Introducing IPv6 Networks

Foreword

- With the gradual exhaustion of the IPv4 address space, new solutions for continued address space were needed. Temporary measures in the form of NAT were applied, however long term solutions were required. The IPv6 addressing architecture is a developing solution for IP to provide for the next generation of networks and beyond. The transition to an all IPv6 architecture, while progressive, requires a major overhaul of many protocols and applications as well as standards. The IPv6 network however aims to resolve many limitations within the current TCP/IP suite, most notably addressing the need for integrated security measures and the streamlining of protocols to minimize overhead. A deep knowledge of the IPv6 architecture is required by engineers as IPv6 continues to evolve as an integral part of the enterprise network.

Objectives

- Upon completion of this section, you will be able to:
  - Explain the characteristics of IPv6.
  - Explain the IPv6 address format and addressing types.
  - Describe the process for IPv6 stateless address auto-configuration.

IPv6 Addressing - RoadMap

Anno	Note
1980	RFC791 – Nasce IPv4
1990	Primi segnali di esaurimento dello spazio indirizzi IPv4
199x	Uso di NAT e CIDR mitigano il problema
1995	Nasce IPv6
2011	IANA assegna l'ultimo blocco /8 IPv4
2012	RIPE NCC assegna l'ultimo blocco /8 IPv4
2015	ARIN assegna l'ultimo blocco IPv4

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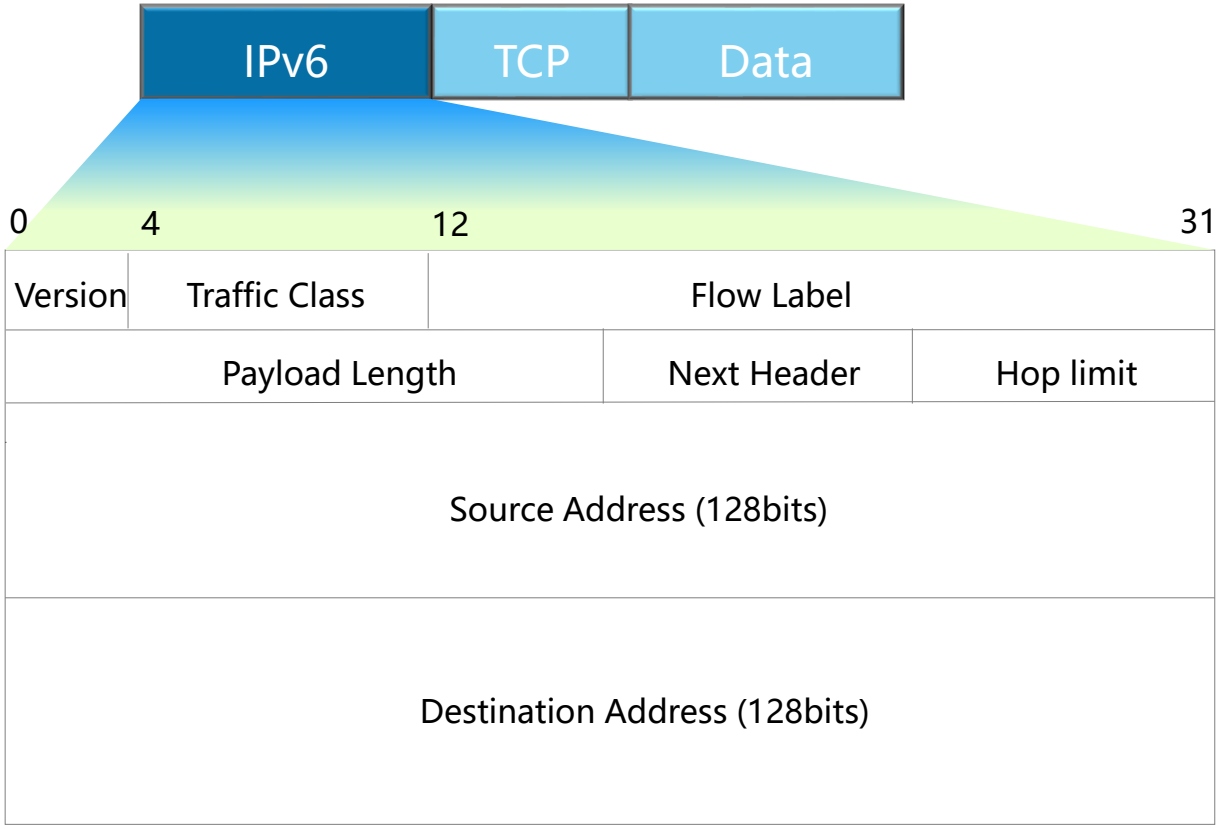
IPv6 Addressing

Version	Address size	Total Number of Addresses
IPv4	32 bit	4,294,967,296
IPv6	128 bit	340,282,366,920,938,463,463,374,607,431,768,211,456

- Exhaustion of the limited IPv4 address space.
- IPv6 addressing implemented to resolve address shortages.

IPv6 Header Format (RFC 8200)



- IPv6 header has been streamlined to reduce overhead.

IPv6 Header Format

Flow Label

può essere utilizzata dal mittente per identificare delle sequenze di pacchetti per i quali richiede un trattamento speciale da parte del router, come ad esempio un servizio “real-time”.

Traffic Classes

può essere utilizzato dal mittente o da un router per identificare e distinguere tra differenti classi di priorità dei pacchetti IPv6.

Next Header

Identifica il tipo di header che segue l’header IPv6. Ha funzioni simili al campo “protocol” di IPv4

Hop Limit

Campo il cui valore viene decrementato di 1 ogni volta che il pacchetto attraversa un router.

