Routing in IPv6

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- Routing Header
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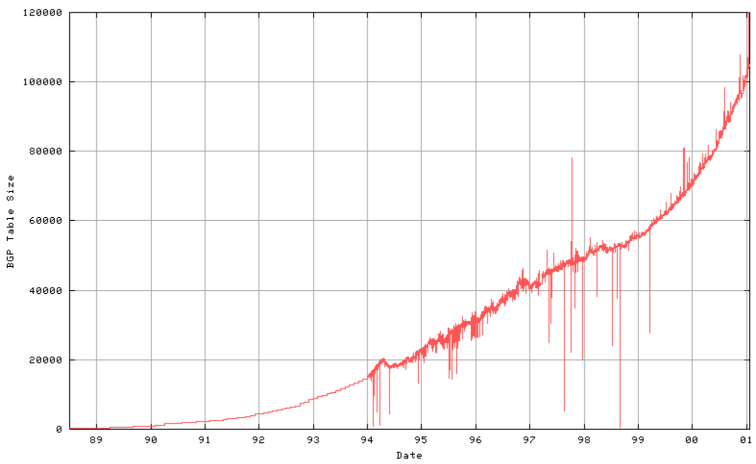
Routing in IPv4

- 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!!***

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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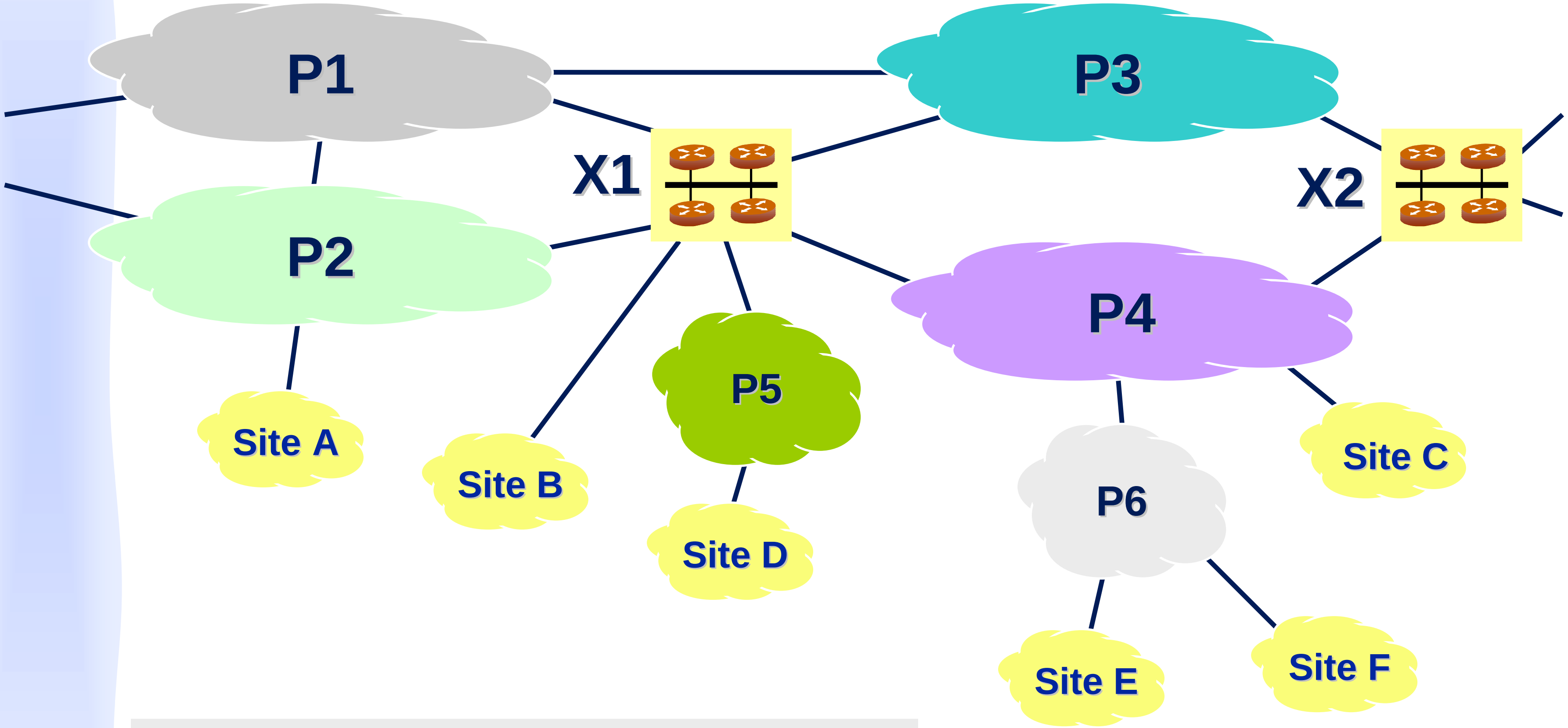
Public Topology



