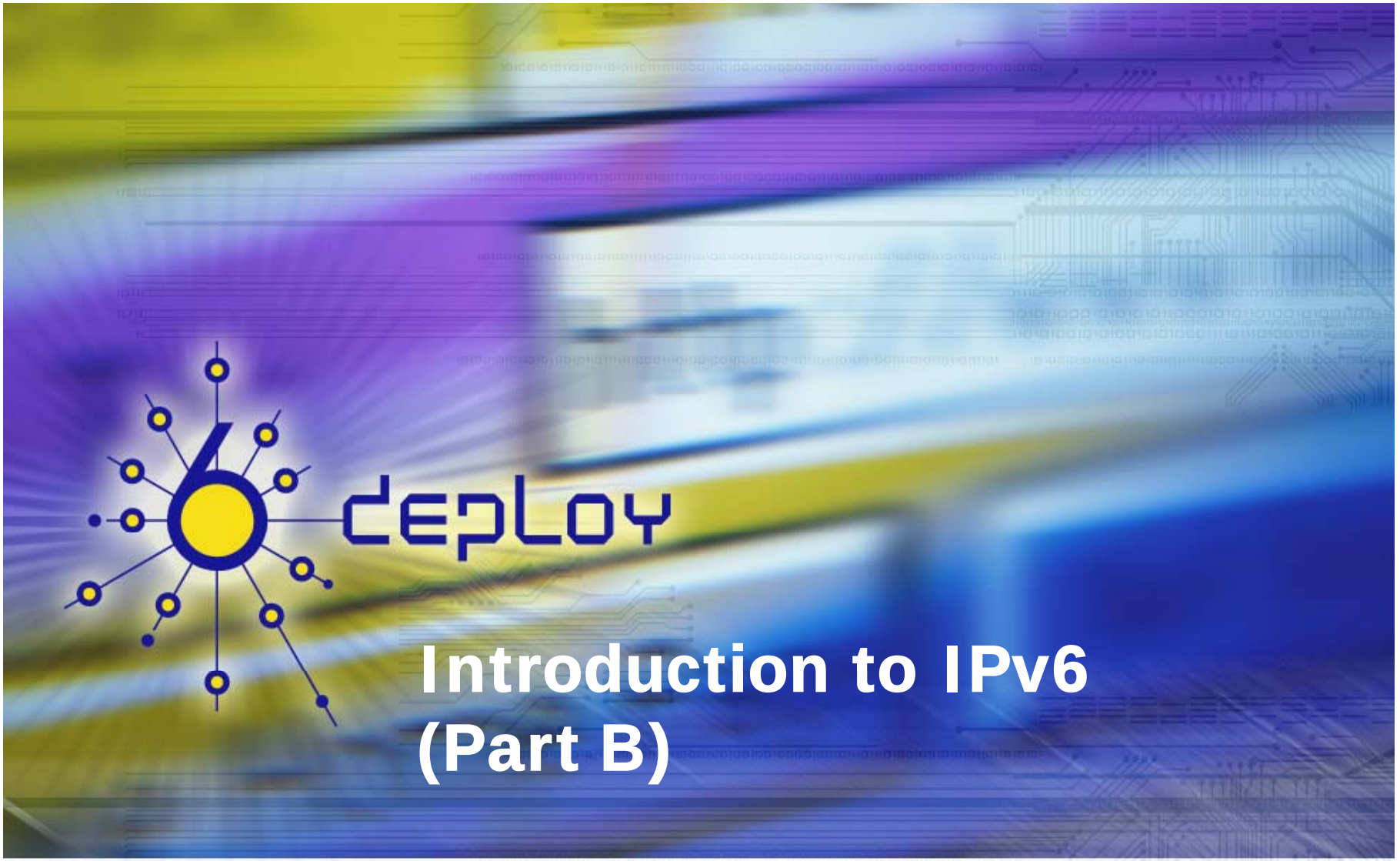

Introduction to IPv6 (Part B)

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Slovenian IPv6 Training, Ljubljana, May 2010

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Looking for a contact ?

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- ***or:*** *bernard.tuy@renater.fr*

IPv6 Addressing Scheme

RFC4291 defines IPv6 addressing scheme

RFC3587 defines IPv6 global unicast address format

128 bit long addresses

- Allow hierarchy
- Flexibility for network evolutions

Use CIDR principles:

- Prefix / prefix length
  - 2001:660:3003::/48
  - 2001:660:3003:2:a00:20ff:fe18:964c/64
- Aggregation reduces routing table size

Hexadecimal representation

Interfaces have several IPv6 addresses

IPv6 - Addressing Model

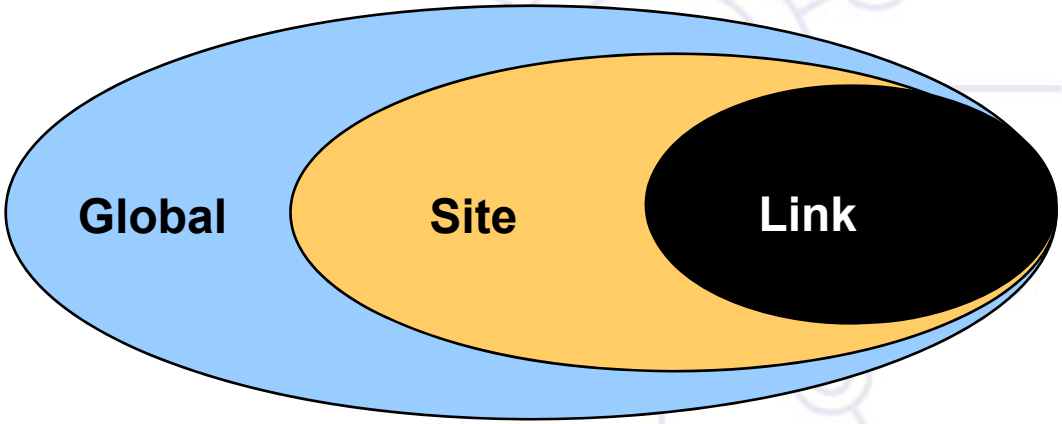
Addresses are assigned to interfaces

change from IPv4 model :

Interface 'expected' to have multiple addresses

Addresses have scope

- **Link Local**
- **Site Local**
- **Global**



Addresses have lifetime

- **Valid and Preferred lifetime**

Site-Local Address Deprecated in RFC 3879 now it is Unique Local Address (ULA) RFC 4193

IPv6 Address Types

Unicast (one-to-one)

- global
- link-local
- site-local (deprecated in RFC3897)
- Unique Local (ULA)
- IPv4-compatible (deprecated in RFC4291)
- IPv6-mapped

Multicast (one-to-many)

Anycast (one-to-nearest)

Reserved

Textual Address Format

Preferred Form (a 16-byte Global IPv6 Address):

2001:0DB8:3003:0001:0000:0000:6543:210F

Compact Format:

2001:DB8:3003:1::6543:210F

IPv4-mapped: ::FFFF:134.1.68.3

Literal representation

- [2001:DB8:3003:2:a00:20ff:fe18:964c]
- http://[2001:DB8::43]:80/index.html

IPv6 Address Type Prefixes

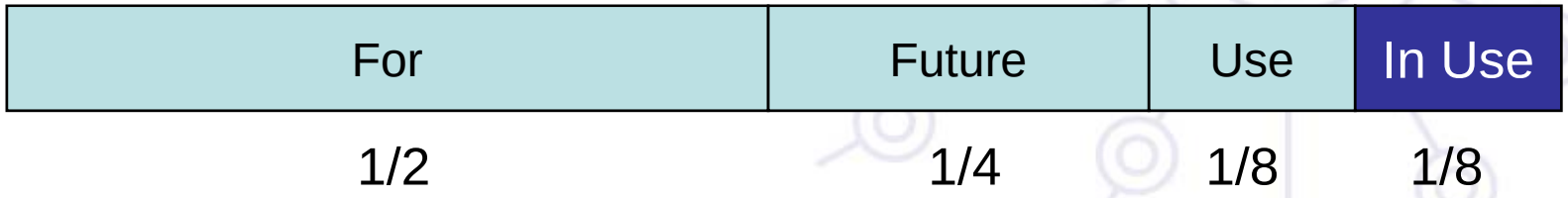
Address Type	Binary Prefix	IPv6 Notation
Unspecified	00...0 (128 bits)	**::/128**
Loopback	00...1 (128 bits)	**::1/128**
Multicast	1111 1111	**FF00::/8**
Link-Local Unicast	1111 1110 10	**FE80::/10**
ULA	1111 110	**FC00::/7**
Global Unicast	(everything else)	
IPv4-mapped	00...0:1111 1111:IPv4	**::FFFF:IPv4/128**
Site-Local Unicast (deprecated)	1111 1110 11	**FEC0::/10**
IPv4-compatible (deprecated)	00...0 (96 bits)	**::IPv4/128**

Global Unicast assigments actually use 2000::/3 (001 prefix)

Anycast addresses allocated from unicast prefixes

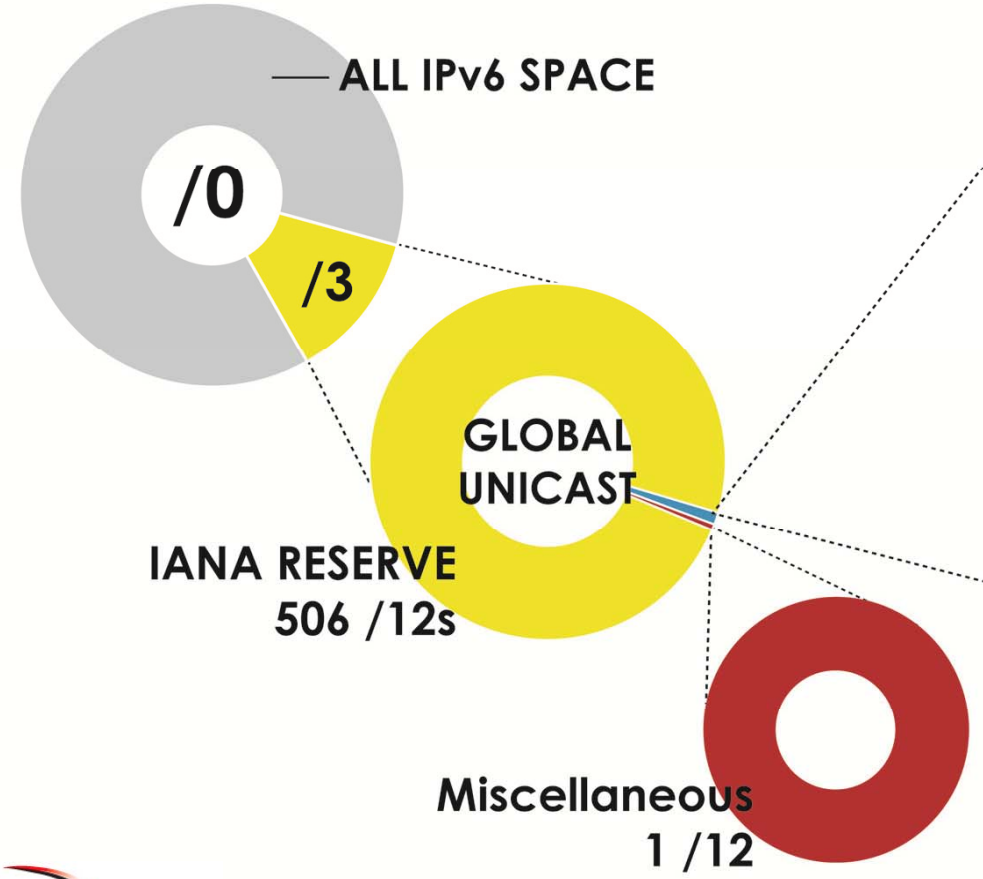
IPv6 Address Space

Aggregatable Global Unicast Addresses (001): 1/8
Unique Local Unicast addresses (1111 1110 00): 1/128
Link-Local Unicast Addresses (1111 1110 10): 1/1024
Multicast Addresses (1111 1111): 1/256



More info:
http://www.iana.org/assignments/ipv6-address-space

IPv6 Address Space



RIRs 5 /12s (October 2006)

RIR	IPv6 ADDRESS
AfriNIC	2C00:0000::/12
APNIC	2400:0000::/12
ARIN	2600:0000::/12
LACNIC	2800:0000::/12
RIPE NCC	2A00:0000::/12

NRO

Some Special-Purpose Unicast Addresses

Listed in RFC5156

The **unspecified address,** used as a placeholder when no address is available:

0:0:0:0:0:0:0:0 or **::/128**

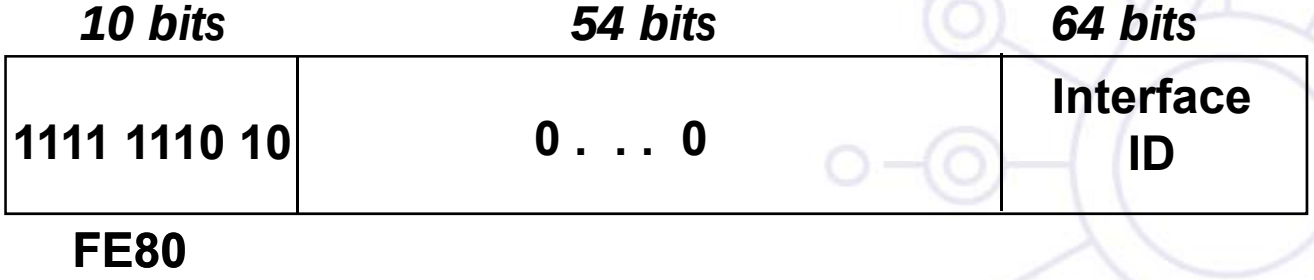
The **loopback address,** for sending packets to itself:

0:0:0:0:0:0:0:1 or **::1/128**

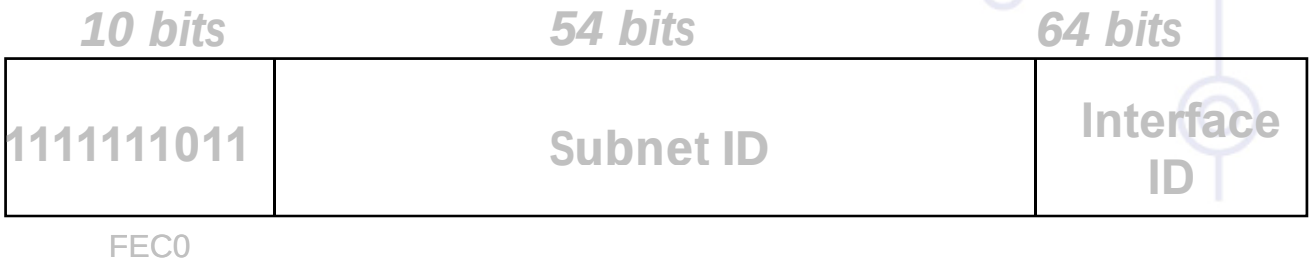
The **documentation prefix** [RFC3849]: **2001:db8::/32**

Link-Local & Site-Local Unicast Addresses

Link-local addresses for use during auto-configuration and when no routers are present **(FE80::/10):**



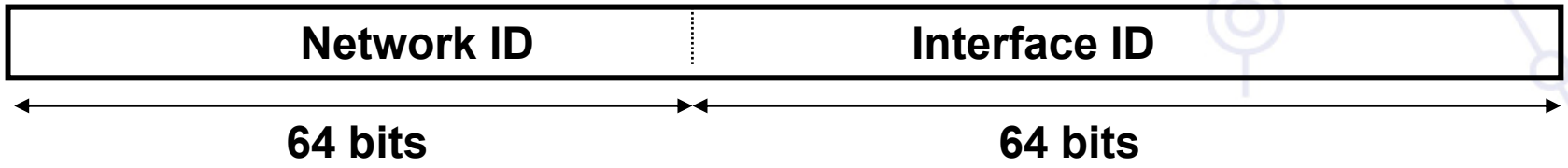
Site-local addresses for independence from changes of TLA / NLA* **(FEC0::/10):** (deprecated by RFC3879)



Interface IDs

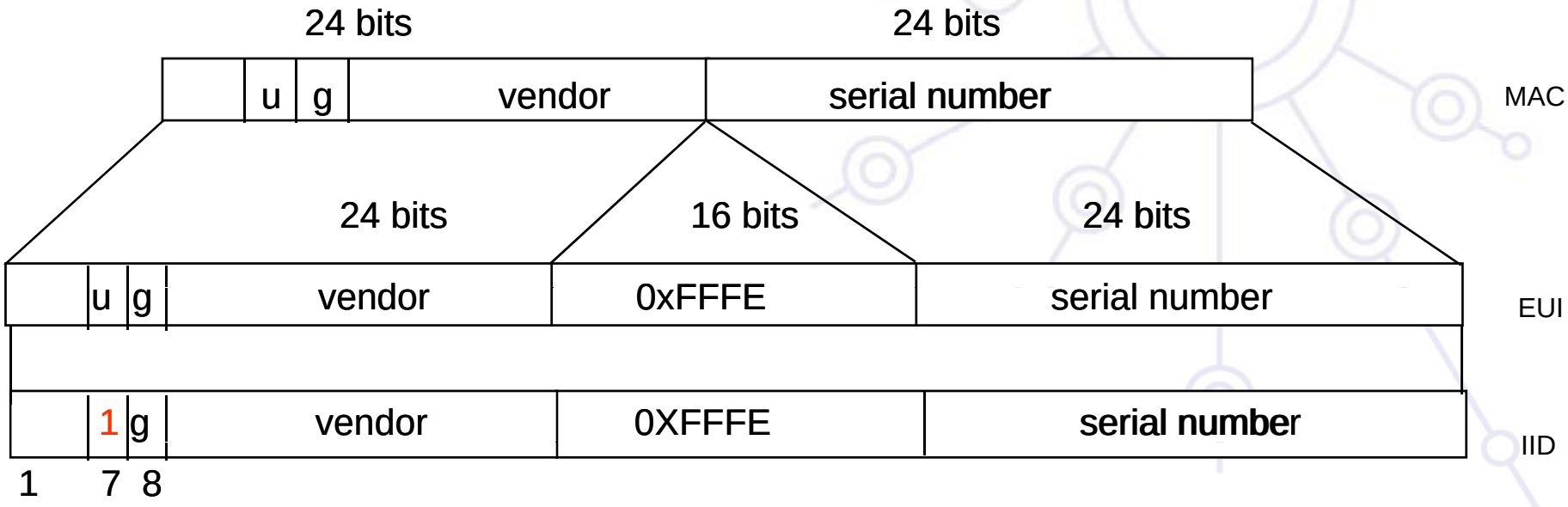
The lowest-order 64-bit field of unicast addresses may be assigned in several different ways:

- auto-configured from a 64-bit MAC address
- auto-configured from a 48-bit MAC address (e.g., Ethernet) expanded into a 64-bit EUI-64 format
- assigned via DHCP
- manually configured
- auto-generated pseudo-random number (to counter some privacy concerns)
- CGA (Cryptographically Generated Address)
- possibly other methods in the future



Autoconfigured Interface IDs (1)

- 64 bits to be compatible with IEEE 1394 (FireWire)
- Eases auto-configuration
- IEEE defines the mechanism to create an EUI-64 from IEEE 802 MAC addresses (Ethernet, FDDI)



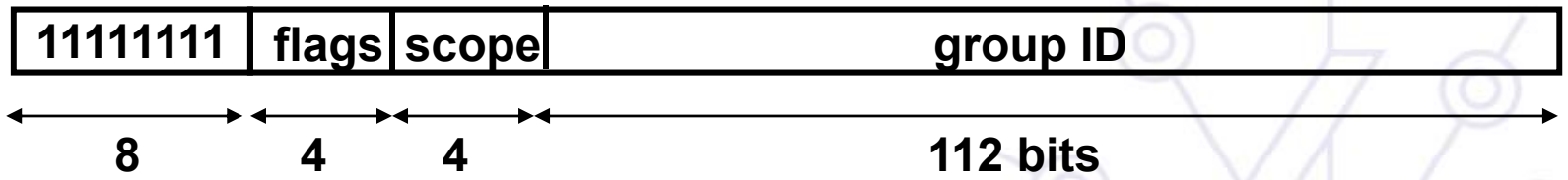
Autoconfigured Interface IDs (2)

Links with non global identifier (e.g., the Localtalk 8 bit node identifier) → fill first left bits with 0

For links without identifiers, there are different ways to proceed (e.g., tunnels, PPP) to have a subnet-prefix-unique identifier:

- Choose the universal identifier of another interface
- Manual configuration
- Node Serial Number
- Other Node-Specific Token

Multicast Addresses



Flags: 0RPT: The high-order flag is reserved, and must be initialized to 0.

