63	01100011	c
4	04	00000100	EOT	36	24	00100100	\$	68	44	01000100	D	100	64	01100100	d
5	05	00000101	ENQ	37	25	00100101	%	69	45	01000101	E	101	65	01100101	e
6	06	00000110	ACK	38	26	00100110	&	70	46	01000110	F	102	66	01100110	f
7	07	00000111	BEL	39	27	00100111	'	71	47	01000111	G	103	67	01100111	g
8	08	00001000	BS	40	28	00101000	(	72	48	01001000	H	104	68	01101000	h
9	09	00001001	HT	41	29	00101001	)	73	49	01001001	I	105	69	01101001	i
10	0a	00001010	LF	42	2a	00101010	*	74	4a	01001010	J	106	6a	01101010	j
11	0b	00001011	VT	43	2b	00101011	+	75	4b	01001011	K	107	6b	01101011	k
12	0c	00001100	FF	44	2c	00101100	,	76	4c	01001100	L	108	6c	01101100	l
13	0d	00001101	CR	45	2d	00101101	-	77	4d	01001101	M	109	6d	01101101	m
14	0e	00001110	SO	46	2e	00101110	.	78	4e	01001110	N	110	6e	01101110	n
15	0f	00001111	SI	47	2f	00101111	/	79	4f	01001111	O	111	6f	01101111	o
16	10	00010000	DLE	48	30	00110000	0	80	50	01010000	P	112	70	01110000	p
17	11	00010001	DC1	49	31	00110001	1	81	51	01010001	Q	113	71	01110001	q
18	12	00010010	DC2	50	32	00110010	2	82	52	01010010	R	114	72	01110010	r
19	13	00010011	DC3	51	33	00110011	3	83	53	01010011	S	115	73	01110011	s
20	14	00010100	DC4	52	34	00110100	4	84	54	01010100	T	116	74	01110100	t
21	15	00010101	NAK	53	35	00110101	5	85	55	01010101	U	117	75	01110101	u
22	16	00010110	SYN	54	36	00110110	6	86	56	01010110	V	118	76	01110110	v
23	17	00010111	ETB	55	37	00110111	7	87	57	01010111	W	119	77	01110111	w
24	18	00011000	CAN	56	38	00111000	8	88	58	01011000	X	120	78	01111000	x
25	19	00011001	EM	57	39	00111001	9	89	59	01011001	Y	121	79	01111001	y
26	1a	00011010	SUB	58	3a	00111010	:	90	5a	01011010	Z	122	7a	01111010	z
27	1b	00011011	ESC	59	3b	00111011	;	91	5b	01011011	[	123	7b	01111011	{
28	1c	00011100	FS	60	3c	00111100	<	92	5c	01011100	\	124	7c	01111100	|
29	1d	00011101	GS	61	3d	00111101	=	93	5d	01011101	]	125	7d	01111101	}
30	1e	00011110	RS	62	3e	00111110	>	94	5e	01011110	^	126	7e	01111110	~
31	1f	00011111	US	63	3f	00111111	?	95	5f	01011111	_	127	7f	01111111	DE