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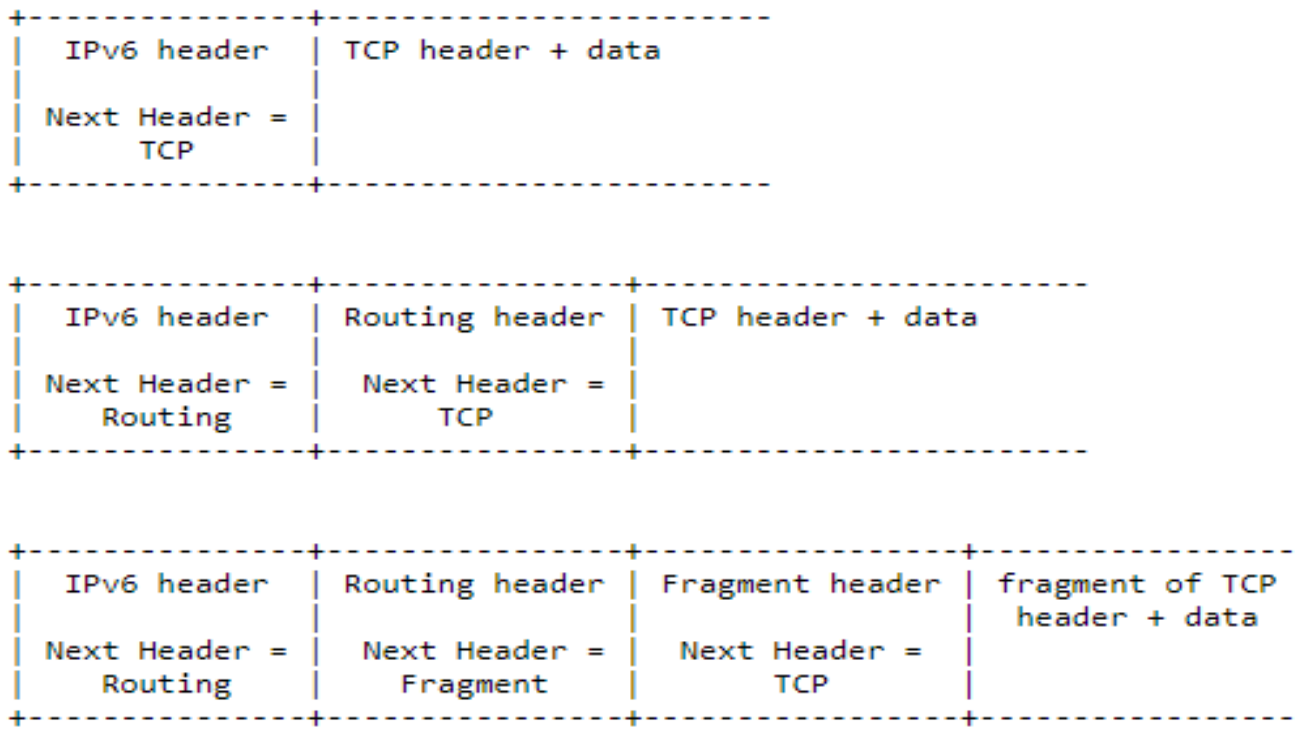
IPv6 Extension Header



- Extension headers are used to support parameters that are not required in every IP packet, such as fragmentation and IPSec.

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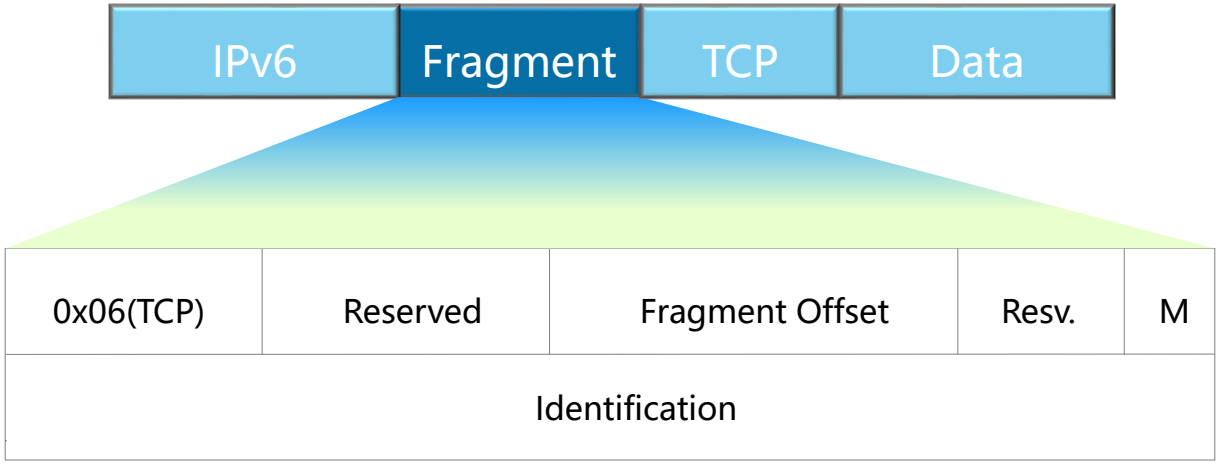
IPv6 Extension Header



- Nota:

  gli extension headers non sono processati dai nodi di transito, ma solo dal nodo di destinazione che procede al decapsulamento delle informazioni.

  Solo “hop-by-hop” viene processato ANCHE dai nodi di transito.

IPv6 Extension Header

Lista degli extension header e della loro sequenza:

- IPv6 header
- Hop-by-Hop Options header
- Destination Options header
- Routing header
- Fragment header
- Authentication header
- Encapsulating Security Payload header
- Destination Options header
- Upper-layer header (as in IPv6 tunneling)

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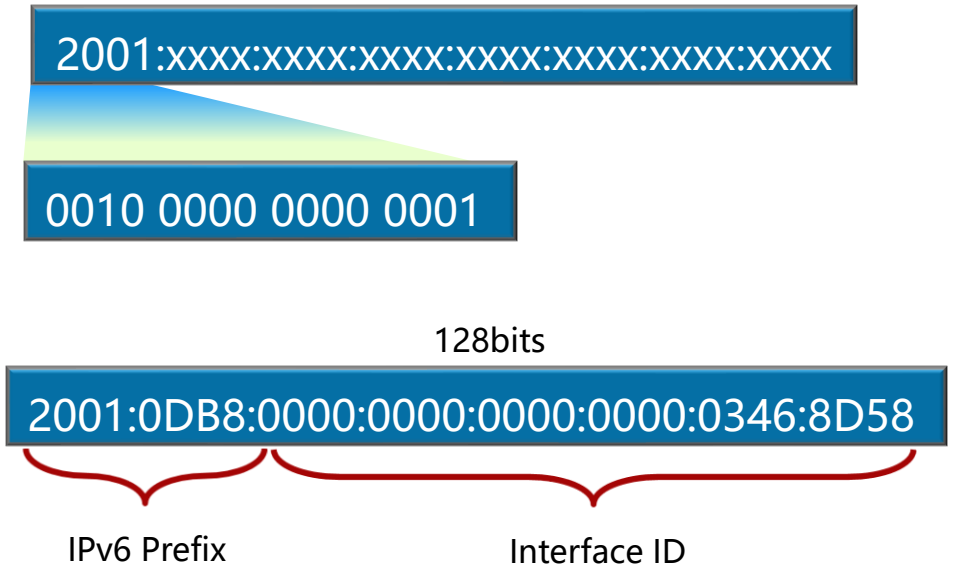
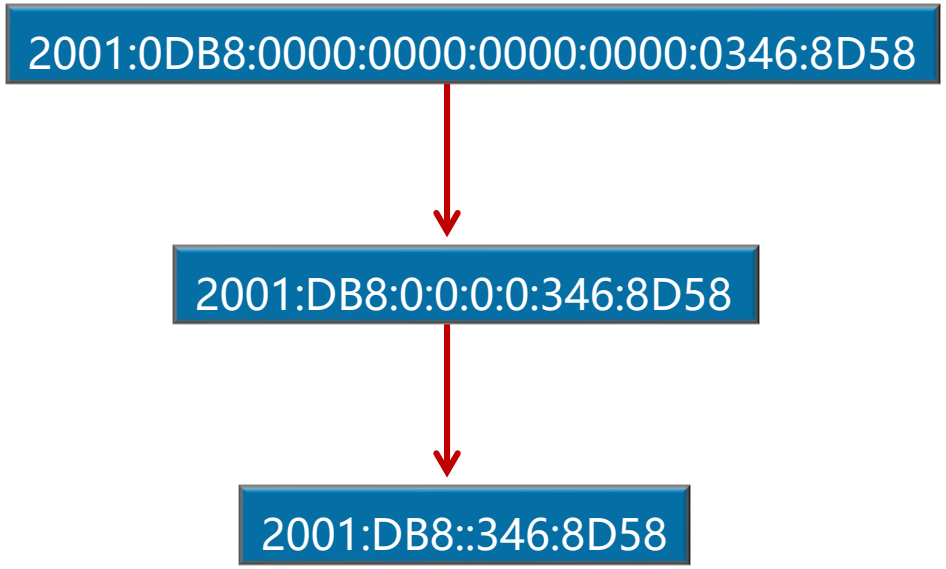
IPv6 Address Architecture



- IPv6 address consists of a prefix and an interface identifier.
- Addresses are commonly displayed in hexadecimal format.

