IPv6, transition technologies

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Agenda

- History
- IPv6 header
- Addressing Schema
- SLAAC, DHCPv6
- Cooexistence of IPv4 and IPv6
- NAT
- Security

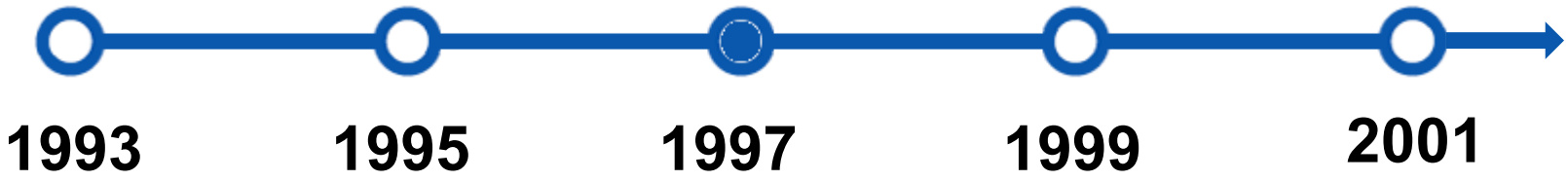
History

- **RFC 1550**: IPng white paper solicitation
- **RFC 1707**: CATNIP
- **RFC 1710**: SIPP
- **RFC 1955**: ENCAPS
- **RFC 1347**: TUBA

History

- **RFC 1883**: Internet Protocol, Version 6 (IPv6) Specification
- **RFC 1884**: IP Version 6 Addressing Architecture
- **RFC 1885**: Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6)

History



- **RFC 1971**: IPv6 Stateless Address Autoconfiguration (1996)
- **RFC 1970:** Neighbor Discovery for IP Version 6 (IPv6) (1996)
- **RFC 2133**: Basic Socket Interface Extensions for IPv6 (1997)

- **RFC 2131**: Dynamic Host Configuration Protocol (1997)

History

- **RFC 2462**: IPv6 Stateless Address Autoconfiguration (1998)
- **RFC 2461:** Neighbor Discovery for IP Version 6 (IPv6) (1998)
- **RFC 2553**: Basic Socket Interface Extensions for IPv6 (1999)

- **RFC 2740**: OSPF for IPv6 (1999)

History

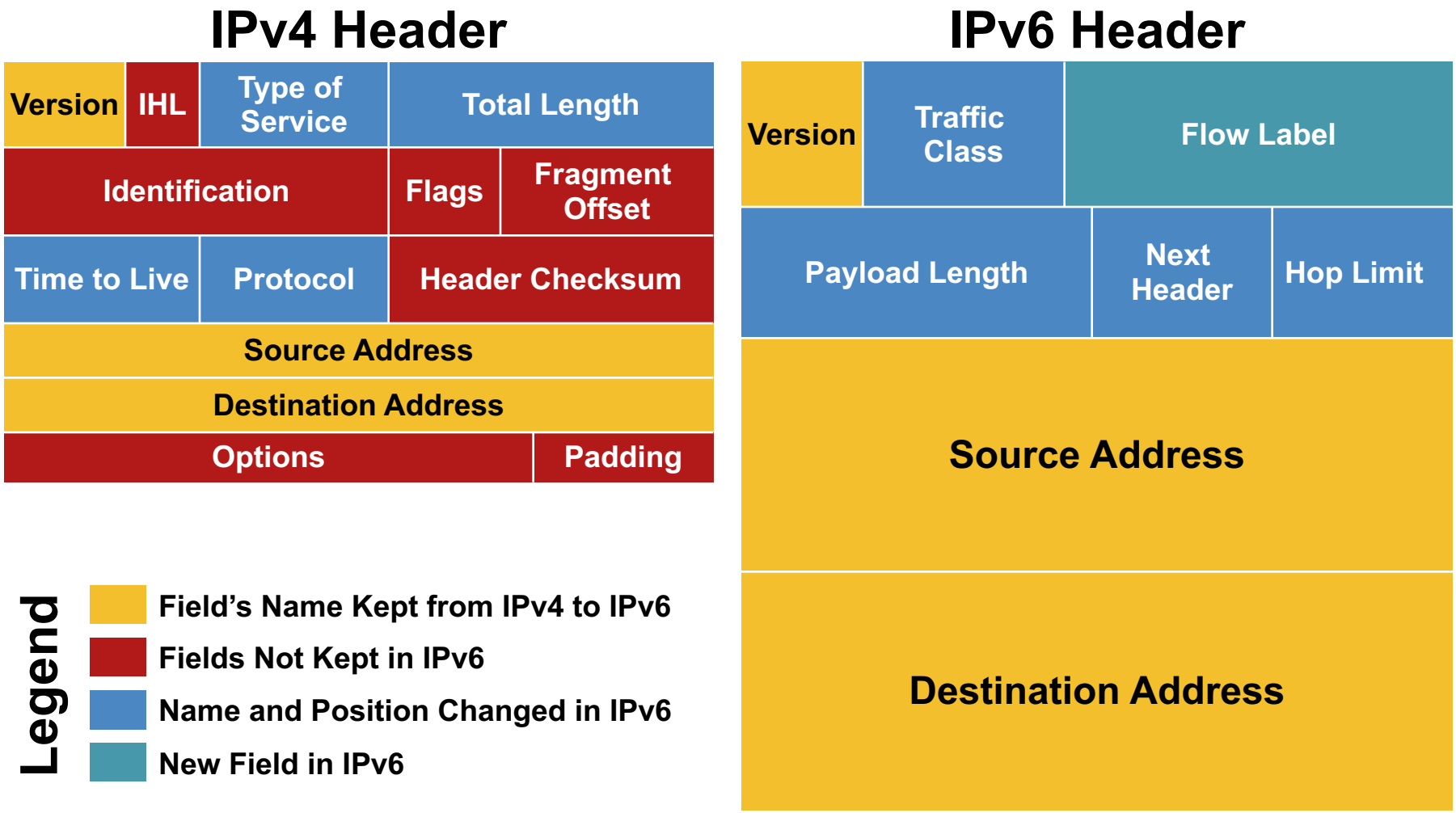
- **RFC 3041**: Privacy Extensions for Stateless Address Autoconfiguration in IPv6 (2001)
- **RFC 3315:** Dynamic Host Configuration Protocol for IPv6 (DHCPv6) (2003)
- **RFC 6106**: IPv6 Router Advertisement Options for DNS Configuration (2011)

„The nice thing about standards is that you have so many to choose from.“

Andrew Tanenbaum

IPv6 Packet

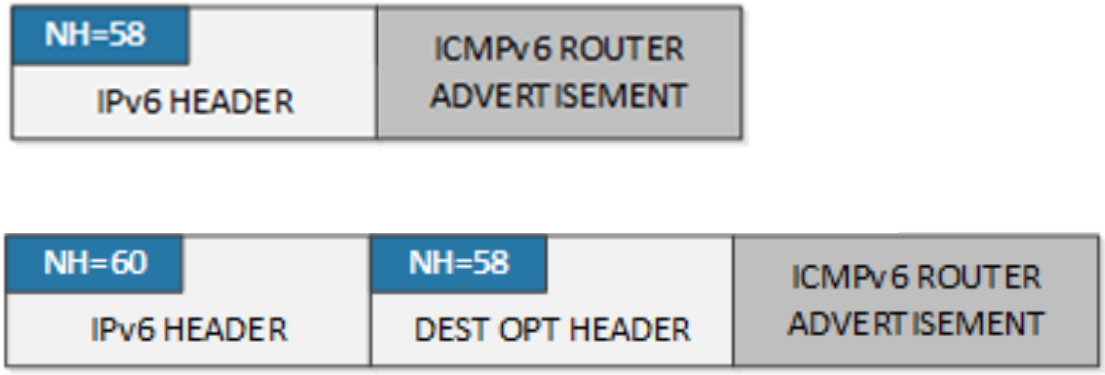
IPv6 Header


IPv4 Header
Version
IHL
Type of Service
Total Length
Identification
Flags
Fragment Offset
Time to Live
Protocol
Header Checksum
Source Address
Destination Address
Options
Padding
IPv6 Header
Version
Traffic Class
Flow Label
Payload Length
Next Header
Hop Limit
Source Address
Destination Address
Legend
Field's Name Kept from IPv4 to IPv6
Fields Not Kept in IPv6
Name and Position Changed in IPv6
New Field in IPv6

Extension headers

Extension headers

- Several IPv4 features have been moved to extension headers
- **Extension headers** offers future extension, however, processing chain of extension headers is complicated



Extension headers

- Hop-by-Hop, Routing
- Fragmentation
- AH/ESP
- No Next Header
- Destination Options
- Protocol (TCP, UDP, EIGRP …)

- RFC 6564: A Uniform Format for IPv6 Extension Headers
- RFC 7045: Transmission and Processing of IPv6 Extension Headers

IPv6 addressing

IPv6 Address Representation

- $x:x:x:x:x:x:x:x$, where x is a 16-bit hexadecimal field
- Huge mess with address representation

2001:db8:0:0:1:0:0:1	2001:0db8:0:0:1:0:0:1
2001:db8::1:0:0:1	2001:db8::0:1:0:0:1
2001:0db8::1:0:0:1	2001:db8:0:0:1::1
2001:dB8:0000:0:1::1	2001:DB8:0:0:1::1

