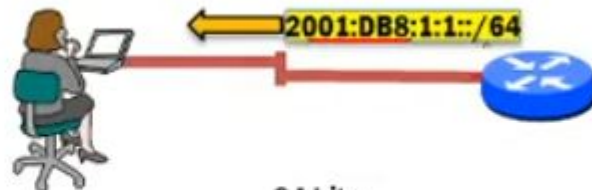


# IPv6(Continued..)

## EUI-64 (Extended Unique Identifier - 64)

How do routers automatically generate a unique interface ID

modified EUI-64 (Extended Unique Identifier)



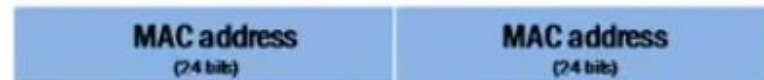
64 bits



Take MAC address of the interface



Split MAC into two parts



Insert FFFE between MAC parts

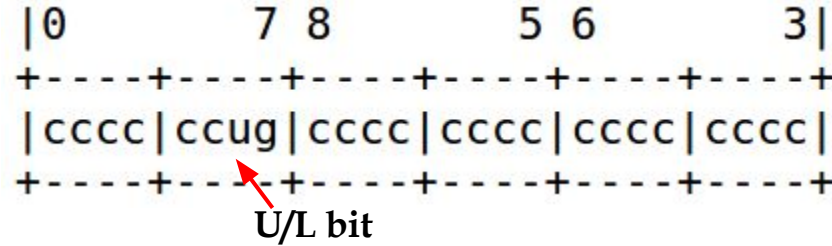


Invert the 7<sup>th</sup> bit of first MAC part

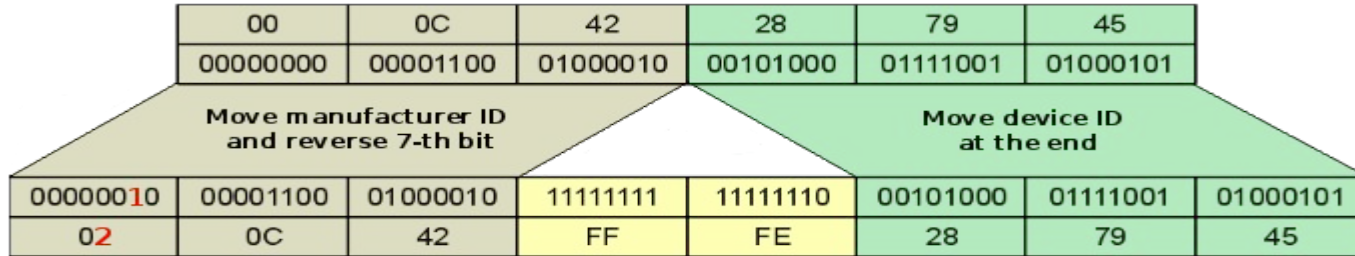


1011 0101 1010 1101 1100 1101

# How to derive 64 bit Interface Id from 48 bit MAC Address?



**48-bit MAC address**



**64-bit EUI-64 address**

When IANA assigns an Organizationally Unique Identifier (OUI) to a NIC card vendor, the 7th bit will be 0, indicating the OUI was universally assigned. **Should a user manually change their MAC address, this 7th bit would be set to 1, indicating the Ethernet address was locally administered.**

# 64-Bit Extended Unique Identifier (EUI-64)

**Step #1:** Split the 48-bit MAC address in the middle

**Step #2:** Insert FF.FE in the middle

**Step #3:** Change format to use a colon delimiter

**Step #4:** Convert the first eight bits to binary

**Step #5:** Flip the 7<sup>th</sup> bit

**Step #6:** Convert the first eight bits back into hexadecimal

0015.2BE4.9B60

0015.2BFF.FEE4.9B60

0015:2BFF:FEE4:9B60



0215:2BFF:FEE4:9B60



Fa 0/0 (MAC Address :0015.2BE4.9B60)

Link Local Address: FE80::215:2BFF:FEE4:9B60



# Problems:

1. Given a MAC Address : 00:1B:44:11:3A:B7

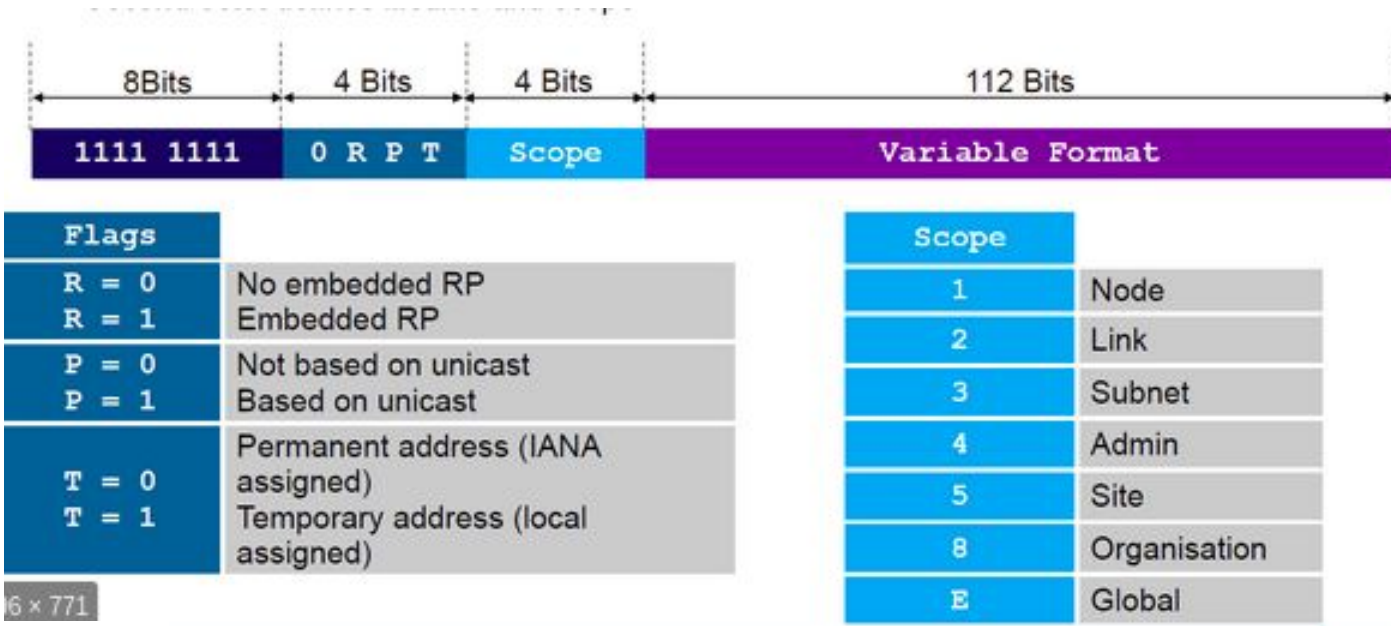
Find the Link Local IPv6 Address.

1. Assume that the network prefix is : 2001:DB8:0:1::/64 and MAC - 00:1B:44:11:3A:B7

Find the IPv6 address. What type of IPv6 address is this?

# IPv6 Multicast Address:

- Always has the prefix : FF00::/8



**Note:** Multicast addresses can only be destination addresses and not source addresses.

# Few Multicast Addresses:

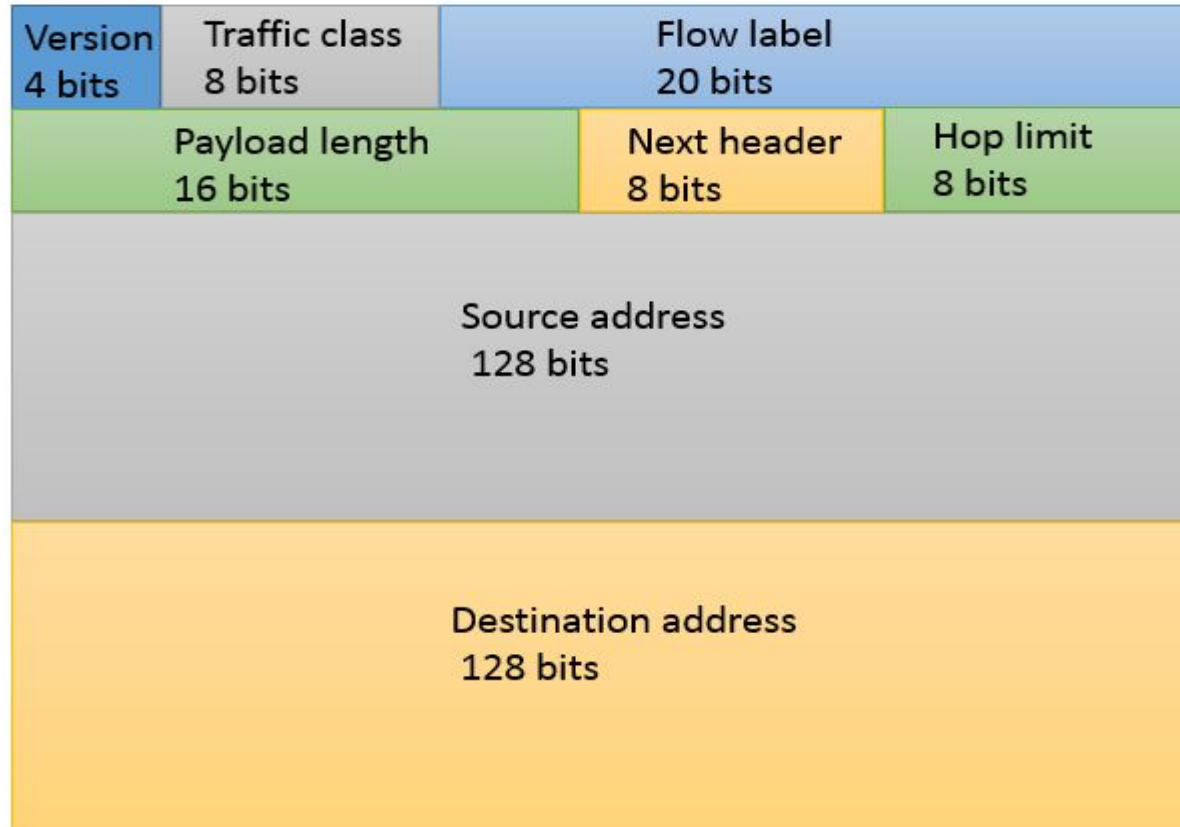
Prefix	Flag	Scope	Predefined Group ID	Compressed Format	Description (IPv6 assumed)
FF	0	2	0:0:0:0:0:0:0:1	FF02::1	All-devices
FF	0	2	0:0:0:0:0:0:0:2	FF02::2	All-routers
FF	0	2	0:0:0:0:0:0:0:5	FF02::5	OSPF routers
FF	0	2	0:0:0:0:0:0:0:6	FF02::6	OSPF DRs
FF	0	2	0:0:0:0:0:0:0:9	FF02::9	RIP routers
FF	0	2	0:0:0:0:0:0:0:A	FF02::A	EIGRP routers
FF	0	2	0:0:0:0:0:1:0:2	FF02::1:2	DHCP servers/relay agents