IPv6 Address Condensing



- Addresses can be condensed by removing the leading zeroes.
- The :: operator will further condense strings of zero values.

IPv6 Address Reservations

Address Range	Description
2000::/3	Current Global Unicast Range
2001:0DB8::/32	Reserved for Documentation
FE80::/10	Link Local Unicast Address Range
FF00::/8	Multicast Address Range
::/128	Unspecified Address
::1/128	Loopback Address

- Address ranges have been allocated in IPv6 for unicast and multicast, along with special addresses for operational support.

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IPv6 Address Reservations

Address Range	Description
2400::/12	APNIC (Asia)
2600::/12	ARIN (America)
2800::/12	LACNIC (Latin America and Caribbean)
2A00::/12	RIPE NCC (Europa)
2C00::/12	AfriNIC (Africa)
2001:0DB8::/32	Documentation

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IPv6 Addressing – Unicast

Famiglie di indirizzi:

- **Global Unicast** – sono paragonabili agli indirizzi IPv4 pubblici. Sono gestiti a livello globale da IANA;
- **Unique Local** – sono paragonabili agli indirizzi IPv4 privati
- **Link Local** – indirizzi autoconfigurati.

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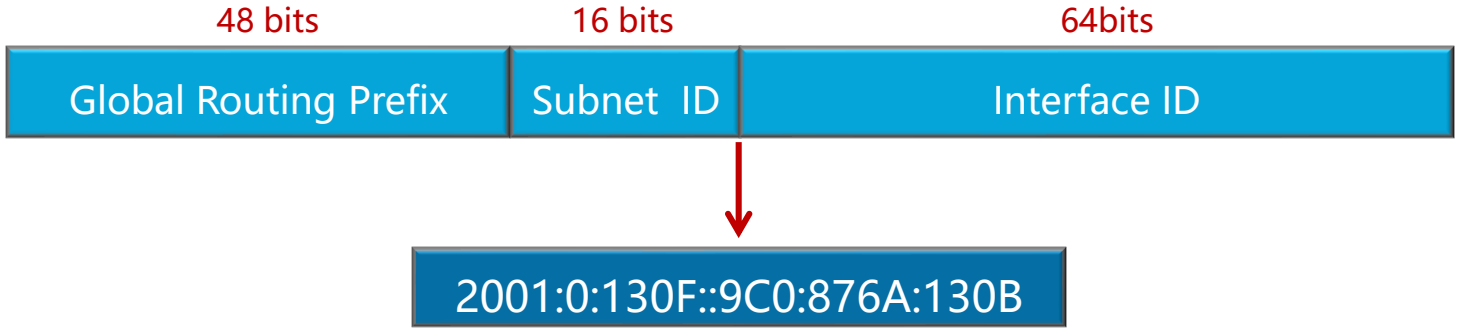
IPv6 Addressing – Unicast

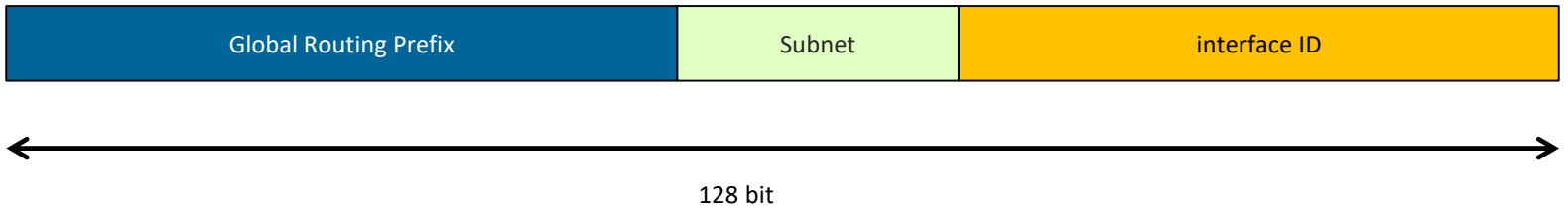


- Global unicast address prefixes are used for public networks.
- Prefix ranges are reserved for various IP transmission methods.

SubNetting con Global Unicast

Similitudine con IPv4:

- global routing prefix -> IPv4 network part;
- subnet -> IPv4 subnet;
- InterfaceID -> IPv4 host field.



SubNetting con Global Unicast

Gestione Gerarchica:

- IANA assegna a RIPE NCC i prefissi 2001::/16;
- RIPE NCC assegna ad un ISP i prefissi 2001:0DB8::/32;
- ISP assegna ad un cliente 2001:0DB8:1111::/48
  - Il cliente ha a disposizione 65536 sottoreti (128-64-48);
  - Ragiona esattamente come nel caso IPv4.

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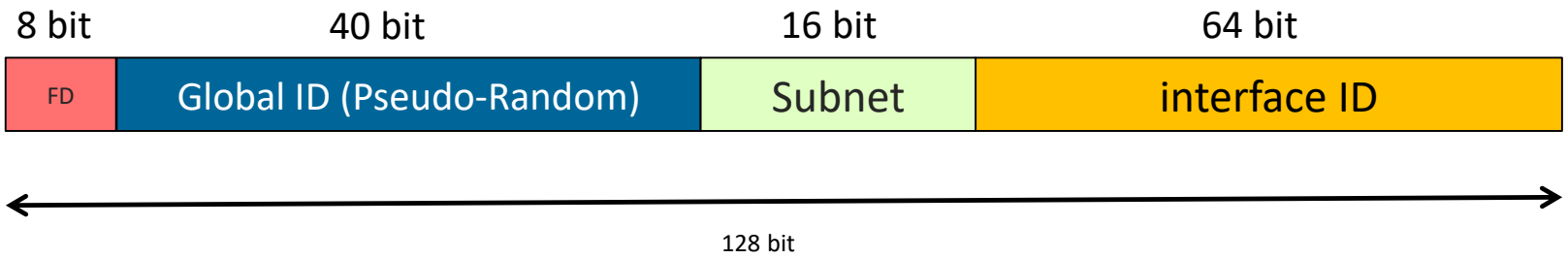
Unique Local Unicast

Possono essere considerati degli indirizzi “privati” IPv6;

Non sono registrati dallo IANA;



