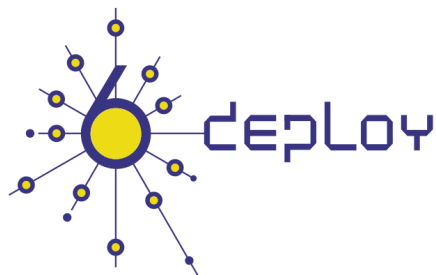


# IPv6 Basics

**APNIC Training  
Vientiane, Laos  
August, 2011**

**Jordi Palet, Consulintel  
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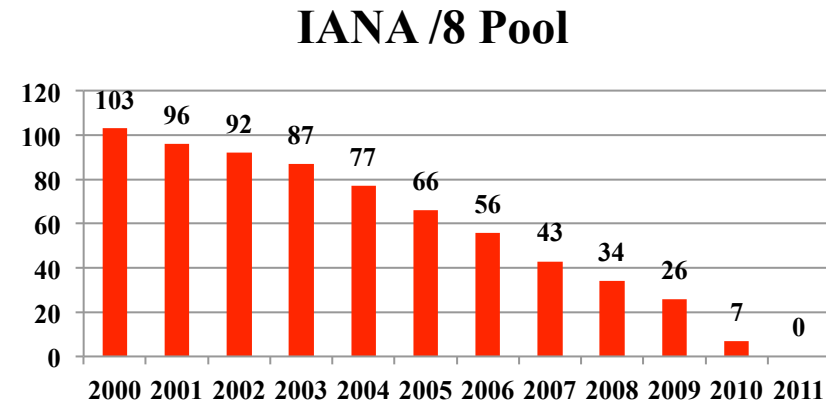
# Why a New IP?

Only *compelling* reason: more addresses!

- for billions of new devices,  
e.g., cell phones, PDAs, appliances, cars, etc.
- for billions of new users,  
e.g., in China, India, etc.
- for “always-on” access technologies,  
e.g., xDSL, cable, ethernet-to-the-home, PLC/  
BPL, etc.

# But Isn't There Still Lots of IPv4 Address Space Left?

- IPv4 addresses availability
  - 10% early 2010
  - 6% middle 2010
  - 5% a couple of months after
  - 2% at the end of 2010
  - 0% February 3<sup>rd</sup> 2011
- Today we deny unique IPv4 addresses to most new hosts
  - we make them use methods like NAT, PPP, etc. to share addresses
- But new types of applications and new types of access need unique addresses!



# Why Are NAT's Not Adequate?

- They won't work for large numbers of “servers”, i.e., devices that are “called” by others (e.g., IP phones)
- They inhibit deployment of new applications and services
- They compromise the performance, robustness, security, and manageability of the Internet



# Incidental Benefits of Bigger Addresses

- Easy address auto-configuration
- Easier address management/delegation
- Room for more levels of hierarchy, for route aggregation
- Ability to do end-to-end IPsec (because NATs not needed)

# Incidental Benefits of New Deployment

- Chance to eliminate some complexity, e.g., in IP header
- Chance to upgrade functionality, e.g., multicast, QoS, mobility
- Chance to include new enabling features, e.g., binding updates

# Summary of Main IPv6 Benefits

- Expanded addressing capabilities
- Server-less autoconfiguration (“plug-n-play”) and reconfiguration
- More efficient and robust mobility mechanisms
- Built-in, strong IP-layer encryption and authentication
- Streamlined header format and flow identification
- Improved support for options / extensions

# Why Was 128 Bits Chosen as the IPv6 Address Size?

- Some wanted fixed-length, 64-bit addresses
  - easily good for  $10^{12}$  sites,  $10^{15}$  nodes, at .0001 allocation efficiency (3 orders of mag. more than IPng requirement)
  - minimizes growth of per-packet header overhead
  - efficient for software processing
- Some wanted variable-length, up to 160 bits
  - compatible with OSI NSAP addressing plans
  - big enough for autoconfiguration using IEEE 802 addresses
  - could start with addresses shorter than 64 bits & grow later
- Settled on fixed-length, 128-bit addresses
  - (340,282,366,920,938,463,463,374,607,431,768,211,456 in all!)



# What Ever Happened to IPv5?

0–3		unassigned
4	IPv4	(today' s widespread version of IP)
5	ST	(Stream Protocol, not a new IP)
6	IPv6	(formerly SIP, SIPP)
7	CATNIP	(formerly IPv7, TP/IX; deprecated)
8	PIP	(deprecated)
9	TUBA	(deprecated)
10-15		unassigned

# IPv6 Tutorial

## Header Formats

# RFC2460

- Internet Protocol, Version 6: Specification
- Changes from IPv4 to IPv6:
  - Expanded Addressing Capabilities
  - Header Format Simplification
  - Improved Support for Extensions and Options
  - Flow Labeling Capability
  - Authentication and Privacy Capabilities