- **RFC 5952**: A Recommendation for IPv6 Address Text Representation (2010)
  - 2001:db8::1:0:0:1

RFC 5952

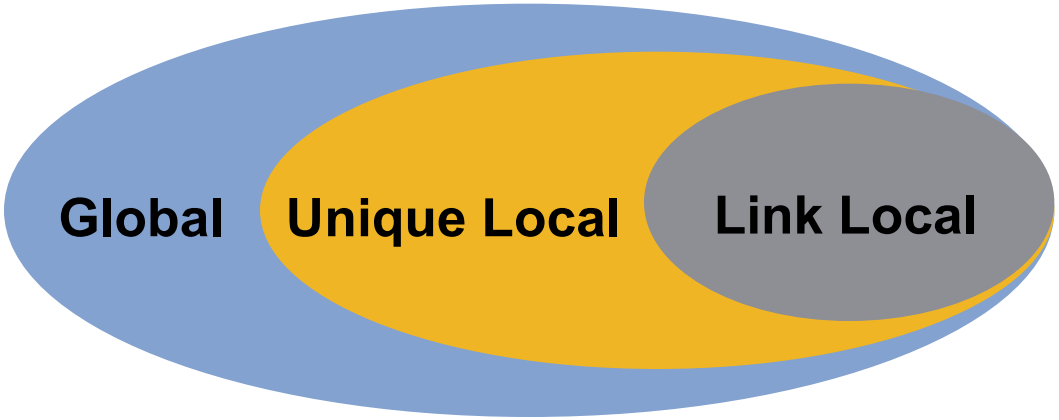
- Leading zeros MUST be suppressed
  - `2001:0db8::0001` → `2001:db8::1`
- A single 16- bit 0000 field MUST be represented as 0
- :: → **Shorten as Much as Possible**
  - When the length of the consecutive 16-bit 0 fields are equal (i.e., 2001:db8:0:0:1:0:0:1), the first sequence of zero bits MUST be shortened.
  - :: MUST NOT be used to shorten just one 16-bit 0 field
- The characters MUST be represented in lowercase.

IPv6 Address Representation

- Different and very open representative create several problems for log analysis
  - `grep` could be a problem – every log use different IPv6 address syntax
- Larger logfiles
- Some apps cannot log IPv6 addresses at all
- Necessary to move from NetFlow5 to NetFlow9

Addressing Model

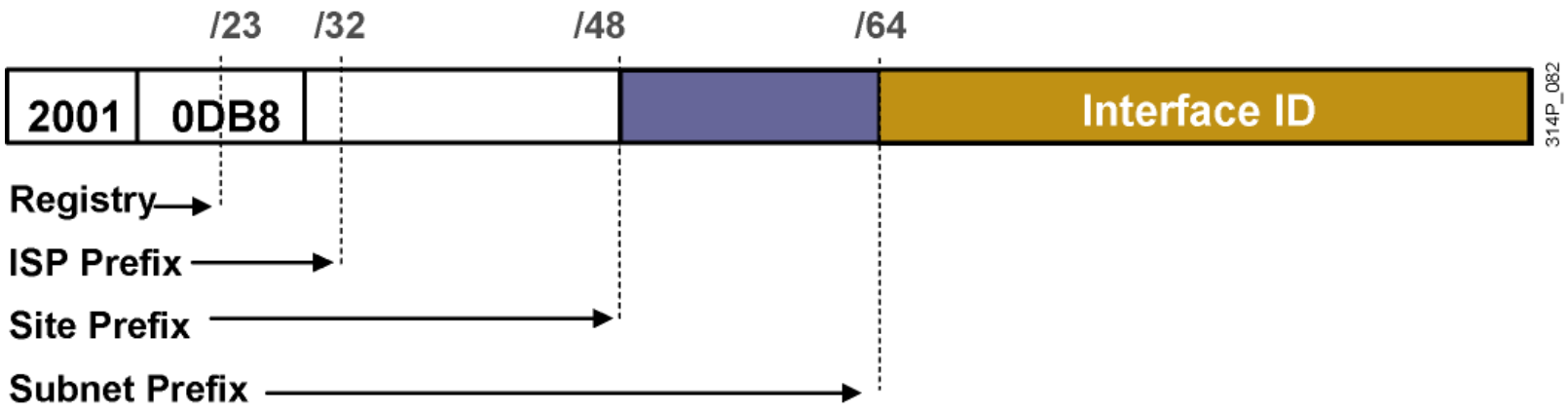
- Addresses are assigned to **interfaces**
- Interface can have multiple addresses
  - In IPv4, interface has (usually) only 1 address
- Addresses have scope
  - Link Local
  - Unique Local
  - Global
- Addresses have lifetime
  - Valid and preferred lifetime
  - Used in autoconfiguration



Addressed Overview

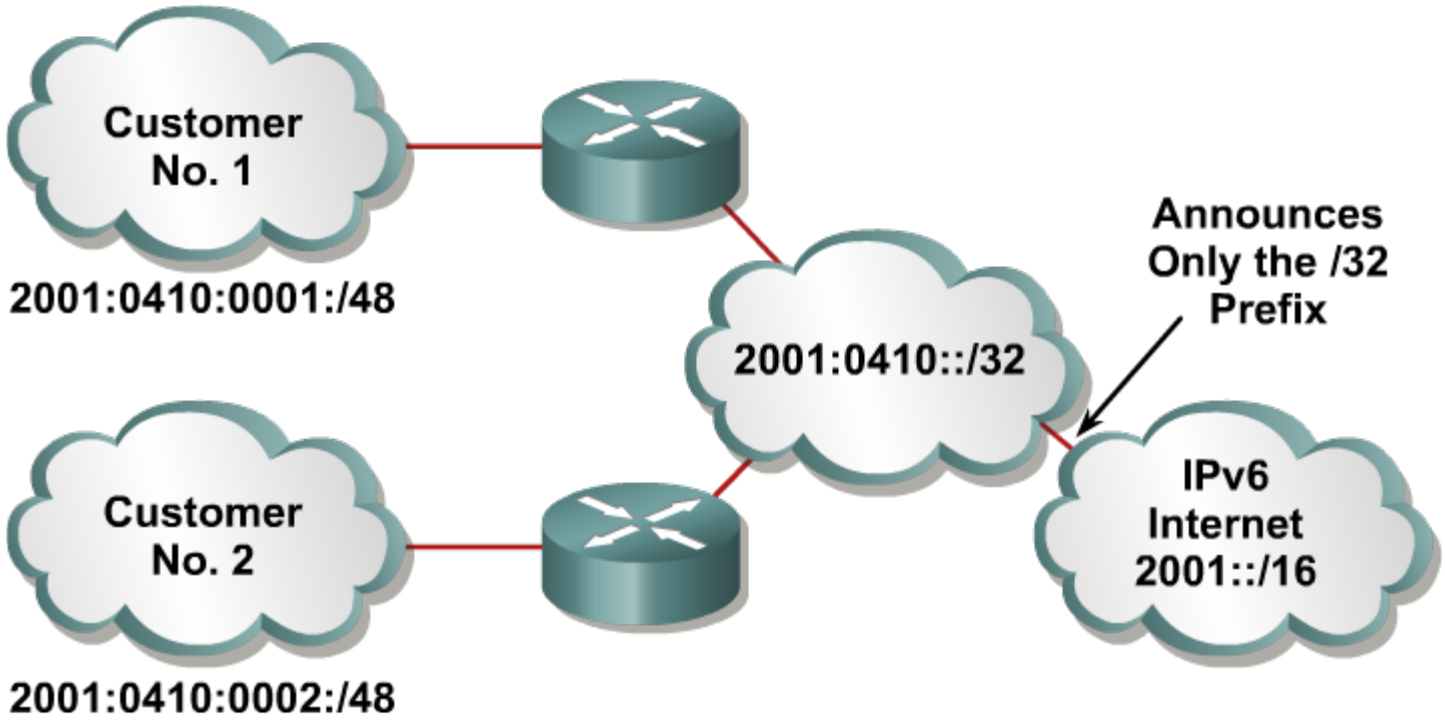
- As described in RFC 4291:
  - **::/128** Not specified address
  - **::0/0** Default-gateway
  - **::1/128** Loopback
  - **ff00::/8** Multicast
  - **fe80::/10** Link-Local Unicast
  - **fc00::/7** Unique Local Unicast, RFC 4193
  - **::ffff:A.B.C.D** IPv4-mapped address
  - All others Global Unicast – with some exceptions (site local, documentation prefix, 6to4 prefix ...)