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

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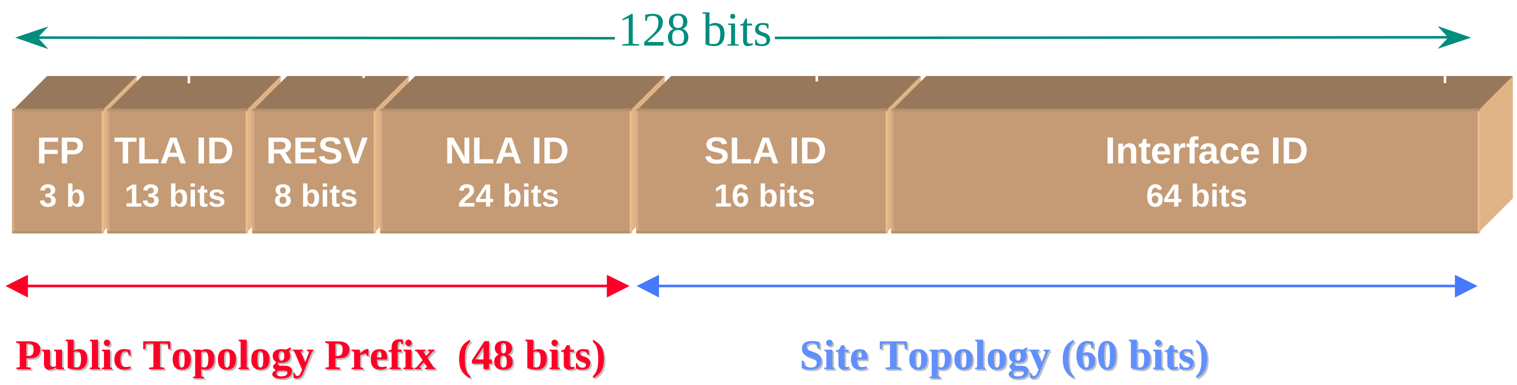
Unicast Addresses

- 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)

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Identifiers: Characteristics

- TLA Id: Top Level Aggregator Identifier
  - Identify Main Providers
  - Default-free routers should have one routing table entry for each active TLA (+additional entries for routing optimization)
  - Capacity for 8192 TLAs (can be enlarged using reserved field)
- NLA Id: Next Level Aggregator Identifier
  - Used by providers to create an addressing hierarchy and to identify sites
  - Typically:

  - 24 bits ≈ as many organizations as IPv4 supports
- SLA Id: Site Level Aggregator Identifier
  - Used by sites to create addressing hierarchy and identify subnets

Recommendations for the Assignment of TLAs and NLAs

- Defined in:
  - RFC 2450: Proposed TLA and NLA Assignment Rules
  - Specific documents from ARIN, RIPE, etc
- Assign TLAs only to transit Providers, not to leaf sites (even if they are multihomed)
- Assign TLAs to organizations who are capable and intend to provide operational IPv6 transit services within three months
- TLAs asigned must be publically known
- Procedure to asign TLA (two stages):
  - First, temporal assignation of a sub-TLA id.
  - Later, definitive assignation of the TLA id. when the provider shows evidence of IPv6 transit services

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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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IPv6 Exchanges

- 6TAP: IPv6 Transit Access Point (Chicago)
  - Esnet, Viagenie, CANARIE
  - Info in: www.6tap.net
- AMSIX: Amsterdam Internet Exchange
  - Info in: www.ams-ix.net
- NSPIXP-6: IPv6 Internet Exchange in Tokio
  - WIDE project
  - Info in: www.wide.ad.jp/nspixp6