- **T**: Transient, or not, assignment
- **P**: Assigned, or not, based on network prefix
- **R**: Rendezvous Point Address embedded, or not

Scope field:
1 - Interface-Local
2 - link-local
4 - admin-local
5 - site-local
8 - organization-local
E - global

(3,F reserved)(6,7,9,A,B,C,D unassigned)

Unique Local IPv6 Unicast Addresses (1)

ULAs are defined in RFC4193:

- Globally unique prefix with high probability of uniqueness
- Intended for local communications, usually inside a site
- They are not expected to be routable on the Global Internet
- They are routable inside of a more limited area such as a site
- They may also be routed between a limited set of sites
- Locally-Assigned Local addresses vs. Centrally-Assigned Local addresses

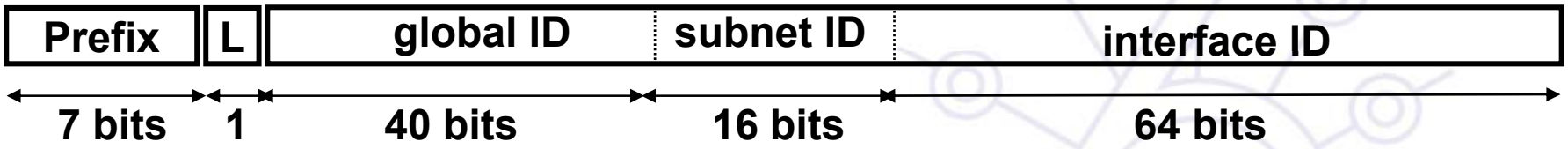
Unique Local IPv6 Unicast Addresses (2)

ULA characteristics:

- Well-known prefix to allow for easy filtering at site boundaries
- ISP independent and can be used for communications inside of a site without having any permanent or intermittent Internet connectivity
- If accidentally leaked outside of a site via routing or DNS, there is no conflict with any other addresses
- In practice, applications may treat these addresses like global scoped addresses

Unique Local IPv6 Unicast Addresses (3)

Format:



FC00::/7 Prefix identifies the Local IPv6 unicast addresses

L = 1 if the prefix is **locally assigned**

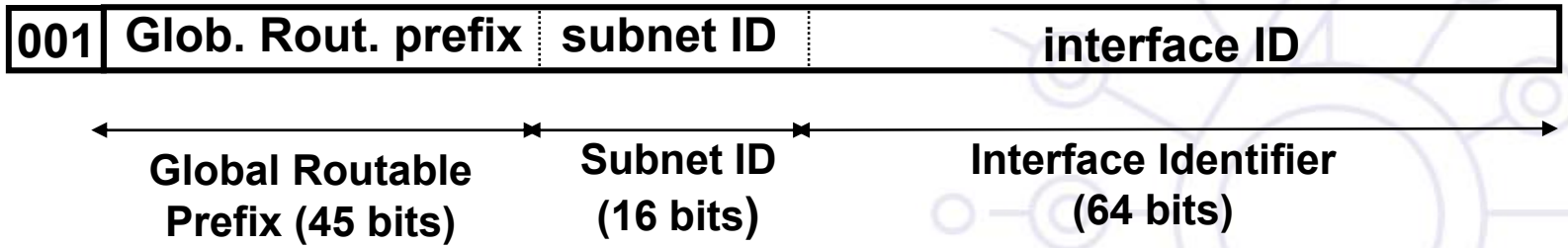
L = 0 may be defined in the future (in practice used for **centrally assigned** prefixes)

ULA are created using a pseudo-randomly allocated global ID

- This ensures that there is not any relationship between allocations and clarifies that these prefixes are not intended to be routed globally

Global Unicast Addresses

Defined in RFC3587



The global routing prefix is a value assigned to a zone (site, a set of subnetworks/links)

- It has been designed as an hierarchical structure from the Global Routing perspective

The subnetwork ID, identifies a subnetwork within a site

- Has been designed to be an hierarchical structure from the site administrator perspective

Anycast Addresses

Identifier for a set of interfaces (typically in different nodes). A packet sent to an anycast address is delivered to the "nearest" interface (routing protocols' distance)

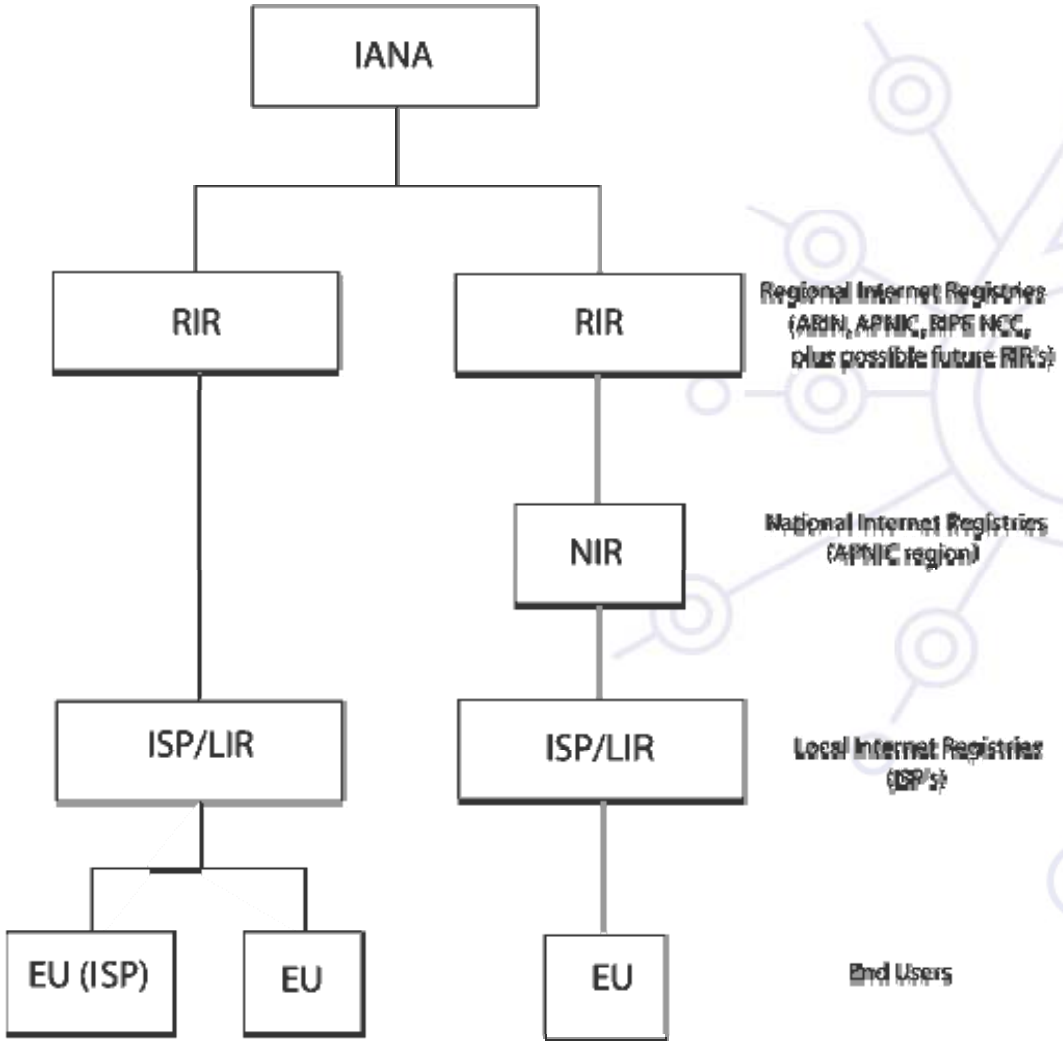
Taken from the unicast address space (of any scope).**Not syntactically distinguishable from unicast addresses**

