

Exploring IPv6

The end of the Internet as we know today?



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Conclusion

- The end of the Internet as we know today?
  - IPv4 address space is getting scarce
  - IPv4 will still be available for a long time
  - IPv6 is getting slowly deployed
  - IPv6 will boost from this year on
    - Not because we like it, but because we have no choice
    - No need to be afraid of IPv6 (after this talk :)
    - Dual stack with IPv4, or 6to4 tunnels



Abbreviations

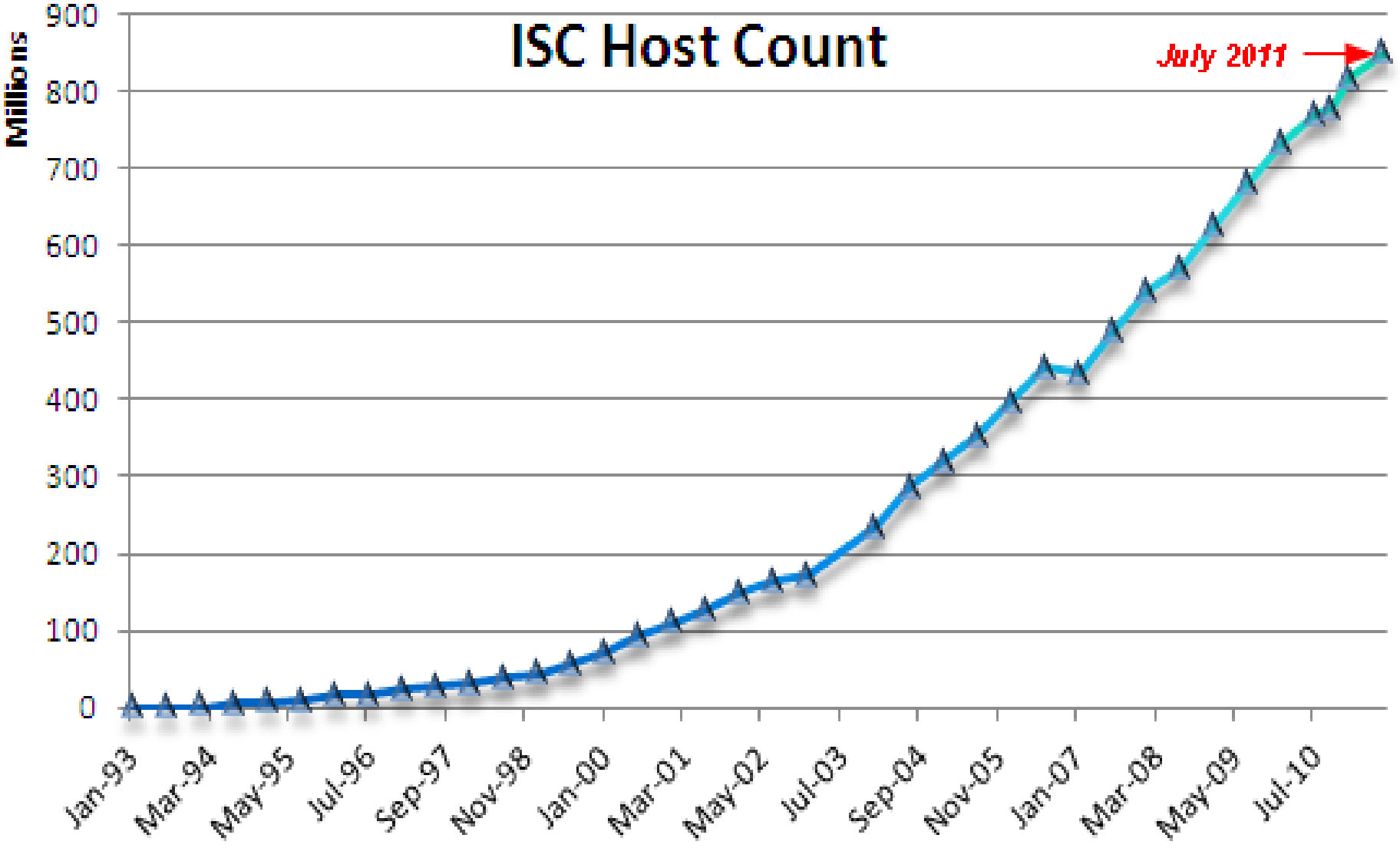
- IPv4/6: Internet Protocol 4/6
- ISC: Internet Systems Consortium
- IANA: Internet Assigned Numbers Authority
- RIR: Regional Internet Number Registries
- CIDR: Classless Inter-domain Routing
- NAT: Network Address Translation
- AS: Autonomous System



IPv6 history

- Designed in 1994 [RFC 1752 and many more]
- In the nineties estimated run-out of IPv4 addresses was expecting between 2000-2008
- The usage of CIDR and NAT slowed down the depletion of IPv4 addresses, but also
  - The dot com crisis, and
  - Financial crisis in 2008-2009
- The Internet still grows rapidly (mobile devices,...)

The IPv4 host count 'till today
(data coming from ISC)