# IPv4 Header Format

- 20 Bytes + Options

bits:	4	8	16	20	32
Version	H. Length	TOS	Total Length		
Identification			Flags	Fragment Offset	
Time To Live	Protocol		Header Checksum		
32 bits Source Address					
32 bits Destination Address					
Options					

Modified Field

Deleted Field



# IPv6 Header Format

- From 12 to 8 Fields (40 bytes)

bits:	4	12	16	24	32
Version	Class of Traffic	Flow Label			
Payload Length			Next Header	Hop Limit	
128 bits Source Address					
128 bits Destination Address					

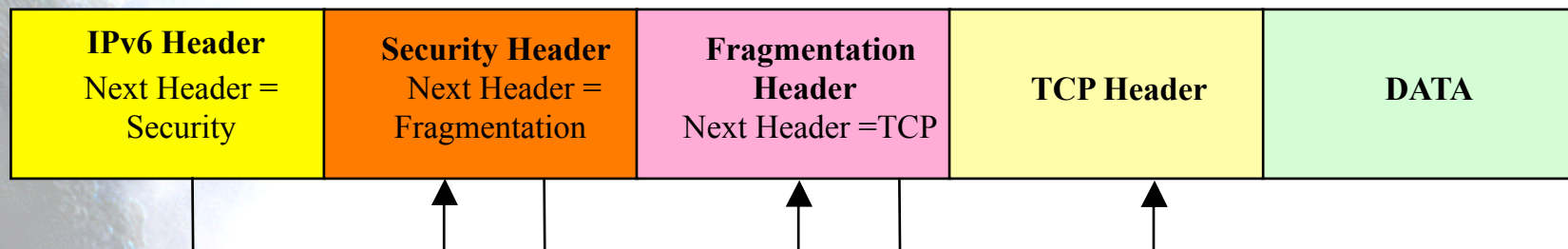
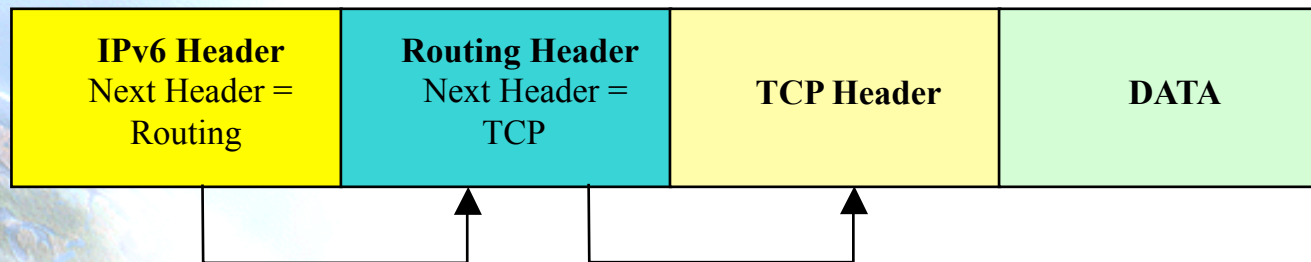
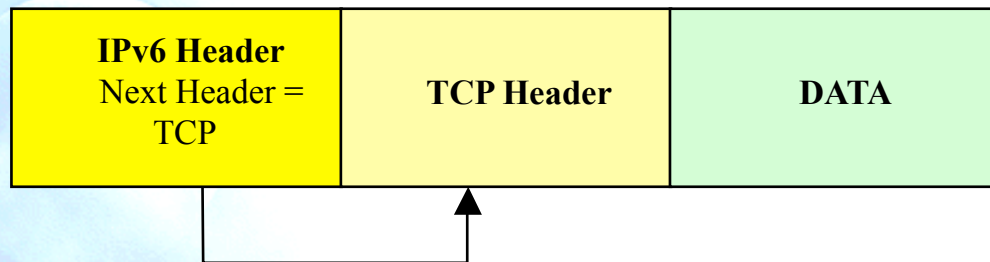
- Avoid checksum redundancy
- Fragmentation end to end

# Summary of Header Changes

- 40 bytes
- Address increased from 32 to 128 bits
- Fragmentation and options fields removed from base header
- Header checksum removed
- Header length is only payload (because fixed length header)
- New Flow Label field
- TOS -> Traffic Class
- Protocol -> Next Header (extension headers)
- Time To Live -> Hop Limit
- Alignment changed to 64 bits