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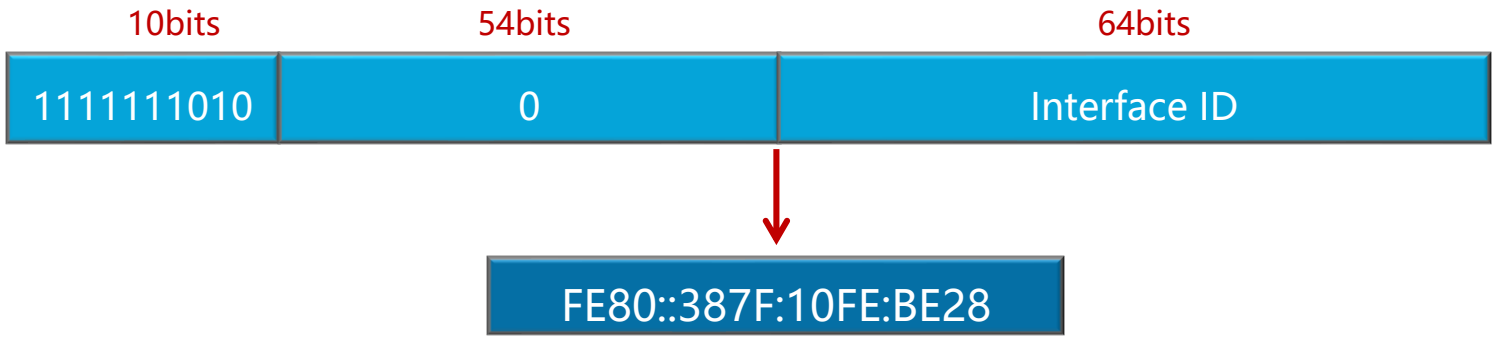
IPv6 Addressing – Link Local



- Vengono utilizzati per veicolare dati di protocolli accessori e per i protocolli di routing.
- Non vengono inoltrati dai router;
- Sono generati in modo automatico.
- Iniziano con “FE”.

IPv6 Addressing – Multicast

Address Range	Description
FF02::1	All Nodes Addresses (Link Local)
FF02::2	All Routers Addresses (Link Local)

- Multicast addresses are distinguished by an FF00::/8 prefix.
- Select multicast address groups are reserved for protocol use.

IPv6 Addressing – Multicast

Address Range	Description
FF02::1	All Nodes Addresses (Link Local)
FF02::2	All Routers Addresses (Link Local)

Esempio	Descrizione
FF02::5	Tutti i router OSPF
FF02::6	Tutti i DR OSPF
FF02::9	Tutti i router RIP

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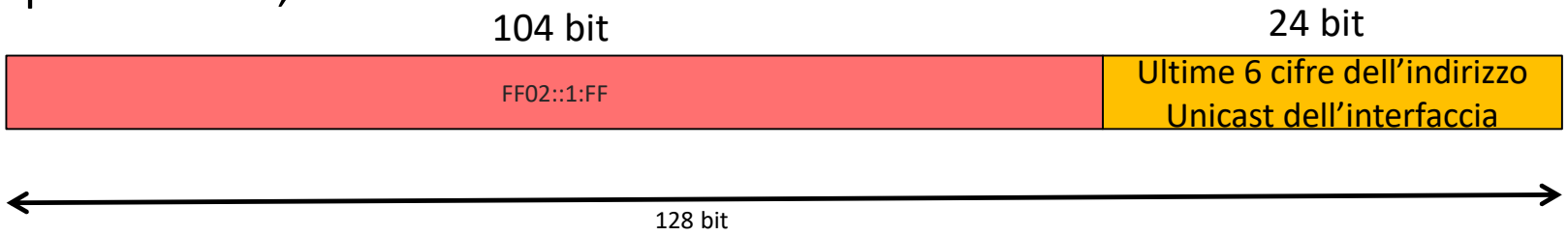
Solicited Node Multicast

La maggiore parte degli indirizzi Multicast sono definiti su RFC;

Il solicited node multicast address varia da host ad host:

- viene calcolato a partire dall'indirizzo IPv6;
- Scope link-local;



Link Local: FE80::1FF:FE01:101

Solicited Node Multicast: FF02::1:FF01:101

Global unicast: 2001:0DB8:1111:1::1

Solicited Node Multicast: FF02::1:FF00:1

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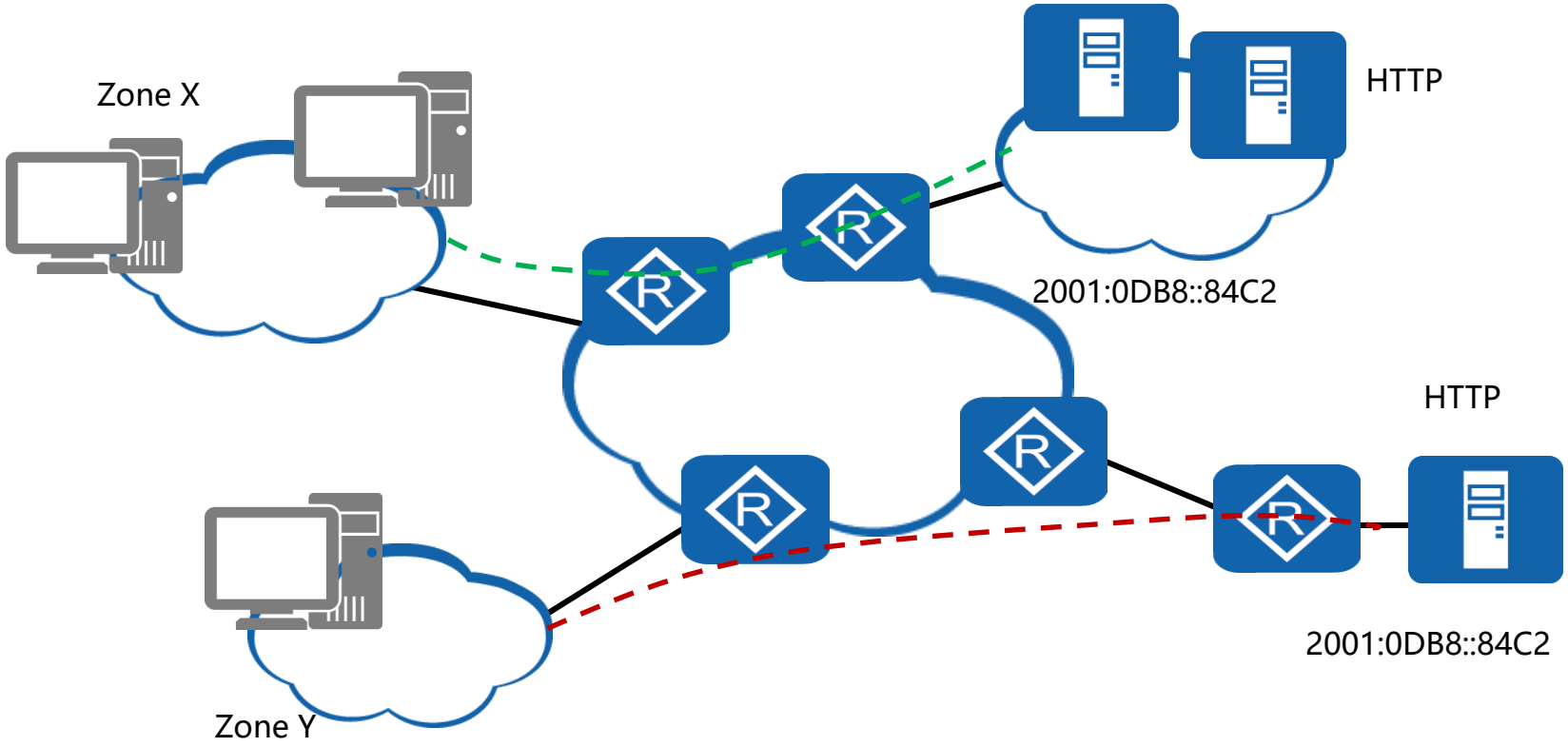
IPv6 Addressing – Anycast



- Anycast allows multiple instances of a service to be associated with a single address, enabling a variety of service applications.