# IPv4 Addressing Concepts and their IPv6 equivalents

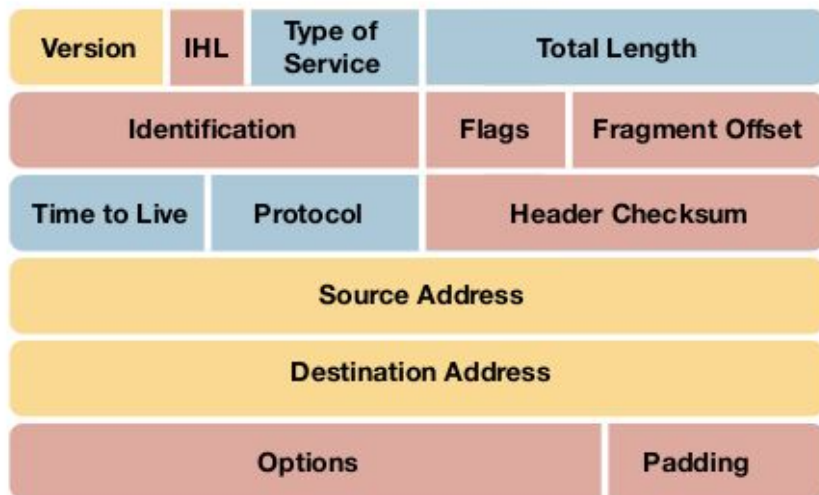
IPv4 Address	IPv6 Address
Address Length – 32 bits	128 bits
Address Representation - decimal	hexadecimal
Internet address classes	Not applicable in IPv6
Multicast addresses (224.0.0.0/4)	IPv6 multicast addresses (FF00::/8)
Broadcast addresses	Not applicable in IPv6
Unspecified address is 0.0.0.0	Unspecified address is ::
Loopback address is 127.0.0.1	Loopback address is ::1
Public IP addresses	Global unicast addresses
Private IP addresses (10.0.0.0/8, 172.16.0.0/12, and 192.168.0.0/16)	Site-local addresses (FEC0::/10)
Autoconfigured addresses (169.254.0.0/16)	Link-local addresses (FE80::/64)



# IPv6 Header Format



## IPv4 Header



### LEGEND

- Field's name kept from IPv4 to IPv6
- Field not kept in IPv6
- Name and position changed in IPv6
- New field in IPv6

## IPv6 Header



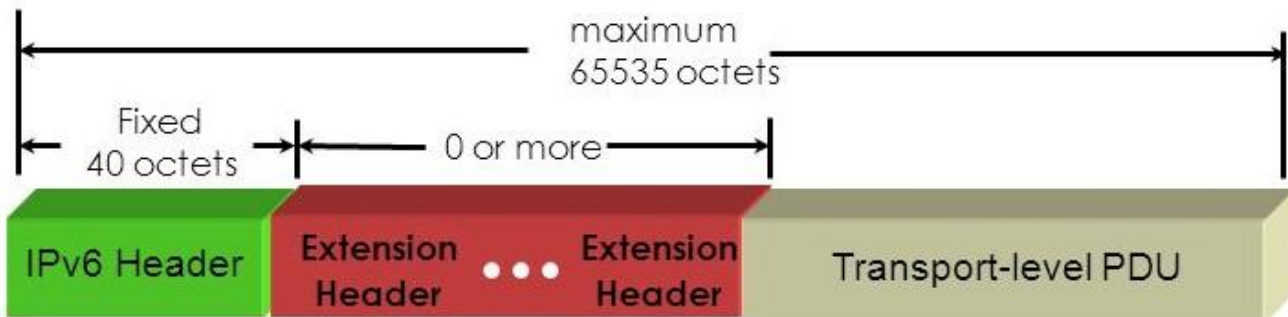
80% of the  
Header is IPv6  
Addresses  
(Source and  
Destination)

VER		TRAFFIC CLASS										FLOW LABEL										
PAYLOAD LENGTH												NEXT HEADER					HOP LIMIT					
IPv6 SOURCE ADDRESS																						
IPv6 DESTINATION ADDRESS																						
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	32	33	34	35	36	37	38	39	40	41	42	43	44	45
46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114
115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137
138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183
184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206
207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229
230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252
253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275
276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298
299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321
322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344
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437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459
460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482
483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505
506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528
529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551
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713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735
736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758
759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781
782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804
805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827
828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850
851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873
874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896
897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919
920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942
943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965
966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988
989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011
1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034
1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057
1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080
1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103
1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126
1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149
1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172
1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195
1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218
1219	1220	1221	1222	1223	1224	1225	1226	1227	1228	1229	1230	1231	1232	1233	1234	1235	1236	1237	1238	1239	1240	1241
1242	1243	1244	1245	1246	1247	1248	1249	1250	1251	1252	1253	1254	1255	1256	1257	1258	1259	1260	1261	1262	1263	1264
1265	1266	1267	1268	1269	1270	1271	1272	1273	1274	1275	1276	1277	1278	1279	1280	1281	1282	1283	1284	1285	1286	1287
1288	1289	1290	1291	1292	1293	1294	1295	1296	1297	1298	1299	1300	1301	1302	1303	1304	1305	1306	1307	1308	1309	1310
1311	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321	1322	1323	1324	1325	1326	1327	1328	1329	1330	1331	1332	1333
1334	1335	1336	1337	1338	1339	1340	1341	1342	1343	1344	1345	1346	1347	1348	1349	1350	1351	1352	1353	1354	1355	1356
1357	1358	1359	1360	1361	1362	1363	1364	1365	1366	1367	1368	1369	1370	1371	1372	1373	1374	1375	1376	1377	1378	1379
1380	1381	1382	1383	1384	1385	1386	1387	1388	1389	1390	1391	1392	1393	1394	1395	1396	1397	1398	1399	1400	1401	1402
1403	1404	1405	1406	1407	1408	1409	1410	1411	1412	1413	1414	1415	1416	1417	1418	1419	1420	1421	14			

**Ipv6 Fixed Header  
is followed by  
Extension Headers**



**IPv4 PDU**



**IPv6 PDU**

# IPv6 Header Fields

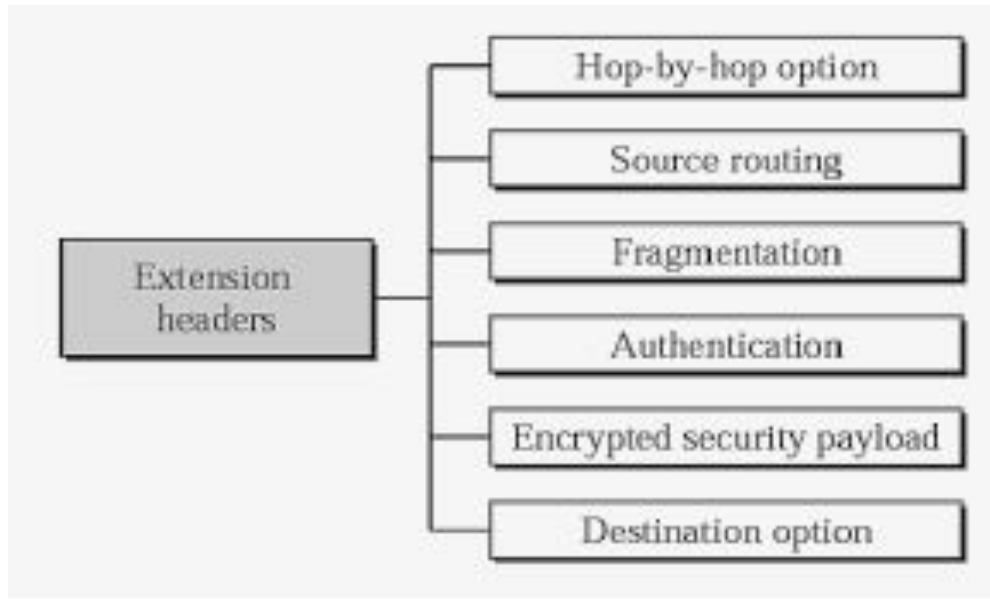
- Version : 4-bit field defines the version number of IP.
- Traffic class: This 8-bit field is used to distinguish different payloads with different delivery requirements.
- Flow label: 20-bit field that is designed to provide special handling for a particular flow of data.
- Payload length: 2-byte field defines the length of the IP datagram excluding the base header.
- Next header: 8-bit field defines the header that follows the base header in the datagram.
  - Either one of the optional extension headers used by IP or the header of an encapsulated packet such as UDP or TCP.
  - Each extension header also contains this field.
  - Protocol field in IPv4.

# IPv6 Header Fields

- Hop limit: 8-bit field same as TTL.
- Source address: 128-bit
- Destination address: 128-bit. If Source routing is used, this field contains the address of the next router.

# Extension Headers

- Goal is to give more functionality to the IP datagram.
- Six types of extension headers have been defined.