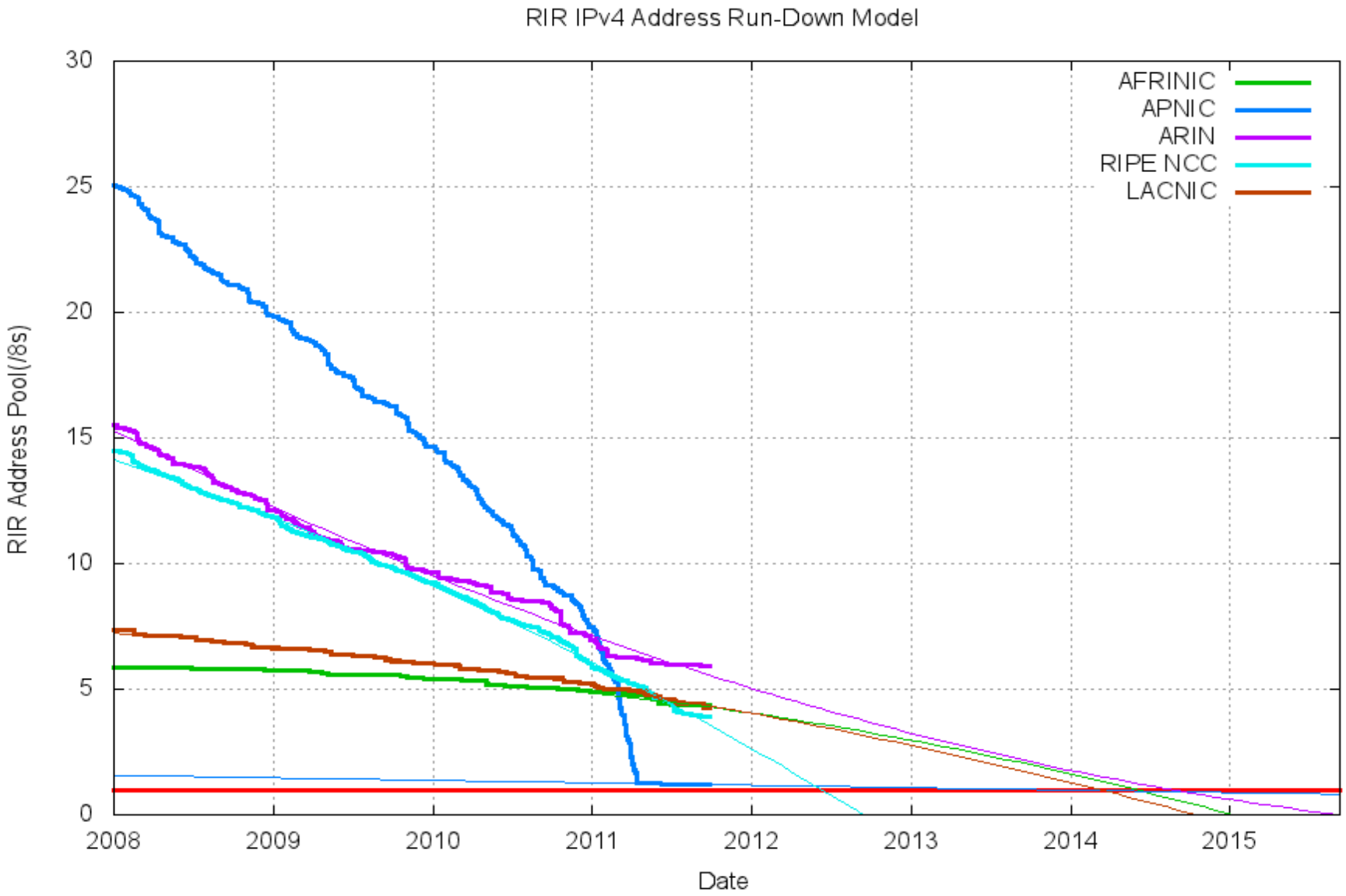


IPv4 Address Space

- 32-bit number => 2^{32} (4.294.967.296)
- 4 dotted decimal notation, e.g. 18.2.45.78
- Divided into classes
  - A Class: 8-bit network (128 * 16,8 million)
  - B Class: 16-bit network (16.384 * 65.536)
  - C Class: 24-bit network (2 million * 256)
- 70% of A and B Classes are allocated to big companies and incredible under-used (approx. 3 billion addresses wasted)

