FRANKFURT UNIVERSITY OF APPLIED SCIENCES

IoT Project
IPv6

Prof. Dr. Oliver Hahm
Frankfurt University of Applied Sciences
Faculty 2: Computer Science and Engineering
oliver.hahm@fb2.fra-uas.de
https://teaching.dahahm.de

FRANKFURT UNIVERSITY OF APPLIED SCIENCES

Agenda

Agenda

A "new" Internet Protocol

Limitations of IPv4

- The IPv4 **packet format** has drawbacks
- **Newer hardware** obsoletes some of the design choices
- The **address space** is exhausted [1]

A very short history of IPv6

- In 1992 the IETF working group **IPng** proposed seven ideas for a successor
- In 1995 IPv6 was specified as RFC 2460
- In 2011 all major OS provide a product-ready IPv6 implementation
- In 2018 only $\approx$ 25 % of all autonomous systems advertise IPv6 prefixes

[1] The IANA assigned the last free IPv4 address block to a Regional Internet Registry (RIR) in 2011.

IPv6 Improvements

- **Addressing**
  - $3.4 * 10^{38}$ addresses should suffice for the foreseeable future
  - Simplifies address hierarchies
  - More than one address per interface is common
- **Simplified administration**
  - Auto-configuration without additional protocols (like **DHCP** for IPv4)
  - Renumbering of entire networks is much easier
- **Security**
  - The **IPsec** header extension enables authentication, integrity, and confidentiality
- **Simplified format**
  - Lean header with a fixed size plus optional next headers with a standardized format
  - No checksum, no fragmentation
- **Improved Support for mobile applications**
  - Improved support for **multicast** and **anycast**
  - Support for mobile devices

Representation of IPv6 Addresses

- Rules for simplification (RFC 5952):
  - **Leading zeros** within a block may be **omitted**
  - Successive blocks with value 0 (= 0000), may be omitted **exactly once within an IPv6 address**
    - If blocks are omitted, this is indicated by **two consecutive colons**
    - If several groups of null blocks exist, it is recommended to shorten the group with the most null blocks
- Example:
  - The IPv6 address of `j.root-servers.net` is:
    `2001:0503:0c27:0000:0000:0000:0002:0030`
    $\Longrightarrow$ `2001:503:c27::2:30`

Notation of IPv6 addresses (URLs)

- IPv6 addresses are enclosed in square brackets
- Port numbers are appended outside the brackets
  `http://[2001:500:1::803f:235]:8080/`
- This prevents the port number from being interpreted as part of the IPv6 address

Structure of IPv6 Addresses

- IPv6 addresses consist of two parts

64 Bits	64 Bits
Network Prefix	Interface Identifier
2001:638:208:ef34	:0:ff:fe00:65

1. **Prefix** (Network Prefix)
   - Identifies the network
2. **Interface identifier** (Interface ID)
   - Identifies a network device in a network
   - Can be manually set, assigned via DHCPv6 or calculated from the MAC address of the network interface
   - If the interface identifier is calculated from the MAC address, it is called **Extended Unique Identifier** (EUI)
     - When this is done, the MAC address (48 bits) is converted into a 64-bit address $\Longrightarrow$ **modified EUI-64 address format**

IPv6 Address Types

Described in RFC 4291.

- **Unicast**

  `fc00::/7` (`1111 110`) $\Longrightarrow$ Unique local address, may be routed only in private networks.[2]

  `fe80::/10` (`1111 1110 10`) $\Longrightarrow$ Link local addresses, may not be routed.[2]

  `::1/128` (`0000..1`) $\Longrightarrow$ Loopback address

  `::/128` (`0000..0`) $\Longrightarrow$ Unspecified

  Anything else $\Longrightarrow$ Global unicast address, e.g., `2000::/3` (`2000...` until `3fff...`)

- **Multicast**

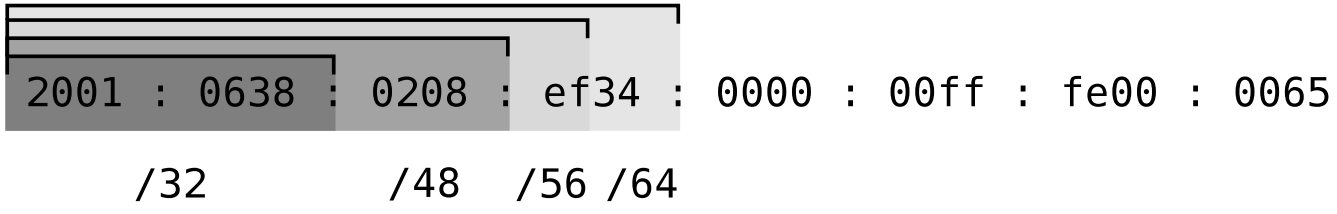
  `ff00::/8` (`1111 1111`) $\Longrightarrow$ Multicast addresses. (No explicit broadcast addresses, but multicast groups for **all nodes** (`ff01::1` and `ff02::1`) and **all routers** (`ff01::2`, `ff02::2` and `ff05::2`).