Numbering Systems 2/2

Dec	Hex	Binary	Dec	Hex	Binary	Dec	Hex	Binary	Dec	Hex	Binary
128	80	10000000	160	a0	10100000	192	c0	11000000	224	e0	11100000
129	81	10000001	161	a1	10100001	193	c1	11000001	225	e1	11100001
130	82	10000010	162	a2	10100010	194	c2	11000010	226	e2	11100010
131	83	10000011	163	a3	10100011	195	c3	11000011	227	e3	11100011
132	84	10000100	164	a4	10100100	196	c4	11000100	228	e4	11100100
133	85	10000101	165	a5	10100101	197	c5	11000101	229	e5	11100101
134	86	10000110	166	a6	10100110	198	c6	11000110	230	e6	11100110
135	87	10000111	167	a7	10100111	199	c7	11000111	231	e7	11100111
136	88	10001000	168	a8	10101000	200	c8	11001000	232	e8	11101000
137	89	10001001	169	a9	10101001	201	c9	11001001	233	e9	11101001
138	8a	10001010	170	aa	10101010	202	ca	11001010	234	ea	11101010
139	8b	10001011	171	ab	10101011	203	cb	11001011	235	eb	11101011
140	8c	10001100	172	ac	10101100	204	cc	11001100	236	ec	11101100
141	8d	10001101	173	ad	10101101	205	cd	11001101	237	ed	11101101
142	8e	10001110	174	ae	10101110	206	ce	11001110	238	ee	11101110
143	8f	10001111	175	af	10101111	207	cf	11001111	239	ef	11101111
144	90	10010000	176	b0	10110000	208	d0	11010000	240	f0	11110000
145	91	10010001	177	b1	10110001	209	d1	11010001	241	f1	11110001
146	92	10010010	178	b2	10110010	210	d2	11010010	242	f2	11110010
147	93	10010011	179	b3	10110011	211	d3	11010011	243	f3	11110011
148	94	10010100	180	b4	10110100	212	d4	11010100	244	f4	11110100
149	95	10010101	181	b5	10110101	213	d5	11010101	245	f5	11110101
150	96	10010110	182	b6	10110110	214	d6	11010110	246	f6	11110110
151	97	10010111	183	b7	10110111	215	d7	11010111	247	f7	11110111
152	98	10011000	184	b8	10111000	216	d8	11011000	248	f8	11111000
153	99	10011001	185	b9	10111001	217	d9	11011001	249	f9	11111001
154	9a	10011010	186	ba	10111010	218	da	11011010	250	fa	11111010
155	9b	10011011	187	bb	10111011	219	db	11011011	251	fb	11111011
156	9c	10011100	188	bc	10111100	220	dc	11011100	252	fc	11111100
157	9d	10011101	189	bd	10111101	221	dd	11011101	253	fd	11111101
158	9e	10011110	190	be	10111110	222	de	11011110	254	fe	11111110
159	9f	10011111	191	bf	10111111	223	df	11011111	255	ff	11111111

Addresses

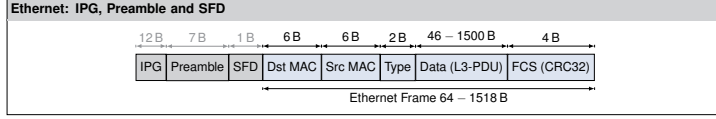
Structure of MAC Addresses according to IEEE 802-Standards (e.g. Ethernet, WLAN, Bluetooth):

Special IP Addresses and Prefixes:

Prefix	Function	Prefix	Function
0.0.0.0/8	"This network"	::/128	Unspecified Address
127.0.0.0/8	Loopback, especially 127.0.0.1	::1/128	Loopback Address
10.0.0.0/8	Private-Use	::ffff:0:0/96	IPv4-mapped Addresses
100.64.0.0/10	Shared Address Space for CG-NAT	fe80::/10	Link-Local Addresses
172.16.0.0/12	Private-Use	fc00::/7	Unique-Local Unicast Addresses
192.168.0.0/16	Private-Use	ff00::/8	Multicast Addresses
169.254.0.0/16	Automatic Private IP Addressing	ff02::1:1/128	All Nodes
255.255.255.255/32	Limited Broadcast	ff02::1:ff00:0/104	Solicited Node Addresses

IPv4/6 Address Format: (examples)

In IPv4 one does not differentiate between prefix and subnet (the prefix defines the corresponding subnet). In IPv6, the *subnet identifier* together with the prefix defines the corresponding subnet. The notation <address>/N identifies the length of the network part.



Domain Name System: Parameters and Numbers

DNS Resource Records

Type	Value	Meaning	Representation
A	1	an IPv4 host address	32 bit address
AAAA	28	an IPv6 host address	128 bit address
CNAME	5	canonical name for an alias	a domain name
NS	2	authoritative name server	domain name
SOA	6	start of zone authority	Various fields
MX	15	Mail exchange address	Preference (16-bit, lower are preferred) and mail server domain name
TXT	16	TXT record	Arbitrary text (character-strings)
PTR	12	points to a domain name	domain name
SVCB	64	service binding record	Information on services
HTTPS	65	HTTPS service binding record	Information on the HTTPS service

DNS Classes

Decimal	Hexadecimal	Name
1	0x0001	Internet (IN)
3	0x0003	Chaos (CH)
4	0x0004	Hesiod (HS)
254	0x00FE	QCLASS None (NONE)
255	0x00FF	QCLASS* (ANY)

DNS OpCodes

Decimal	Name
0	Query
1	!Query (Inverse Query, obsolete)
2	Status
3	Unassigned
4	Notify
5	Update
6	DNS Stateful Operations (DSO)
7-15	Unassigned

DNS RCODEs

RCODE	Name	Description
0	NoError	No Error
1	FormErr	Format Error
2	ServFail	Server Failure
3	NXDomain	Non-Existent Domain
4	NotImp	Not Implemented
5	Refused	Query Refused

Reverse DNS Zones
 IPv4: in-addr.arpa., IPv6: ip6.arpa.