IPv4 Depletion rate

www.potaroo.net/tools/ipv4/



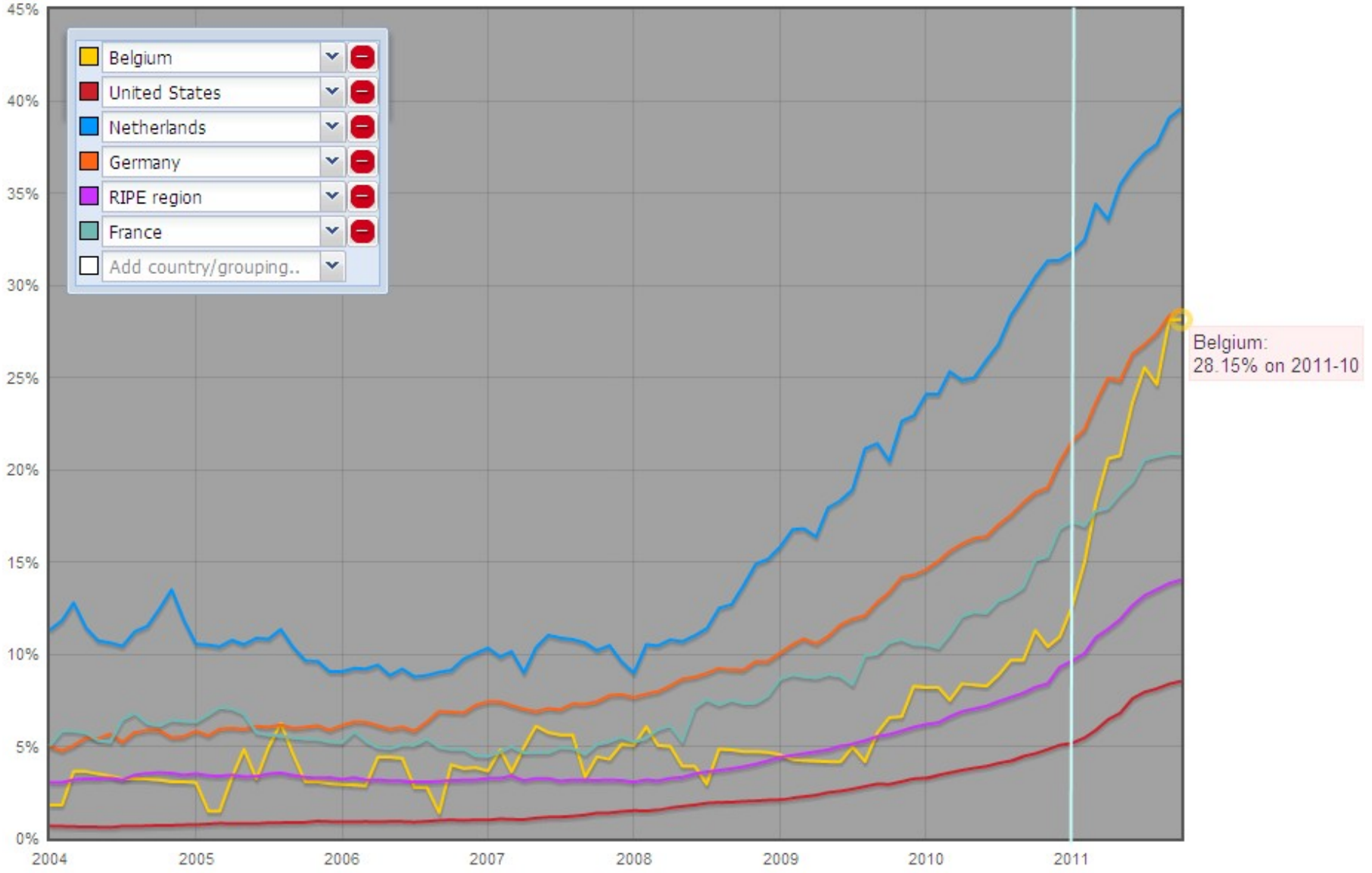


IPv6 history

- Backbone routers (vendors): took time to become IPv6 ready
  - Today these limitations are behind us
  - But, are all ISP's capable for serving IPv6 traffic?
- The main Operating Systems (Linux, Mac OS/X and Windows) now support IPv6
- IPv6 has been implemented more widely in Europe and Asia than in the USA.

IPv6 enabled ASs in global routing

http://v6asns.ripe.net/



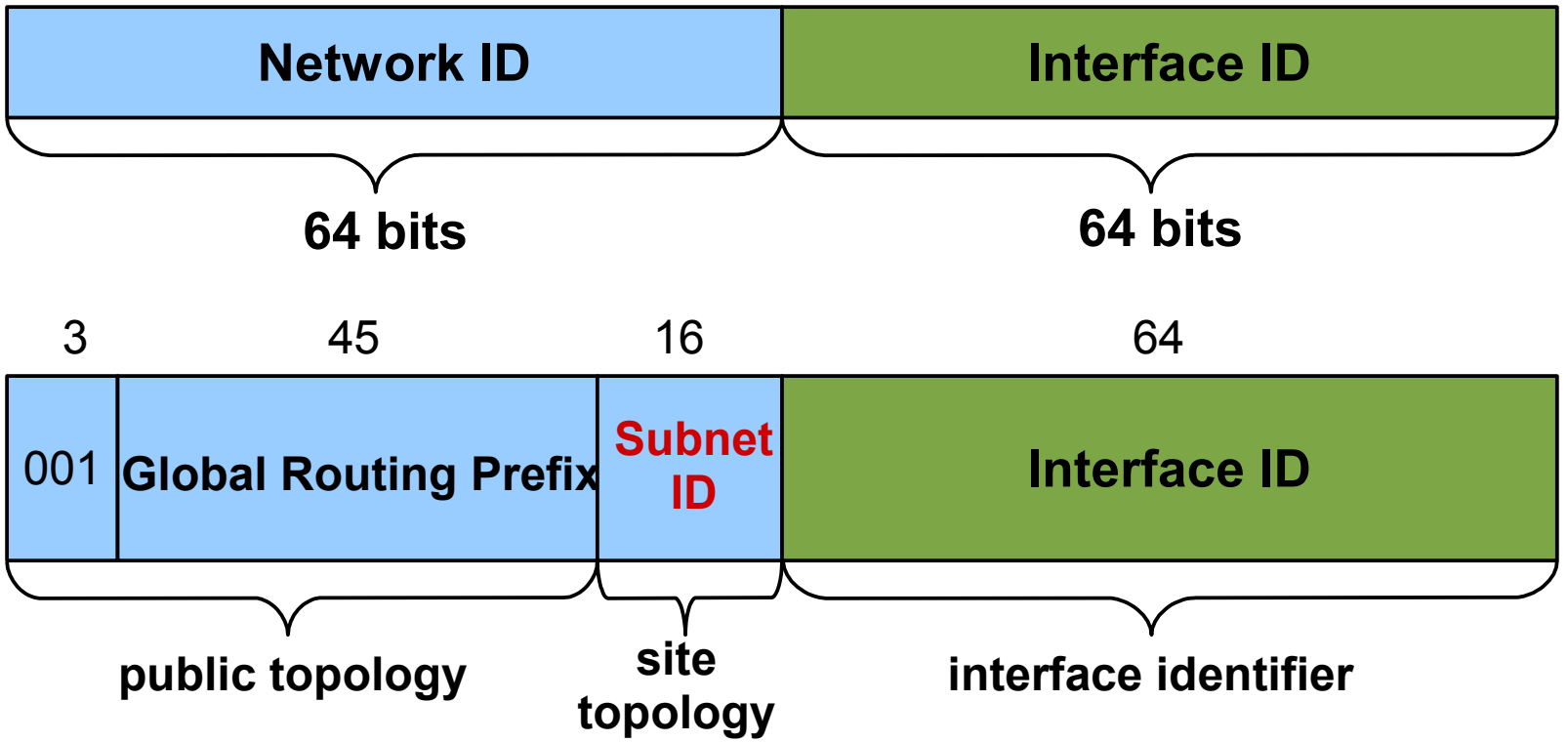


Is your ISP IPv6 ready ?