- **Anycast** $\Longrightarrow$ from Unicast address range

[2] Only valid in the local network, not forwarded by routers in the Internet.

Structure of IPv6 Networks

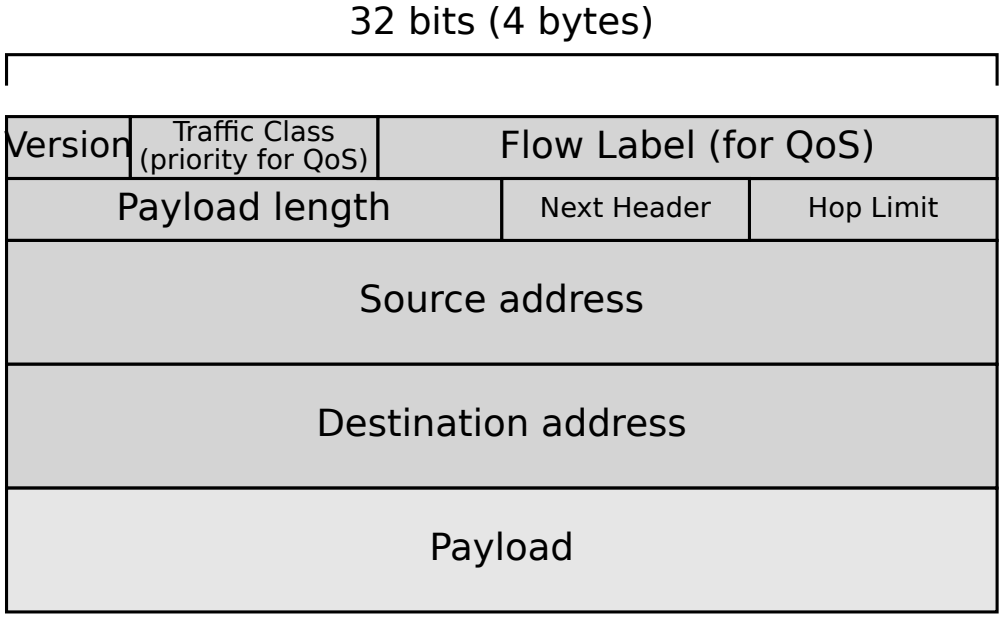
- (Sub-)netmasks do not exist in IPv6
  - The subdivision of address ranges into subnets is done by specifying the **prefix length**
- IPv6 networks are specified in CIDR notation
  - The address of a single device sometimes has /128 attached
  - An example is the loopback address of IPv6: `::1/128`
    - All bits – except the last one – have value 0
      (For IPv4, the loopback address is: `127.0.0.1`)
  - Internet Providers (ISPs) or operators of large networks get the first 32 or 48 bits assigned from a Regional Internet Registry (RIR)
    - The ISPs or network operators split this address space into subnets
    - **End users usually get a /64 or even a /56 network assigned**