Global Unicast and Anycast Addresses



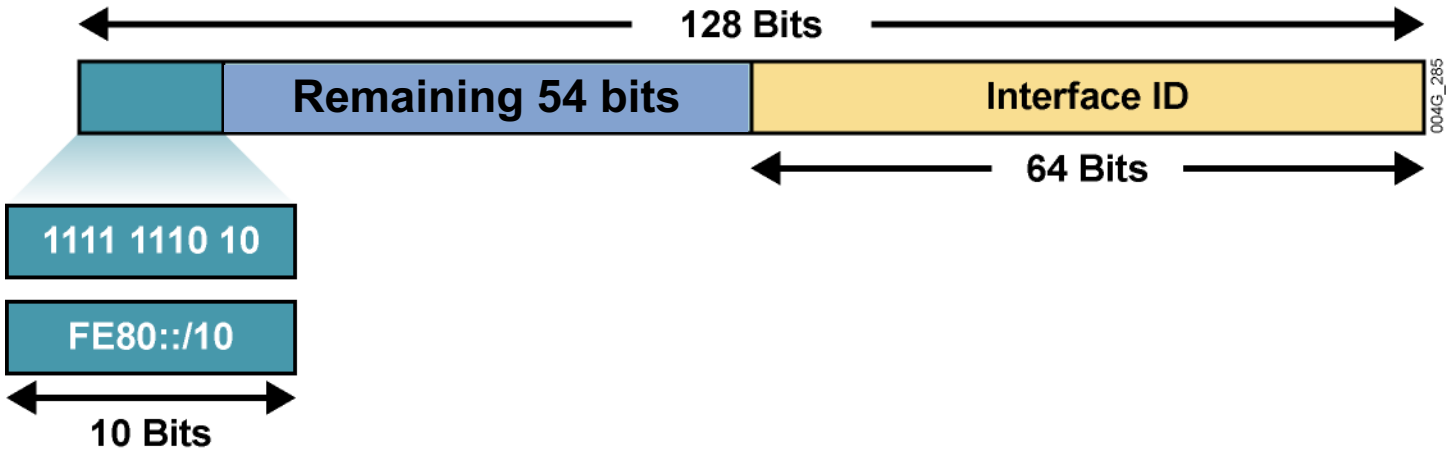
- Prefix and subnet ID lengths are not fixed
- Interface ID is generally 64 bits

Address Aggregation



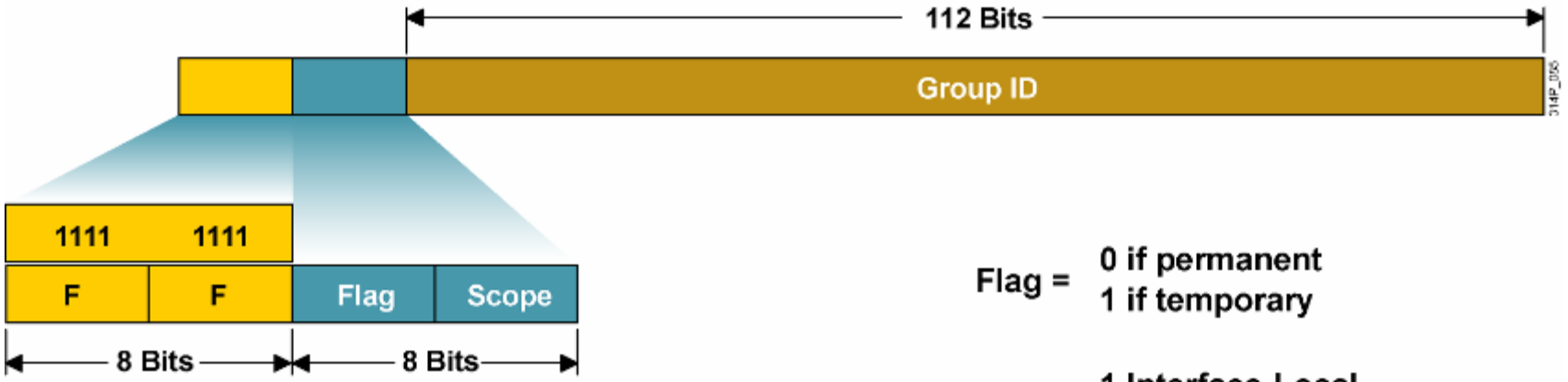
- Aggregation of prefixes announced in the global routing table – similar to classful routing
- Efficient and scalable routing

Link-Local Address



- Mandatory address
- Unique and valid only on link
- Zones ID

IPv6 Multicast Addresses



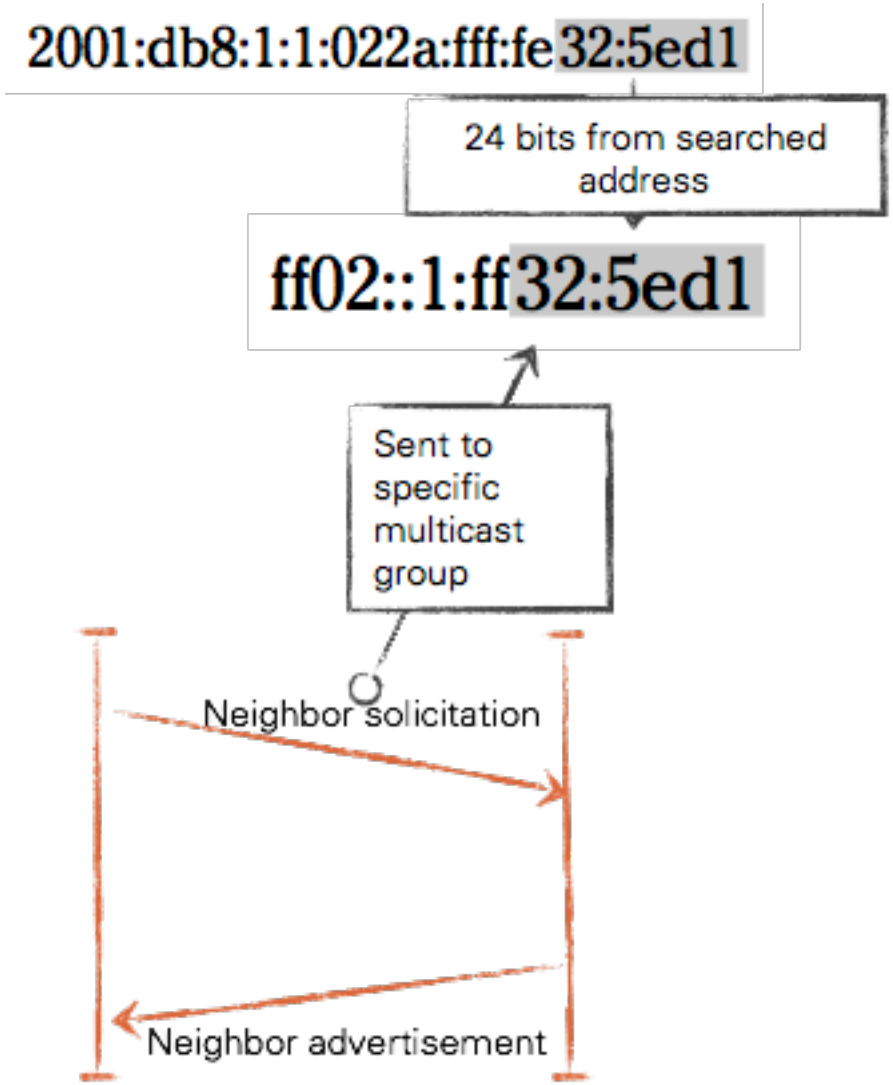
- IPv6 heavily uses multicast
  - Replaces „*broadcast*“
  - Prefix ff00::/8

SLAAC

ICMPv6

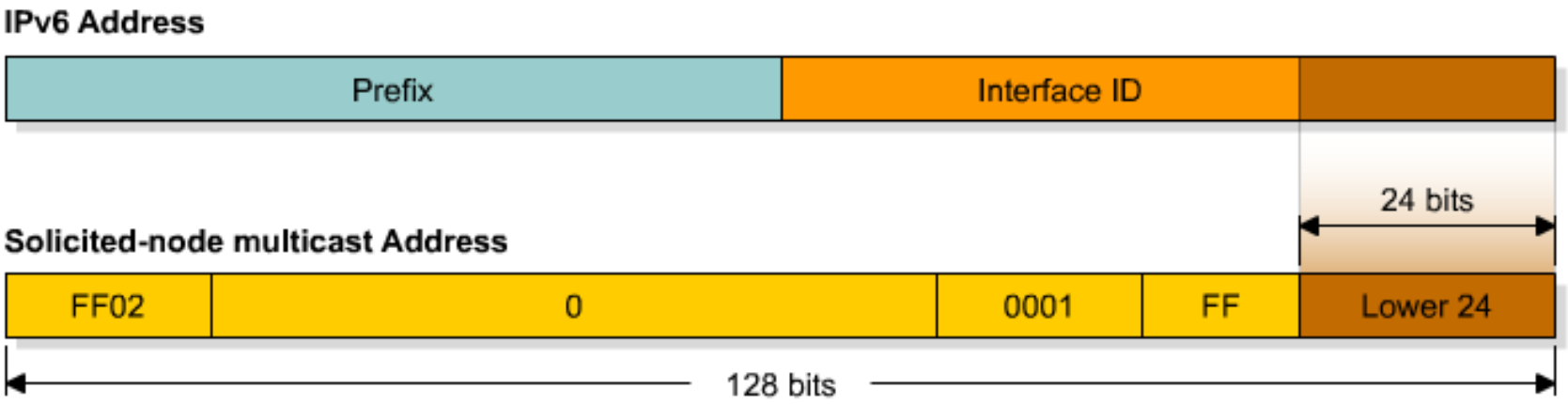
- *ICMPv6 is more important than ICMP for IPv4!!!*
- Supports all messages as ICMP
  - Destination Unreachable, Packet Too Big, Time Exceeded, Parameter Problem, Echo/Echo Reply, Redirect
  - Add new messages
    - Router Solicitation, Advertisement (plug-an-play configuration)
    - Neighbor Solicitation, Advertisement (ARP replacement)
- Added features are used for:
  - Finding routers
  - IPv6 plug-an-play configuration
  - IPv6 address to MAC address translation
  - **Duplicate IPv6 address detection**