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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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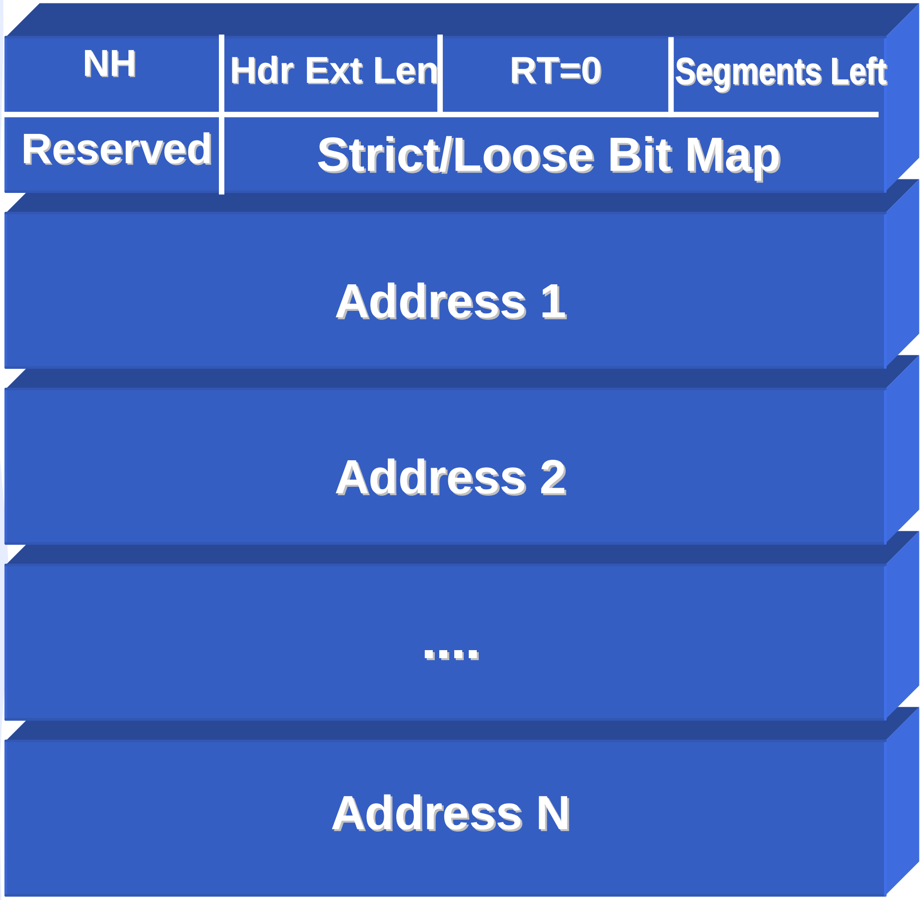
Routing Header

- Format:



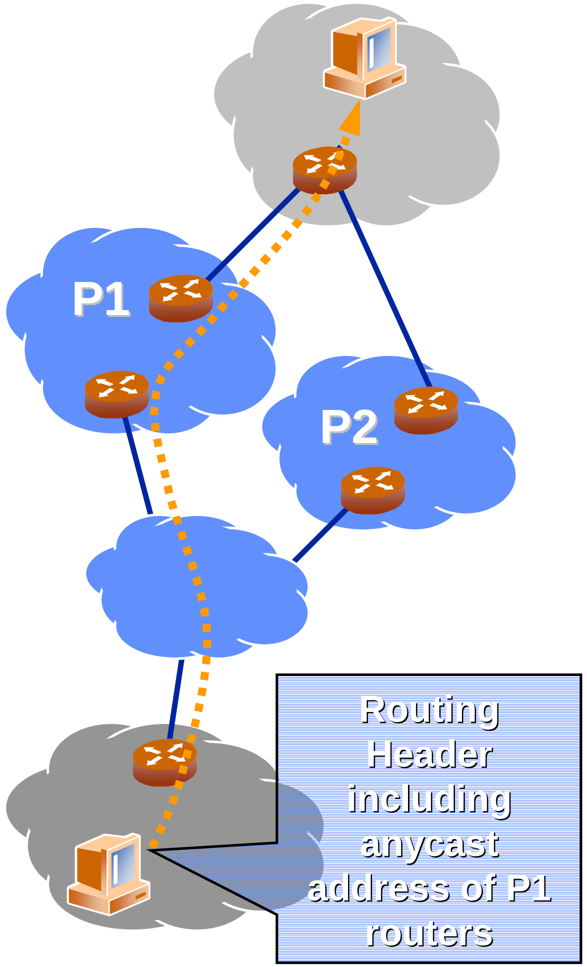
- Differences with IPv4:
  - Datagram destination address is substituted by the next address in the list.
  - Responses to datagrams with RH must include the same RH but with the list of addresses inverted.
  - Strict/loose option improved. Each address in the list can be strict or loose.