Agenda

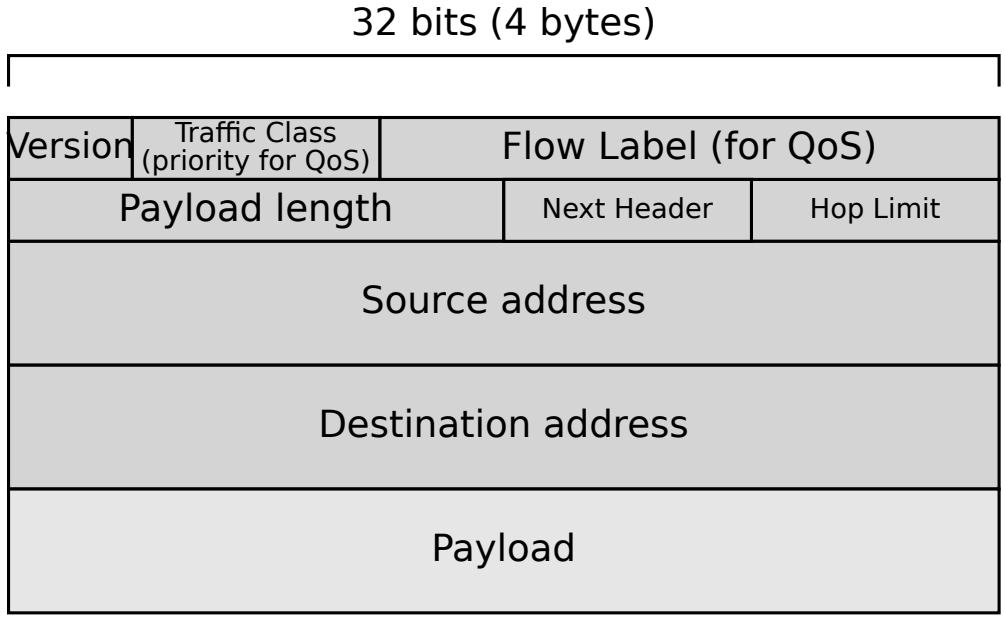
Structure of IPv6 Packets: Design

- The size of the IPv6 header is fixed (320 bits $\Longrightarrow$ 40 bytes)



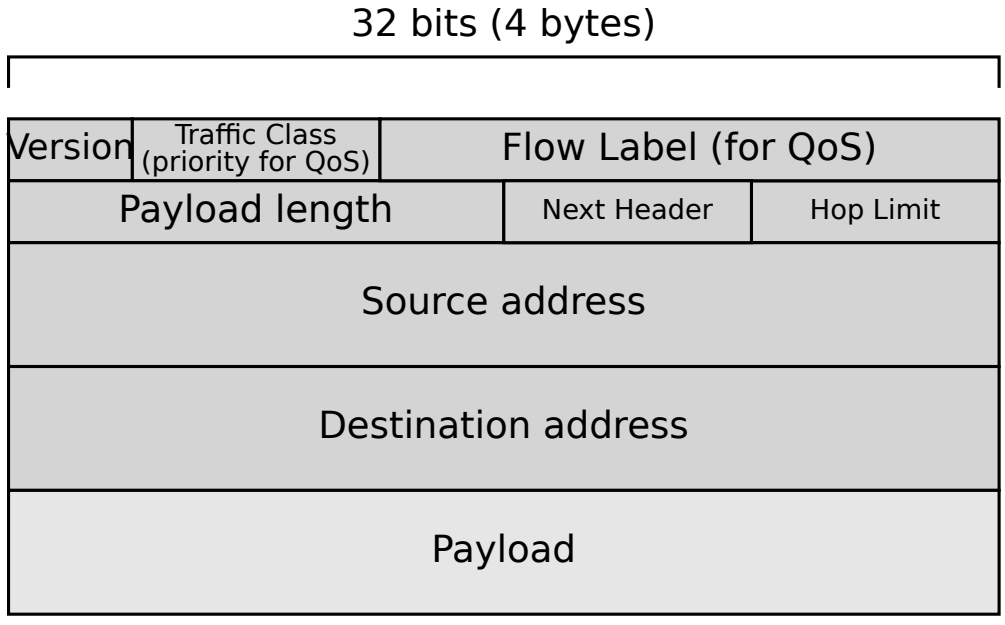
- Simplified package structure, but simple option to add additional (new) features with a chain of extension headers
- No IHL, fragmentation fields, checksum, options, and padding

Structure of IPv6 Packets: Version and QoS



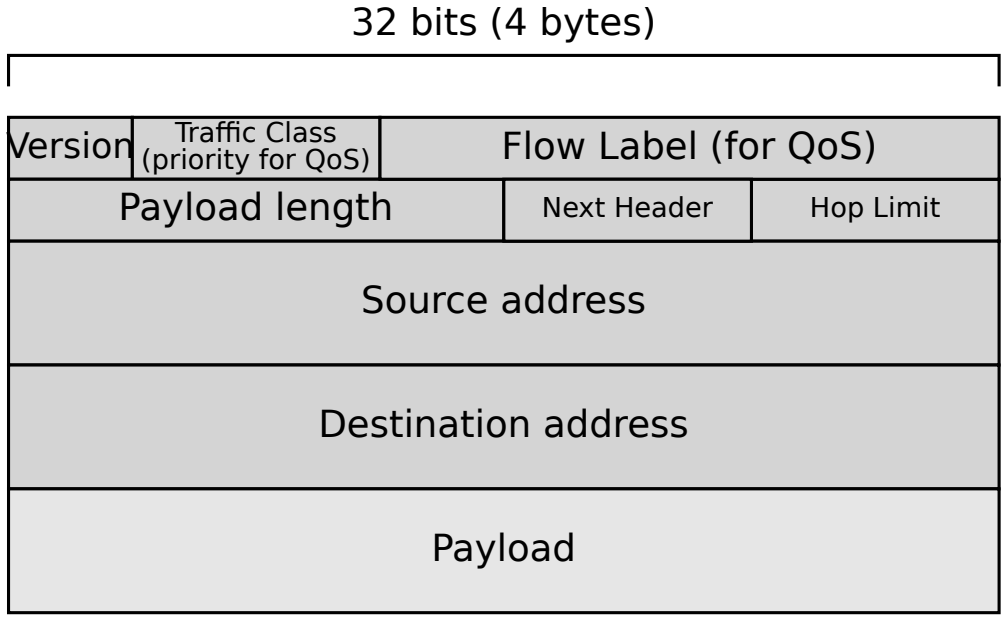
- After the four bit version field, one byte is assigned for DiffServ and Congestion Control
- The 20 bits Flow Label represent an identifier to group packets (e.g., belonging to one stream)