NS/NA



ff02:0:0:0:0:1:ff00::/104

Solicited-Node Multicast Address



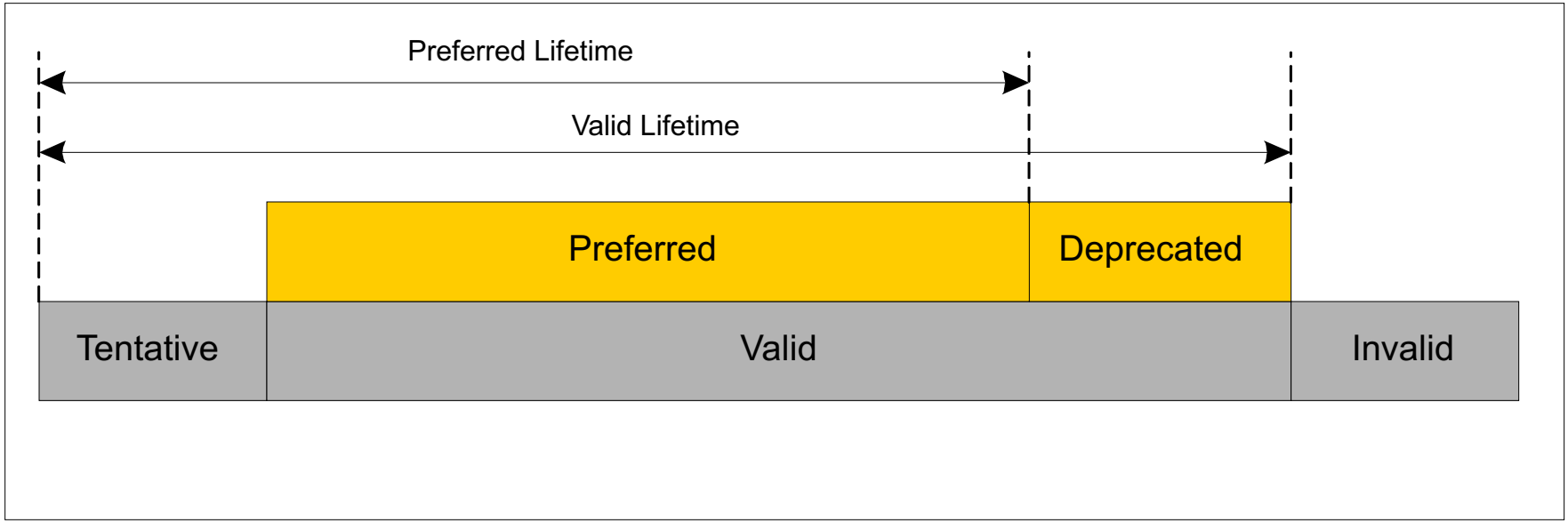
- **Solicited-node multicast address** consists of prefix ff02::1:ff:/104 + lower 24 bits corresponding unicast or anycast address of the node
- Address with link-local scope

Autoconfigured Addresses States

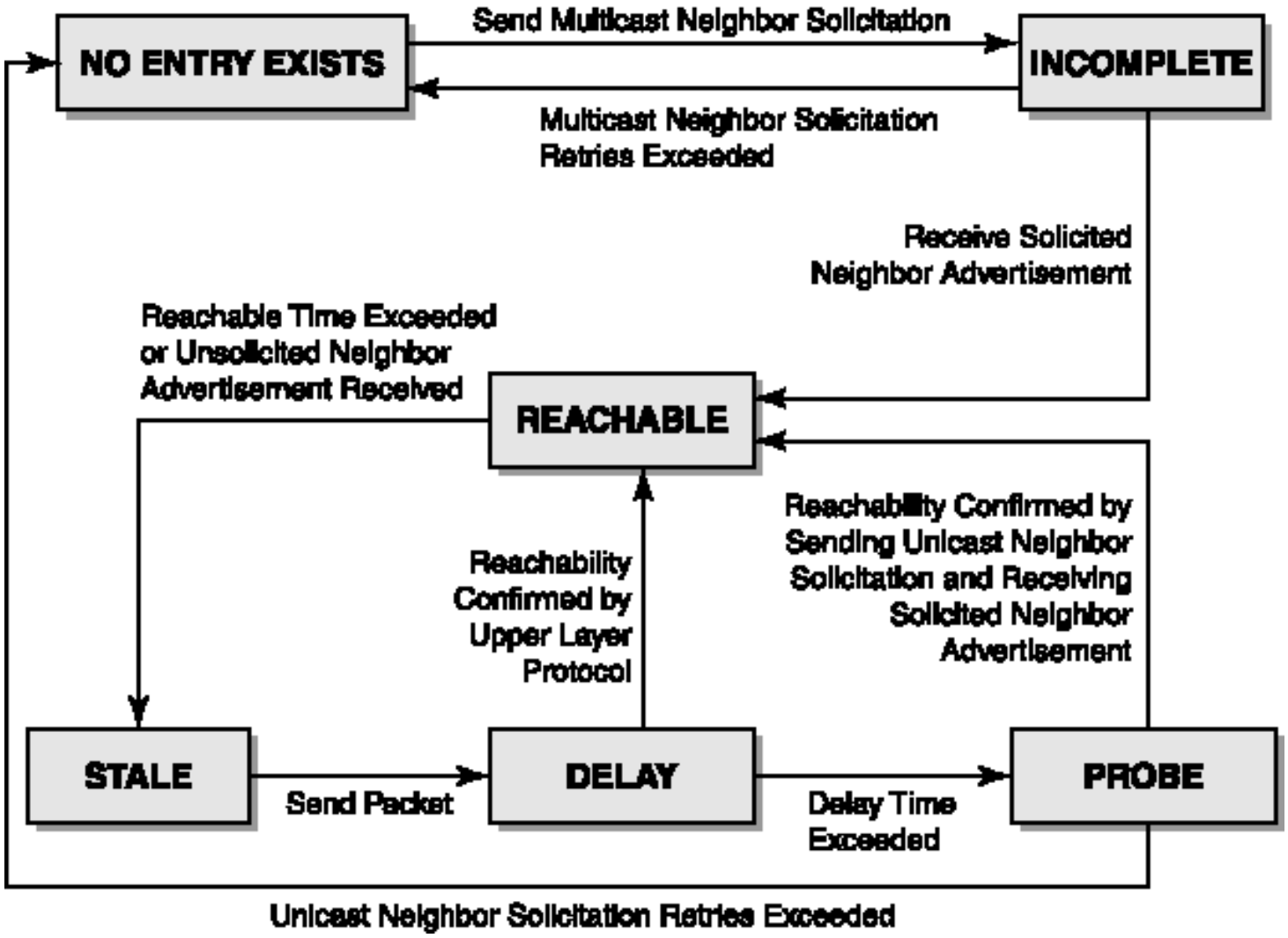
- **Tentative**
  - Duplicate address Detection phase
  - Unicast communication is forbidden
  - Multicast communication – only Neighbor Advertisement
- **Valid**
  - Address is unique and can be used
  - Valid contains another two states: **Preferred** and **Deprecated**
    - Preferred – address is valid
    - Deprecated – address is valid, but can not be used for a new connection, only existing connection can be accepted
- **Invalid**
  - After expiration of Valid Lifetime timer
  - Address cannot be used