A unicast address assigned to more than one interface, turning it into an anycast address, the nodes the address is assigned must be explicitly configured to know that it is an anycast address

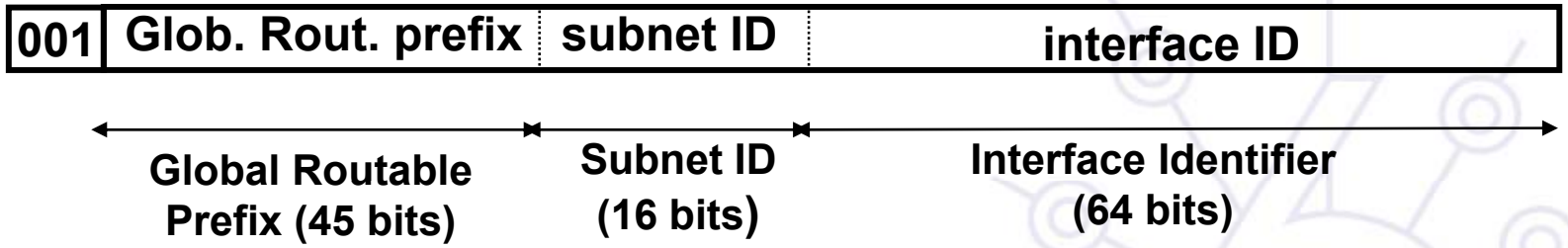
Reserved anycast addresses are defined in **RFC2526**

The Subnet-Router anycast address is predefined (mandatory on all routers):

Production Addressing Scheme (1)



Production Addressing Scheme (2)



LIRs receive by default /32

- Production addresses today are from prefixes 2001, 2003, 2400, etc.
- Can request for more if justified

/48 used only within the LIR network, with some exceptions for critical infrastructures

/48 to /128 is delegated to end users

- Recommendations following RFC3177 and current policies
- /48 general case, /47 if justified for bigger networks
- /64 if one and only one network is required
- /128 if it is sure that one and only one device is going to be connected

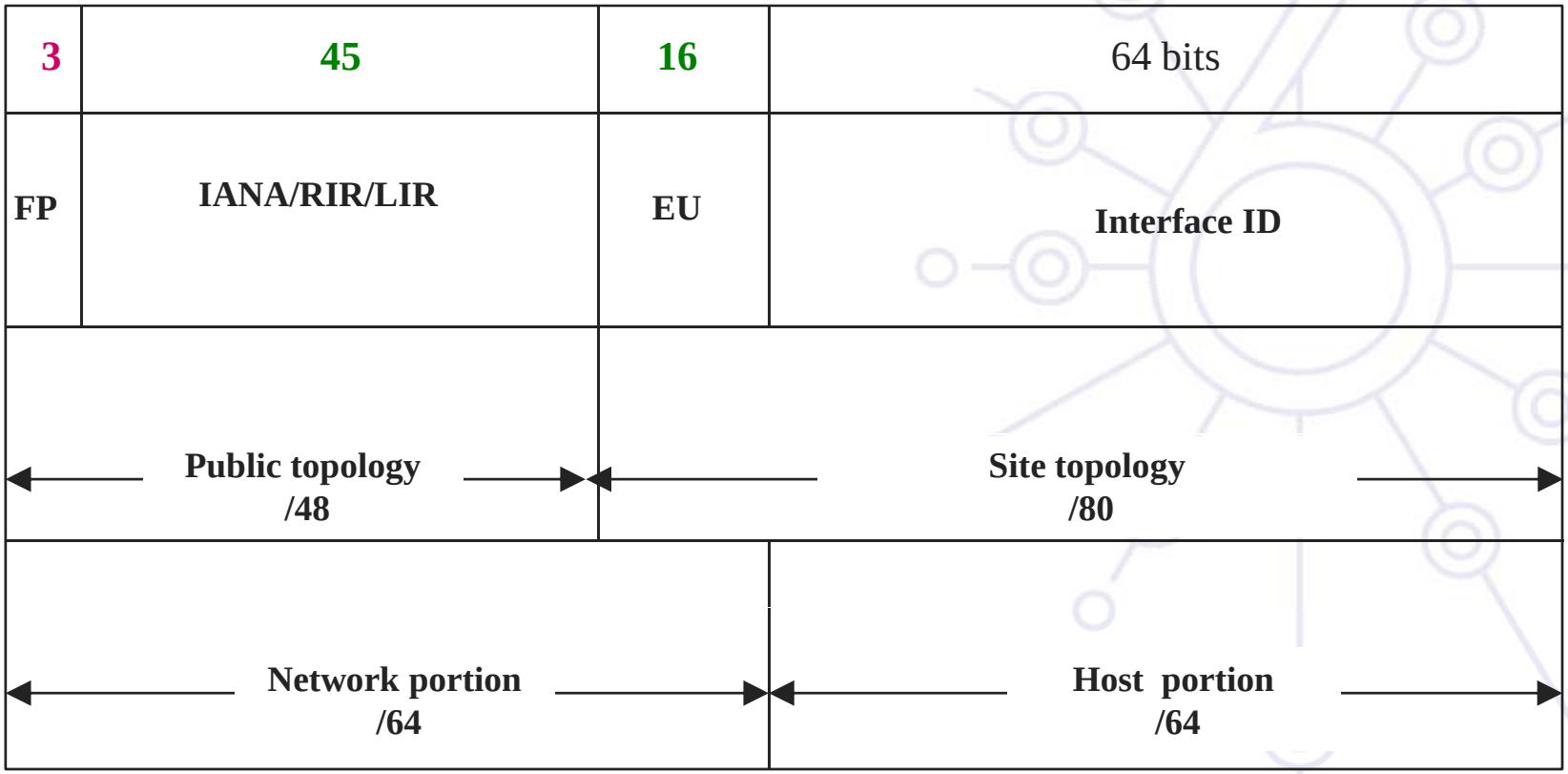
Production Addressing Scheme (3)

Source:
http://www.iana.org/assignments/ipv6-unicast-address-assignments

IPv6 Global Unicast Address Assignments [0]
[last updated 2008-05-13]

Global Unicast Prefix	Assignment	Date	Note
2001:0000::/23	IANA	01 Jul 99	[1]
2001:0200::/23	APNIC	01 Jul 99	
2001:0400::/23	ARIN	01 Jul 99	
2001:0600::/23	RIPE NCC	01 Jul 99	
2001:0800::/23	RIPE NCC	01 May 02	
2001:0A00::/23	RIPE NCC	02 Nov 02	
2001:0C00::/23	APNIC	01 May 02	[2]
2001:0E00::/23	APNIC	01 Jan 03	
2001:1200::/23	LACNIC	01 Nov 02	
. . .			