- Have a look at
  - http://ripeness.ripe.net/4star/BE.html
  - http://www.vyncke.org/ipv6status/detailed.php?country=be&type=ISP
- Most ISPs will deliver IPv6 to home consumers not before 2012 (or 2013?) ...
- Around 48% ISPs can provide IPv6 addresses
  - See http://ripeness.ripe.net/pies.html
  - Mostly through IPv6-to-IPv4 tunneling
  - One year ago it was only 31%

IPv6 Addressing

- $2^{128} = 3.4 \times 10^{38}$ addresses (128 bits!!)
  = 340.282.366.920.938.463.463.374.607.431.768.211.456
- IPv6 address is divided into





IPv6 Addressing (cont.)

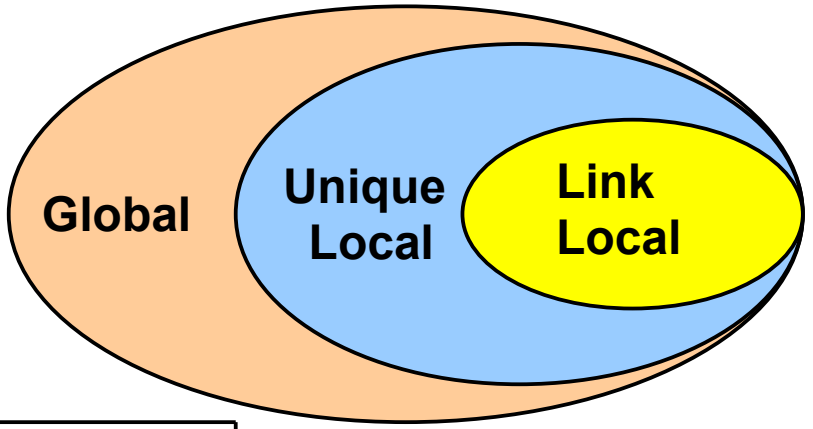
- Notation
  - IPv6 address written as eight groups of four hexadecimal digits
    - 2001:0db9:85a6:07c4:1243:8a81:0301:7351
  - Leading zeros may be dropped
    - 2001:9a03:0000:12c2:0000:0000:0fa1:0001
    - 2001:9a03:0:12c2:0:0:fa1:1
  - Up to one double colon substitution is permitted
    - 2001:9a03:0:12c2::fa1:1
    - :: means one or more groups of 16 bits of zeroes



IPv6 Addressing Types

- Unicast
  - Identify one system on the Internet
  - Globally routable
  - Highest order bits are 001 (of Network Id)
- Multicast
  - Deliver to an entire group of systems
- Anycast
  - Deliver to any one of a group of systems
  - Ideal for mobile devices

Addressing Types



- **Multicast**
  - Assigned — FF00::/8
  - Solicited node — FF02::1:FF00:0000/104
- **Unicast**
  - Unspecified Loopback — ::/128, ::1/128
  - Link Local — FF80::/10
  - Aggregatable Global — 2001::/16
  - Unique Local — FC00::/7
  - IPv4 Compatible — 0:0:0:0:0:0::/96
- **Anycast**
  - Link Local — FF80::/10
  - Aggregatable Global — 2001::/16
  - Unique Local — FC00::/7

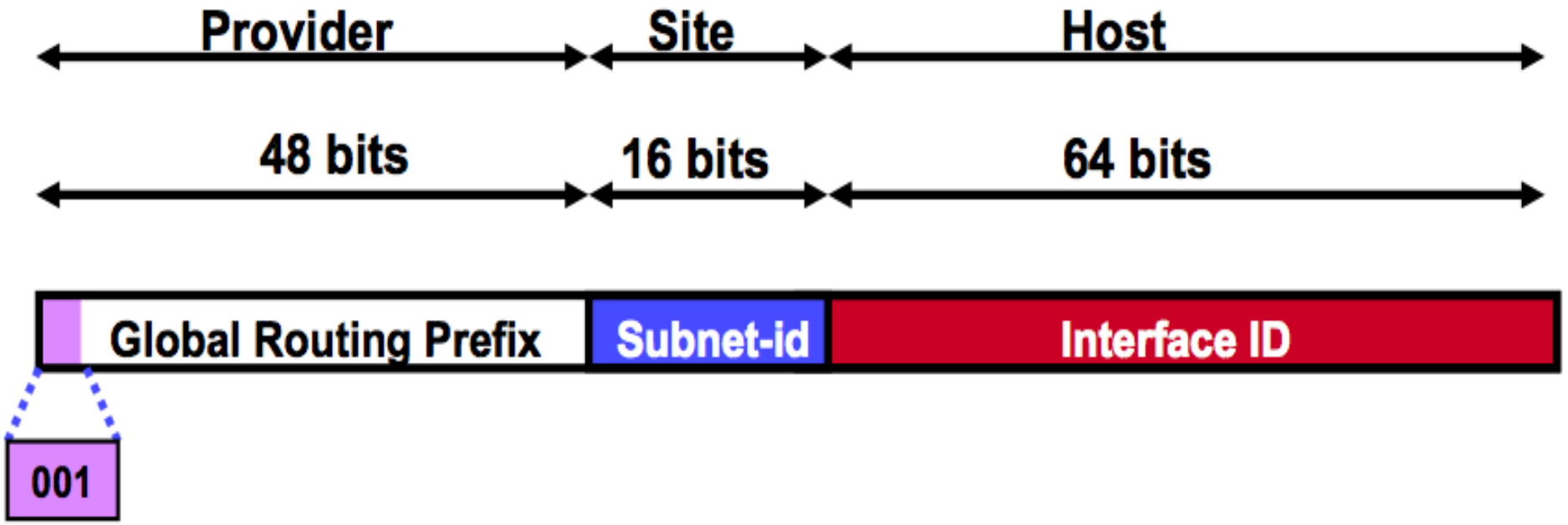


IPv6 Address Types (cont.)