## Next Headers:

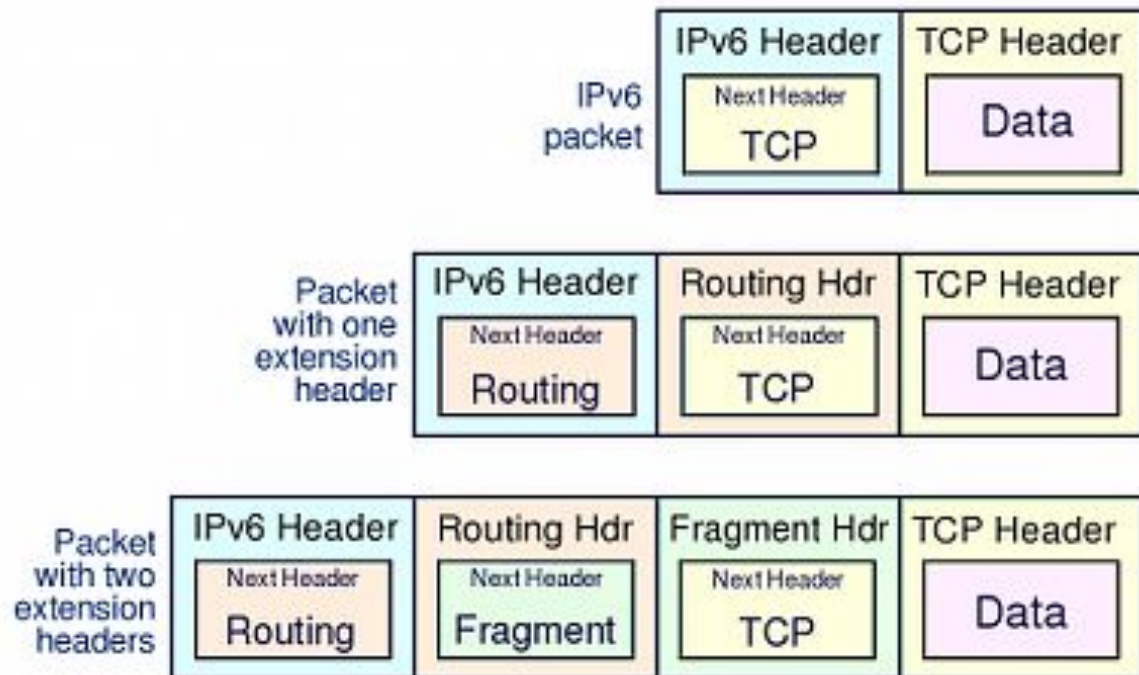
<i>Code</i>	<i>Next Header</i>
0	Hop-by-hop option
2	ICMP
6	TCP
17	UDP
43	Source routing
44	Fragmentation
50	Encrypted security payload
51	Authentication
59	Null (No next header)
60	Destination option

Routing Header

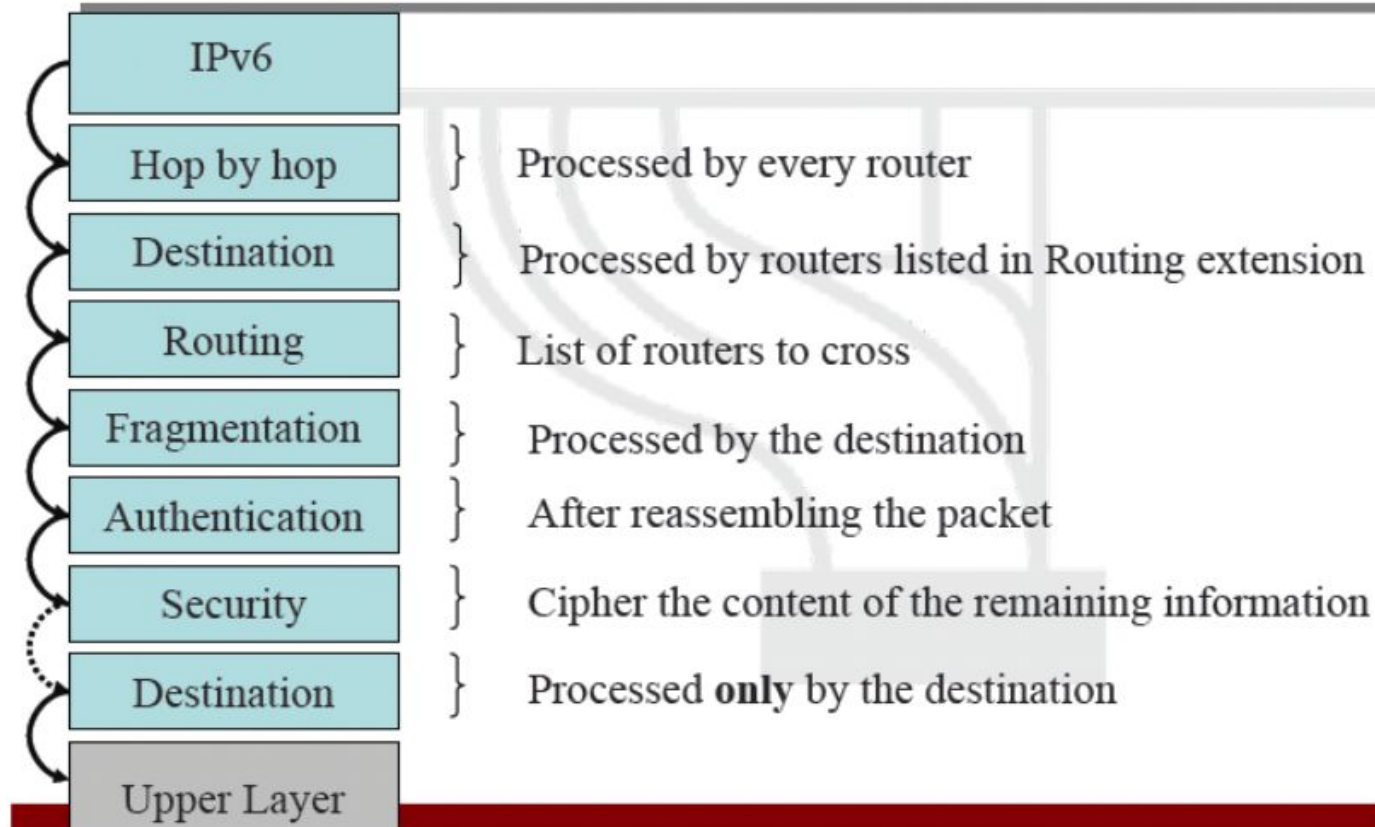


Next Header Value (Decimal)	Extension Header Name	Extension Header Length (Bytes)	Variable-Length Options (TLV) Used?	Extension Header Description
0	Hop-by-Hop Options	Variable	Yes	Used to carry optional information, which must be examined by every router along the path of the packet.
43	Routing	Variable	No	Allows the source of the packet to specify the path to the destination.
44	Fragment	8	No	Used to fragment IPv6 packets.
50	Encapsulating Security Payload (ESP)	Variable	No	Used to provide authentication, integrity, and encryption.
51	Authentication Header (AH)	Variable	No	Used to provide authentication and integrity.
60	Destination Options	Variable	Yes	Used to carry optional information that only needs to be examined by a packet's destination node(s).

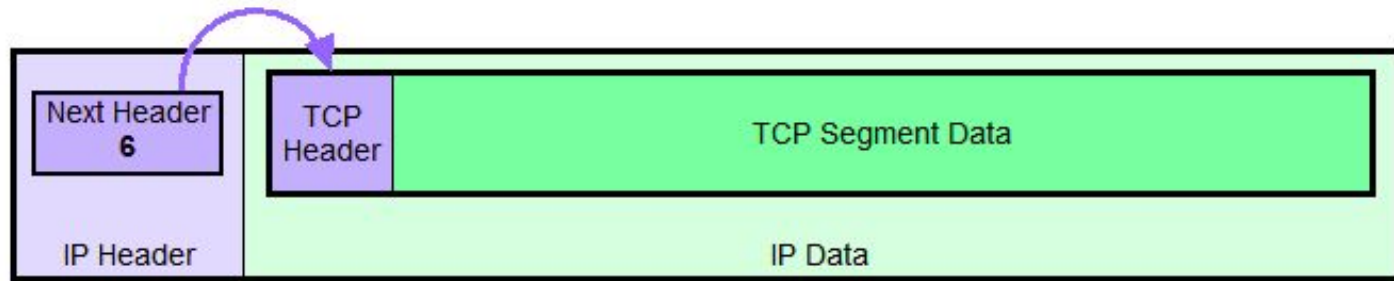
# Extension Headers



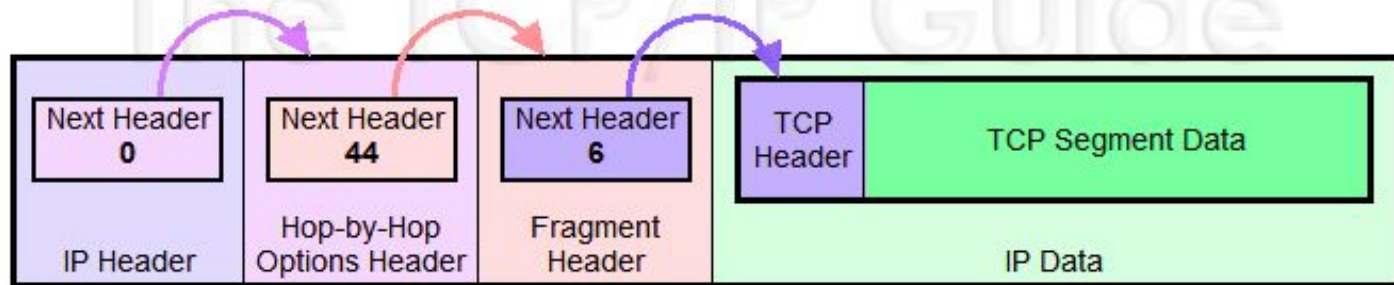
# Order of Extension Headers:



# Example:



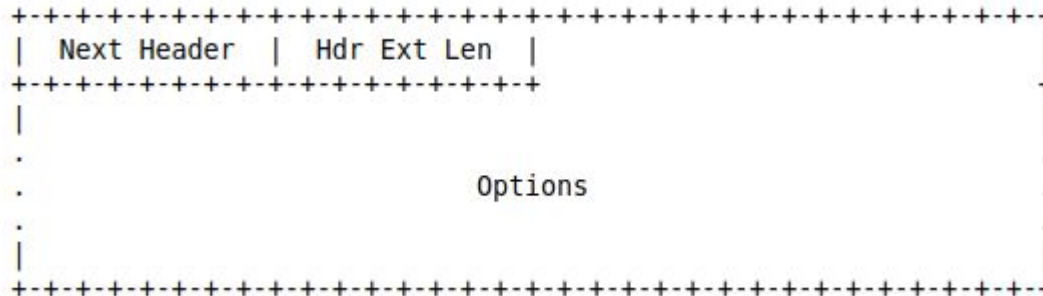
**IPv6 Datagram With No Extension Headers Carrying TCP Segment**



