Jeroen Massar <jma@zurich.ibm.com>
ETH Zurich, Switzerland - 10th May 2010

IPv6

Who is Jeroen?

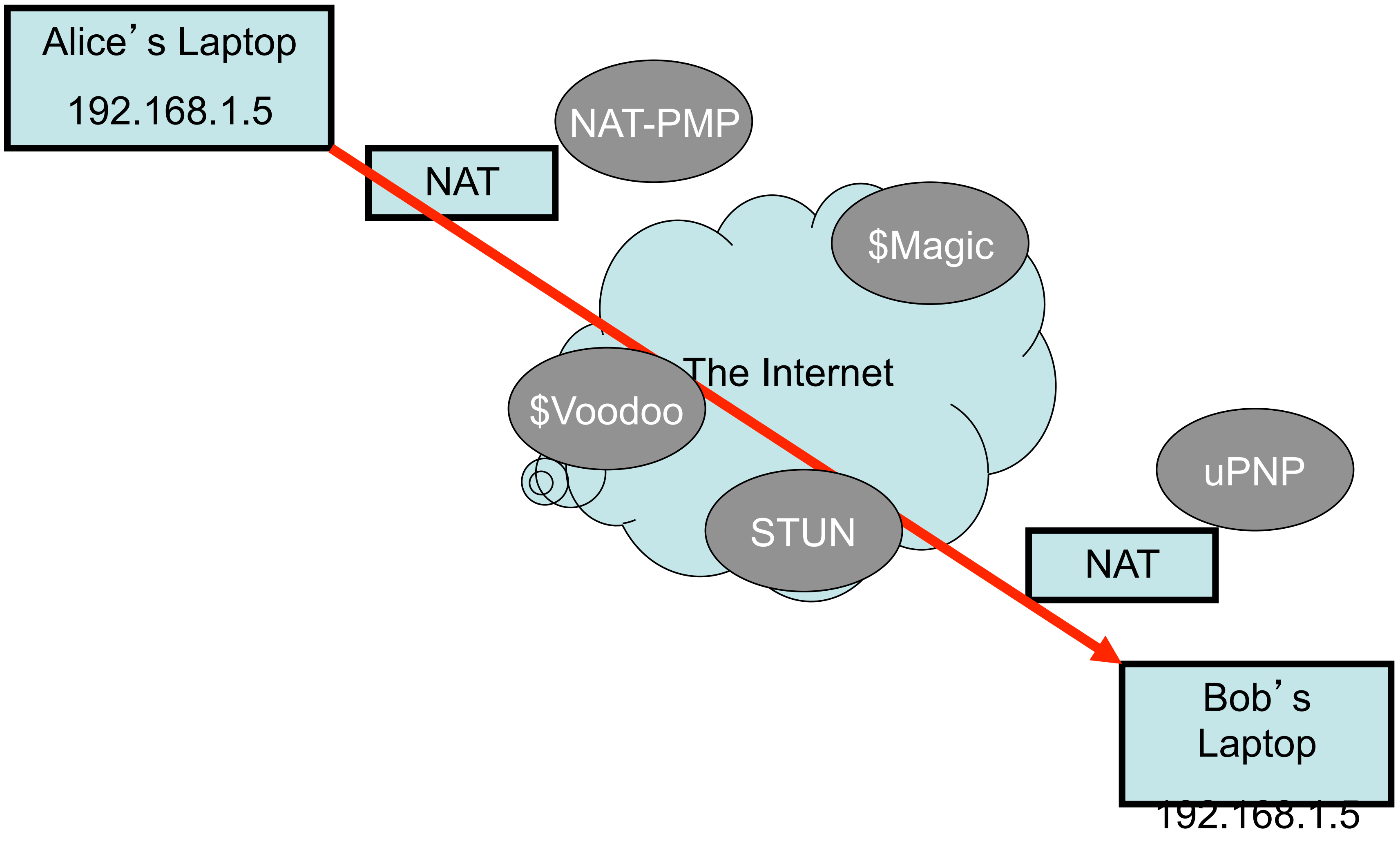
- Working at IBM Zurich Research Laboratory which is located in Rüschlikon, working on IPv6 projects, a high performance analyzer called AURORA for monitoring large-scale networks (http://www.zurich.ibm.com/aurora/) and various network security related projects.