Address Type	Binary Prefix	Prefix
unspecified	000...0 (128 bits)	::/128
loopback	000...01 (128 bits)	::1/128
link-local unicast	1111 1110 10	FE80::/10
multicast	1111 1111	FF00::/8
global unicast	All other addresses	

Unicast Addresses

- Global Unicast addresses are in 2000::/3 block
  - 2001:5c0:1400:b::9773/128



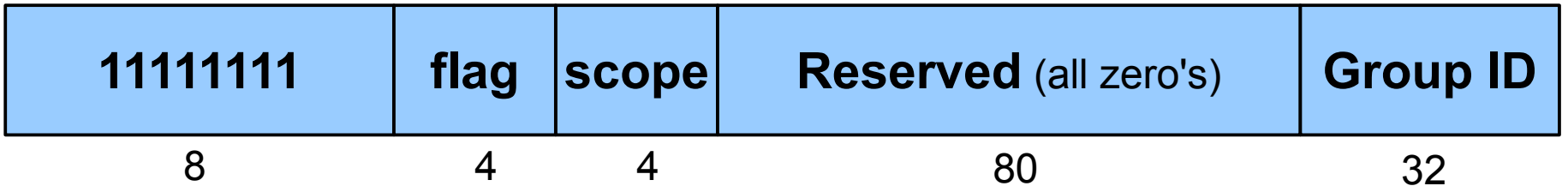


Anycast Addresses

- The same anycast address is assigned to a group of interfaces (nodes)
- However, a packet sent to an anycast address is delivered to the nearest one having this address
- Assigned from unicast address range
- Usage in the area of DNS discovery and Universal Plug and Play, but also used for multiple name, web and mail servers

Multicast Addresses

- In IPv6 multicast replaces IPv4 “broadcast”



- Identify a participating group of hosts
- Start with 0xFF (8 1-bits)
- One flag indicates transient (=1) or permanent (=0 or well-known address assigned)
- Must define a scope (global, site, link, node)
- Group ID: 1 = all nodes; 2 = all routers; etc



Multicast Scope

- A 4-bit field
- Likely values are
  - 1 : Node-local scope (interface)
  - 2 : Link-local scope (e.g. LAN)
  - 5 : Site-local (deprecated)
  - 8 : Organization-local scope
  - E : Global scope
- No broadcast address in IPv6, multicast to "*all nodes on the local link*" *(scope 2; group-ID 1)* FF02::1



Well-known multicast group-numbers

Multicast Address	Meaning
FF02::1	All nodes on this link
FF02::2	All routers on this link
FF02::5	All OSPF routers on this link
FF02::9	All RIP routers on this link
FF02::1:2	All DHCP agents on this link
FF05::1:3	All DHCP servers on this link
FF05::101	All NTP servers on this link
FF02:0:0:0:1:FF::/104 combined with 24 low order bits from IPv6 address	Solicited-node multicast group (used to map MAC addresses)



Solicited node multicast addresses (for NDP)

- Multicast address built from unicast address
- Concatenation of FF02::1:FF00:0/104 and
  - 24 low order bits of unicast address (interface id)
- Nodes build their own IPv6 solicited node multicast address
- Nodes can use this technique to find of a destination host its MAC address, e.g.
  - 2001:001A:003F:1021:0100:0028:00**3F:0020**
  - FF02:0000:0000:0000:0000:0001:**FF**00:0000/104
  - FF02:0000:0000:0000:0000:0001:**FF3F:0020**
  - 33-33-FF-3F-00-20 (multicast MAC address)



Neighbor Discovery Protocol

- Used to discover other hosts and routers on local network (stateless autoconfiguration)
- Makes use of the IPv6 multicast addresses (no ARP anymore)
- Uses ICMPv6 messages
  - Neighbor solicitation
  - Neighbor advertisement
  - Router solicitation
  - Router advertisement
  - redirect