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

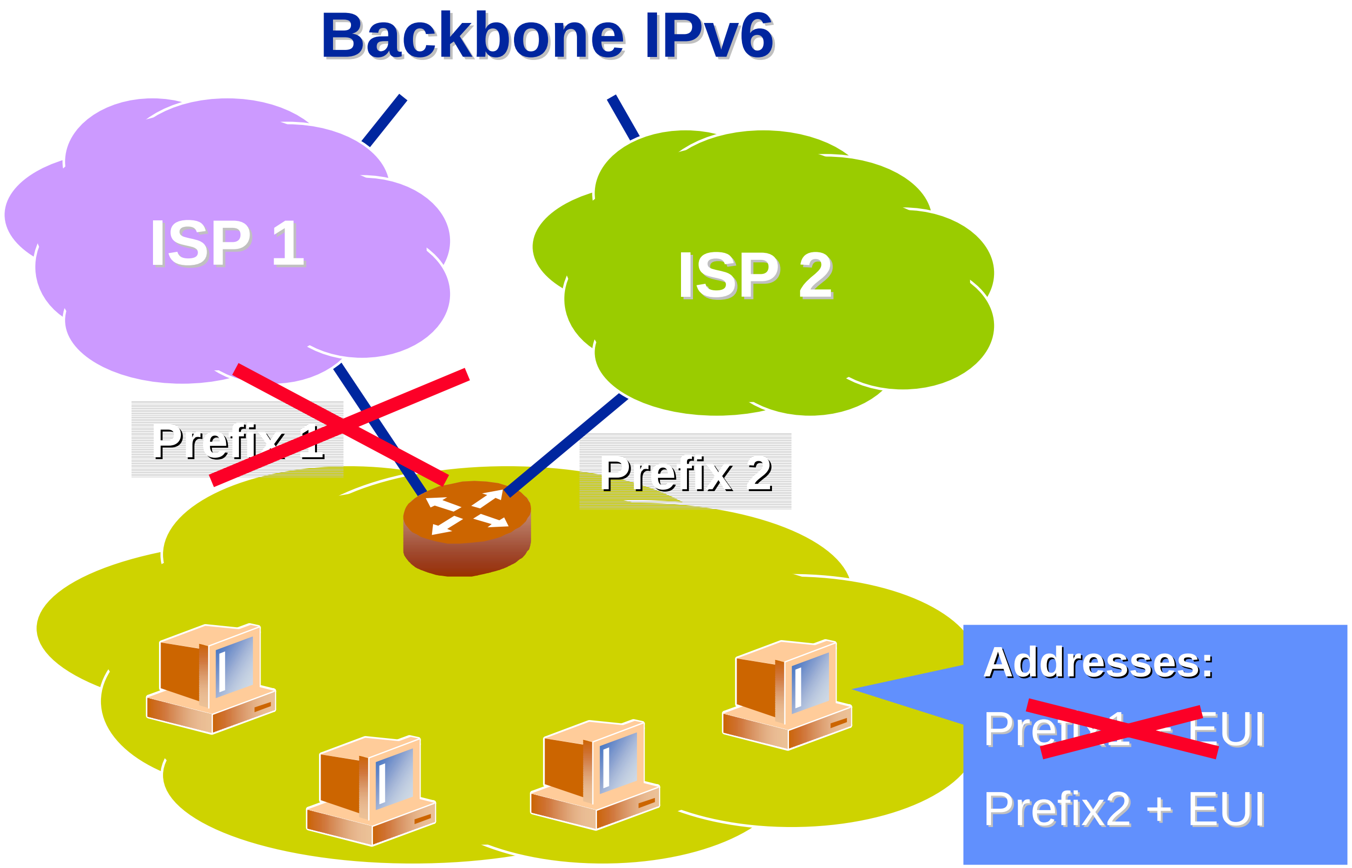
Subnet Prefix (n bits)	000000 (128-n bits)

- 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

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Routers Renumbering

- Based on the sending of packets with renumbering commands (Prefix Control Operations, PCO)
- Each command specifies:
  - *Operation Code* (ADD, CHANGE, SET-GLOBAL)
  - A *Match-Prefix*
  - Zero or more *Use-Prefixes*
- A router processes each PCO by applying the operation defined on each interface whose addresses match the *Match-Prefix*

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Renumbering Operations

- ADD:
  - Add *Use-Prefixes* to the list of configured prefixes
- CHANGE:
  - Replace *Match-Prefix* by *Use-Prefixes*
- SET-GLOBAL:
  - Replace all global prefixes by *Use-Prefixes*
- If the list of *Use-Prefixes* is empty, ADD does nothing and CHANGE/SET-GLOBAL is used to delete prefixes.