Anycast

- Gli indirizzi Anycast sono indistinguibili dai Global Unicast;
- La differenza si ha in fase di impostazione dell'indirizzo sul nodo.
- Viene utilizzata la keyword "anycast".
- Sono di solito annunciate come /128 dai protocolli di routing.

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IPv6 Addressing – Summary!

Tipologia	Prefisso / Note
Global Unicast	Molti prefissi, IANA
Unique Local	FD00::/8
Link Local	FE80::/10
All Hosts Multicast	FF02::1
All Routers Multicast	FF02::2
Routing Protocol Multicast	Vari indirizzi
Solicited Node Multicast	FF02::1:FF/104
Anycast	Molti prefissi, differente configurazione.

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Stateless Address Auto-configuration

Router Solicitation (RS)

Messaggio inviato a FF02::2 (all-IPv6-routers) per chiedere ai router presenti sul link, di identificarsi.

Router advertisement (RA)

Contiene informazioni sulla configurazione di rete e l'indirizzo del router.

Puo essere:

- in risposta ad un RS – indirizzato al nodo che ha inviato RS.
- unsolicited – indirizzato a FF02::1

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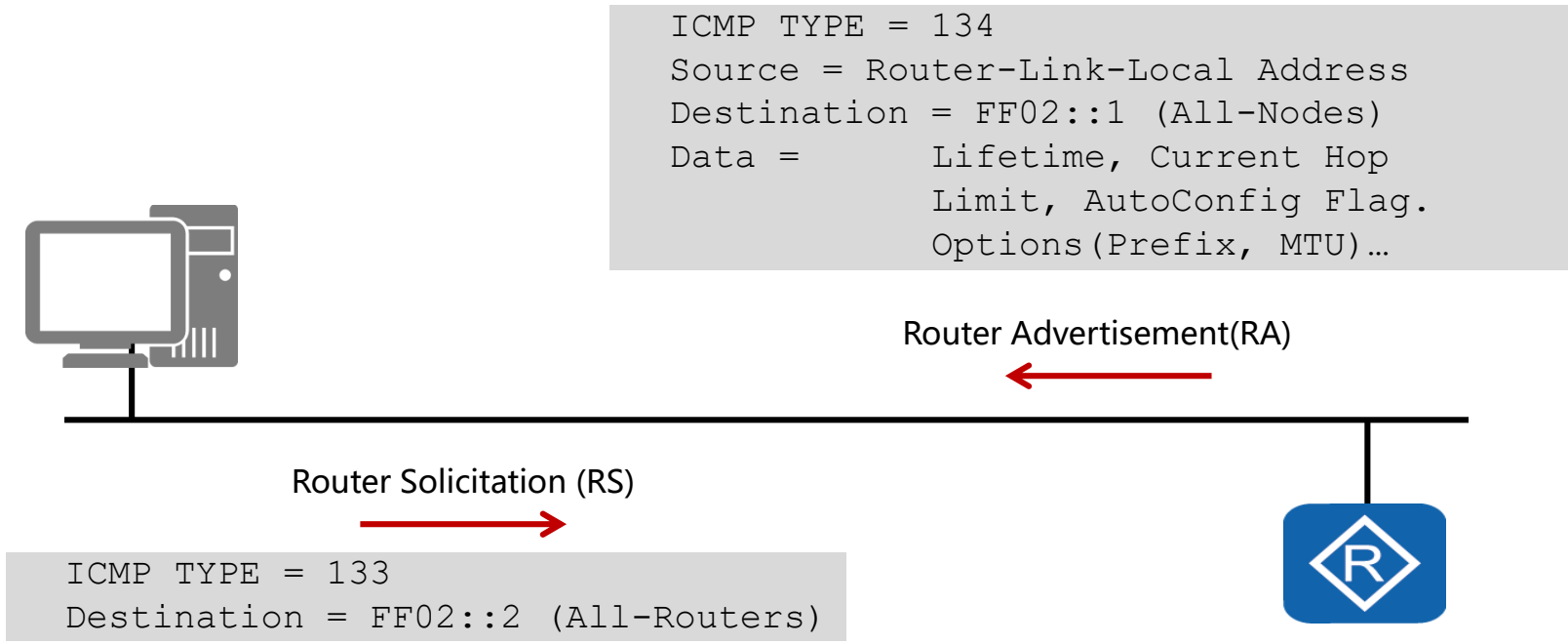
IPv6 Stateless Address Auto-configuration



- Hosts are capable of generating IPv6 addresses independently.
- Router Advertisements deliver network parameter information.

IPv6 Stateless Address Auto-configuration

```
    24 879.328000  fe80::2e0:fcff:fe28:136f        ff02::1           ICMPv6                110 Router Advertisem
> Frame 24: 110 bytes on wire (880 bits), 110 bytes captured (880 bits) on interface 0
> Ethernet II, Src: HuaweiTe_28:13:6f (00:e0:fc:28:13:6f), Dst: IPv6mcast_01 (33:33:00:00:00:01)
v Internet Protocol Version 6, Src: fe80::2e0:fcff:fe28:136f, Dst: ff02::1
    0110 .... = Version: 6
  > .... 1100 0000 .... .... .... .... .... = Traffic class: 0xc0 (DSCP: CS6, ECN: Not-ECT)
    .... .... .... 0000 0000 0000 0000 0000 = Flow label: 0x00000
    Payload length: 56
    Next header: ICMPv6 (58)
    Hop limit: 255
    Source: fe80::2e0:fcff:fe28:136f
    [Source SA MAC: HuaweiTe_28:13:6f (00:e0:fc:28:13:6f)]
    Destination: ff02::1
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
v Internet Control Message Protocol v6
    Type: Router Advertisement (134)
    Code: 0
    Checksum: 0xd7cf [correct]
    [Checksum Status: Good]
    Cur hop limit: 64
  > Flags: 0x00
    Router lifetime (s): 1800
    Reachable time (ms): 0
    Retrans timer (ms): 0
  > ICMPv6 Option (Source link-layer address : 00:e0:fc:28:13:6f)
  > ICMPv6 Option (Prefix information : 2001:db8:1111::/48)
```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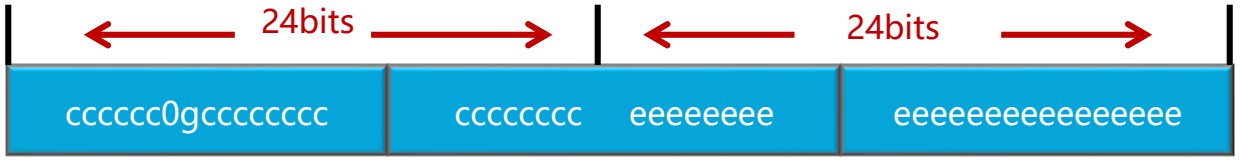
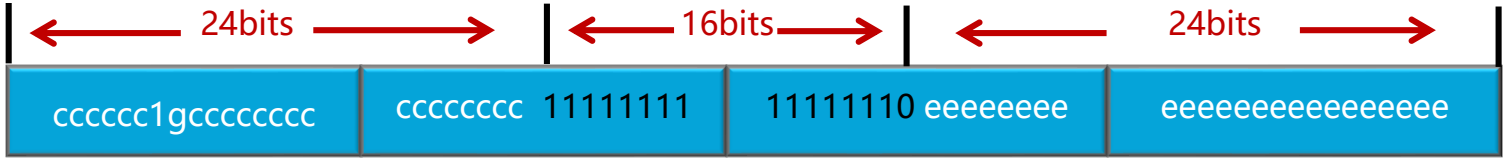
EUI-64 for IP Stateless Address Auto-configuration