Production Addressing Scheme (4)



RIR Allocation Policies

AfriNIC:
http://www.afrinic.net/IPv6/index.htm
http://www.afrinic.net/docs/policies/afpol-v6200407-000.htm *
APNIC:
http://www.apnic.org/docs/index.html
http://www.apnic.org/policy/ipv6-address-policy.html *
ARIN:
http://www.arin.net/policy/index.html
http://www.arin.net/policy/nrpm.html#ipv6 *
LACNIC:
http://lacnic.net/sp/politicas/
http://lacnic.net/sp/politicas/ipv6.html *
RIPE-NCC:
http://www.ripe.net/ripe/docs/ipv6.html
http://www.ripe.net/ripe/docs/ipv6policy.html *

- *describes policies for the allocation and assignment of globally unique IPv6 address space

RIR Allocation Statistics

AfriNIC:

- http://www.afrinic.net/statistics/index.htm

APNIC:

- http://www.apnic.org/info/reports/index.html

ARIN:

- http://www.arin.net/statistics/index.html

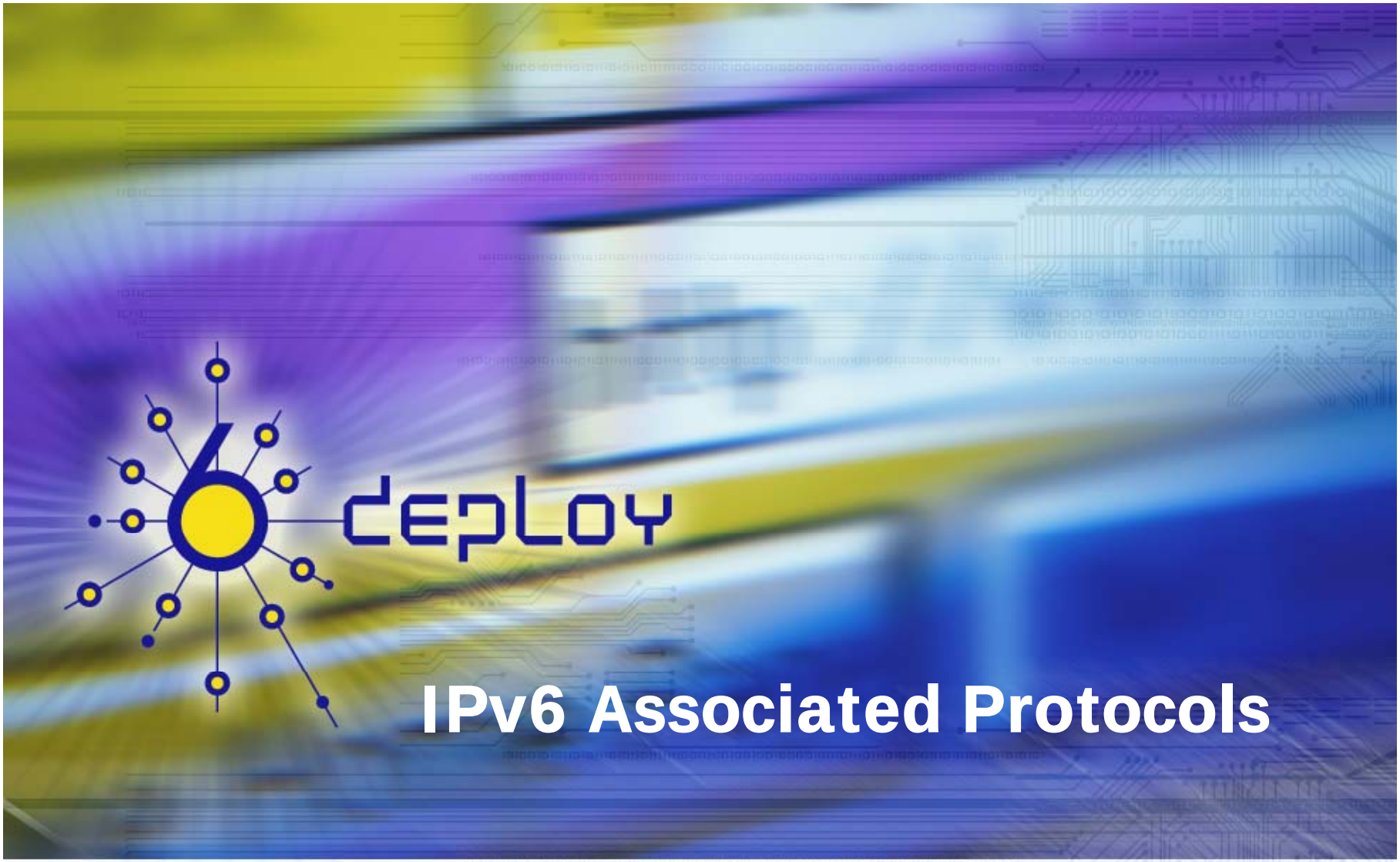
LACNIC:

- http://lacnic.org/sp/est.html

RIPE-NCC:

- http://www.ripe.net/info/stats/index.html

See http://www.ripe.net/rs/ipv6/stats/


deploy
IPv6 Associated Protocols

New Protocols (1)

New features are specified in IPv6 Protocol -*RFC 2460 DS*

Neighbor Discovery (NDP) -*RFC 4861 DS*

Auto-configuration :

- Stateless Address Auto-configuration -*RFC 4862 DS*
- DHCPv6: Dynamic Host Configuration Protocol for IPv6 -*RFC 4361 PS*
- Path MTU discovery (pMTU) -*RFC1981 DS*

New Protocols (2)

MLD (Multicast Listener Discovery) –*RFC 2710 PS*

- Multicast group management over an IPv6 link
- Based on IGMPv2
- MLDv2 (equivalent to IGMPv3 in IPv4)

ICMPv6 (RFC 4443 DS) **"Super" Protocol that :**

- Covers ICMP (v4) features (Error control, Administration, ...)
- Transports ND messages
- Transports MLD messages (Queries, Reports, ...)

Neighbor Discovery for IP version 6 (1)

- **IPv6 nodes** (hosts and routers) on the same physical medium (link) **use Neighbor Discovery** (NDP) to:
  - discover their mutual presence
  - determine link-layer addresses of their neighbors
  - find neighboring routers that are willing to forward packets on their behalf
  - maintain neighbors' reachability information (NUD)
  - not directly applicable to NBMA (Non Broadcast Multi Access) networks

    ➔ NDP uses link-layer multicast for some of its services.

NDP for IPv6 (2)

Protocol features:

- Router Discovery
- Prefix(es) Discovery
- Parameters Discovery (link MTU, Max Hop Limit, ...)
- Address Autoconfiguration
- Address Resolution
- Next Hop Determination
- Neighbor Unreachability Detection
- Duplicate Address Detection
- Redirect

NDP (3) : comparison with IPv4

The IPv6 Neighbor Discovery protocol corresponds to a combination of the IPv4 protocols:

- Address Resolution Protocol (ARP)
- ICMP Router Discovery (RDISC)
- ICMP Redirect (ICMPv4)

Improvements over the IPv4 set of protocols:

- Router Discovery is part of the base protocol set
- Router Advertisements carry link-layer addresses and prefixes for a link, and enable Address Autoconfiguration
- Multiple prefixes can be associated with the same link.
- Neighbor Unreachability Detection is part of the base protocol set
- Detects half-link failures and avoids sending traffic to neighbors with which two-way connectivity is absent
- By setting the Hop Limit to 255, Neighbor Discovery is immune to off-link senders that accidentally or intentionally send ND messages.