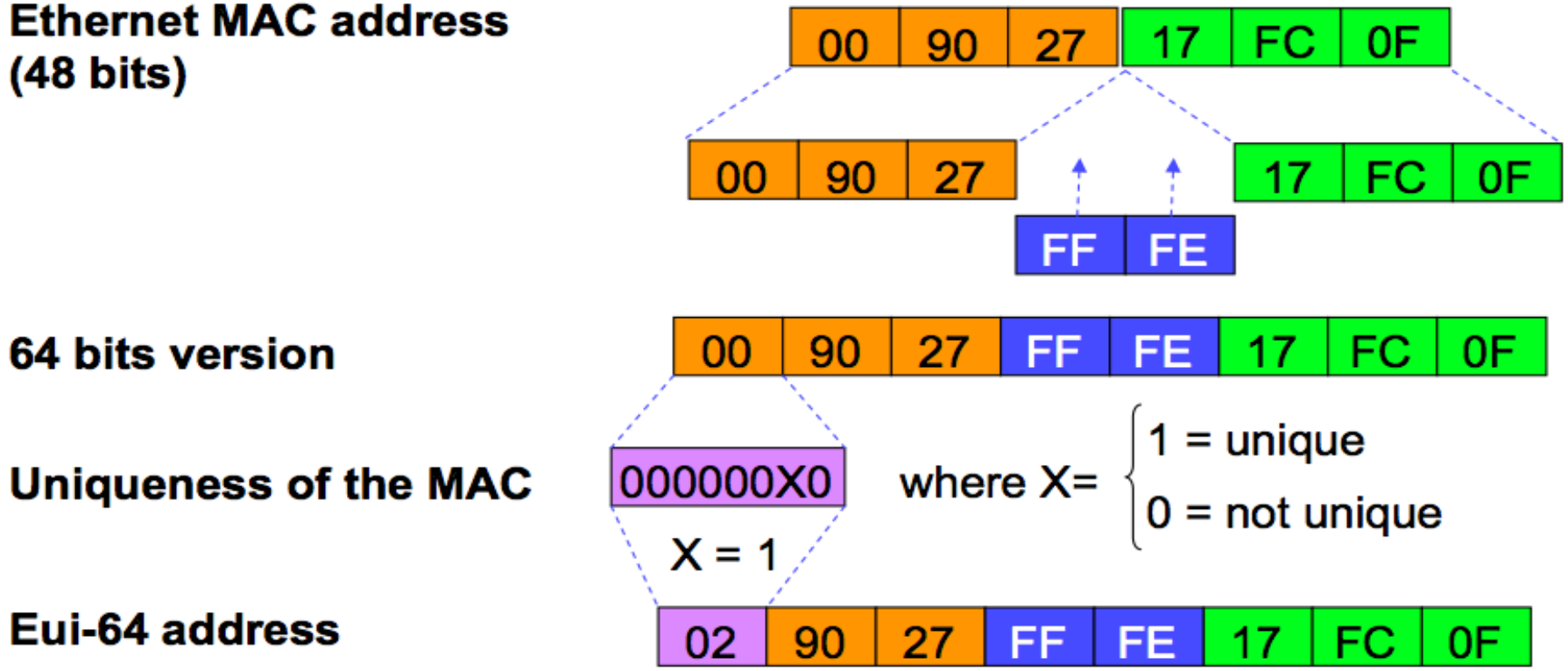


Address Autoconfiguration Process

- Create a Link Local Address (FE80::/10)
  - No router or server required
- IPv6 address node configuration
  - Network ID
    - Manual
    - Auto (stateful or stateless)
    - Pre-defined well known prefix (link-local unicast FF80::/10)
  - Interface ID
    - Manual
    - Auto (stateful or stateless)

Link-Local Address

- Each interface has a Link-Local Address based on their MAC Address (IEEE EUI-64 - Extended Unique Identifier)





Stateless Address Autoconfiguration

- Routers advertise prefixes that identify the subnet(s) associated with a link
- Hosts generate an "interface token" that uniquely identifies an interface on a subnet
  - Based on EUI-64 MAC address (security?)
  - Privacy Extensions:
    echo 1 > /proc/sys/net/ipv6/conf/all/use_tempaddr
- An address is formed by combining the two



Router Solicitation (RS)

- Host sends a multicast Router solicitation when an interface is enabled
  - To discover IPv6 routers present on the link
  - To request an immediate Router advertisement
  - Sent to All-Router Multicast Address
  - Source link layer address of sender may be sent as an option
- IPv6 address
  - Source: unspecified (all zeros, ::/128)
  - Destination: sollicited-node multicast



Router Advertisement (RA)

- Router multicasts periodically (or on demand) its availability
- Router advertisements carry
  - Lifetime as a default router
  - Managed flag to inform hosts how to perform Address Autoconfiguration
  - List of prefixes used for a link
  - Link-layer address
  - Advertise an MTU for hosts to use on the link



Radvd daemon

- Stateless autoconfiguration with “router advertisement daemon (radvd)”

```
# cat /etc/radvd.conf
interface eth0
{
        AdvSendAdvert on;
        MinRtrAdvInterval 30;
        MaxRtrAdvInterval 100;
        prefix 2001:470:1f09:11b8::/64        # IPv6 address received for tunnel
        {
                AdvOnLink on;
                AdvAutonomous on;
                AdvRouterAddr off;
        };
};
```

```
# echo 1 > /proc/sys/net/ipv6/conf/all/forwarding
```



Stateful Address Autoconfiguration

- Clients obtain address and other optional parameters from DHCPv6 server
- DHCP server maintains the database and controls the address assignment
- Clients send DHCP solicit (DHCPv6 multicast address)
- Server responds with a DHCPv6 advertisement



Domain Name Server

- Using ISC BIND
- A system can now have an IPv4 and IPv6 address
  - sloeber IN A 192.168.0.13
    sloeber IN AAAA 2001:470:1f09:11b8::1
- Reverse delegation
  - 1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.8.b.1.1.9.0.f.1.0.7.4.0.1.0.0.2.ip6.arpa. IN PTR
  - $ORIGIN 8.b.1.1.9.0.f.1.0.7.4.0.1.0.0.2.ip6.arpa.
    1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0 IN PTR



DNS/Service Discovery @home

- How do I find my local file server?
- Multicast DNS (mDNS) = serverless DNS
  - DNS queries over IP Multicast in a small network where no DNS server is installed
  - Network prefix can change after modem reboots (no need to update /etc/hosts file!)
  - mDNS doesn't cross router boundary
- Service Discovery
  - DNS Service Discovery (mDNS/DNS-SD)
  - Universal Plug and Play (UPnP)

Multicast DNS (mDNS) @home



(1) mDNS Query to FF02::FB, port 5353,
Asking for AAAA record for fileserverHome

fileserverHome



(2) mDNS responder on
'fileserverHome' responds
To Multicast Group with
AAAA record