# Extension Headers

- “Next Header” Field

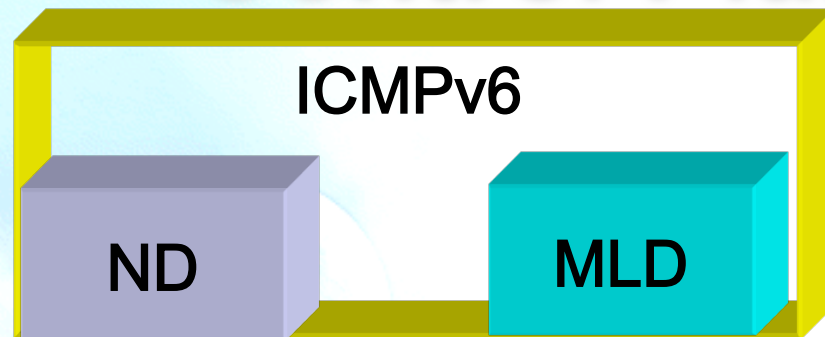


# Extension Headers Goodies

- Processed Only by Destination Node
  - Exception: Hop-by-Hop Options Header
- No more “40 byte limit” on options (IPv4)
- Extension Headers defined currently (to be used in the following order):
  - Hop-by-Hop Options (0)
  - Routing (43)
  - Fragment (44)
  - Authentication (RFC4302, next header = 51)
  - Encapsulating Security Payload (RFC4303, next header = 50)
  - Destination Options (60)
  - Mobility Header (135)
  - No next header (59)
    - TCP (6), UDP (17), ICMPv6 (58)



# Control Plane IPv4 vs. IPv6



Multicast



Broadcast

Multicast

# IPv6 Tutorial

## Addressing and Routing

# Text Representation of Addresses

“Preferred” form: 2001:DB8:FF:0:8:7:200C:417A

Compressed form: FF01:0:0:0:0:0:0:43  
becomes FF01::43

IPv4-compatible: ::13.1.68.3 (deprecated)

IPv4-mapped: ::FFFF:13.1.68.3

URL: [http://\[FF01::43\]:80/index.html](http://[FF01::43]:80/index.html)

# Address Types

Unicast (one-to-one)

- global
- link-local
- site-local (deprecated)
- Unique Local (ULA)
- IPv4-compatible (deprecated)
- IPv4-mapped

Multicast (one-to-many)

Anycast (one-to-nearest)

Reserved



# 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	FEF0::/10
IPv4-compatible (deprecated)	00...0 (96 bits)	::/96

- **Anycast** addresses allocated from unicast prefixes

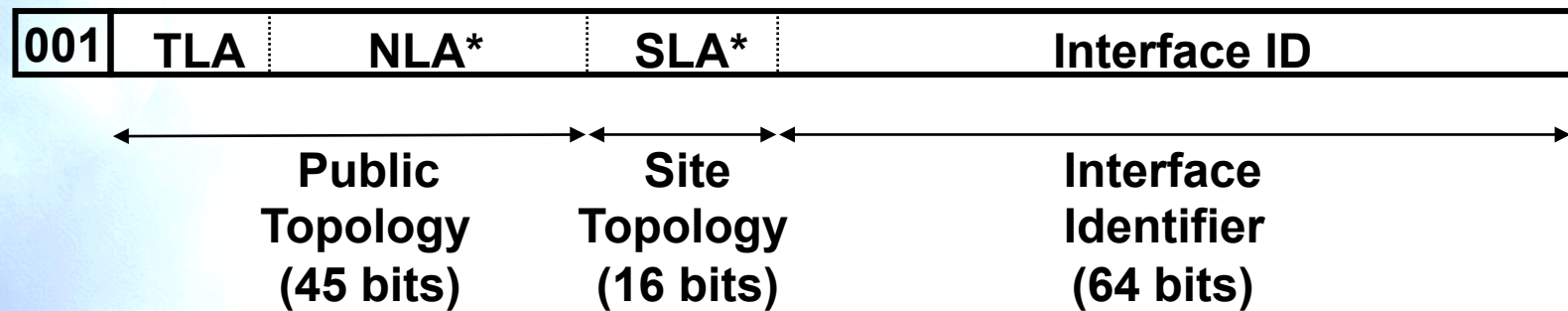
# Global Unicast Prefixes

<u>Address Type</u>	<u>Binary Prefix</u>
IPv4-compatible	0000...0 (96 zero bits) (deprecated)
IPv4-mapped	00...0FFFF (80 zero+ 16 one bits)
Global unicast	001
ULA	1111 110x (1= Locally assigned) (0=Centrally assigned)

- **2000::/3** prefix is being allocated for Global Unicast, all other prefixes reserved (approx. 7/8ths of total)

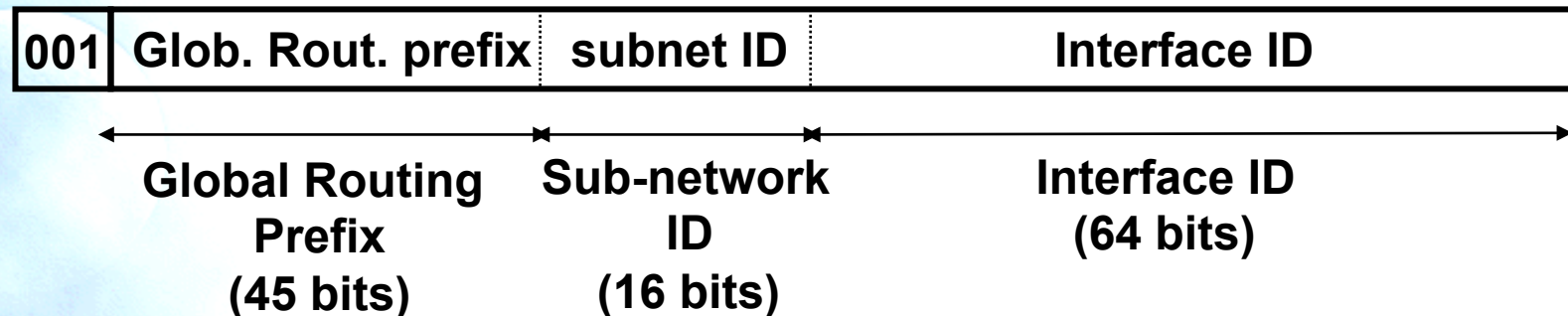
# Aggregatable Global Unicast Addresses (RFC2374)