Autoconfigured Addresses States

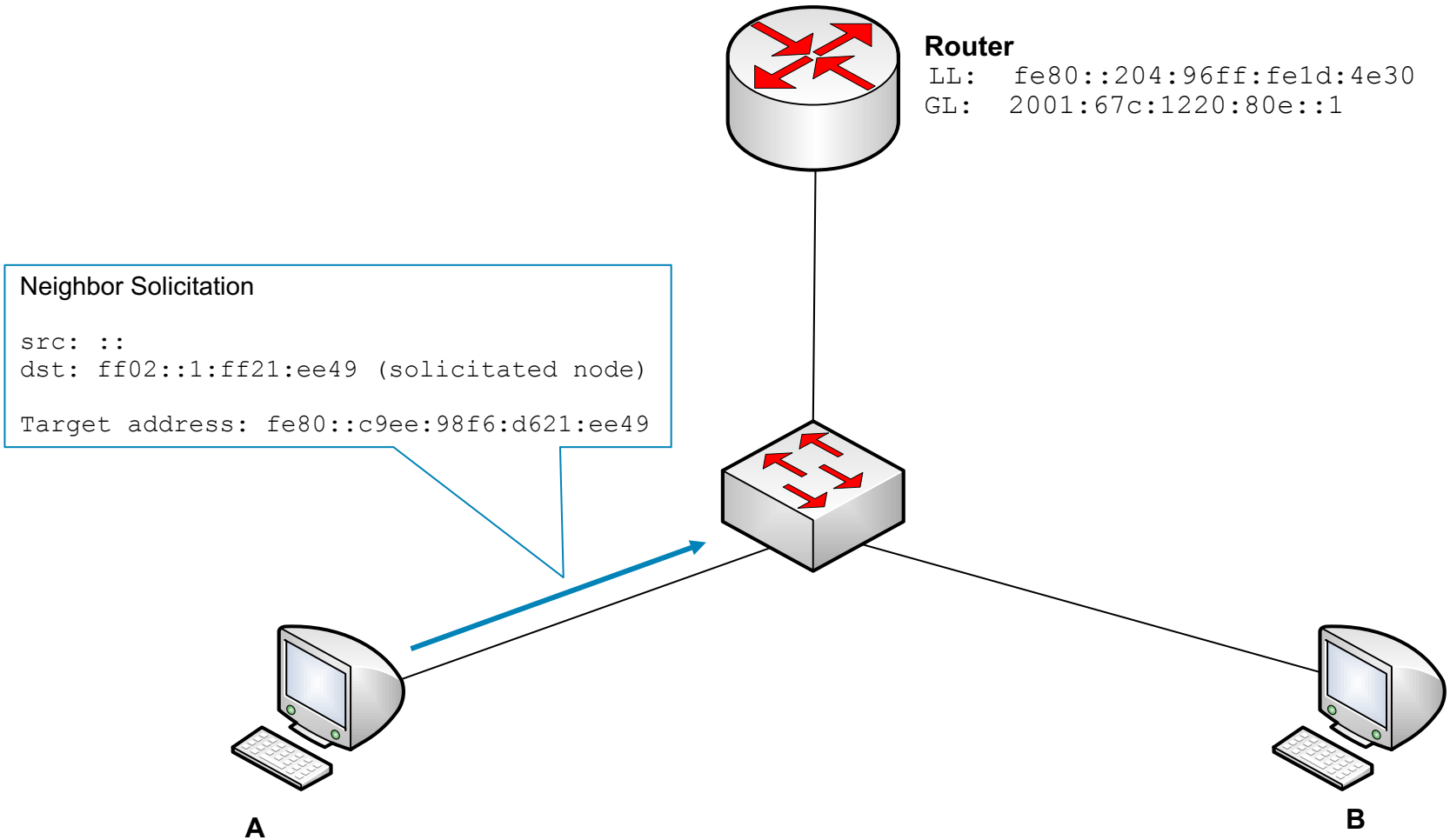
- Autoconfigured address reset timers if RA message is received
- Autoconfigured addresses are mainly for end stations – not for routers or servers