Implementations
Apple: Bonjour
Linux: Avahi

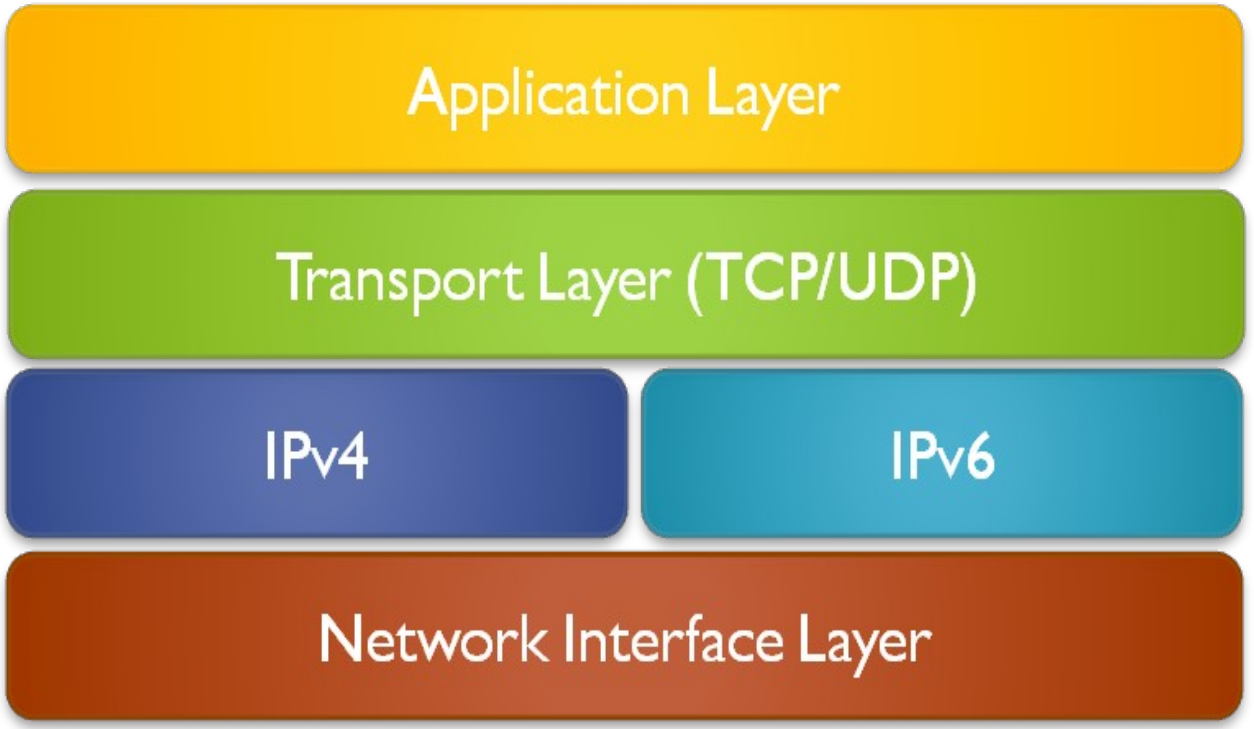


Transition Mechanisms

- Transition mechanisms are needed for IPv6 only host to reach IPv4 services.
- In the future we will see also IPv4 hosts need to be able to reach IPv6 services.
  - Dual Stack
  - Tunneling
  - Translation

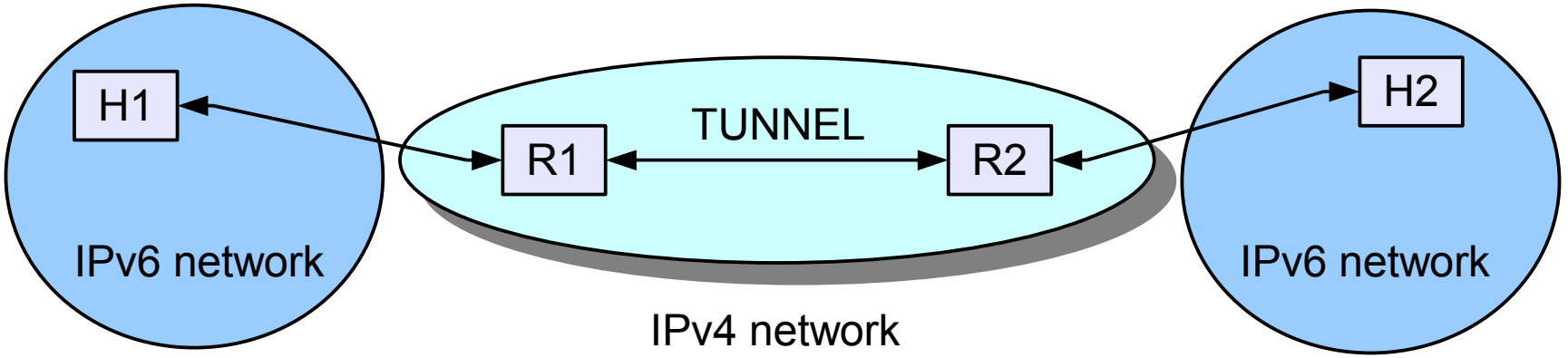
Dual Stack

- Dual stack host can speak both IPv4 and IPv6
  - Communicate with IPv4 host by IPv4
  - Communicate with IPv6 host by IPv6

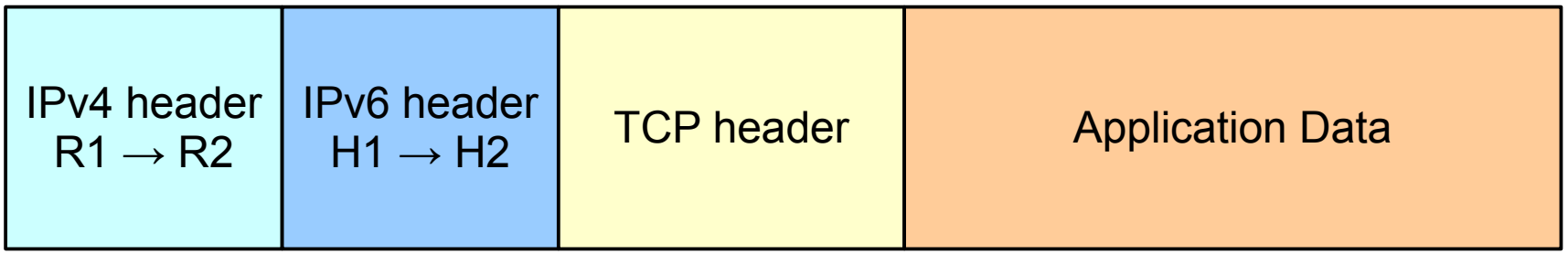


Tunneling

- Through an IPv4 tunnel we can connect two IPv6 networks
- Ideal to start experimenting with IPv6 topology