Structure of IPv6 Packets: Payload Length



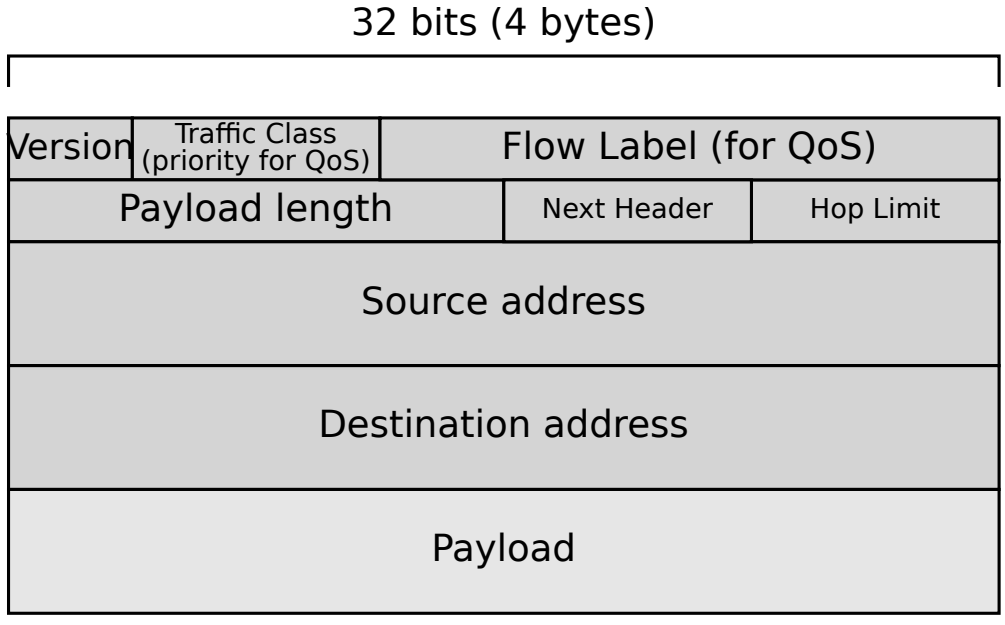
- The 16 bits of the payload length field specify the size of the payload in bytes (octets) including any extension headers
- In the special case of an extension header carries a Jumbo Payload option this field may be 0

Structure of IPv6 Packets: Next Header



- The field **next header** points to an extension header field or identifies the Transport Layer protocol (e.g. TCP = type 6 or UDP = type 17) which is carried in the payload of the packet

Structure of IPv6 Packets: TTL, Addresses, and Payload



- The **hop limit** replaces the TTL field of IPv4
- **Source** and **destination addresses** keep their meaning
- After the address either the data from the transport layer or an extension header follows

Agenda

Link-Local Addresses

- Link-local addresses are valid inside a **local physical network**
- IPv6 uses the prefix `fe80::/10` for link-local addresses
- Are **not guaranteed to be unique** beyond their network segment, i.e., not globally routable
- In IPv6 it can be derived from the MAC address (in absence of privacy extensions)
- A mechanism for **Duplicate Address Detection (DAD)** is mandatory
- A link-local address can serve as a **temporary solution** until a globally routable or private address becomes available

Stateless Auto Address Configuration (SLAAC)

- SLAAC is specified for IPv6 in RFC 2462
- Functioning of SLAAC
  - A host generates a **tentative** link-local address
  - **DAD**: The host sends a **Neighbor Solicitation (NS)** with the chosen IP address as destination address
  - If no host responds to the NS with an **Neighbor Advertisement (NA)** it keeps this address
  - **Router solicitations (RS)** or **Router Advertisements (RAs)** are used to find the responsible router for the network
  - The RA contains the **network prefix** which is used to determine a routable IP address

Any Questions?