48-bit MAC address



EUI-64 generated interface ID



- A host MAC address is injected with 16 bit ‘FF’ ‘ FE’ values, as well as the 7th bit is negated, to generate a 64-bit interface identifier for the IPv6 address.

Stateless Address Auto-configuration NDP

Neighbor Discovery Protocol

Definisce una coppia di messaggi che hanno una funzione simile ad ARP in IPv4:

- Neighbor Solicitation (NS) - chiede ad un host con un dato indirizzo IPv6, di rispondere con il suo MAC-address.
- Neighbor Advertisment (NA) – può essere:
  - in risposta ad un NS (inviato unicast al richiedente);
  - unsolicited (inviato a FF02::1);

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Stateless Address Auto-configuration NDP

```
> Frame 3: 86 bytes on wire (688 bits), 86 bytes captured (688 bits) on interface 0
> Ethernet II, Src: HuaweiTe_28:13:6f (00:e0:fc:28:13:6f), Dst: IPv6mcast_ff:02:31:49 (33:33:ff:02:31:49)
v Internet Protocol Version 6, Src: 2001:db8:1111:0:2e0:fcff:fe28:136f, Dst: ff02::1:ff02:3149
    0110 .... = Version: 6
  > .... 1100 0000 .... .... .... .... .... = Traffic class: 0xc0 (DSCP: CS6, ECN: Not-ECT)
    .... .... .... 0000 0000 0000 0000 0000 = Flow label: 0x00000
    Payload length: 32
    Next header: ICMPv6 (58)
    Hop limit: 255
    Source: 2001:db8:1111:0:2e0:fcff:fe28:136f
    [Source SA MAC: HuaweiTe_28:13:6f (00:e0:fc:28:13:6f)]
    Destination: ff02::1:ff02:3149
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
v Internet Control Message Protocol v6
    Type: Neighbor Solicitation (135)
    Code: 0
    Checksum: 0x79a3 [correct]
    [Checksum Status: Good]
    Reserved: 00000000
    Target Address: 2001:db8:1111:0:2e0:fcff:fe02:3149
  v ICMPv6 Option (Source link-layer address : 00:e0:fc:28:13:6f)
      Type: Source link-layer address (1)
      Length: 1 (8 bytes)
      Link-layer address: HuaweiTe_28:13:6f (00:e0:fc:28:13:6f)
```


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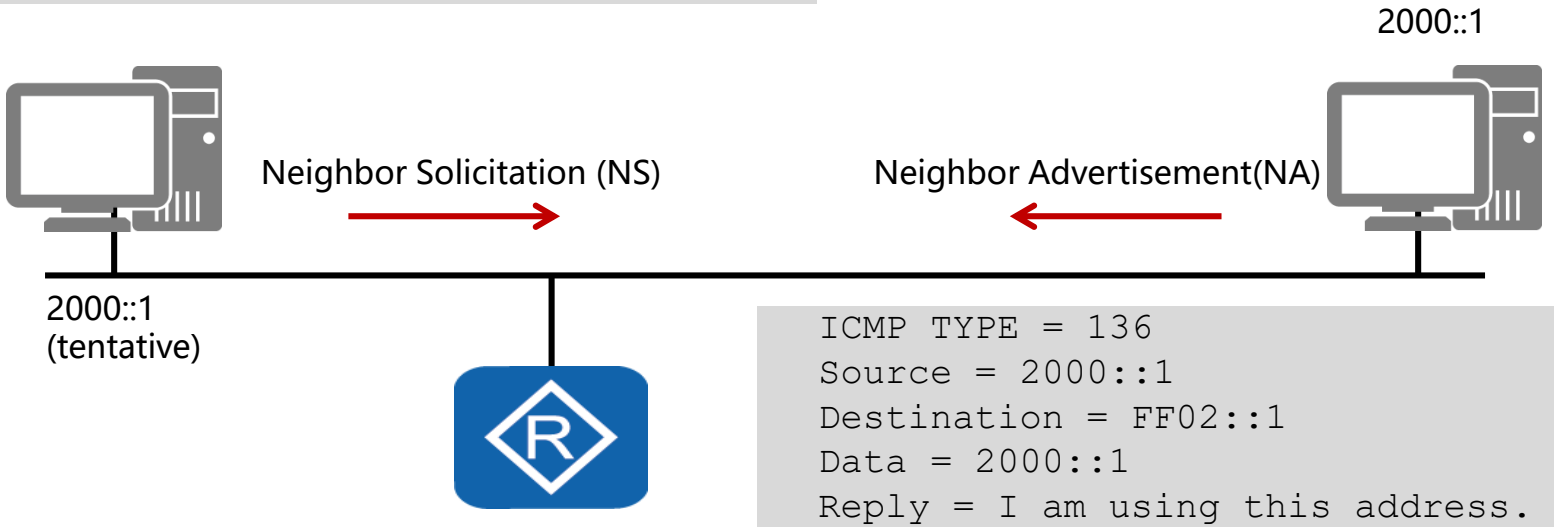
IPv6 Stateless Address Auto-configuration DAD