**IPv6 Datagram With Two Extension Headers Carrying TCP Segment**

## Hop-by-Hop option:

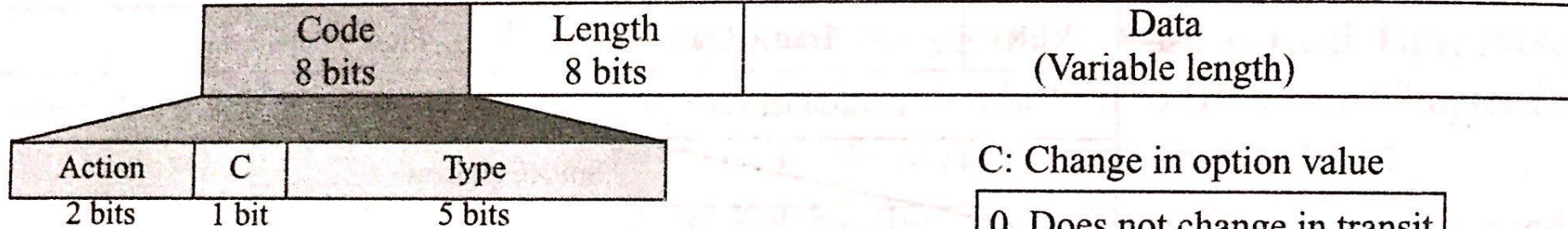
- When source needs to pass information to all routers visited by the datagram.
- Ex: debugging, control functions, if the length of the datagram is more than 65535 bytes.
- Hop by hop header format:



• **OPTIONS:**

- Type-Length-Value format.
- The Option Type field both identifies the option and determines the way it is handled by the processing node.
- The Option Length field indicates the number of bytes in the option
- The option data is the specific data associated with the option.

# The Code or Type field



Action: if the option not recognized

- |    |   |
|----|---|
| 00 | Skip this option                                    |
| 01 | Discard datagram, no more action                    |
| 10 | Discard datagram and send ICMP message              |
| 11 | Discard datagram send ICMP message if not multicast |

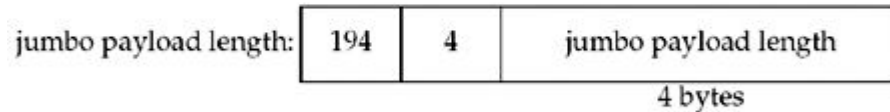
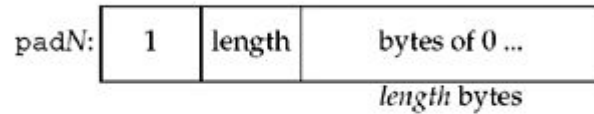
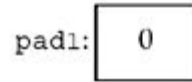
C: Change in option value

- |   |                            |
|---|----------------------------|
| 0 | Does not change in transit |
| 1 | May be changed in transit  |

Type

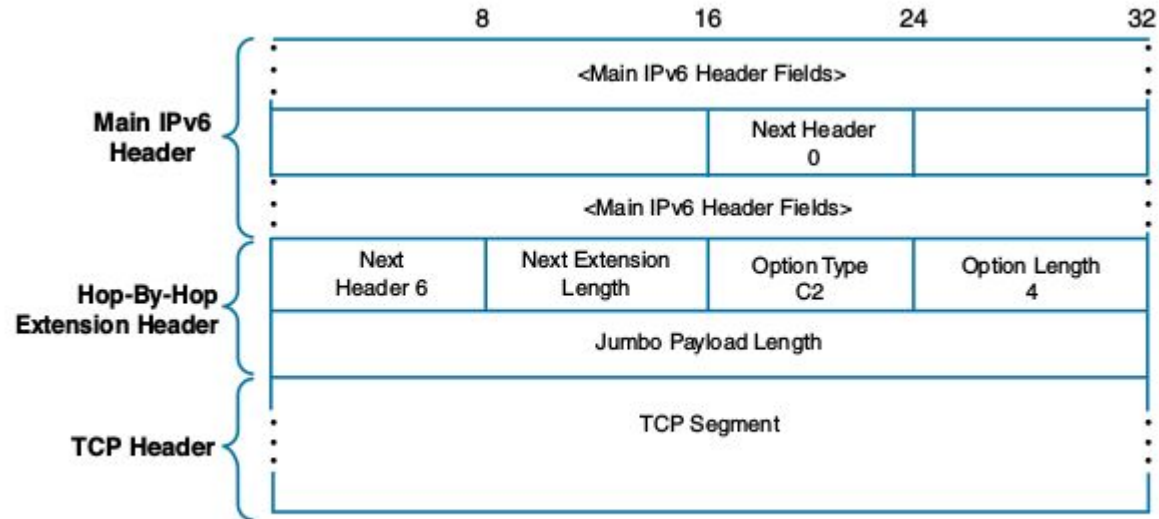
- |       |               |
|-------|---------------|
| 00000 | Pad1          |
| 00001 | PadN          |
| 00010 | Jumbo payload |

# Different types





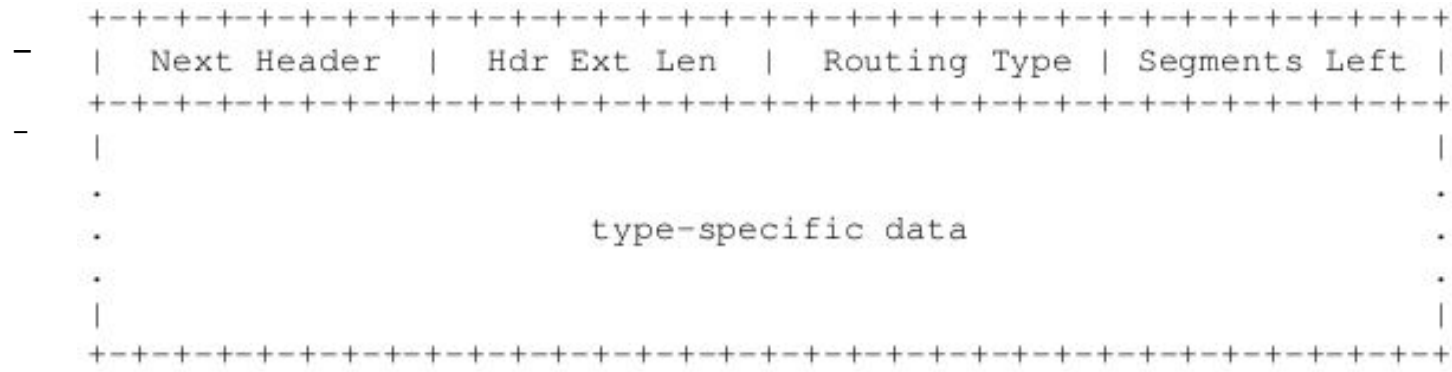
# Example:



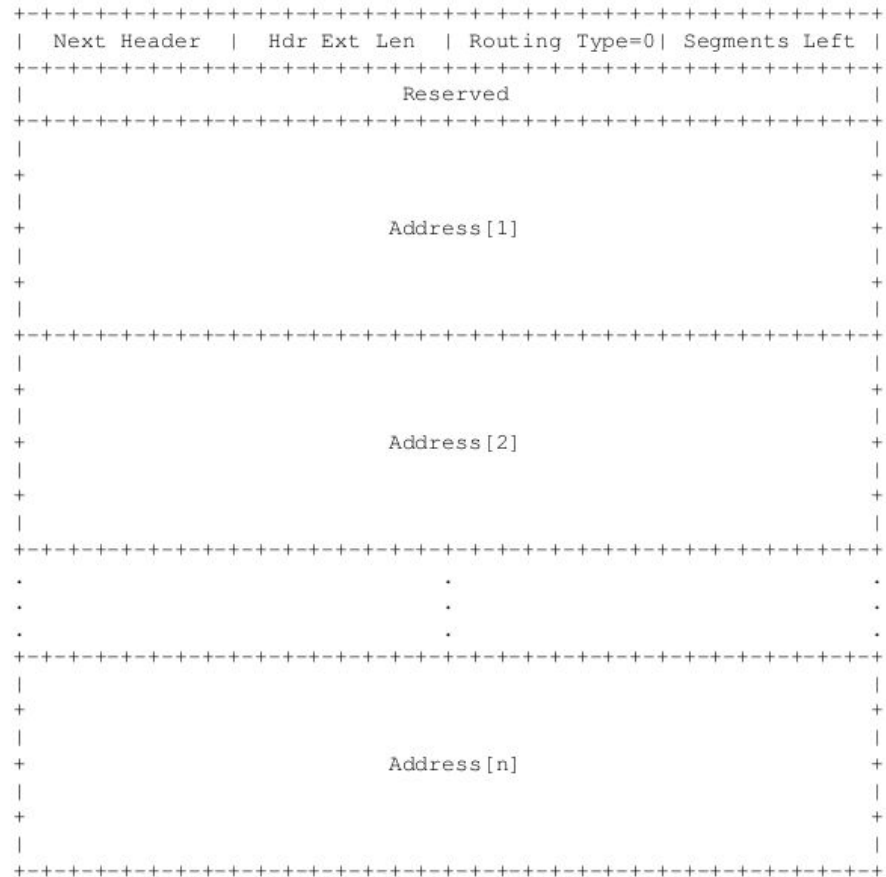
**Figure 3-22** *Hop-by-Hop Extension Header with a Jumbo Payload Option*

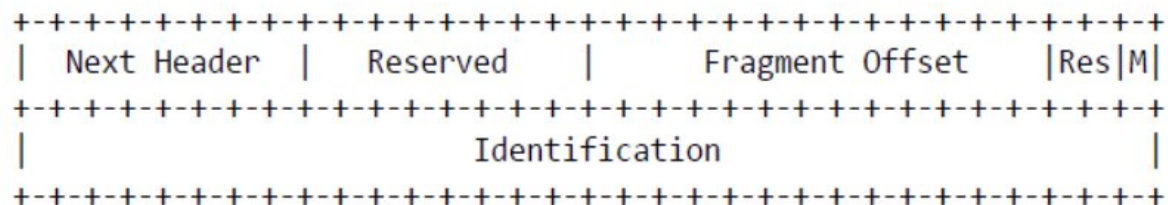
- **Routing Header:**

- Combines the concept of strict source route and loose source route options of IPv4.



