Addressing and Routing in IPv6

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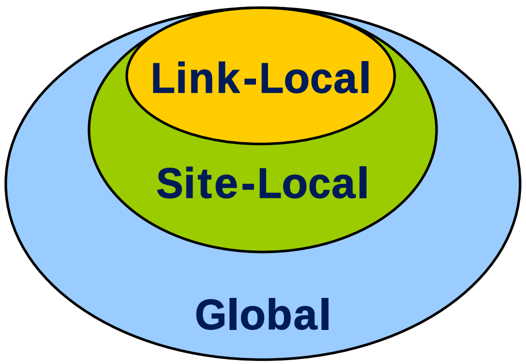
IPv6 Addressing Model (I)

- Addresses of 128 bits
  - more than 10^{38} possible addresses
  - more than 1500 addresses per m^2 having into account hierarchical assignment –and being pessimistic- (C. Huitema)
- Addresses are assigned to interfaces
- Multiple addresses per interface
- Addresses have scope
  - Link-Local
  - Site-Local
  - Global



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IPv6 Addressing Model (II)

- Address Structure:
  - IPv6 Address = Prefix + Interface Id
- Separation of “who you are” from “where you are connected to”
  - Prefix: depends on routing topology
  - Interface Id: identifies a node
- New Anycast addresses:
  - Unicast: from one host to another
  - Multicast: from one to all belonging to a group
  - Anycast: from one to the nearest belonging to a group
- Broadcast disappears

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Text Representation of Addresses (I)

- Preferred form:

  X:X:X:X:X:X:X:X (X = 2 bytes written in hex.)

- Example:

  3ffe:3328:4:3:250:4ff:fe5c:b3f4

  Prefix **Interface Id**

- Contiguous zeros can be eliminated:

  FF01:0:0:0:0:0:0:43 = FF01::43

- IPv4 compatible addresses:

  0:0:0:0:0:0:194.179.46.78 = ::194.179.46.78

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Text Representation of Addresses (II)

- Special addresses:
  - 0:0:0:0:0:0:0:1 - Loopback
  - 0:0:0:0:0:0:0:0 - Unspecified Address
- Prefix representation:
  - 3ffe:0000:0000:CD30:0000:0000:0000:0000/60
  - 3ffe::CD30:0:0:0:0/60
  - 3ffe:0:0:CD30::/60

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IPv6 Assigned Prefixes

- Address type indicated by *Format Prefix (FP):*

Type	FP	Fraction	Prefix
NSAP	0000 001	1/128	0200::/7
IPX	0000 010	1/128	0400::/7
Global Unicast	001	1/8	2000::/3
Link-Local	1111 1110 10	1/1024	fe80::/12
Site-Local	1111 1110 11	1/1024	fec0::/12
Multicast	1111 1111	1/256	ff00::/8

- Anycast addresses allocated from unicast prefixes
- Approximately only 1/8 of addressing space has been allocated

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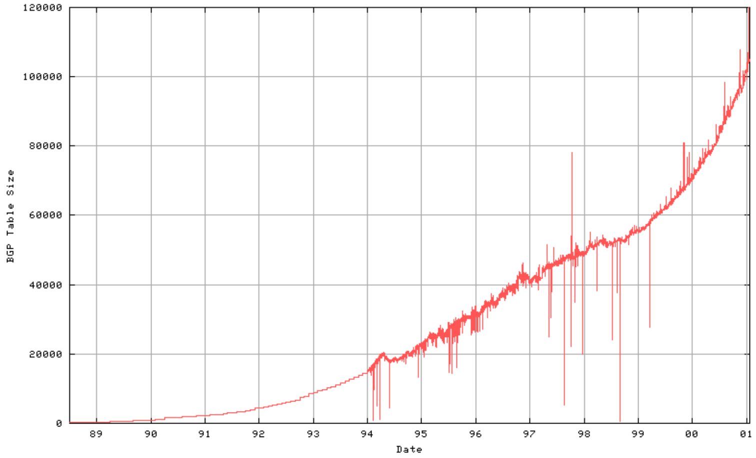
Routing in IPv4

- Main Problems:
  - Shortage of addresses
  - Routing Table Size



BGP Table Size Evolution

= { **High Resources Comsumption:**
- **CPU**
- **Memory**
- **Bandwidth**

- CIDR allowed to survive the first big crisis (92-95), but, ¿will it be able to survive next years growth (xDSL, mobile terminals, etc)?
- The answer is......***IPv6!!***

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Routing in IPv6

- Summary:
  - Similar to IPv4 routing with CIDR, but with the flexibility that 128 bits addresses allow.
  - Minimal modifications to dynamic routing protocols (OSPF, IDRP, RIP, IS-IS, BGP) in order to work with IPv6 (address formats).
  - Improved source routing option (Routing Header). Used for:
    - Provider Selection
    - Mobility
    - ...