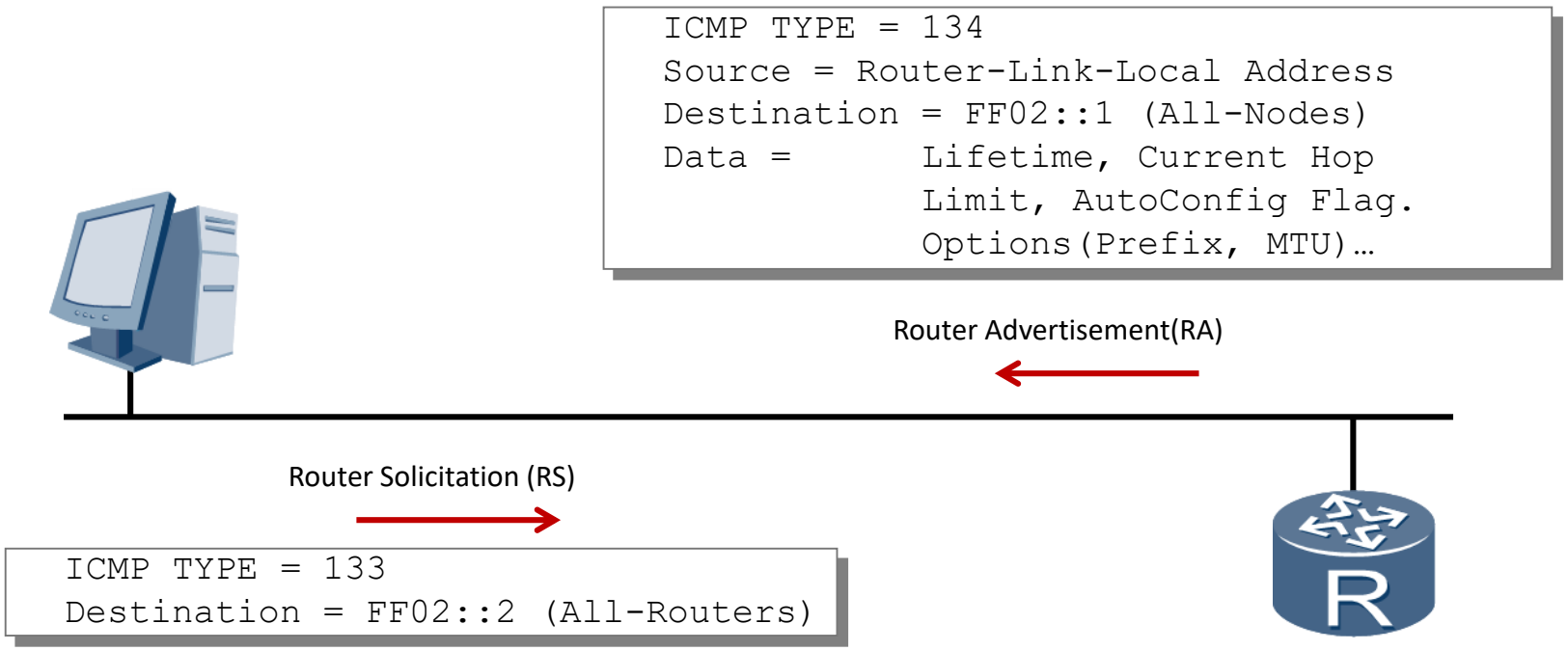
```
ICMP TYPE = 135
Source = ::
Destination = FF02::1:FF00:1
Data = 2000::1
Query = Is this address in use?
```




```
ICMP TYPE = 136
Source = 2000::1
Destination = FF02::1
Data = 2000::1
Reply = I am using this address.
```

- Duplicate Address Detection (DAD) is used in IPv6 to verify that an address is unique before it is applied to the host interface.

IPv6 Stateless Address Auto-configuration



- Hosts are capable of generating IPv6 addresses independently.
- Router Advertisements deliver network parameter information.

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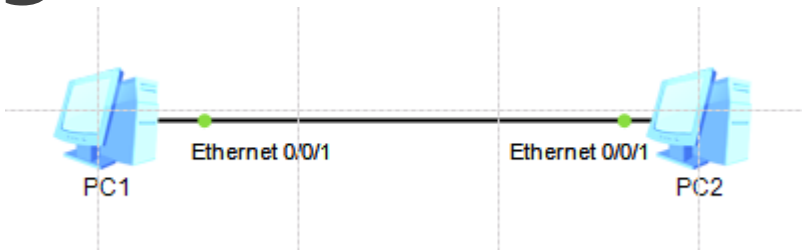
IPv6 Configurazione e Verifica



- Non sono configurati servizi aggiuntivi sulla rete.
- I due host impostano automaticamente un indirizzo Link-Local su base EUI-64

```
PC>ipconfig

Link local IPv6 address...........: fe80::5689:98ff:fe2e:423a
IPv6 address......................: :: / 128
IPv6 gateway......................: ::
IPv4 address......................: 0.0.0.0
Subnet mask.......................: 0.0.0.0
Gateway...........................: 0.0.0.0
Physical address..................: 54-89-98-2E-42-3A
DNS server........................:
```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IPv6 Link-Local

- Si possono configurare 10 indirizzi per ogni interfaccia;
- L'indirizzo Link-Local è utilizzato nel network discovery e nella comunicazione tra i nodi sul link locale.
- Il link-local address può anche essere configurato manualmente, anche se è preferibile generarlo automaticamente.

- Prima di procedere alla configurazione è necessario abilitare IPv6 sul router sia nella system-view che in interface-view:

```
[R1]ipv6
[R1]int gig 0/0/0
[R1-GigabitEthernet0/0/0]ipv6 enable
[R1-GigabitEthernet0/0/0]
```


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IPv6 Link-Local

L’indirizzo Link-Local dell’interfaccia può essere impostato in due modi differenti:

- Automatico

```
[R1]int gig 0/0/0
[R1-GigabitEthernet0/0/0] ipv6 address auto link-local
```

- Manuale

```
[R1]int gig 0/0/0
[R1-GigabitEthernet0/0/0] ipv6 address <address> link-local
```

```
[R1]dis ipv6 interface brief
*down: administratively down
(l): loopback
(s): spoofing
Interface                   Physical              Protocol
GigabitEthernet0/0/0        up                    up
[IPv6 Address] FE80::2E0:FCFF:FE02:3149
[R1]
```


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IPv6 GLobal-Unicast

Indirizzi Global Unicast possono essere configurati direttamente o ricorrendo ad EUI-64:

```
[R1]int gig 0/0/0
[R1-GigabitEthernet0/0/0] ipv6 address { ipv6-address prefix-length
| ipv6-address/prefix-length }
```

```
[R1]int gig 0/0/0
[R1-GigabitEthernet0/0/0] ipv6
address { ipv6-address prefix-length | ipv6-address/prefix-length }
eui-64
```

```
[R1]int gig 0/0/0
[R1-GigabitEthernet0/0/0]ipv6 address 2001:0db8:1111::/48 eui-64
```


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IPv6 Anycast

Indirizzi Anycast sono utilizzati per identificare un gruppo di interfacce, che non appartengono allo stesso dispositivo.

