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Exercise Count the number of network attached devices you have at home

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Unless the gateway is intelligent enough to realise this is an FTP exchange, look inside the data and know where the IP addresses are to be found (in the application layer data) and rewrite them (in the application layer data) the addresses will remain untranslated and the protocol will fail

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Exercise Read about FTP, *Universal Plug and Play* (UPnP) and the *Simple Service Discovery Protocol* (SSDP)

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Exercise Read RFC6598 and about 100.64.0.0/10

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- Difficulty of making end-to-end connections when both ends are behind a NAT gateway (e.g., Skype, SIP)
- Loss of “an IP address identifies a host uniquely”: a problem for law enforcement

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Exercise Read about port forwarding (later)

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Exercise Read about STUN

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Even to the extent of using multi-level NAT (NAT within NAT)!

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We need a more radical solution

IPv6

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Exercise Find out about IPv5. And IPv0-IPv3

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- simplify the protocol so routers can process packets faster
- provide security and authentication
- pay proper attention to type of service (DS)

IPv6

- have better multicasting support

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- have mobile hosts with fixed IP addresses

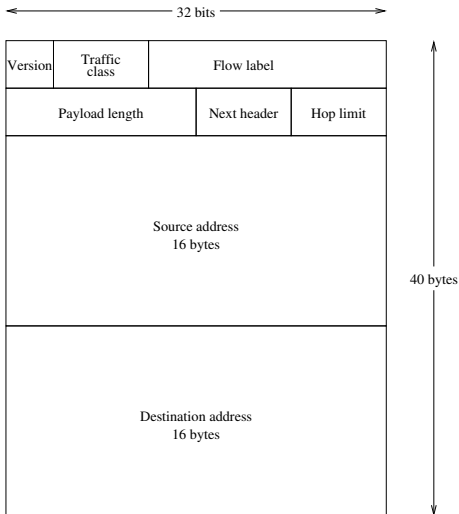
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- allow room for evolution of the protocol
- permit IPv4 and IPv6 to coexist during the transition

IPv6



IPv6 Header

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- Version, 4 bits. The number 6. This is identical in position to IPv4 and can be used to distinguish packets in mixed-version environments. Additionally, in an Ethernet frame, IPv4 has protocol number 0800, while IPv6 is 86DD, but remember you might be using a different physical layer that does not give the type of its data

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- Traffic class, 8 bits. Like TOS (DS) in v4
- Flow label, 20 bits. Allows routers to recognise related packets in a single flow and treat them identically (and so faster)

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- Hop limit, 8 bits. The TTL field, renamed to make it clear how it is actually used

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There are unicast, multicast and anycast addresses: details later

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Or:

```
1111111010000000 0000000000000000 0000000000000000  
0000000000000000 0000001000011100 1100000011111111  
1111111010100011 1001100111110100
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2001:0630:00e1::/48

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Exercise Check my arithmetic

Exercise Look up the IPv6 address of `facebook.com`

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Every IPv6 host is required to do path MTU discovery

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Exercise Reflect on this: aren't sessions supposed to be done in a different layer?

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No checksum field: there are checksums in other layers and networks are moderately reliable nowadays. The protocol designers thought that yet another checksum would not be helpful here

Also we don't have to recompute a checksum in every router as the TTL decreases. Again, faster

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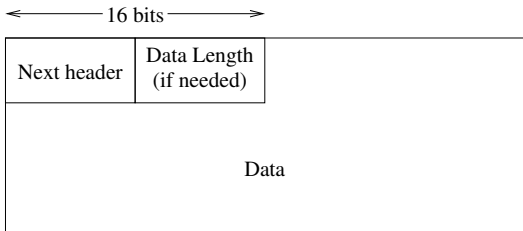
v6 addresses are 4 times the length, but the header is only twice as long

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The *next header* field daisy-chains options, called *extension headers*, or gives the protocol (TCP, UDP, etc.) of the next layer

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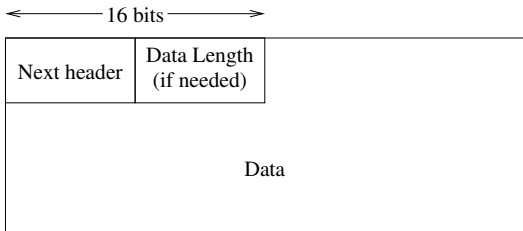
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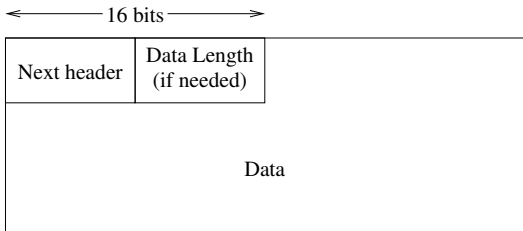


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Option Header

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Furthermore, most options are not even looked at by routers: again to get faster processing in the routers

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Optional headers include:

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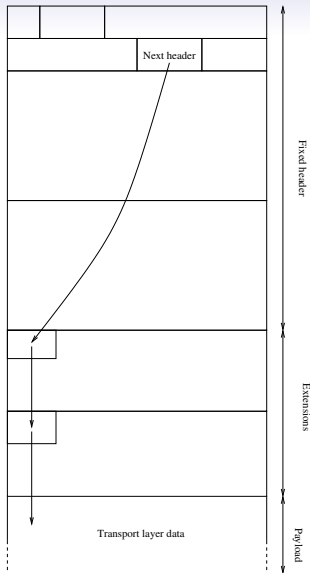
- Routing options: c.f., loose source routing in IPv4
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- And others

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Note the type of the header option is given in the *previous* header option, or the main IPv6 header for the first option



IPv6 options daisychain

IPv6 Jumbograms

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We'll see later that UDP and the handshake TCP MSS have only 16 bit length fields (64k bytes), so tweaks are needed there, too (RFC2675)

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Exercise Frame CRC algorithms were designed when frames were small. Read about the problems they have with jumbograms

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Even though the majority of modern routers and end hosts contain the necessary IP (and transport) level software support

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Though, by design, the two protocols can run side-by-side on the same networks

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UK is 38th; half of countries are under 1%

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But they are all complicated and unsatisfactory, for the same reasons NAT is unsatisfactory

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Transition to v6

Exercise Read about NAT64 (RFC6146) and DNS64 (RFC6147) for connecting IPv6-only clients to IPv4 servers

Exercise Read about *IPv4 mapped addresses*, that allows server code that is purely IPv6, but accepts IPv4 client packets

Exercise Read about 464XLAT (RFC6877) for IPv4-only clients that translates IPv4 addresses to IPv6 addresses for transport and then back to IPv4 addresses for the destination server

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Exercise RFC6177 suggests giving home users a /56 network. How many host addresses does this correspond to?