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Renumbering Protocol

- Other characteristics:
  - Guaranties reliability
  - Allows to create new prefixes conserving some bits of the existing prefixes (only one PCO for all network routers)
  - Security functions:
    - Message Authentication and Integrity
    - Protection to avoid Replay attacks
  - Test option to simulate the result of a renumbering operation
  - Supports Multicast

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Renumbering Example

- Change in global prefix maintaining subnet structure:

IPv6 Header:	Next Header = 58 (ICMPv6)
	Source Address = (Management Station)
	Destination Address = FF05::2 (All Routers, site-local scope)
ICMPv6/RR Hdr:	Type = 138 (Router Renumbering), Code = 0 (Command)
	Flags = 60 hex (R, A)
PCO:	Match-Prefix Part
	OpCode = 3 (SET-GLOBAL)
	OpLength = 7
	Ordinal = 0 (arbitrary)
	MatchLen = 10
	MatchPrefix = FEC0::0
Use-Prefix:	UseLen = 48 (Length of TLA ID + RES + NLA ID)
	KeepLen = 16 (Length of SLA (subnet) ID)
	FlagMask, RAFlags, Lifetimes, V & P flags -- as desired
	UsePrefix = First global /48 prefix

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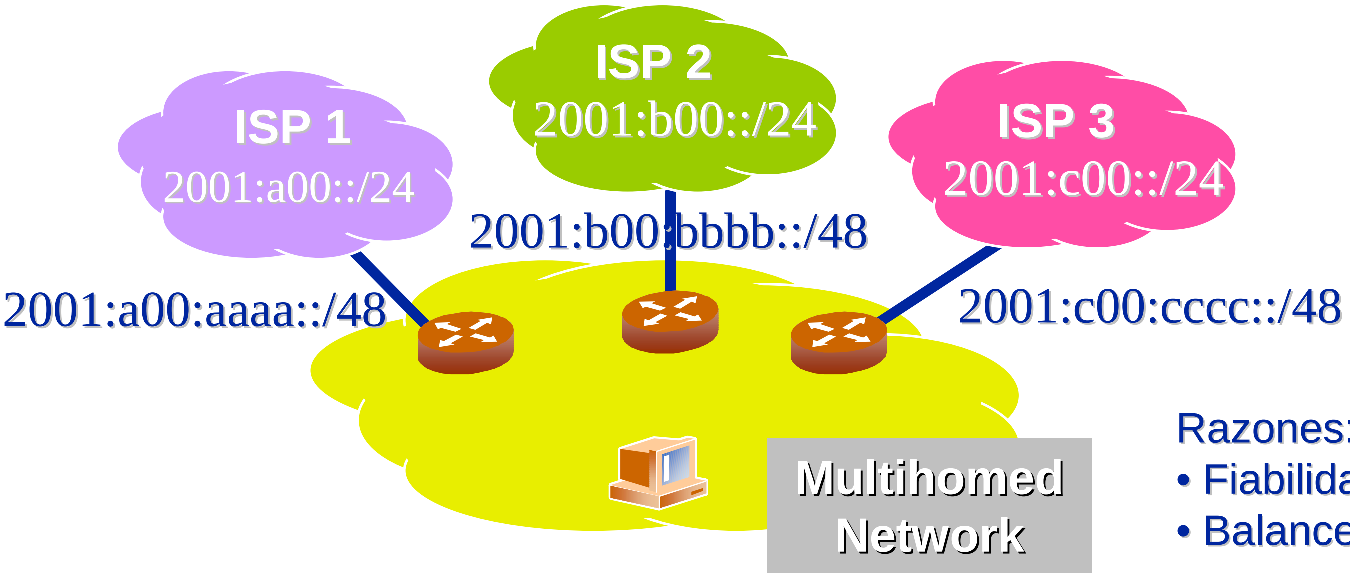
Multihoming

- "Multihomed site": Site connected to two or more providers simultaneously.



Razones:
- Fiabilidad
- Balanceo de Carga
- ...

- Problem: IPv6 routing model explicitely forbids the announcement of prefixes belonging to one ISP through other ISP's connections

Multihoming in IPv6

- Not well understood yet. Work in progress by IETF
- Basic Techniques:
  - Multiple global addresses per host (one for each ISP). Site routers announce all ISP prefixes in their RA.
  - Each border router only announces the prefix belonging to the ISP it is connected to.
  - Hosts need to select source addresses depending on destination.

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Multihoming in IPv6

- Internet Drafts:
  - Default Address Selections for IPv6
  - IPv6 Multi-homing with Route Aggregation
  - Multi-homed Routing Domain Issues for IPv6

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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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- 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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