- Indirizzi anycast sono usati per ricevere informazioni;
- Se ci sono più interfacce con lo stesso indirizzo, risponde quella più vicina al mittente. La distanza è calcolata attraverso il protocollo di routing utilizzato sul Sistema.

```
[R1]int gig 0/0/0
[R1-GigabitEthernet0/0/0] ipv6 address { ipv6-address prefix-length
| ipv6-address/prefix-length } anycast
```


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IPv6 Configurazione e Verifica

Verifica degli indirizzi assegnati:

```
[R1]dis ipv6 interface gig 0/0/0
GigabitEthernet0/0/0 current state : UP
IPv6 protocol current state : UP
IPv6 is enabled, link-local address is FE80::2E0:FCFF:FE02:3149
  Global unicast address(es):
    2001:DB8:1111:0:2E0:FCFF:FE02:3149, subnet is
2001:DB8:1111::/48
  Joined group address(es):
    FF02::1:FF02:3149
    FF02::2
    FF02::1
  MTU is 1500 bytes
  ND DAD is enabled, number of DAD attempts: 1
  ND reachable time is 30000 milliseconds
  ND retransmit interval is 1000 milliseconds
  Hosts use stateless autoconfig for addresses
[R1]
```


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IPv6 Link, interfacce ed indirizzi

LINK:

a communication facility or medium over which nodes can communicate at the link layer, i.e., the layer immediately below IPv6. Examples are Ethernets (simple or bridged); PPP links; X.25, Frame Relay, or ATM networks; and internet (or higher) layer "tunnels", such as tunnels over IPv4 or IPv6 itself.

Interfaccia:

a node's attachment to a link

Neighbors:

nodes attached to the same link.

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IPv6 Addressing – Nota!

Con IPv6 deve cambiare il modo di ragionare:

- le sottoreti IPv6 sono tipicamente /64 per consentire il funzionamento dello SLAAC;
- Questo sposta il problema del “numero degli IP disponibili” al “numero delle sottoreti /64 disponibili”.
- Nei link punto-punto è preferibile usare indirizzi /127;

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IPv6 Addressing – Nota!

Alcune network size utilizzate in IPv6:

- /64 – la dimensione base della singola subnet;
- /56 – un blocco di 256 sottoreti base;
- /48 – un blocco di 65536 sottoreti base;
- /32 – la dimensione del blocco che riceveranno gli ISP;

Gli hosts IPv6 possono avere molti indirizzi IP configurati simultanemanete sulle interface:

- configurati manualmente
- configurati da SLAAC attraverso gli RA.

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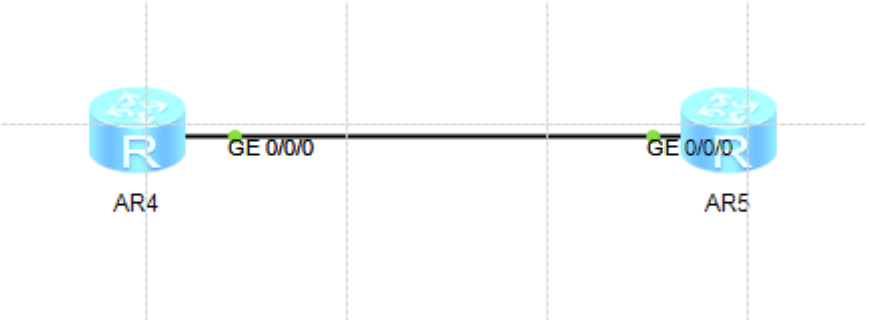
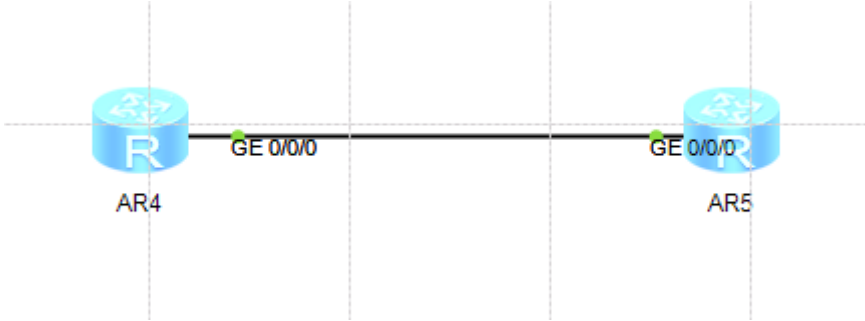
IPv6 Addressing – Nota!




```
[RA]dis ipv6 interface
GigabitEthernet0/0/0 current state : UP
IPv6 protocol current state : UP
IPv6 is enabled, link-local address is FE80::2E0:FCFF:FE70:3180
  Global unicast address(es):
    2001:DB8:1111::3, subnet is 2001:DB8:1111::/48
    2001:DB8:8591:0:2E0:FCFF:FE70:3180, subnet is
2001:DB8:8591::/48
  Joined group address(es):
    FF02::1:FF70:3180
    FF02::2
    FF02::1
    FF02::1:FF00:3
  MTU is 1500 bytes
  ND DAD is enabled, number of DAD attempts: 1
  ND reachable time is 30000 milliseconds
  ND retransmit interval is 1000 milliseconds
  Hosts use stateless autoconfig for addresses
[RA]
```

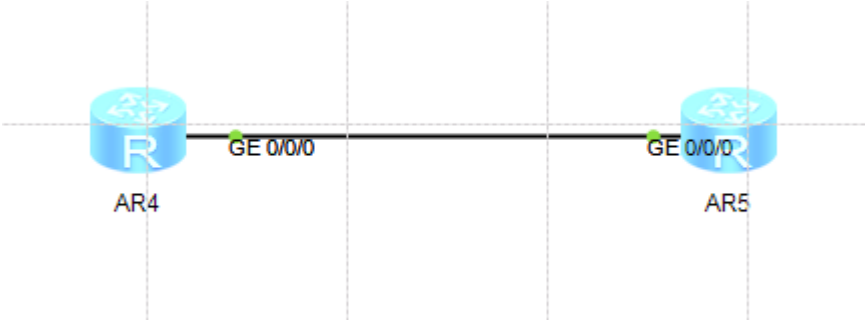
IPv6 Addressing – Nota!




```
<RB>dis ipv6 interface
GigabitEthernet0/0/0 current state : UP
IPv6 protocol current state : UP
IPv6 is enabled, link-local address is FE80::2E0:FCFF:FECD:5231
  Global unicast address(es):
    2001:DB8:2222::3, subnet is 2001:DB8:2222::/48
  Joined group address(es):
    FF02::1:FF00:3
    FF02::2
    FF02::1
    FF02::1:FFCD:5231
  MTU is 1500 bytes
  ND DAD is enabled, number of DAD attempts: 1
  ND reachable time is 30000 milliseconds
  ND retransmit interval is 1000 milliseconds
  Hosts use stateless autoconfig for addresses

<RB>
```

IPv6 Addressing – Nota!



RA

FE80::2E0:FCFF:FE70:3180

2001:DB8:1111::3

2001:DB8:8591:0:2E0:FCFF:FE70:3180

RB

FE80::2E0:FCFF:FECD:5231

2001:DB8:2222::3

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IPv6 Configurazione e Verifica

Comandi per la verifica delle impostazioni IPv6:

- display ipv6 interface <type><number> | brief ;
- display ipv6 statistics
- display ipv6 neighbors

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Summary

- What is the smallest condensed IPv6 value possible for the address 2001:0DB8:0000:0000:0000:0000:032A:2D70
- How is it possible for an end station to independently generate an IPv6 address?


Thank You
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