## (Deprecated)



- TLA = Top-Level Aggregator
- NLA\* = Next-Level Aggregator(s)
- SLA\* = Site-Level Aggregator(s)
- TLAs may be assigned to ISPs and IX

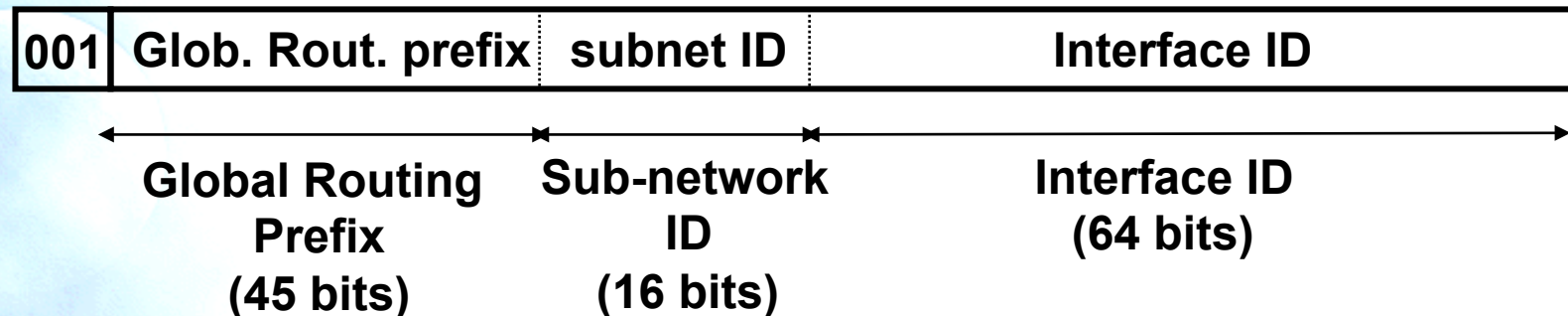
# Global Unicast Addresses (RFC3587)



- 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
- The Interface ID is build following the EUI-64 format

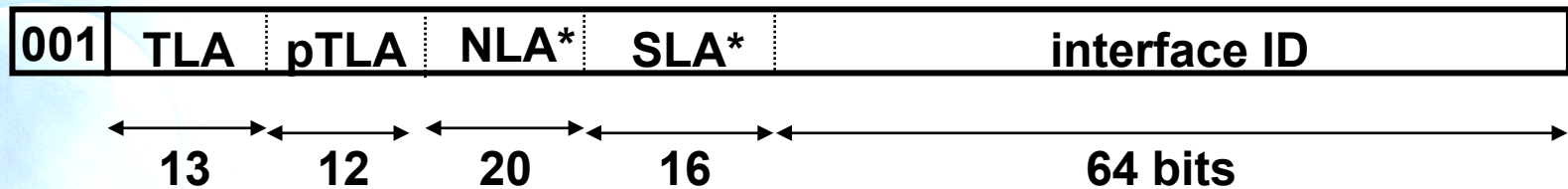


# Global Unicast Addresses in Production Networks



- LIRs receive by default /32
  - Production addresses today are from prefixes 2001, 2003, 2400, 2800, 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 only and only one network is required
    - /128 if it is sure that only and only one device is going to be connected

# Global Unicast Addresses for the 6Bone **Until 06/06/06 !**



- 6Bone: experimental IPv6 network used for testing only
- TLA 1FFE (hex) assigned to the 6Bone
  - thus, 6Bone addresses start with 3FFE:
  - (binary 001 + 1 1111 1111 1110)
- Next 12 bits hold a “pseudo-TLA” (pTLA)
  - thus, each 6Bone pseudo-ISP gets a /28 prefix
- Not to be used for production IPv6 service

# Link-Local & Site-Local Unicast Addresses

Link-local addresses for use during auto-configuration and when no routers are present:

1111111010	0	interface ID
------------	---	--------------

Site-local addresses for independence from changes of TLA / NLA\* (deprecated !):