The Type 0 Routing header has the following format:





## Fragment Header:

Fragment Offset	13-bit unsigned integer. The offset, in 8-octet units, of the data following this header, relative to the start of the Fragmentable Part of the original packet.
Res	2-bit reserved field. Initialized to zero for transmission; ignored on reception.
M flag	1 = more fragments; 0 = last fragment.
Identification	32 bits.

original packet:



				//	
Per-Fragment Headers	Ext & Upper-Layer Headers	first fragment	second fragment	...	last fragment
				//	

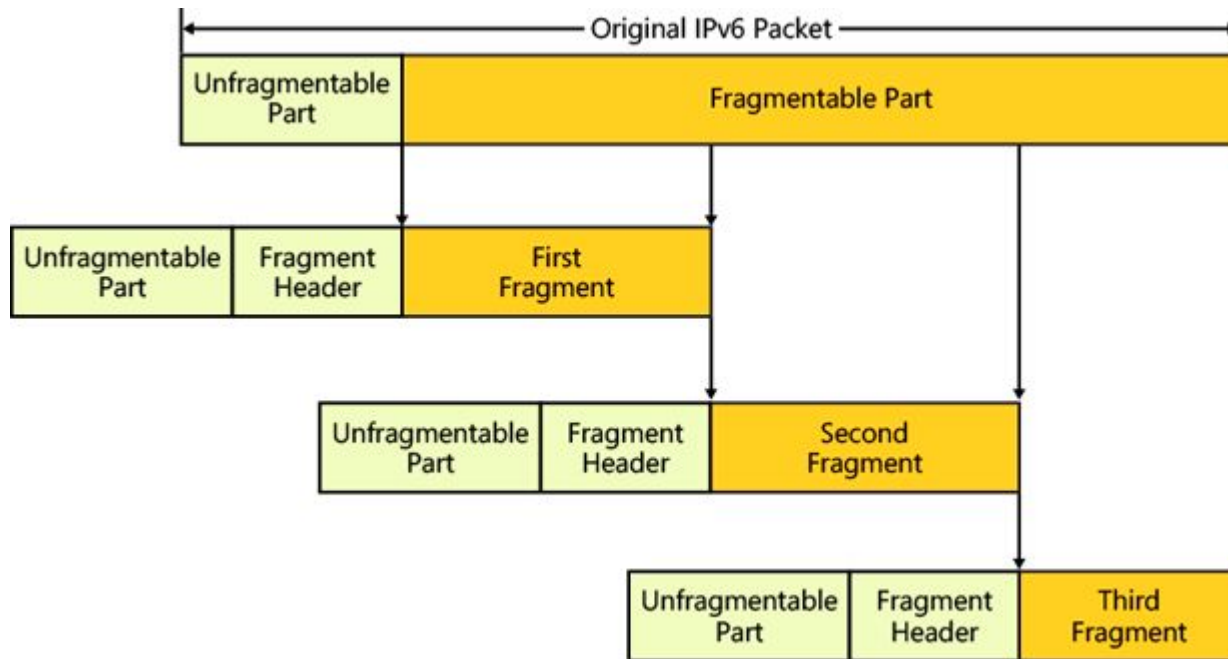
fragment packets:

Per-Fragment Headers	Fragment Header	Ext & Upper-Layer Headers	first fragment
-------------------------	--------------------	------------------------------	-------------------

Per-Fragment Headers	Fragment Header	second fragment
-------------------------	--------------------	--------------------

o  
o  
o

Per-Fragment Headers	Fragment Header	last fragment
-------------------------	--------------------	------------------



- **NO NEXT HEADER:**

- Value 59 indicates there is nothing following the header.

# TRANSITION FROM IPv4 to IPv6

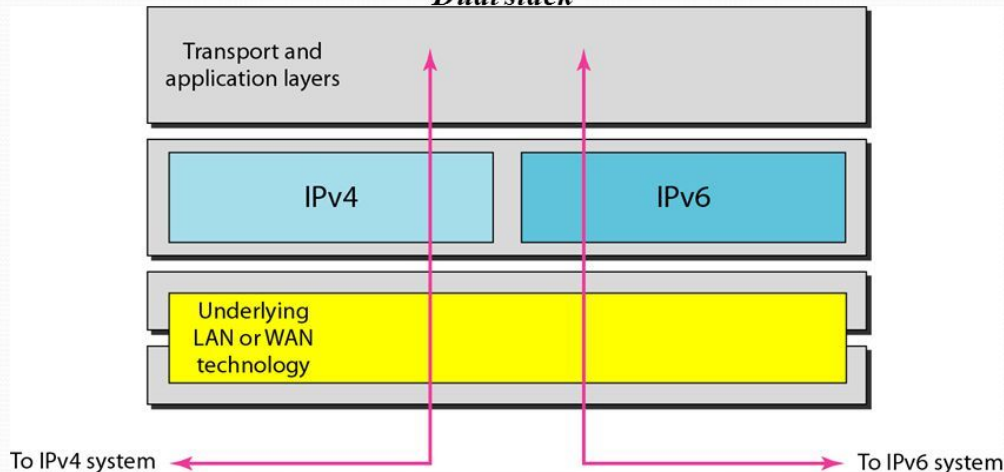
- Transition from IPv4 to IPv6 cannot happen suddenly, because of huge number of systems on the Internet
- Transition must be smooth.
- Three strategies devised by IETF:
  - Dual Stack
  - Tunneling
  - Header Translation