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Unicast Routing Model

- Defined in RFC 2374 (An IPv6 Aggregatable Global Unicast Address Format)
- Strictly hierarchical with three levels:
  - Public Topology: providers and exchanges that offer Internet transit services.
  - Site Topology: local topology of a site that does not offer transit services to nodes external to its organization.
  - Interface Identifier: unique identifier asigned to any interface connected to Internet.
- Main objective: SCALABILITY
- Prefix 2000::/3 (Addresses beginning by 2XXX:... and 3XXX:...)

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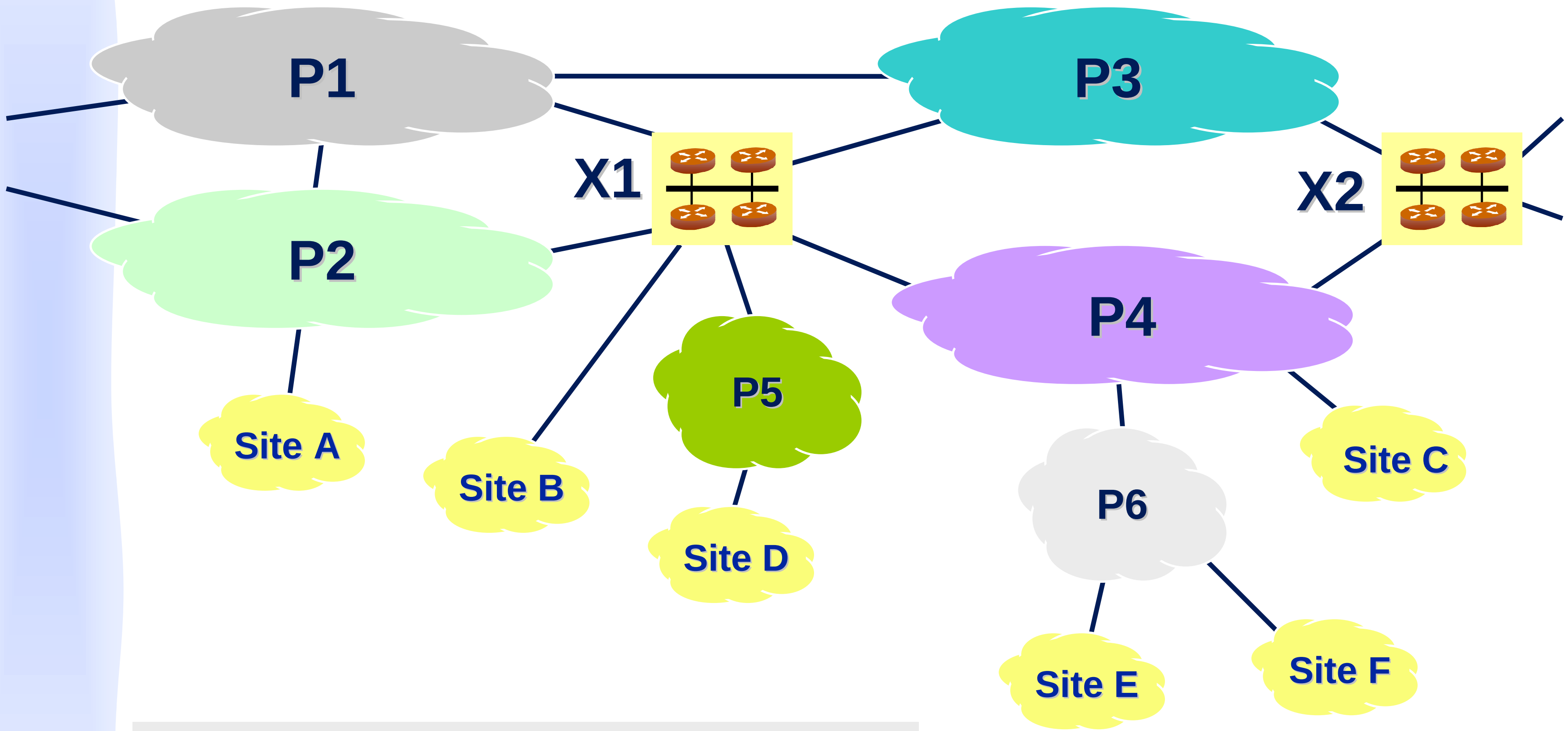
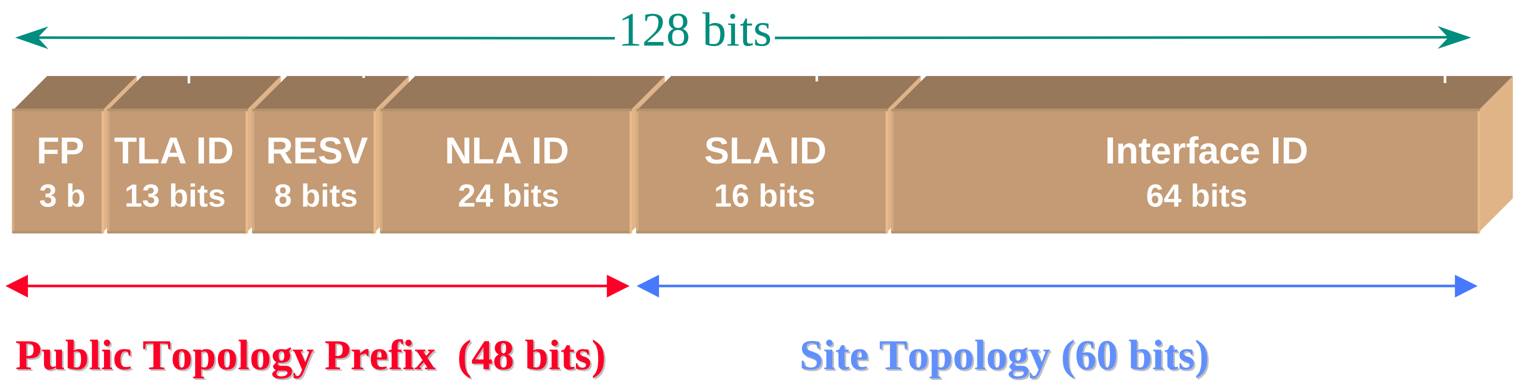
Public Topology