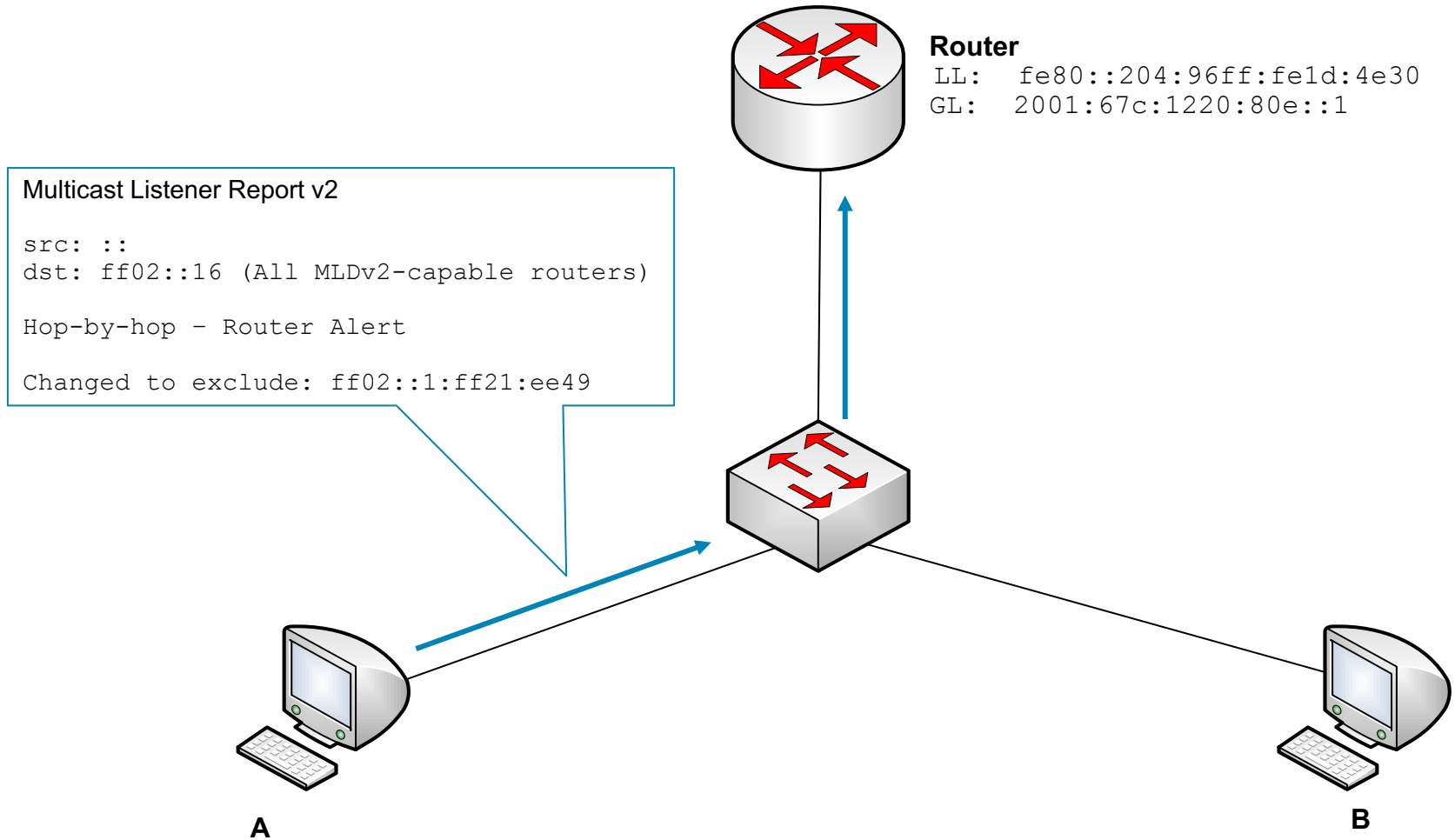
Autoconfigured Addresses States



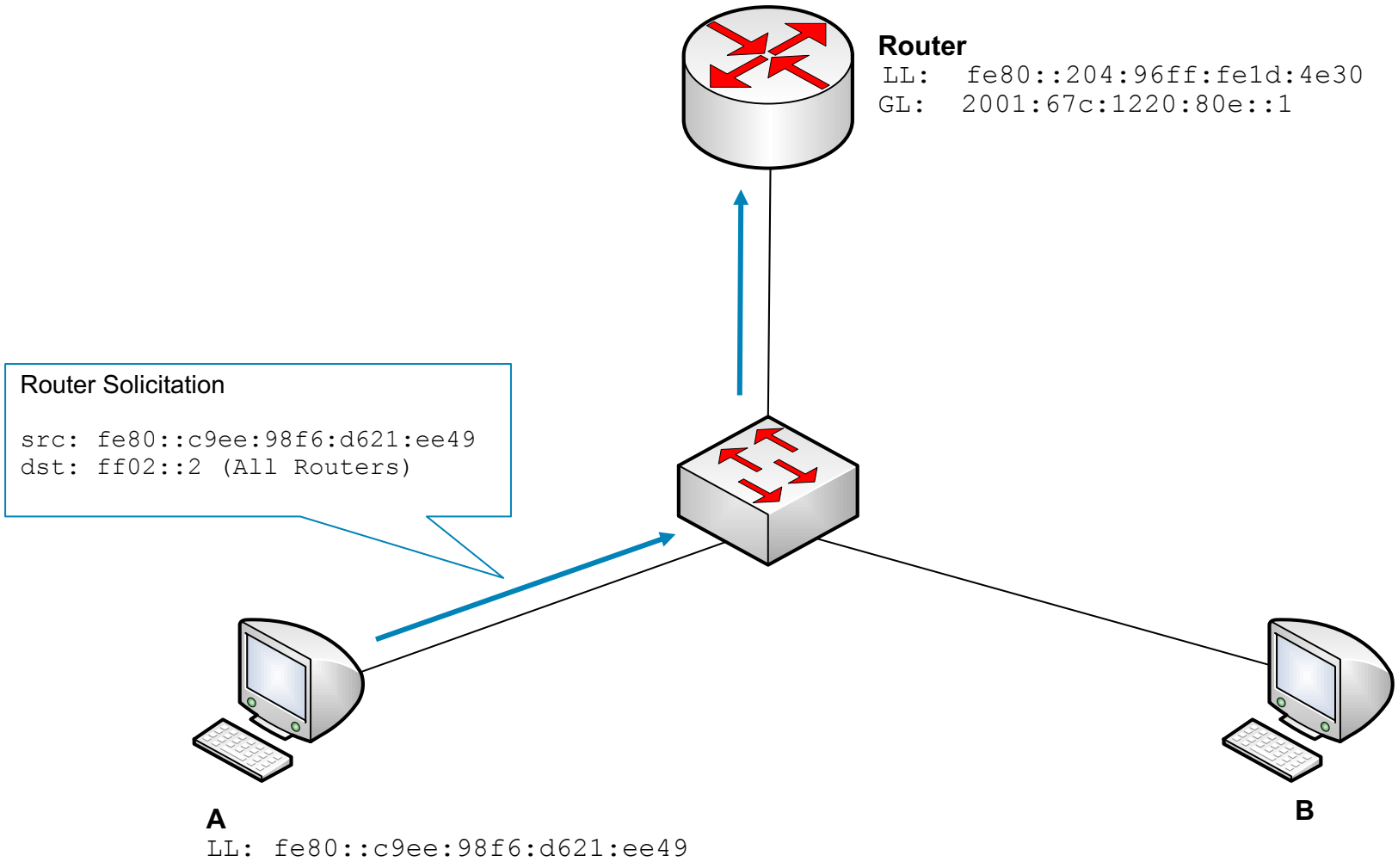
Link-local address



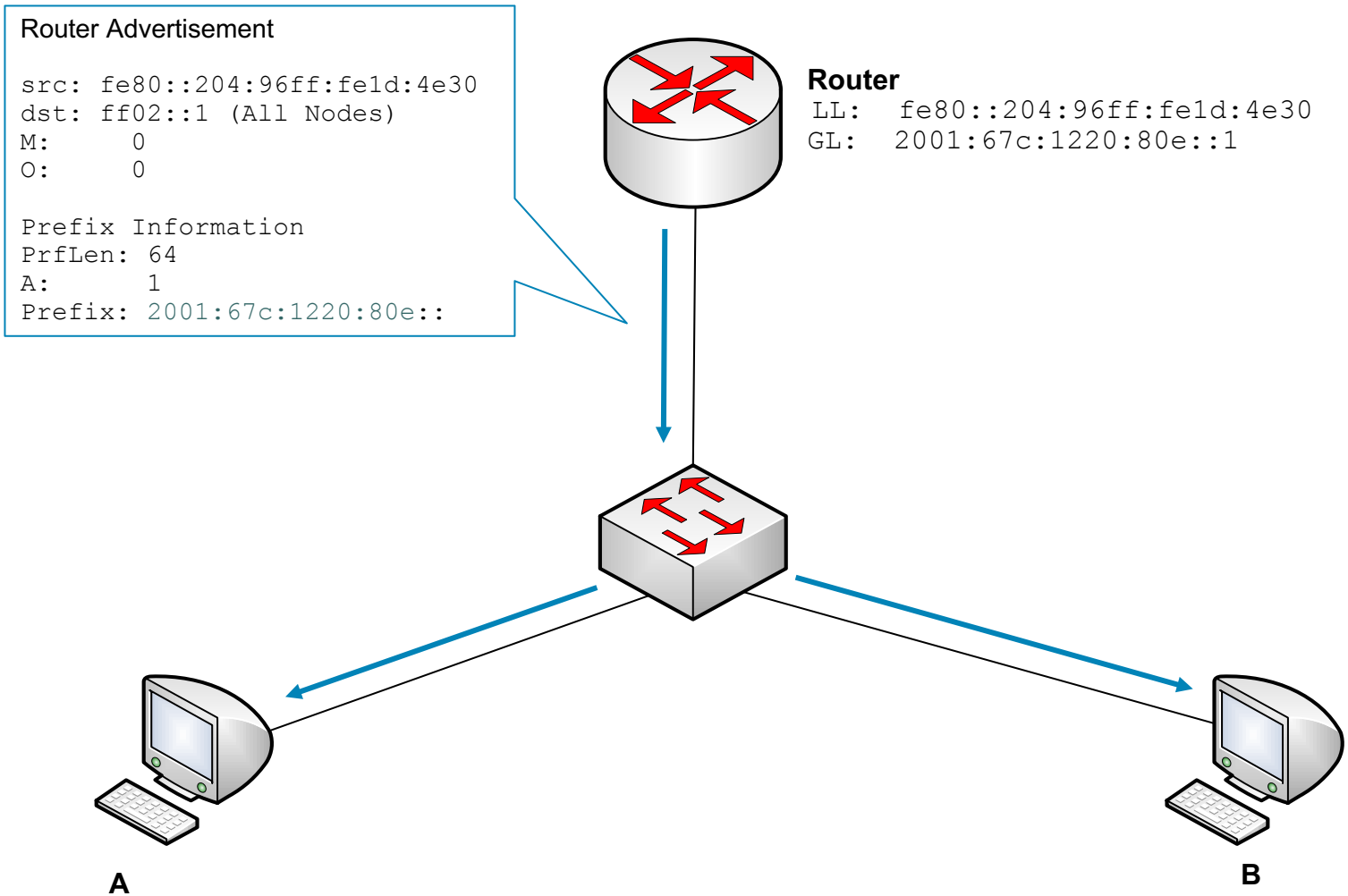
MLD Report


Router
LL: fe80::204:96ff:fe1d:4e30
GL: 2001:67c:1220:80e::1
Multicast Listener Report v2
src: ::
dst: ff02::16 (All MLDv2-capable routers)
Hop-by-hop – Router Alert
Changed to exclude: ff02::1:ff21:ee49
A
LL: fe80::c9ee:98f6:d621:ee49 [TENT]
B

Global address



Global address



Routing

```
C:\Users\igregr\route -6 print
IPv6 Route Table
===========================================================
Active Routes:
 If Metric Network Destination      Gateway
 10    266 ::/0                     fe80::204:96ff:fe1d:4e30
  1    306 ::1/128                  On-link
 10     18 2001:67c:1220:80e::/64   On-link
```

IPv6 SLAAC – issues

- SLAAC alone is not enough – DNS information is missing
  - IPv4 DNS
  - DHCPv6
  - RDNSS

- SLAAC is **mandatory**, DHCPv6 is not:
  - Android – missing support for DHCPv6
  - Windows Vista, 7, 8, Phone 8 – missing support for RDNSS
  - Windows XP – missing support for DHCPv6, RDNSS
  - Windows Phone 7.5 – missing support for IPv6
  - MAC OS < 10.7 – missing support for DHCPv6

Coexistence of IPv4 and IPv6

Transition to IPv6

- IPv4 and IPv6 are incompatible protocols
- How to transit from IPv4 to IPv6?