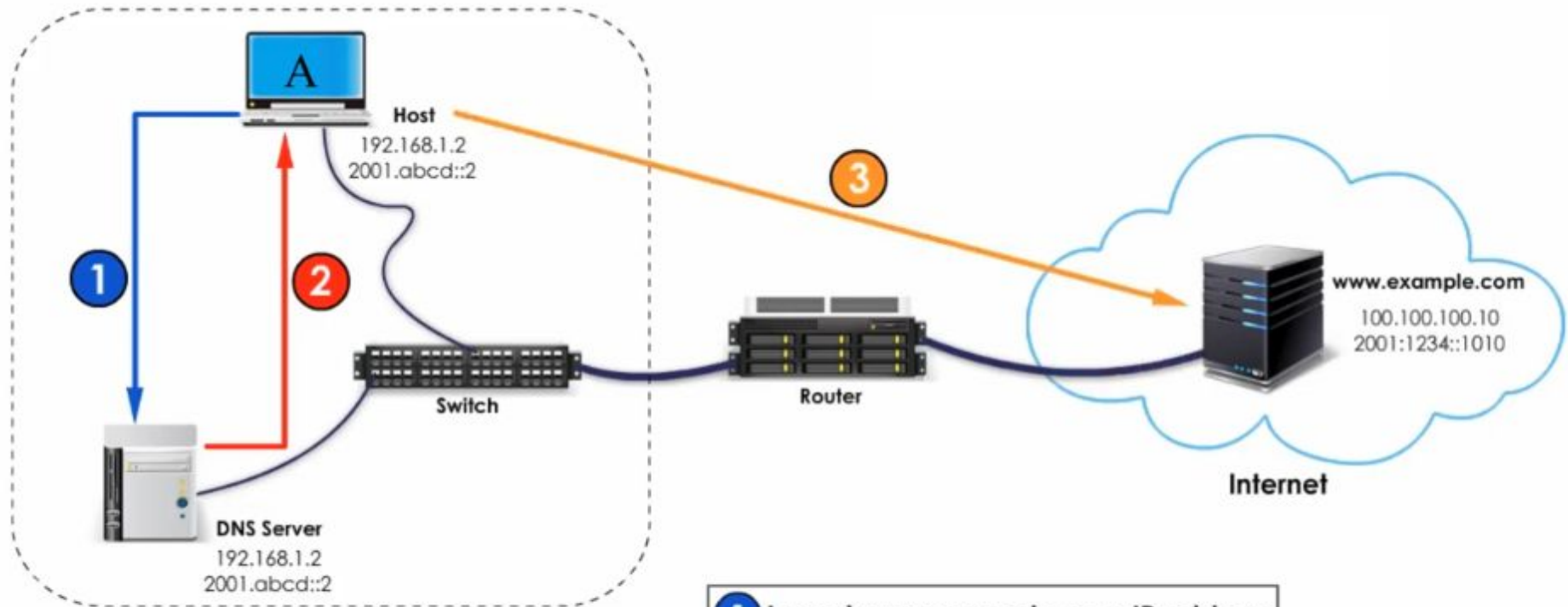
# Transition: Dual Stack

## TRANSITION FROM IPv4 TO IPv6

*Dual stack*



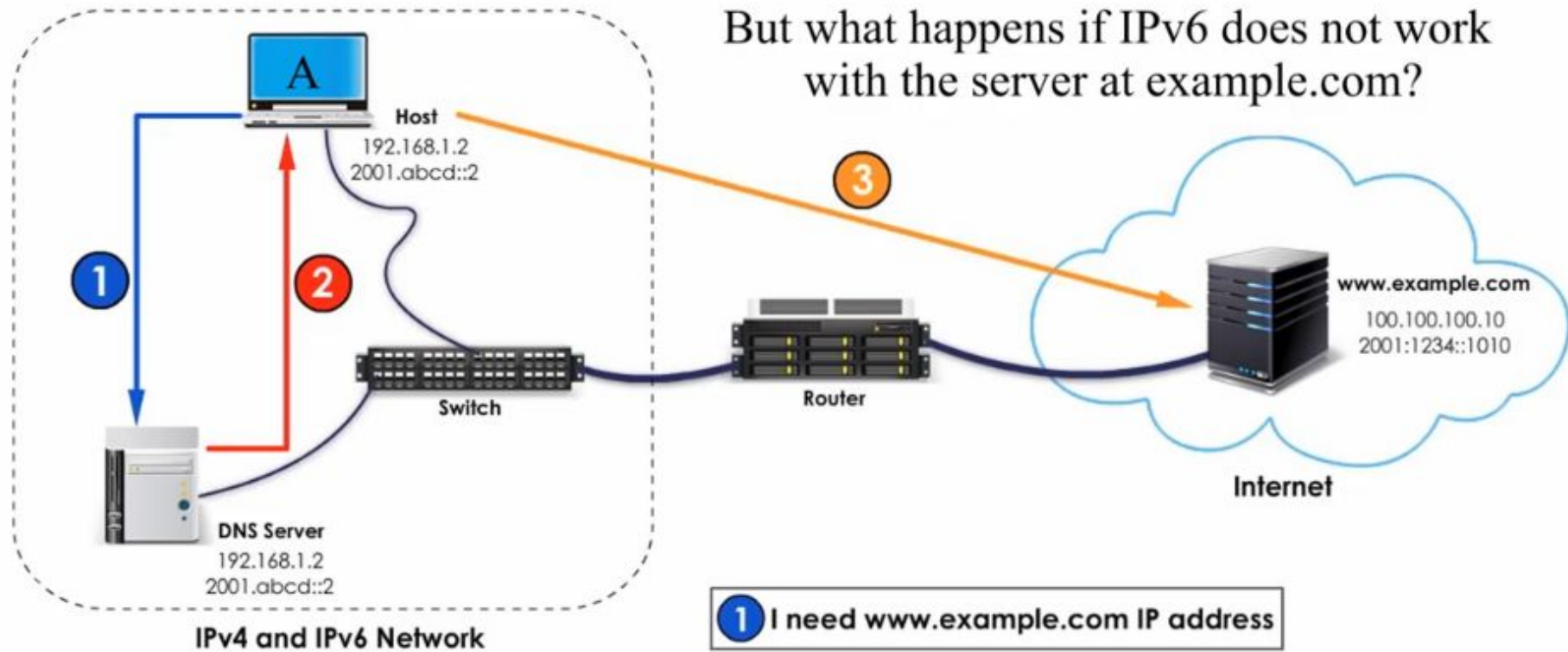
- Each station must run IPv4 and IPv6 simultaneously until all the Internet uses IPv6.
- The source host queries the DNS. If the DNS returns an IPv4 address, the source host sends an IPv4 packet. If the DNS returns an IPv6 address, the source host sends an IPv6 packet.



IPv4 and IPv6 Network

- 1 I need www.example.com IP address
- 2 Type AAAA record: 2001:1234::1010  
Type A record: 100.100.100.10
- 3 IPv6 Session with 2001:1234::1010

But what happens if IPv6 does not work with the server at example.com?

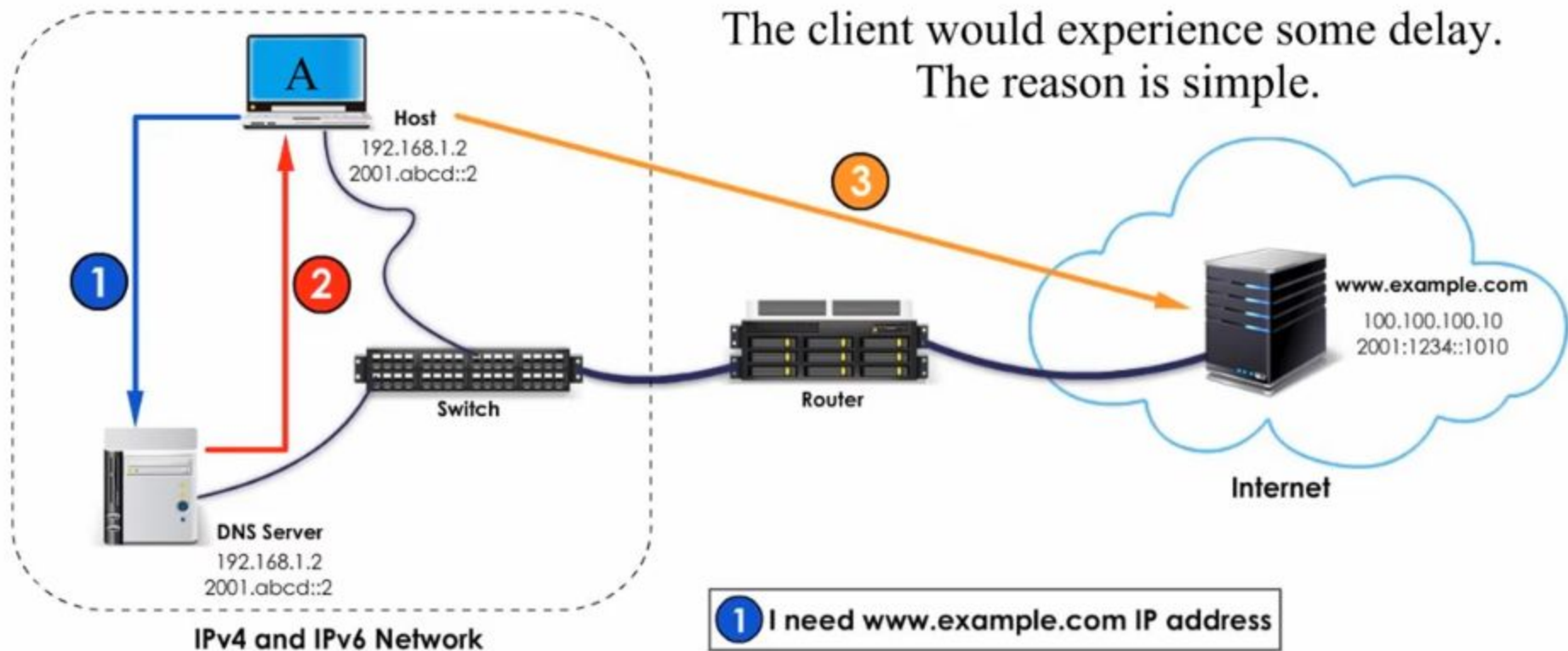


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Type A record: 100.100.100.10

3 IPv6 Session with 2001:1234::1010

The client would experience some delay.  
The reason is simple.