X1, X2: Exchanges (NAP, FIX, etc)
P1, P2, P3, P4: Long-haul Providers
P5, P6: Providers

Unicast Addresses

- Global Aggregatable Unicast Addresses (RFC2374):



FP	Format Prefix (001)
TLA ID	Top-Level Aggregation Identifier
RESV	Reserved (to enlarge TLA o NLA)
NLA ID	Next-Level Aggregation Identifier
SLA ID	Site-Level Aggregation Identifier
Interface ID	Interface Identifier (EUI-64)

Routing Model: Summary

- Hierarchical model: addresses depend strictly of network topology
- Two types of Aggregation:
  - Per Provider: addresses depend on the provider we are connected to
  - Per Exchange: addresses depend on the Exchange we are connected to
- Consequence: If we change Provider or Exchange, we need to *RENUMBER* our network. (The same happens if the provider of our provider changes)

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Routing Header

- Allows to modify routing decissions made by routers (Source Routing):
  - The sender of a datagram can specify a list of addresses to “visit” in the way to the destination
- Very similar to IPv4’s option Loose/Strict Source Routing ...
- ...but without its important limitations (header size, inefficiencies, etc)
- Main aplications:
  - Provider Selection (combined with anycast addresses)
  - Mobility

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Routing Header

- Format:

NH	Hdr Ext Len	RT=0	Segments Left
Reserved	Strict/Loose Bit Map		
Address 1			
Address 2			
....			
Address N			

- Differences with IPv4:
  - Datagram destination address is substituted by the next address in the list.
  - Responses to datagrams with RH must include the same RH but with the list of addresses inverted.
  - Strict/loose option improved. Each address in the list can be strict or loose.