„*We have more transition mechanisms then IPv6 packets.*“

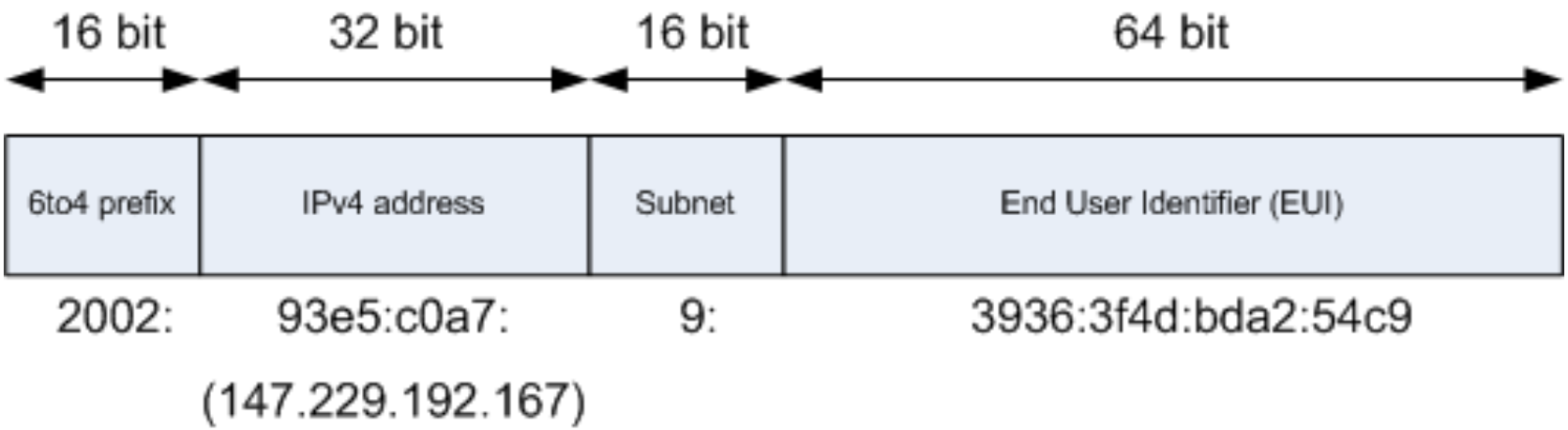
Randy Bush, RIPE62

Transition to IPv6

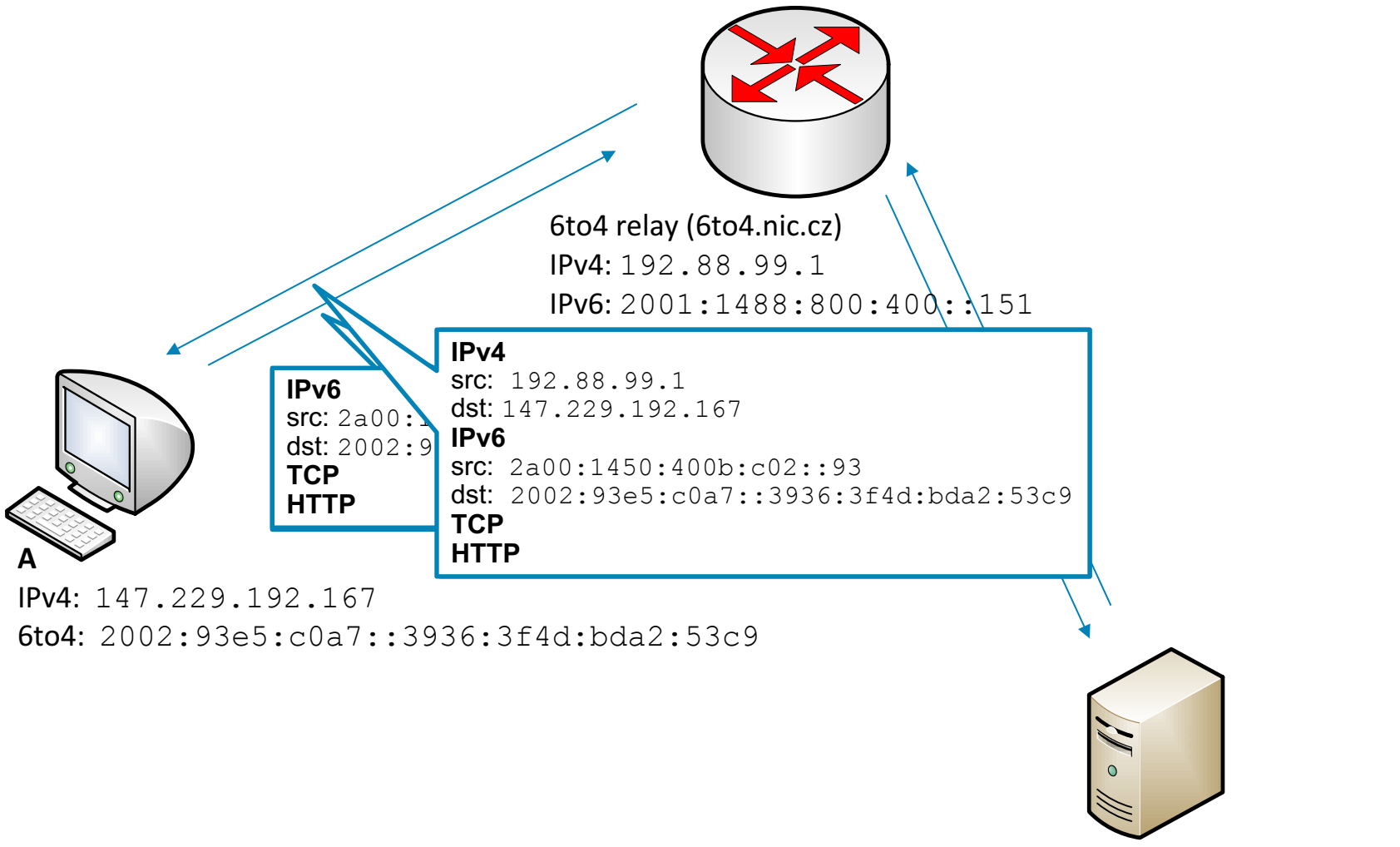
- 6in4
- 6to4
- 6RD
- 6over4
- Teredo
- ISATAP
- NPTv6
- 464XLAT
- AYIYA
- TSP
- IVI
- NAT64 + DNS64
- DS-lite
- A+P, MAP-E, MAP-T
- 4RD
- SIIT
- TRT

6to4

- RFC 3056, RFC 3068
- Requires public IPv4 address
- Reserved prefix `2002::/16`



6to4

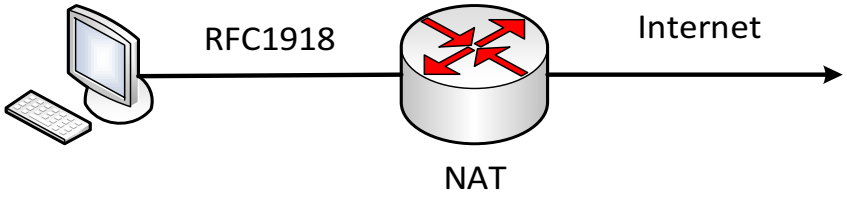

6to4 relay (6to4.nic.cz)
IPv4: 192.88.99.1
IPv6: 2001:1488:800:400::151
IPv6
src: 2a00:1
dst: 2002:9
TCP
HTTP
IPv4
src: 192.88.99.1
dst: 147.229.192.167
IPv6
src: 2a00:1450:400b:c02::93
dst: 2002:93e5:c0a7::3936:3f4d:bda2:53c9
TCP
HTTP
A
IPv4: 147.229.192.167
6to4: 2002:93e5:c0a7::3936:3f4d:bda2:53c9
ipv6.google.com
IPv6: 2a00:1450:400b:c02::93

6to4

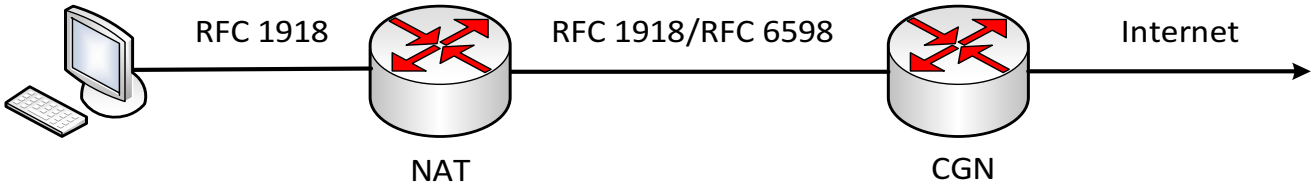
- It is expected that traffic will use different relays in the forward and reverse direction.
- **RFC 7526**: Deprecating the Anycast Prefix for 6to4 Relay Routers
- In router implementations, 6to4 MUST be disabled by default. In particular, enabling IPv6 forwarding on a device MUST NOT automatically enable 6to4.