NDP (4)

NDP specifies 5 types of ICMP packets :

- **Router Advertisement** (RA) :
  - periodic advertisement or response to RS message (of the availability of a router) which contains:
    - list of prefixes used on the link (autoconf)
    - address configuration
    - a possible value for Max Hop Limit (TTL of IPv4)
    - value of MTU
- **Router Solicitation** (RS) :
  - the host needs RA immediately (at boot time)

NDP (5)

- **Neighbor Solicitation** (NS):
  - to determine the link-layer @ of a neighbor
  - or to check a neighbor is still reachable via a cached L2 @
  - also used to detect duplicate addresses (DAD)
- **Neighbor Advertisement** (NA):
  - answer to a NS message
  - to advertise the change of physical address
- **Redirect** :
  - Used by routers to inform hosts of a better first hop for a destination

Address resolution

Address resolution is the process through which a node determines the link-layer address of a neighbor given only its IP address.

Find the mapping:

Dst IP @ ➔ Link-Layer (MAC) @

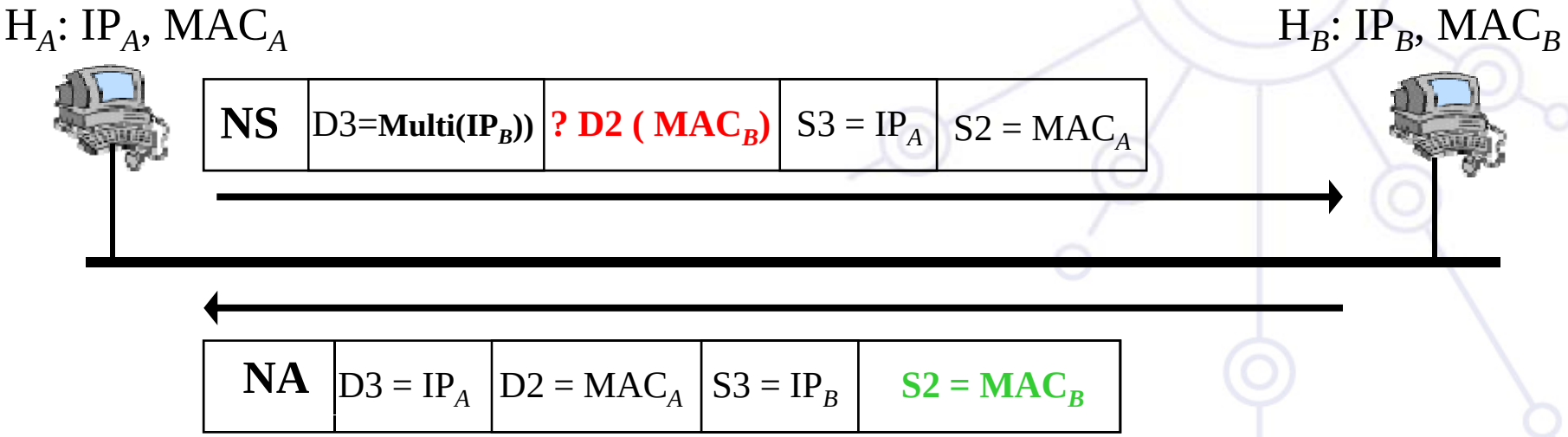
Recalling IPv4 & ARP

- ARP Request is broadcasted
  - Request is sent to `ethernet address: FF-FF-FF-FF-FF-FF`
  - Request contains the src's link local address
- ARP Reply is sent in unicast to the Src
  - Reply contains the dst's link local address

Address resolution (2) with NDP

At boot time, every IPv6 node has to join 2 special multicast groups for each network interface:

- All-nodes multicast group: **`ff02::1`**
- Solicited-node multicast group: **`ff02::1:ffxx:xxxx`**
  - derived from the lower 24 bits of the node's address



Address resolution (3) : multicast solicited address

Concatenation of the prefix `FF02::1:FF00:0/104` with the last 24 bits of the IPv6 address

Example:

Dst IPv6 @: `2001:0660:010a:4002:4421:21FF:FE24:87c1`

Sol. Mcast @: `FF02:0000:0000:0000:0000:0001:FF24:87c1`

Ethernet: `33-33-FF-24-87-c1`

Path MTU discovery (RFC 1981)

Derived from RFC1191 (IPv4 version of the protocol)

Path = set of links

- followed by an IPv6 packet between source and destination

Link MTU = maximum packet length (bytes)

- that can be transmitted on a given link without fragmentation

Path MTU (or pMTU) = min { link MTUs }

- for a given path

Path MTU Discovery = automatic pMTU discovery for a given path

Path MTU discovery (2)

Protocol operation

- makes assumption that pMTU = link MTU to reach a neighbor (first hop)
- if there is an intermediate router such that
  - link MTU < pMTU

  ➔ it sends an ICMPv6 message: "Packet size Too Large"
- source reduces pMTU by using information found in the ICMPv6 message
- ...

=> Intermediate network element aren't allowed to perform packet fragmentation

Stateless Autoconfiguration

- Host should be plug & play
- Uses some of the Neighbor Discovery ICMPv6 messages

When booting, the host asks for network parameters:

- IPv6 prefix(es)
- default router address(es)
- hop limit
- (link local) MTU

Stateless Autoconfiguration

Only routers have to be manually configured

- And/or can use the *Prefix Delegation* option
- RFC 3633

Hosts can get automatically an IPv6 address

- BUT it isn't automatically registered in the DNS

➢ Servers should be manually configured

Stateless Autoconfiguration

IPv6 Stateless Address Autoconfiguration is described in RFC 2462

Hosts are listening for Router Advertisements **(RA) messages, periodically sent out by routers on the local link**

RA messages coming from the router(s) on the link identify the subnet

Allows a host to create a global unicast IPv6 address from:

- Its interface identifier (EUI-64 address)
- Link Prefix (obtained via Router Advertisement)

Global Address **=** ***Link Prefix*** **+** ***EUI-64 address***

Stateless Autoconfiguration

Usually, the router sending the RA messages is used, by hosts, as the default router