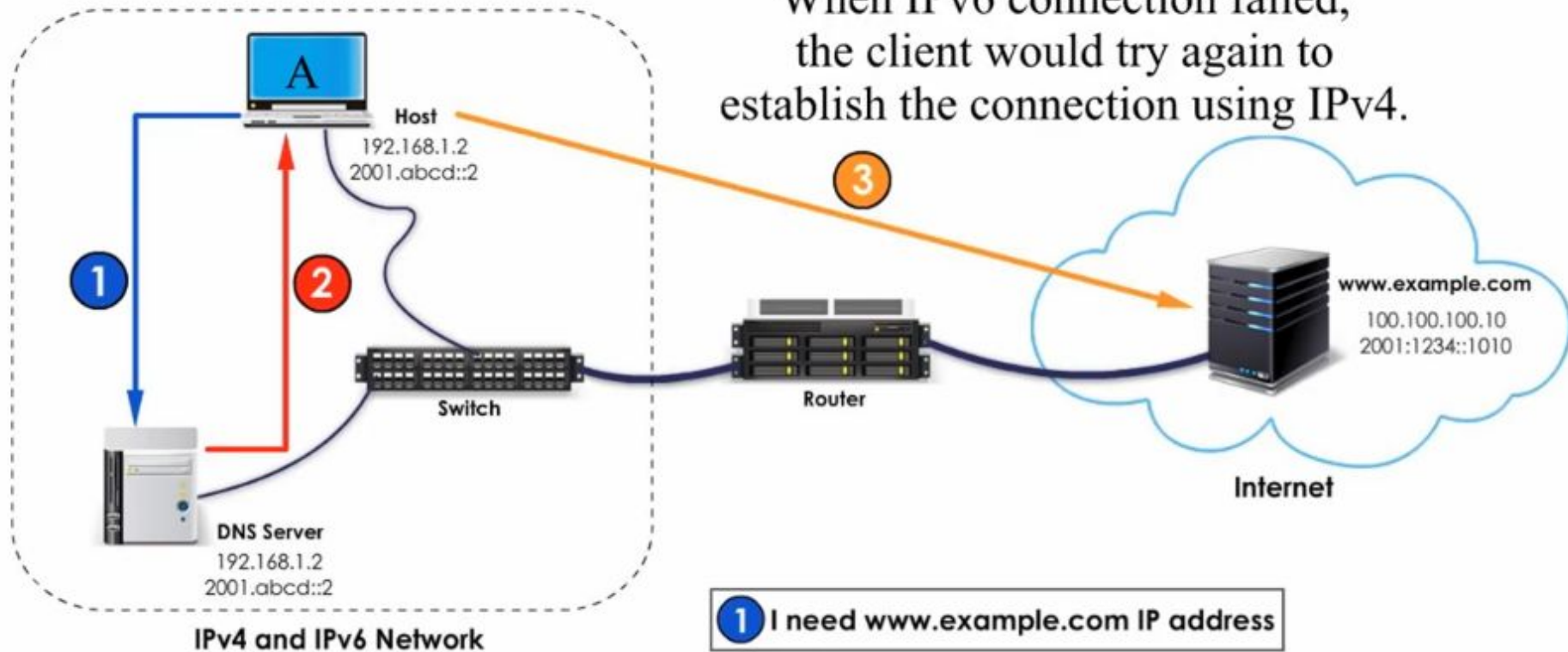


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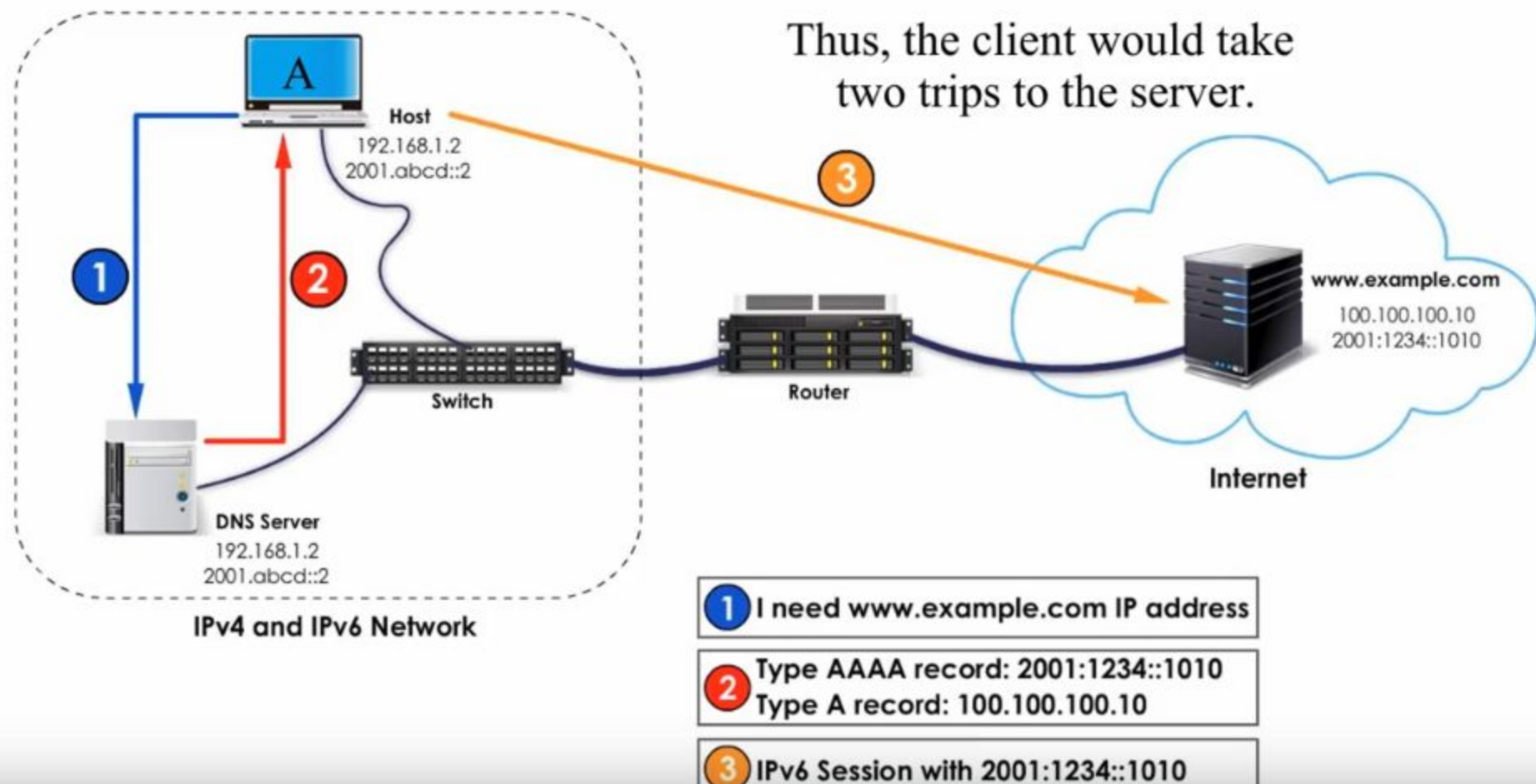
When IPv6 connection failed,  
the client would try again to  
establish the connection using IPv4.