Lack of addresses – current options

NAT44

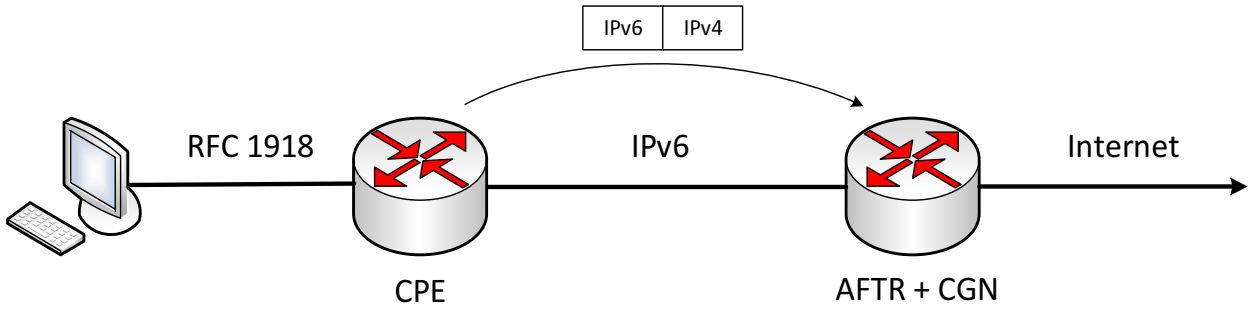


CGN

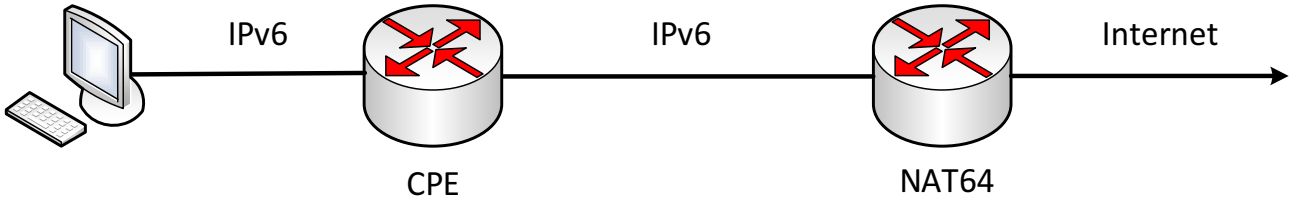


Options for transitions

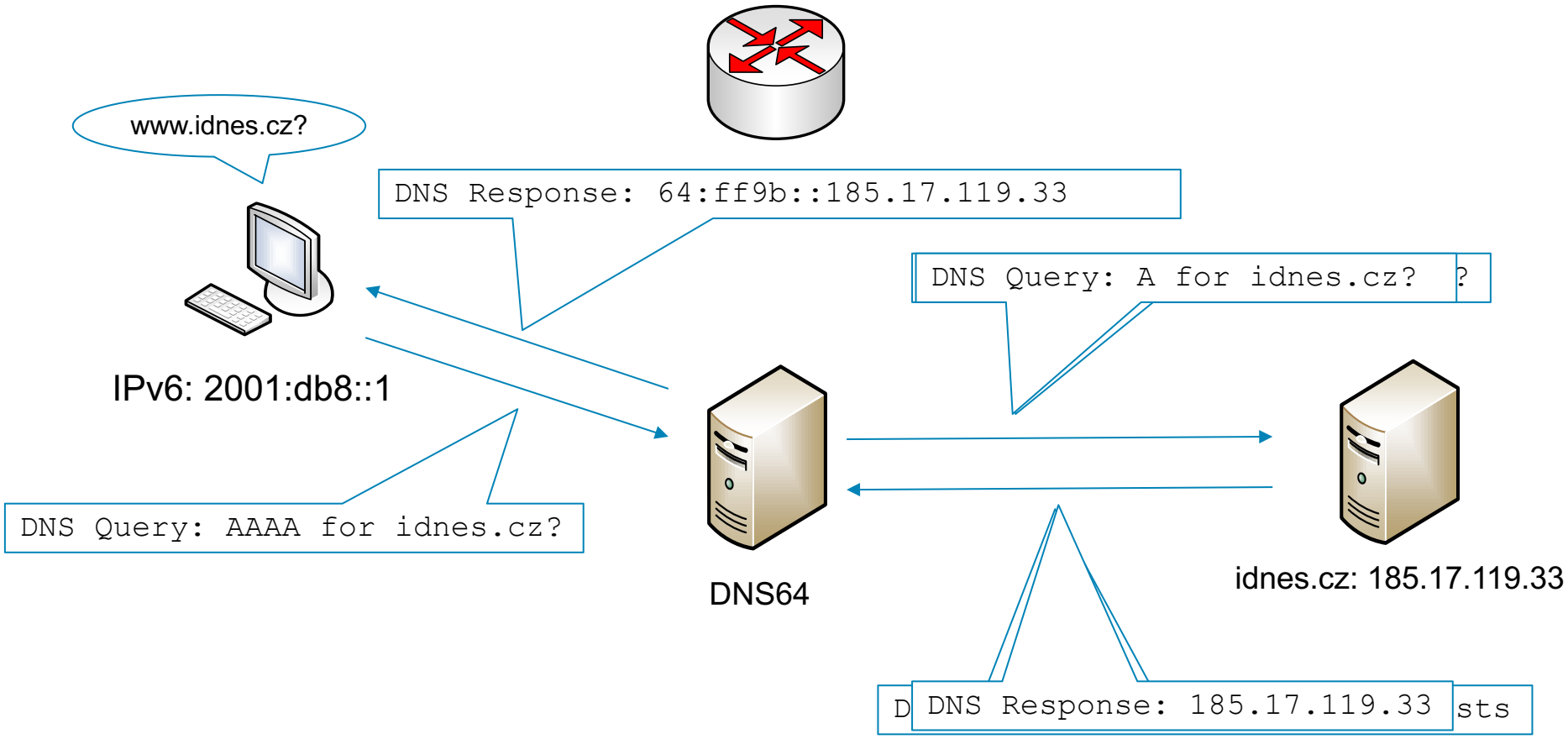
- Dual stack
  - Everything must be configured twice
- DS-Lite
- MAP-E (MAP-T)



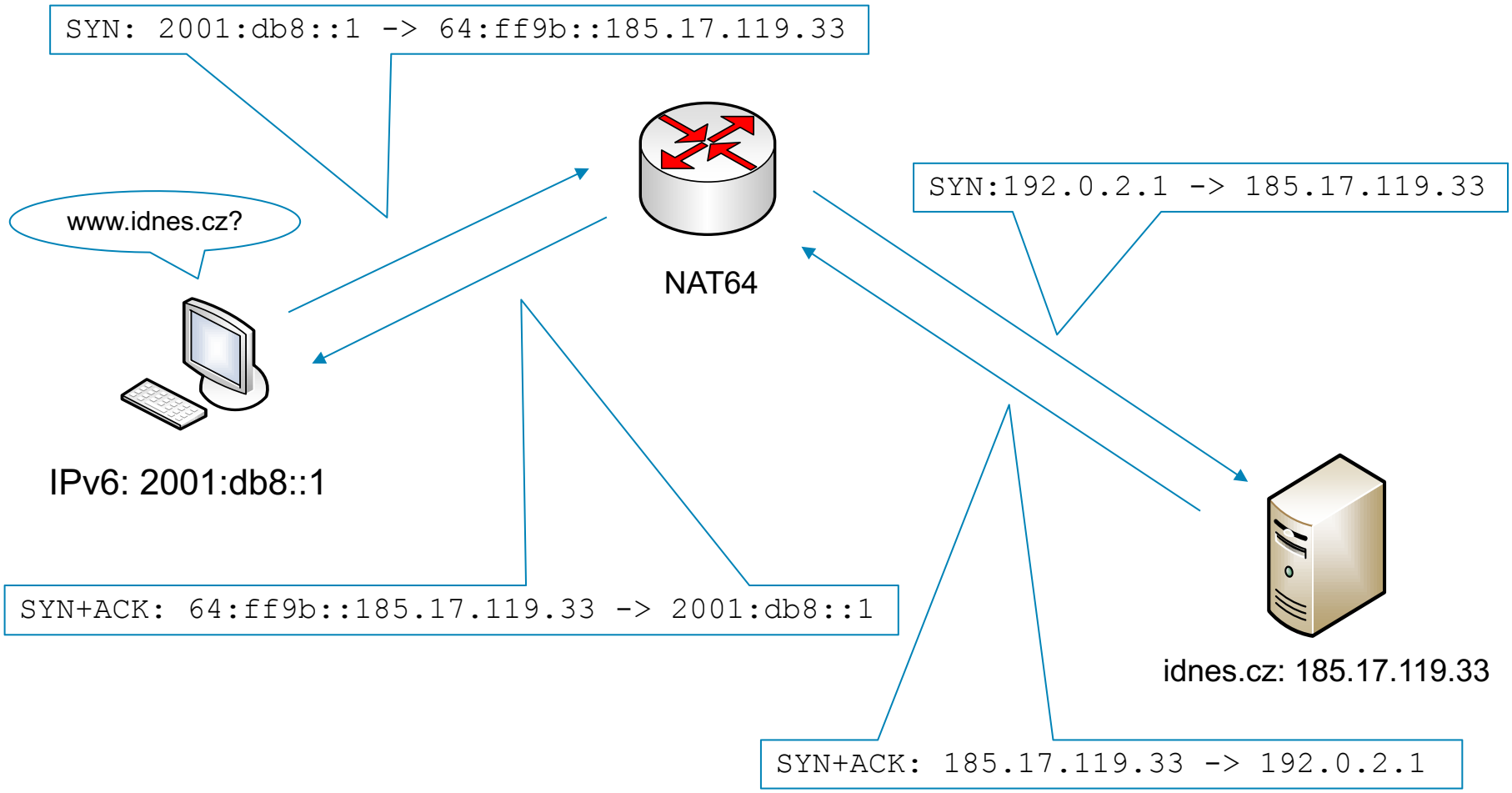
- NAT64



NAT64/DNS64


www.idnes.cz?
DNS Response: 64:ff9b::185.17.119.33
DNS Query: A for idnes.cz?
IPv6: 2001:db8::1
DNS Query: AAAA for idnes.cz?
DNS64
idnes.cz: 185.17.119.33
DNS Response: 185.17.119.33

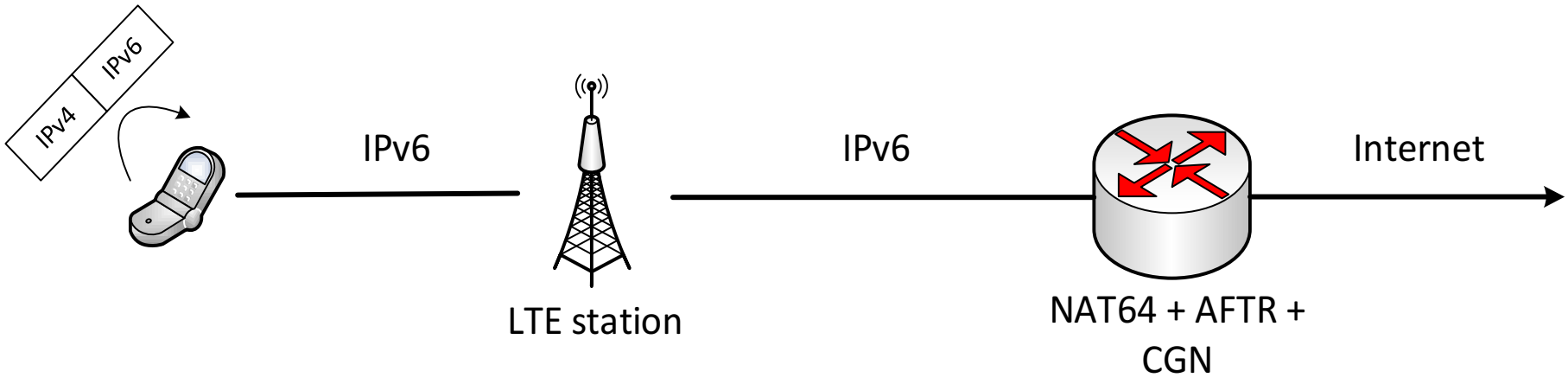
NAT64/DNS64


SYN: 2001:db8::1 -> 64:ff9b::185.17.119.33
www.idnes.cz?
NAT64
SYN:192.0.2.1 -> 185.17.119.33
IPv6: 2001:db8::1
SYN+ACK: 64:ff9b::185.17.119.33 -> 2001:db8::1
idnes.cz: 185.17.119.33
SYN+ACK: 185.17.119.33 -> 192.0.2.1

464xlat

- Several application works only with IPv4
  - NAT64 + DNS64 is not an option in this case

- RFC 6877: 464XLAT: Combination of Stateful and Stateless Translation
  - IPv4 to IPv6 to IPv4



NAT

“Classic” NAT for IPv6?

- Use cases:
  - Multihoming
  - ULA to GUA – very toxic topic in IETF

- NAT is supported in Linux since kernel 3.9.0
  - http://www.tldp.org/HOWTO/Linux+IPv6-HOWTO/nat-netfilter6..html

- Supported in pfsense
- Supported in several routing platforms