- Packet-structure with tunneling





Tunnel brokers

- There are 'free' tunnel brokers available
  - Require user registration
  - Request an IPv6 address (128 and 48 prefix)
  - Perfect to experiment with real IPv6 networking
- Hurricane Electronic
  - http://www.tunnelbroker.net/
- SixXS
  - http://www.sixxs.net/main/
- GogoNET Freenet6
  - http://gogonet.gogo6.com/



Translation

- An extension to NAT techniques to translate header formats as well as addresses
- Translate IPv6 only host to IPv4 host (vice versa is not trivial)
  - Protocol translation
  - Mapping address
- Unreliable and try to avoid it

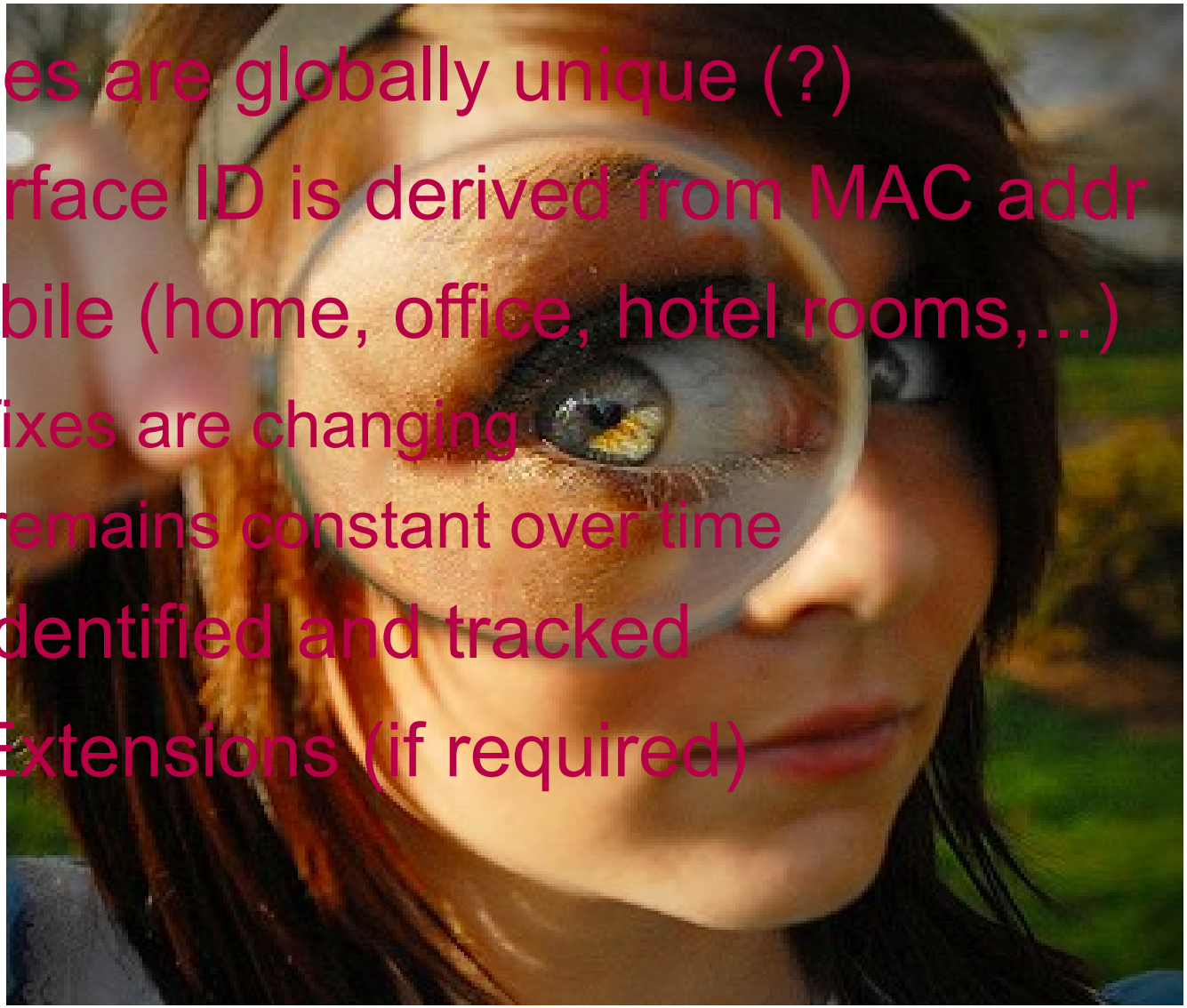


Security: protect yourself

- Once you start with IPv6 you must turn on ip6tables
- The radvd daemon will automatically configure interfaces on Windows (vista/windows7), Mac OS/X and Linux
  - Your IPv6 tunnel will open the gate to the IPv6 world
  - Attacker can send a Router Advertisement and gain access to your internal network (even you're safe on the IPv4 side)

Security Considerations

- MAC addresses are globally unique (?)
- SLAAC – Interface ID is derived from MAC addr
- Users are mobile (home, office, hotel rooms,...)
  - Network prefixes are changing
  - Interface ID remains constant over time
- User can be identified and tracked
- Use Privacy Extensions (if required)





How to become IPv6 ready?

- Buy only new equipment that is IPv6 compliant
- New software must be IPv6 capable
- Make an inventory of all current hard- and software
- Educate yourself via books, courses, and setup a lab environment
- Replace hard- and software were required
- Setup IPv6 DNS servers for public servers
- Get connected natively or via tunneling
- Use IPv6 for internal/external traffic (dual stack with IPv4)



Do and Don'ts

- Phased approach
- Change requirements for new hardware
- Work outside-in; then inside-out
- Dual stack; tunnels
- Think about possible future renumbering

- Don't separate IPv6 features from IPv4
- Don't do everything in one go
- Don't appoint an IPv6 specialist
- Don't buy from vendors unless they support IPv6



Make software IPv6 aware

- If you maintain an Open Source project invest time to make it IPv6 aware (if it uses IPv4 today)!
- Do what you preach:
  - Relax and recover (rear) is IPv6 ready since 1.11.0