1 I need www.example.com IP address

2 Type AAAA record: 2001:1234::1010  
Type A record: 100.100.100.10

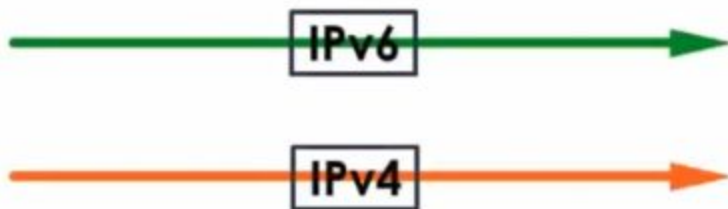
3 IPv6 Session with 2001:1234::1010







Happy Eyeballs



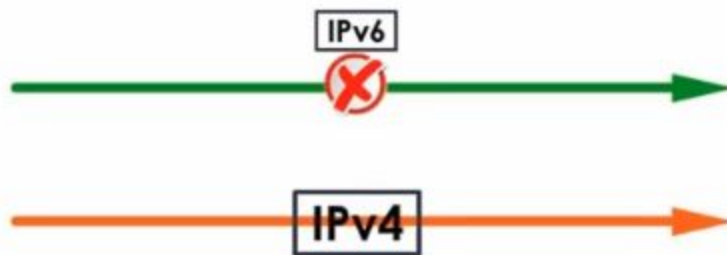
Internet



After 300ms



Happy Eyeballs



Internet





After 300ms

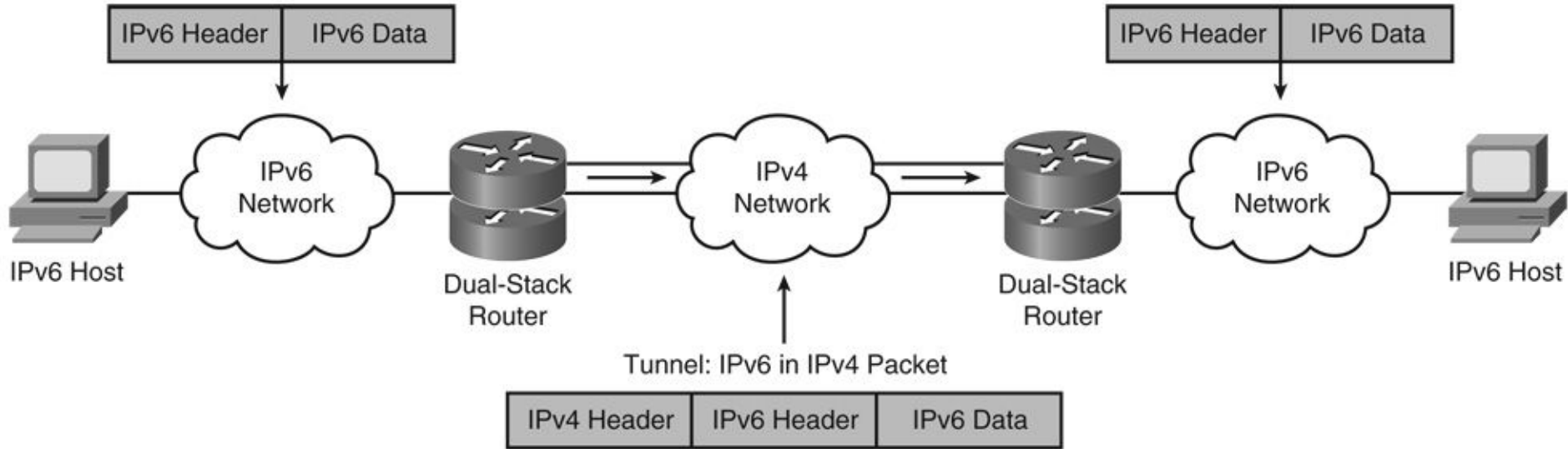


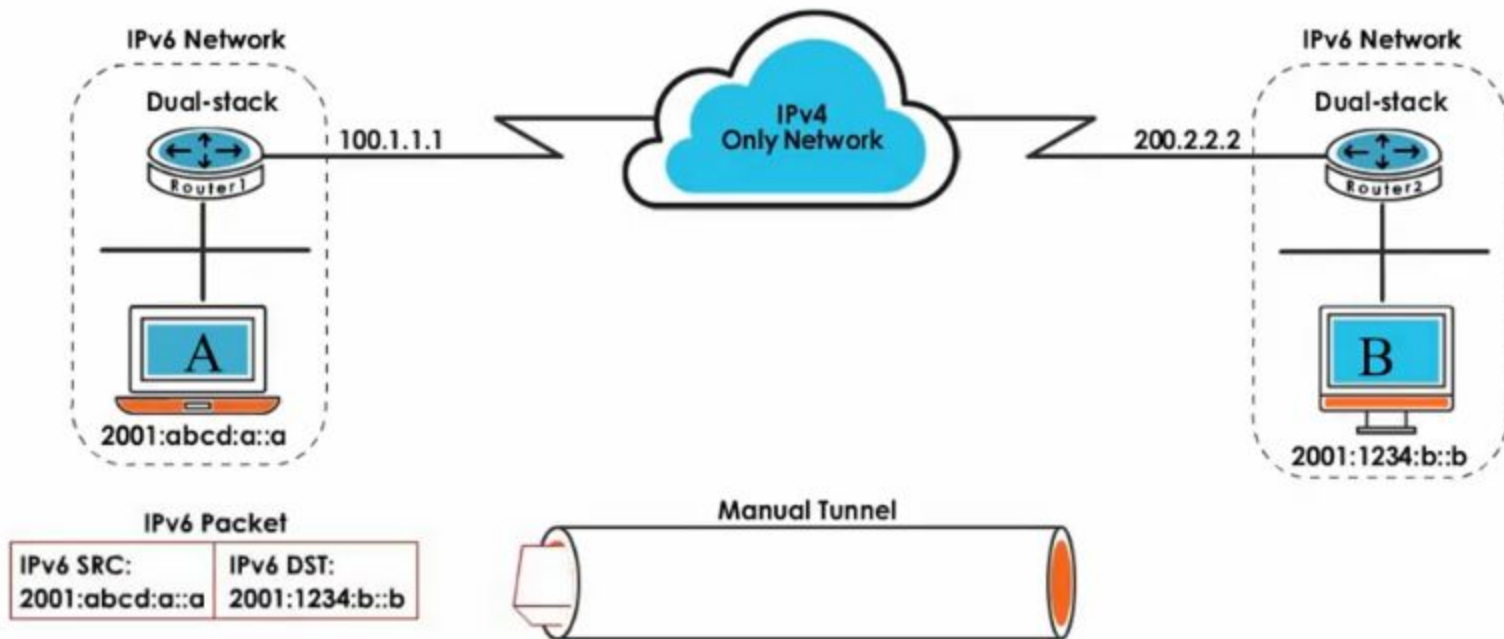
Happy Eyeballs

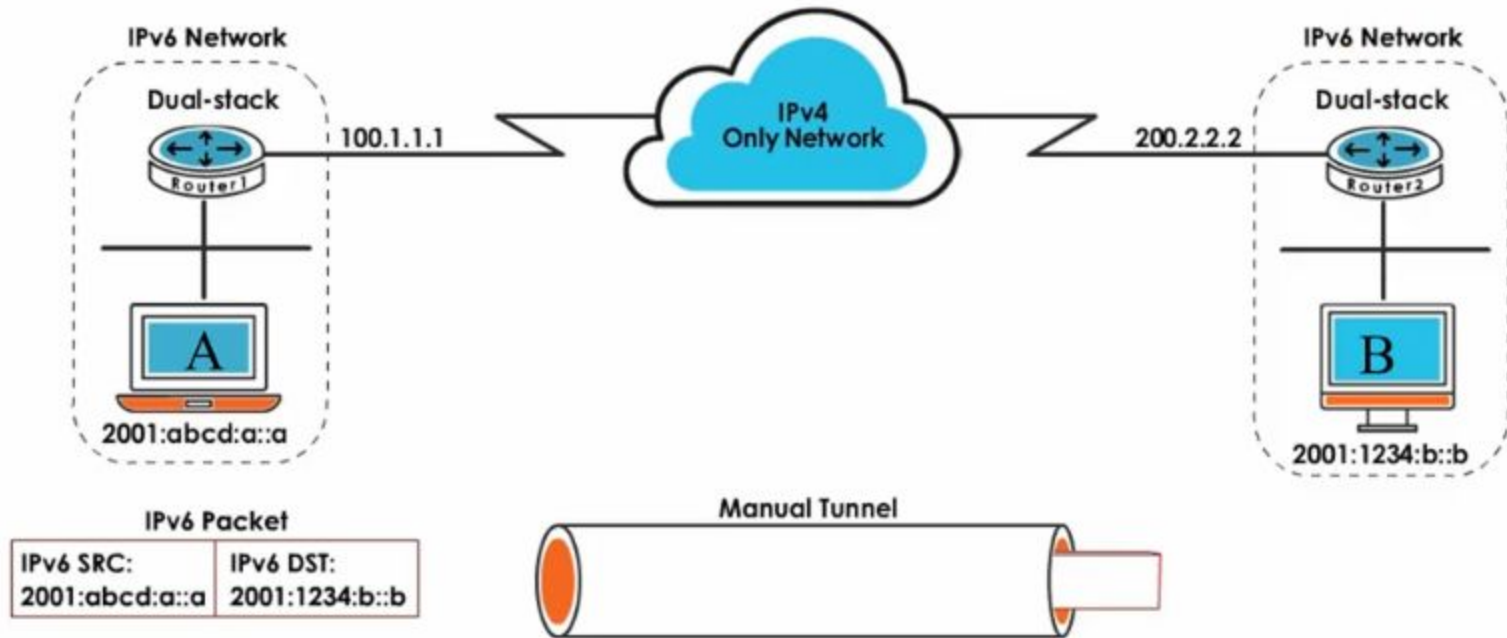


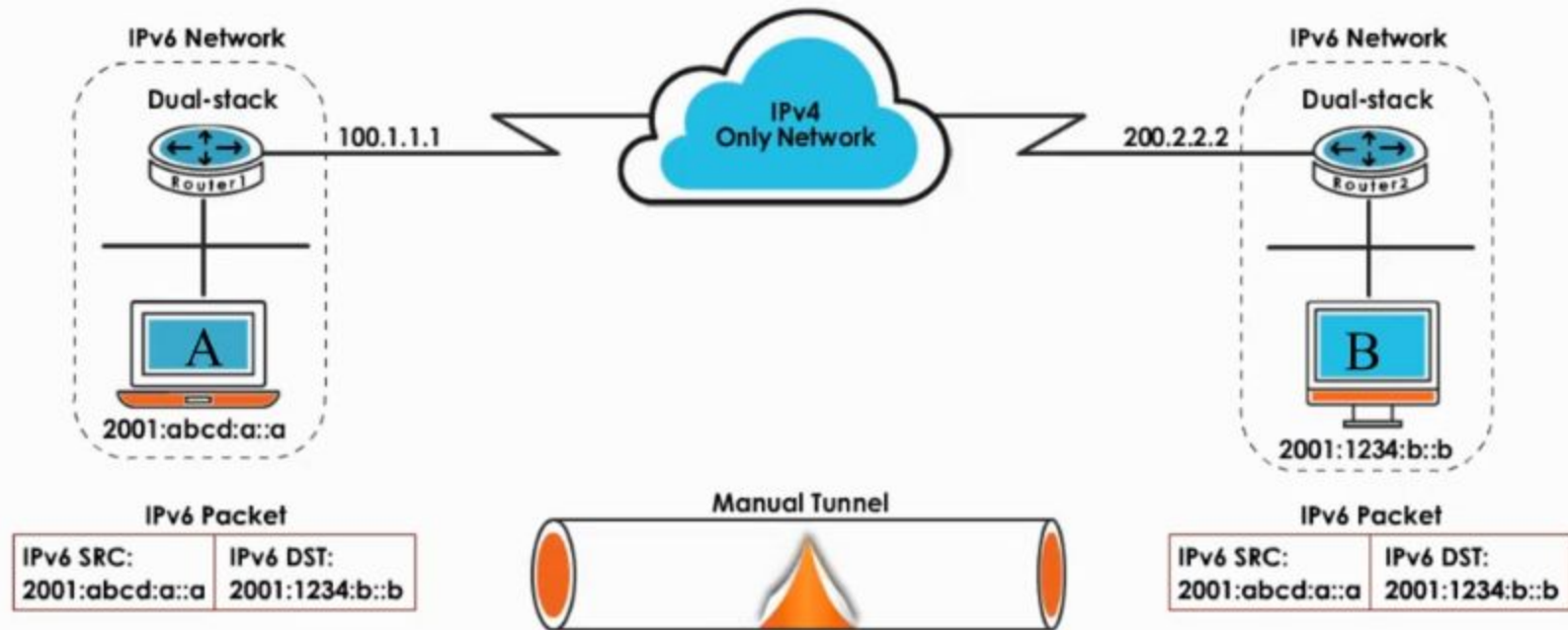
Internet

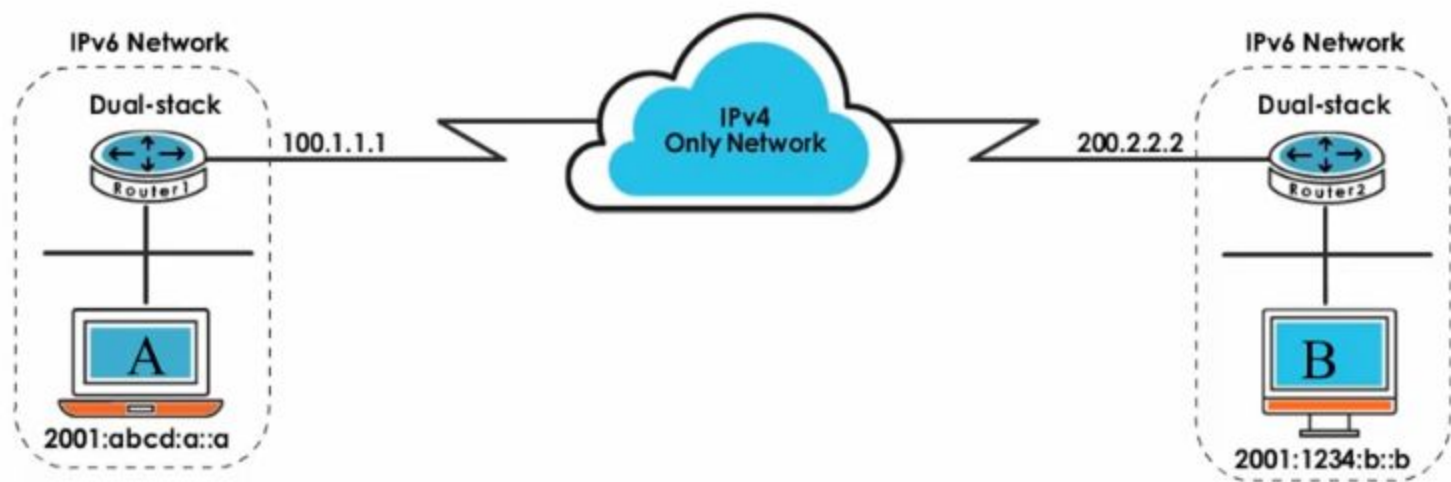
# Transition: Tunneling











IPv6 Packet

IPv6 SRC: 2001:abcd:a::a	IPv6 DST: 2001:1234:b::b
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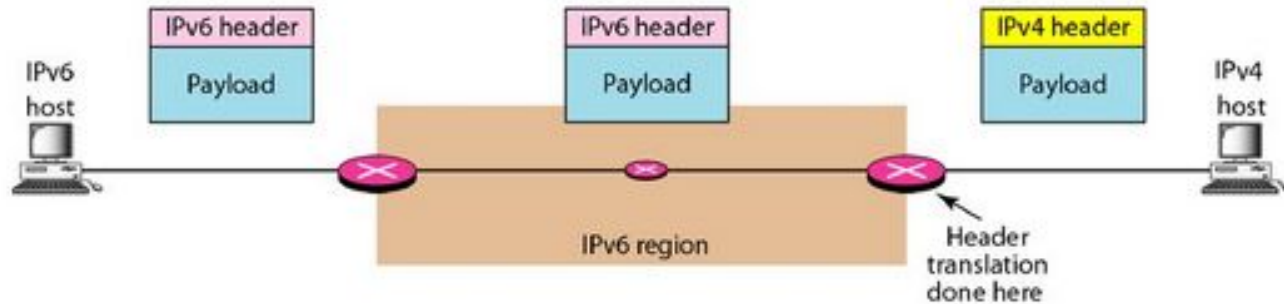


IPv6 Packet

IPv6 SRC: 2001:abcd:a::a	IPv6 DST: 2001:1234:b::b
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# Transition: Header Translation



# RULES FOR HEADER TRANSLATION:

- IPv6 address is changed to IPv4 address by extracting rightmost 32 bits.
- The value of IPv6 priority field is discarded
- The type of service field in IPv4 is set to zero
- The checksum is calculated for IPv4 and placed in corresponding field
- IPv6 flow label is ignored
- Compatible extension headers are converted to options and inserted in the IPv4 header. Some may have to be dropped
- Length of IPv4 header is calculated and inserted into the corresponding field.
- Total length of IPv4 packet is calculated and inserted in the corresponding field