If the RA doesn't carry any prefix

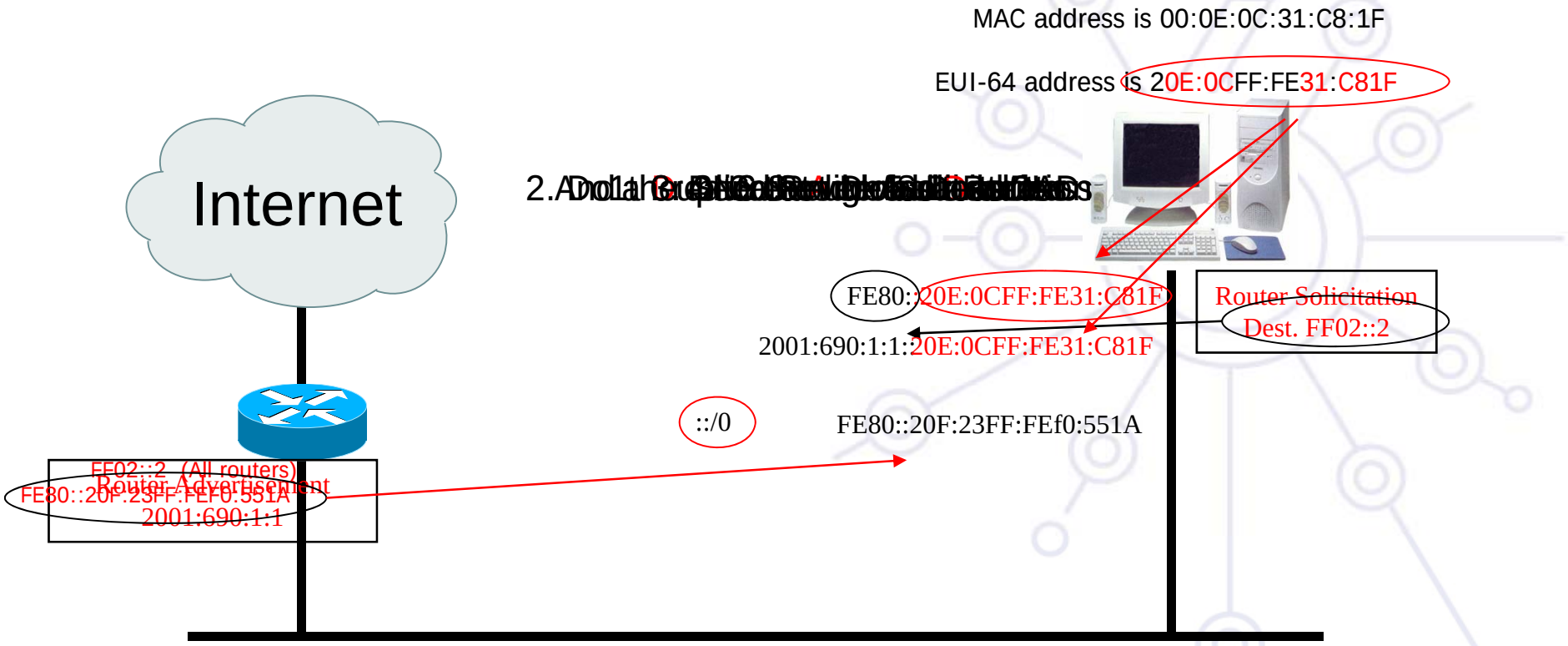
- The hosts don't configure (automatically) any global IPv6 address (but may configure the default gateway address)

RA messages contain two flags indicating what type of stateful autoconfiguration (if any) should be performed

It's impossible to automatically send DNS server addresses

IPv6 addresses depends on NIC card

Stateless Autoconfiguration /2



Statefull Autoconfiguration DHCPv6

Dynamic Host Configuration Protocol for IPv6

- RFC 3315
- stateful counterpart to IPv6 Stateless Address Autoconfiguration.

According to RFC 3315 DHCPv6 is used when:

- no router is found
- Or if Router Advertisement message enables use of DHCP

Statefull Autoconfiguration DHCPv6 /2

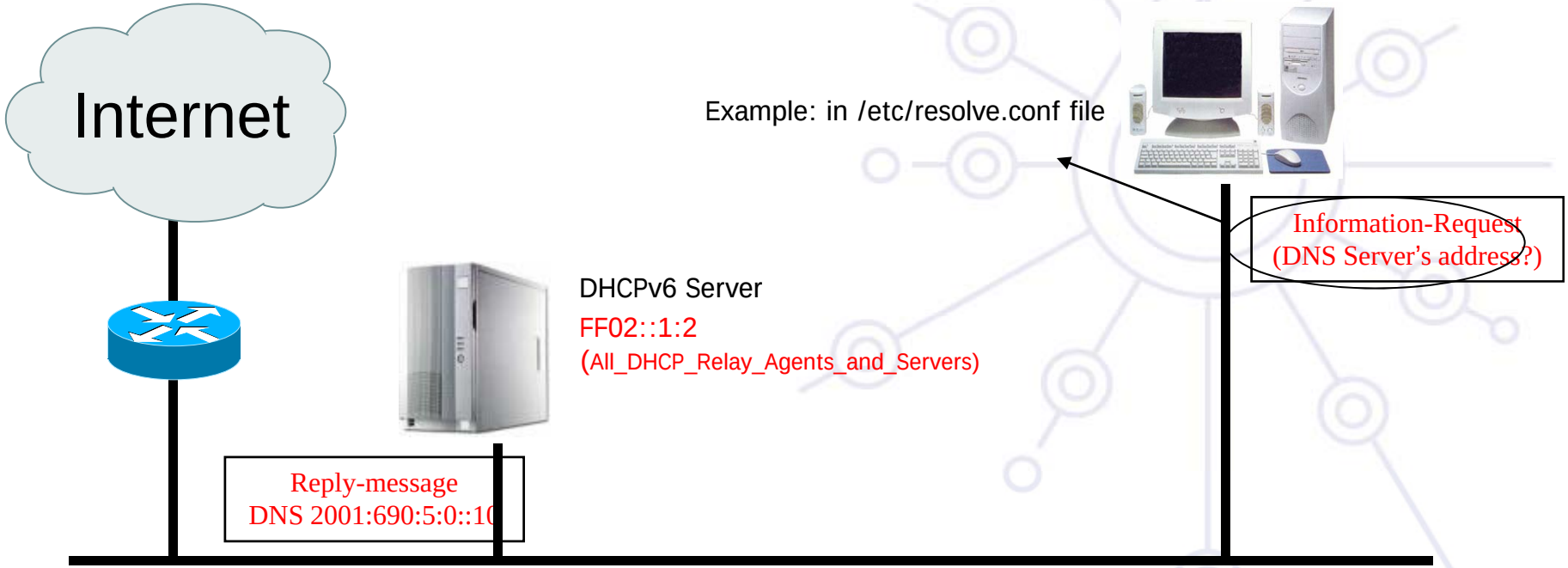
DHCPv6 works in a client / server model

- Server
  - Responds to requests from clients
  - Optionally provides the client with:
    - IPv6 addresses
    - Other configuration parameters (DNS servers...)
  - Is listening on multicast addresses:
    - All_DHCP_Relay_Agents_and_Servers (FF02::1:2)
    - All_DHCP_Servers (FF05::1:3)
  - Memorizes client's state
  - Provides means for securing access control to network resources

Statefull Autoconfiguration DHCPv6 /3

- Client
  - initiates requests on a link to obtain configuration parameters
  - uses its link local address to connect the server
  - Sends requests to FF02::1:2 multicast address (All_DHCP_Relay_Agents_and_Servers)
- Relay agent
  - node that acts as an intermediary to deliver DHCP messages between clients and servers
  - is on the same link as the client
  - Is listening on multicast addresses:
    - All_DHCP_Relay_Agents_and_Servers (FF02::1:2)

Statefull Autoconfiguration DHCPv6 /4



Conclusion

The two types of configuration complement each other

- Example: we can obtain the address from stateless autoconfiguration and the DNS server address from DHCPv6

In dual-stack networks we can obtain DNS server addresses from DHCPv4

DHCPv6 clients aren't still available natively in all Operating Systems.

- So, we still need to install manually a client
- Not transparent to users


deploy
Questions?