1111111011	0	SLA*	interface ID
------------	---	------	--------------

# Unique Local IPv6 Unicast Addresses

## IPv6 ULA (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

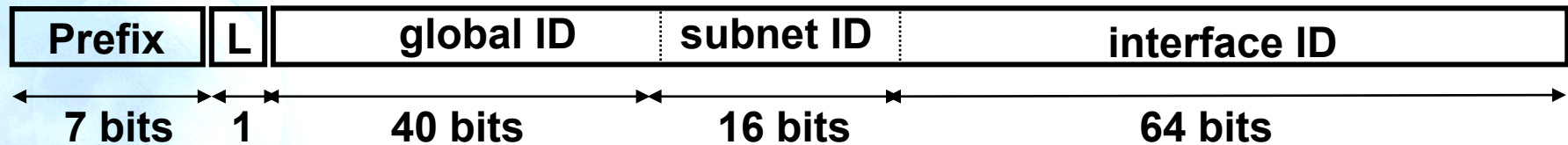


# IPv6 ULA Characteristics

- 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

# IPv6 ULA Format

- 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**
- 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

# Centrally Assigned Unique Local IPv6 Unicast Addresses (1)

- Centrally-Assigned Local addresses
  - vs Locally-Assigned Local addresses
- Latest Draft:
  - draft-ietf-ipv6-ula-central-01.txt
  - February 2005
  - No longer active
  - It defines the characteristics and requirements for Centrally assigned Local IPv6 addresses in the framework defined in IPv6 ULA – RFC4193

# Centrally Assigned Unique Local IPv6 Unicast Addresses (2)

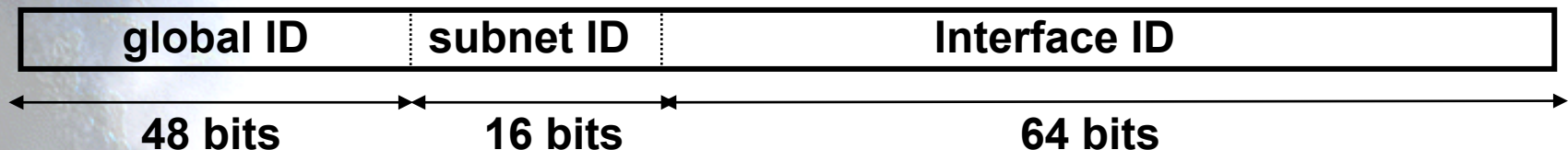
- The major difference between both assignments:
  - the Centrally-Assigned is uniquely assigned and the assignments can be escrowed to resolve any disputes regarding duplicate assignments
- It is recommended that sites planning to use Local IPv6 addresses use a centrally assigned prefix as there is no possibility of assignment conflicts. Sites are free to choose either approach
- The allocation procedure for creating global-IDs for centrally assigned local IPv6 addresses is setting L=0. Remember that the allocation procedure for locally assigned local IPv6 addresses is thru L=1, as is defined in RFC4193