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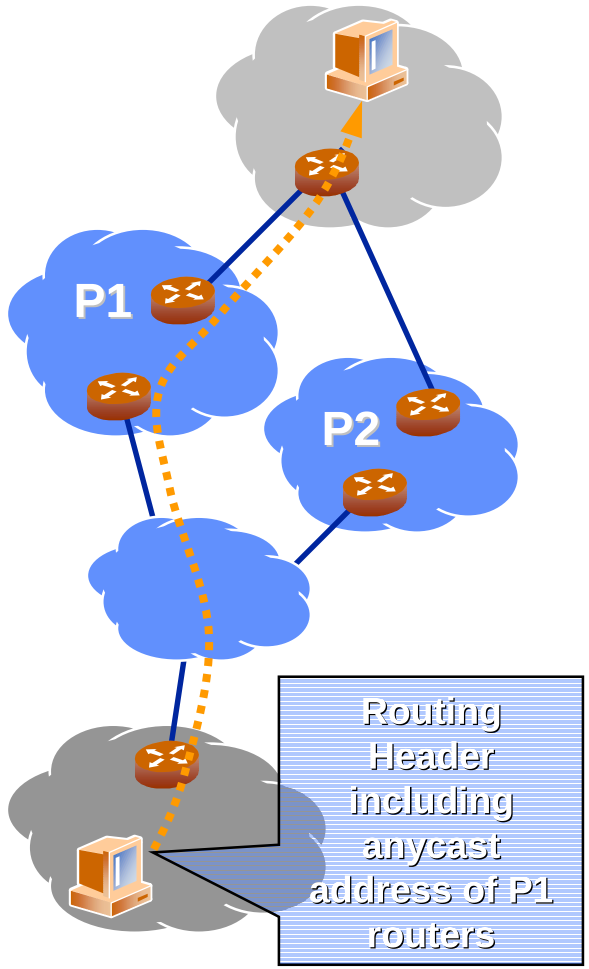
Anycast Addresses

- Anycast addresses are *unicast addresses* asigned to several interfaces (of different nodes tipically)
- A packet sent to an *anycast* address should reach the nearest interface with that address asigned
- For example: Subnet Router Anycast Address

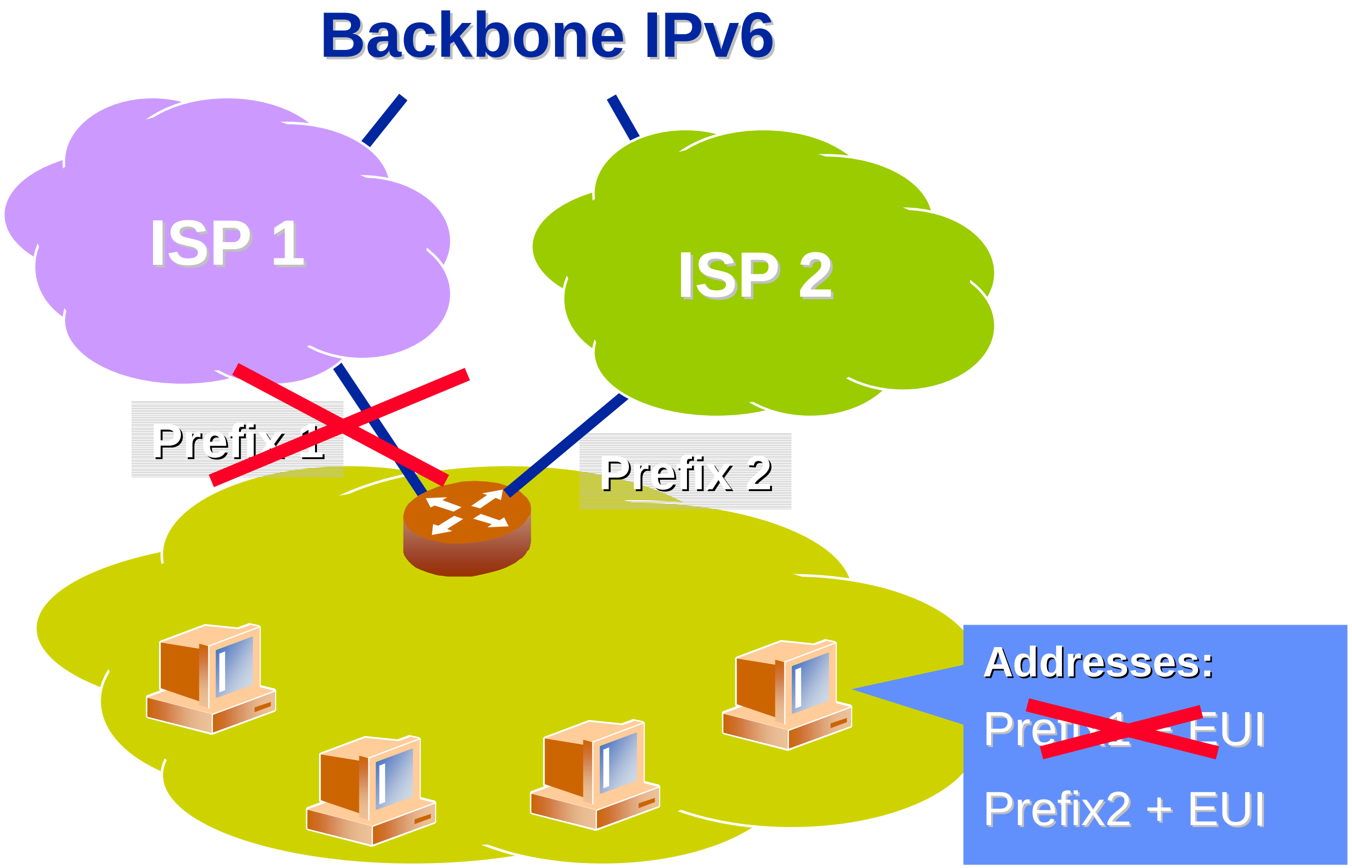
Subnet Prefix (n bits)	000000 (128-n bits)