- One of the two persons behind SixXS (http://www.sixxs.net/) which provides free IPv6 connectivity to users worldwide along with GRH for IPv6 routing monitoring.

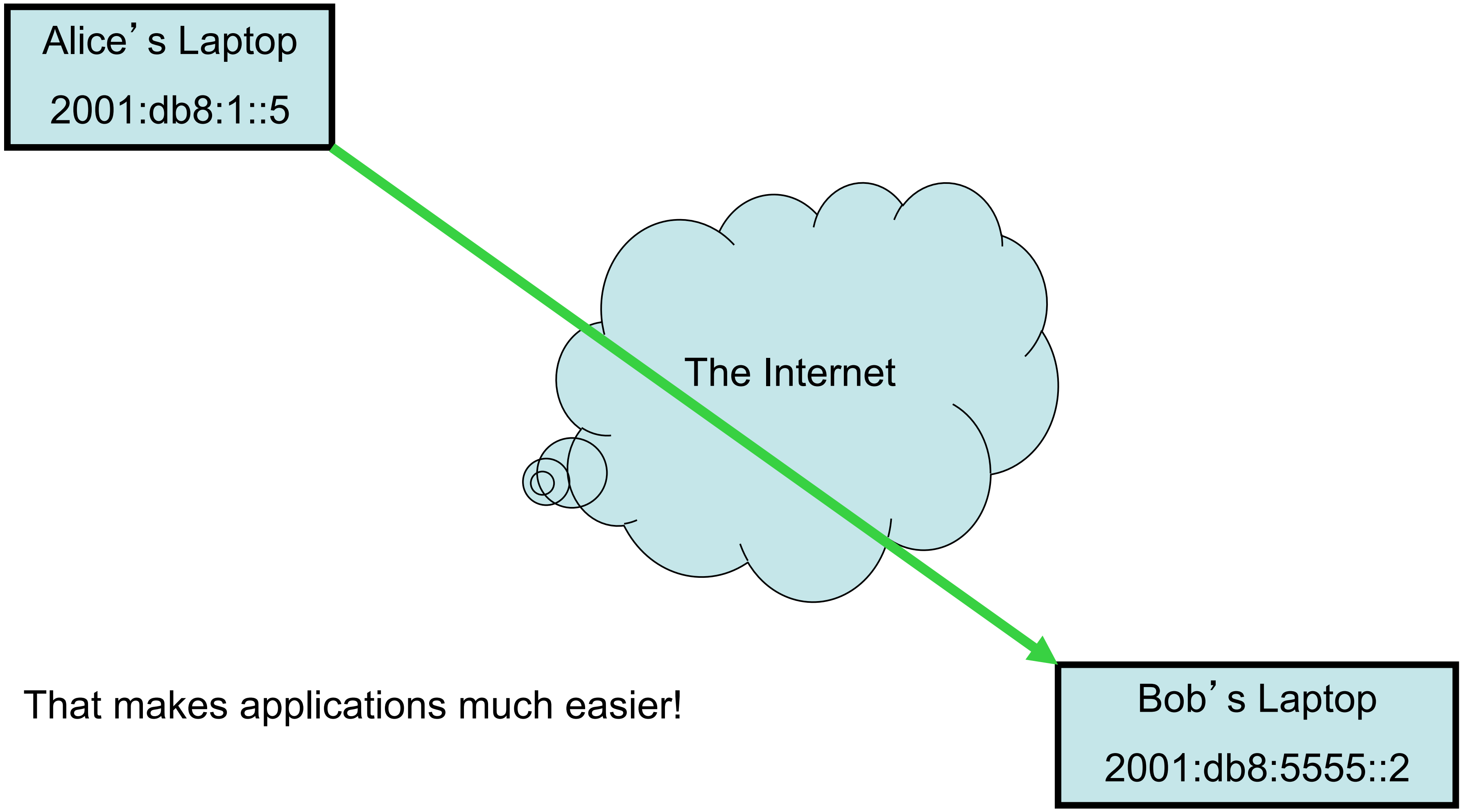
- Contributor to IETF & IRTF on various IPv6 and routing related subjects. Made amongst others PuTTY compatible.