# Interface IDs

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

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

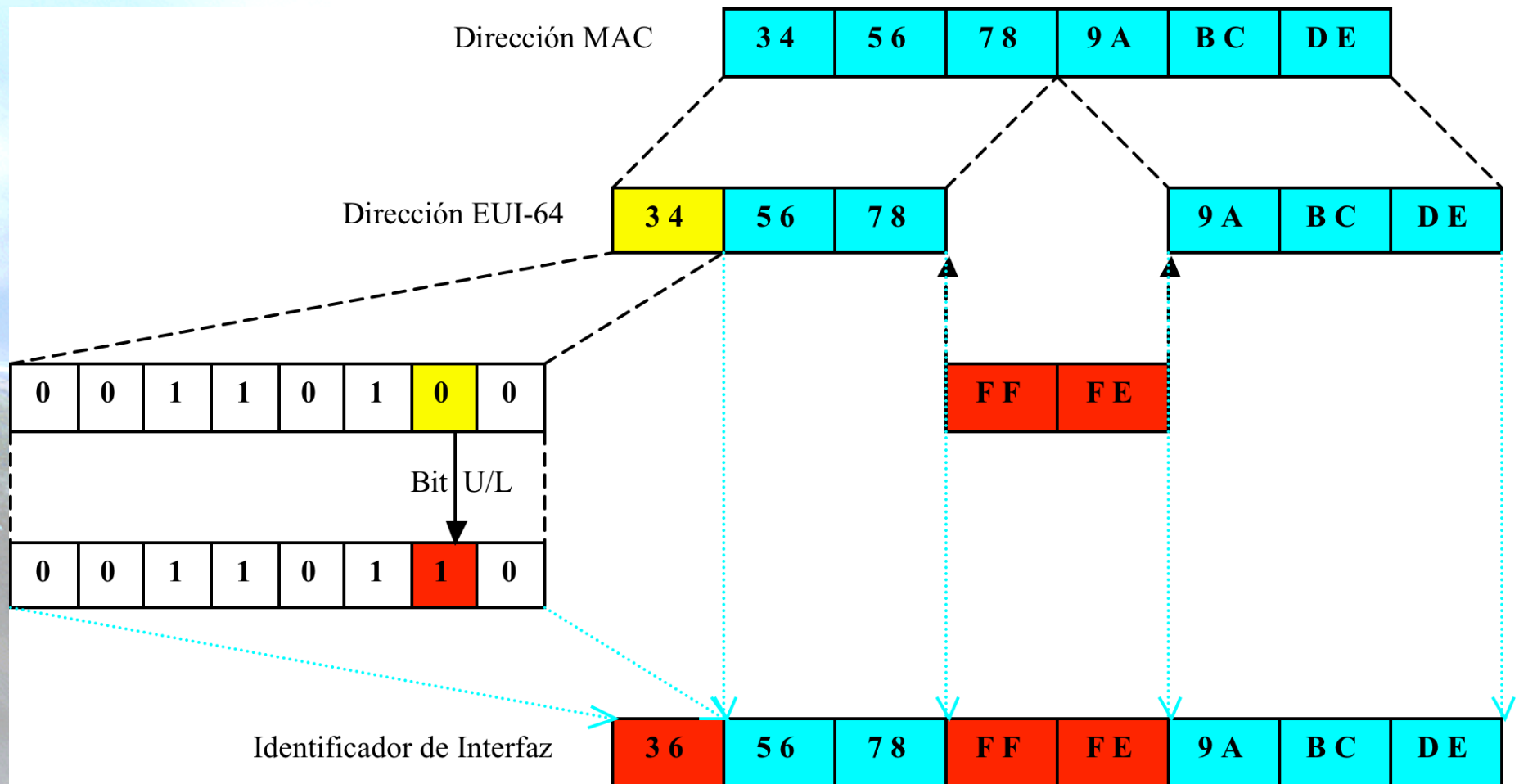




# IPv6 in Ethernet

48 bits	48 bits	16 bits	
Ethernet Destination Address	Ethernet Source Address	1000011011011101 (86DD)	IPv6 Header and Data

# EUI-64



# Some Special-Purpose Unicast Addresses

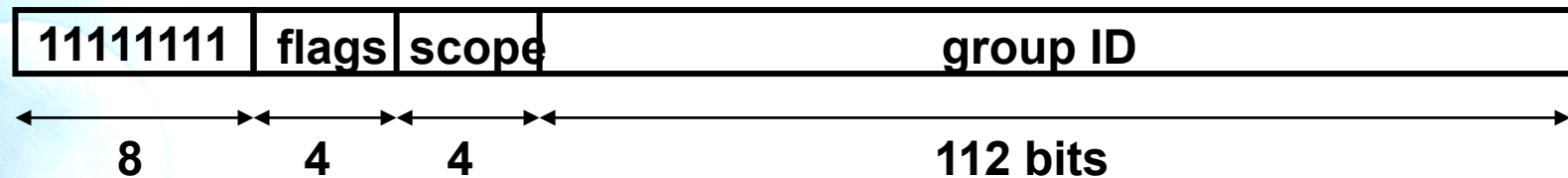
- The unspecified address, used as a placeholder when no address is available:

0:0:0:0:0:0:0:0

- The loopback address, for sending packets to self:

0:0:0:0:0:0:0:1

# Multicast Addresses



- Low-order flag indicates permanent/transient group; three other flags reserved
- Scope field:
  - 1 - node local
  - 2 - link-local
  - 5 - site-local
  - 8 - organization-local
  - B - community-local
  - E - global(all other values reserved)

# Routing

- Uses same “longest-prefix match” routing as IPv4 CIDR
- Straightforward changes to existing IPv4 routing protocols to handle bigger addresses
  - unicast: OSPF, RIP-II, IS-IS, BGP4+, ...
  - multicast: MOSPF, PIM, ...
- Can use Routing header with anycast addresses to route packets through particular regions
  - e.g., for provider selection, policy, performance, etc.