- They are experimental. They can be used, for example, to enable Provider Selection



Network Renumbering in IPv6

◆ Typical Scenario: Change of Provider (ISP)



Renumbering Techniques

- Hosts:
  - Announcement of new prefixes by routers (using Routing Advertisement messages), or
  - Using DHCP (DHCPv6 includes an extension disable addresses asigned)
- Routers:
  - RFC 2894: Router Renumbering for IPv6
  - New Protocol to change prefixes exported by routers.
  - Uses a new ICMPv6 message
- DNS:
  - A6 records. Composed of:
    - An interface identifier
    - A reference to a prefix
  - To renumber you only need to change the prefix DNS record, not the host records

IPv6 Dynamic Routing Protocols

- In general, minimal modifications are needed to existing protocols to adapt them to IPv6:
  - Changes related to address format
  - In some cases, modifications to support IPv4 and IPv6 simultaneously *(Integrated Routing)*
- RIPng (RFC 2080)
  - Minimal modifications to RIP
  - IGP used in small and static LAN
  - Based on distance vector algorithm (important convergence problems)
  - Several implementations: GateD, MRTd, Kame route6d, Zebra, CISCO, etc

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IPv6 Dynamic Routing Protocols (II)

- OSPFv6 = OSPFv3 for IPv6 (RFC 2740)
  - IGP recomended by IETF:
    - Based on Link-State algorithm: fast convergence
    - Network divided in Areas: good scalability
  - Minimal Changes:
    - Format of addresses, prefixes, ids., etc
    - Authentication eliminated (it uses IPv6's)
  - It does not use Integrated Routing: *"Ships in the night" (two copies of OSPF running: for IPv4 and IPv6)*
  - Several implementations: Ericsson-Telebit, IBM, Zebra, Gated, MRTd, CISCO, etc.

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IPv6 Dynamic Routing Protocols (III)

- Inter-Domain Routing: BGP4+
  - Used between ISPs and between ISPs and large corporations
  - Modifications:
    - RFC 2858 defines multiprotocol extensions (IPv6, IPX, etc) to BGP-4. Compatibility with BGP-4
    - RFC 2545 defines how to use extensions for IPv6 (Scopes, Next Hop, etc)
  - Used in 6BONE and in main IPv6 exchanges
  - Several implementations: GateD, MRTd, Kame BGPd, Zebra, CISCO, etc

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- RFC 2374. An IPv6 Aggregatable Global Unicast Address Format
- RFC 1884. IP Version 6 Addressing Architecture. draft-ietf-ipngwg-addr-arch-v3-02.txt.
- RFC 2450. Proposed TLA and NLA Assignment Rules
- RFC 2894. Router Renumbering for IPv6
- RFC 2928. Initial IPv6 Sub-TLA ID Assignments
- RFC 2858. Multiprotocol Extensions for BGP-4
- RFC 2545. Use of BGP-4 Multiprotocol Extensions for IPv6 Inter-Domain Routing
- RFC 2740. OSPF for IPv6
- RFC 2080. RIPng for IPv6

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References (II)

- IPv6 Multihoming with Route Aggregation. draft-ietf-ipngwg-ipv6multihome-with-aggr-01.txt
- IPv6 multihoming support at site exit routers. draft-ietf-ipngwg-ipv6-2260-00.txt
- Default Address Selections for IPv6 (draft-ietf-ipngwg-default-addr-select-00.txt).
- Multi-homed Routing Domain Issues for IPv6 (draft-ietf-ipngwg-multi-isp-00.txt).

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