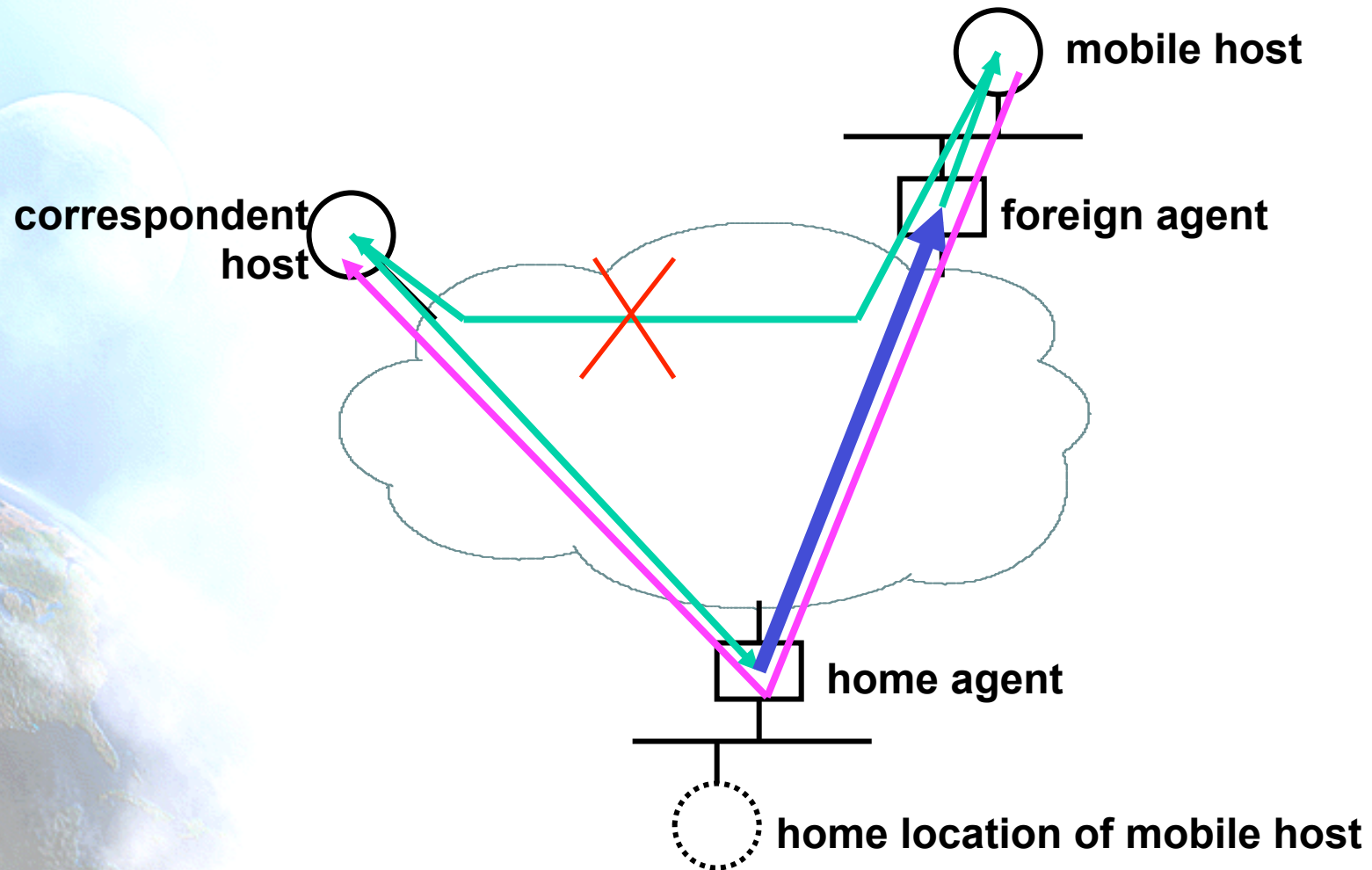
# IPv6 Tutorial

## Mobility

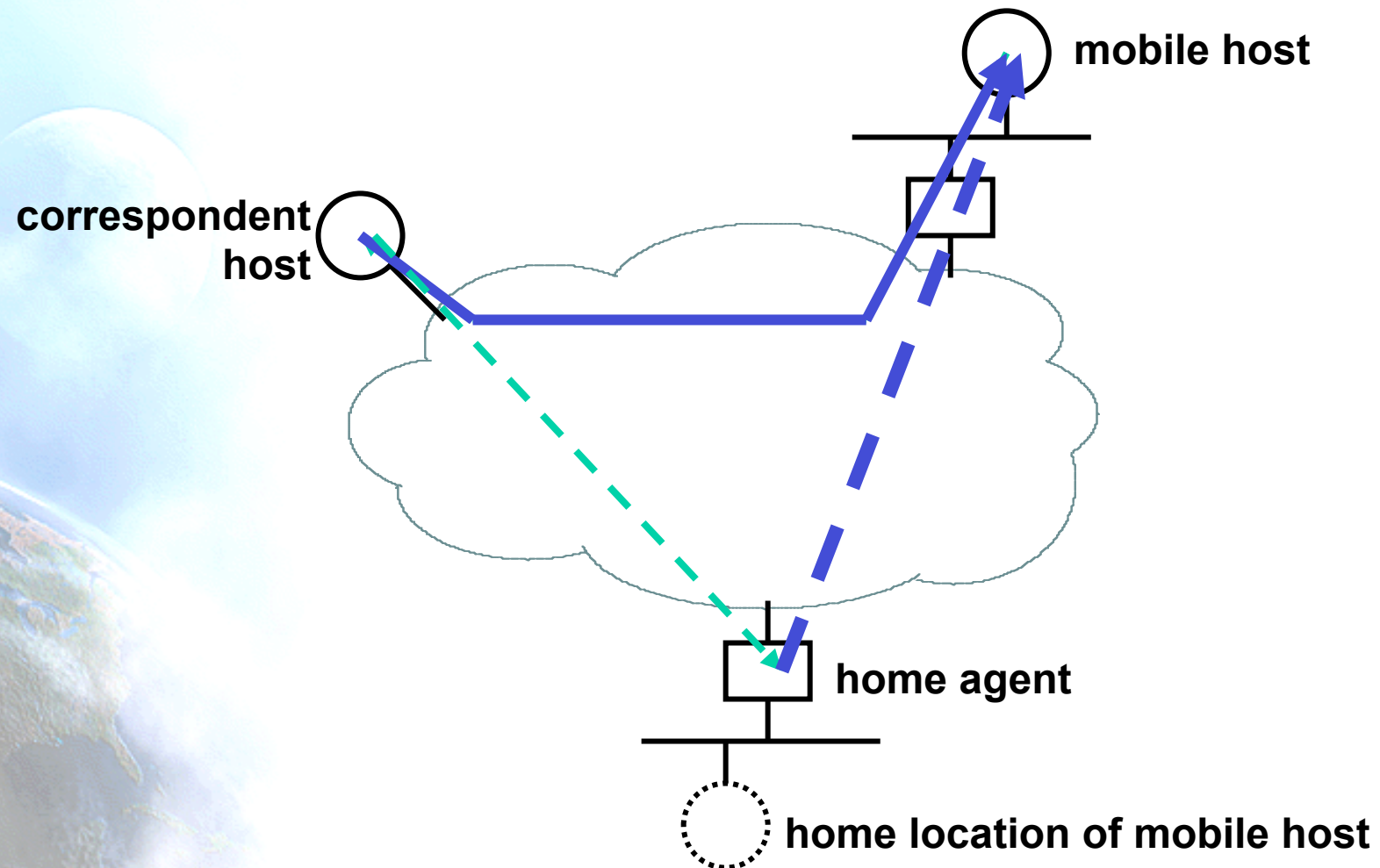
# IPv6 Mobility

- A mobile host has one or more home address(es)
  - relatively stable; associated with host name in DNS
- When it discovers it is in a foreign subnet (i.e., not its home subnet), it acquires a foreign address
  - uses auto-configuration to get the address
  - registers the foreign address with a home agent, i.e, a router on its home subnet
- Packets sent to the mobile' s home address(es) are intercepted by home agent and forwarded to the foreign address, using encapsulation

# Mobile IPv4



# Mobile IPv6





# IPv6 Tutorial

## IPv4-IPv6 Coexistence & Transition

# Transition / Co-Existence Techniques

A wide range of techniques have been identified and implemented, basically falling into three categories:

- (1) dual-stack techniques, to allow IPv4 and IPv6 to co-exist in the same devices and networks
- (2) tunneling techniques, to avoid order dependencies when upgrading hosts, routers, or regions
- (3) translation techniques, to allow IPv6-only devices to communicate with IPv4-only devices

Expect all of these to be used, in combination

# Dual-Stack Approach

- When adding IPv6 to a system, do not delete IPv4
  - this multi-protocol approach is familiar and well-understood (e.g., for AppleTalk, IPX, etc.)
  - note: in most cases, IPv6 will be bundled with new OS releases, not an extra-cost add-on
- Applications (or libraries) choose IP version to use
  - when initiating, based on DNS response:
    - if (destination has AAAA record) use IPv6, else use IPv4
  - when responding, based on version of initiating packet
- This allows indefinite co-existence of IPv4 and IPv6, and gradual app-by-app upgrades to IPv6 usage
- A6 record as experimental

# Tunnels to Get Through IPv6-Ignorant Routers

- Encapsulate IPv6 packets inside IPv4 packets (or MPLS frames)
- Many methods exist for establishing tunnels:
  - manual configuration
  - “tunnel brokers” (using web-based service to create a tunnel)
  - “6-over-4” (intra-domain, using IPv4 multicast as virtual LAN)
  - “6-to-4” (inter-domain, using IPv4 addr as IPv6 site prefix)
- Can view this as:
  - IPv6 using IPv4 as a virtual link-layer, or
  - an IPv6 VPN (virtual public network), over the IPv4 Internet (becoming “less virtual” over time, we hope)



# Translation

- May prefer to use IPv6-IPv4 protocol translation for:
  - new kinds of Internet devices (e.g., cell phones, cars, appliances)
  - benefits of shedding IPv4 stack (e.g., serverless autoconfig)
- This is a simple extension to NAT techniques, to translate header format as well as addresses
  - IPv6 nodes behind a translator get full IPv6 functionality when talking to other IPv6 nodes located anywhere
  - they get the normal (i.e., degraded) NAT functionality when talking to IPv4 devices
  - methods used to improve NAT functionality (e.g, RSIP) can be used equally to improve IPv6-IPv4 functionality

# Thanks !

## Contact:

– Jordi Palet Martínez (Consulintel): [jordi.palet@consulintel.es](mailto:jordi.palet@consulintel.es)

## The IPv6 Portal:

- <http://www.ipv6tf.org>