- Other details:
  - http://unfix.org/~jeroen/
  - http://www.zurich.ibm.com/~jma/

Today: IPv4

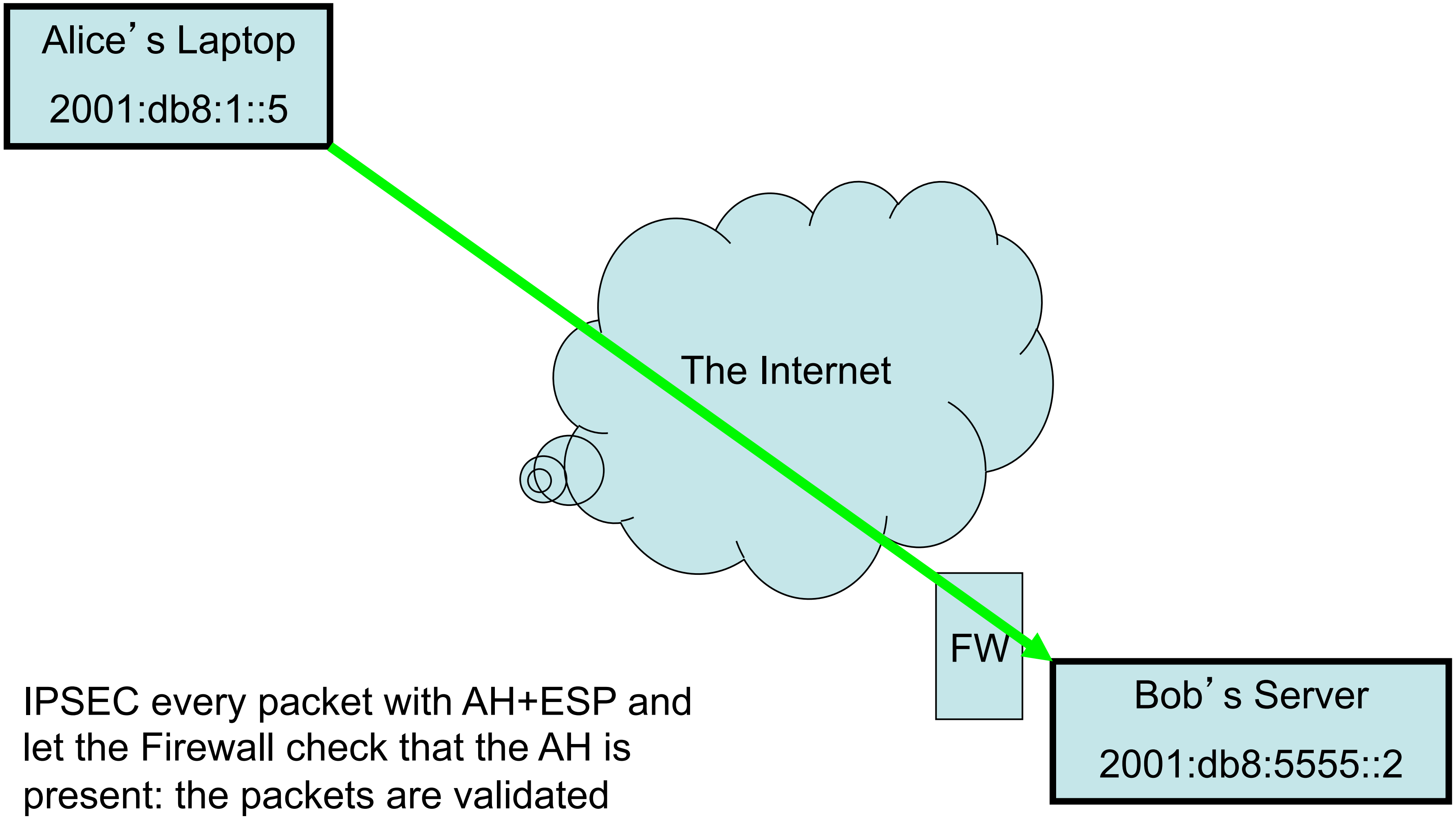

Alice’s Laptop
192.168.1.5
NAT
NAT-PMP
$Magic
The Internet
$Voodoo
STUN
uPNP
NAT
Bob’s Laptop
192.168.1.5

Tomorrow: IPv6



That makes applications much easier!

or protected with IPSEC



IPSEC every packet with AH+ESP and let the Firewall check that the AH is present: the packets are validated

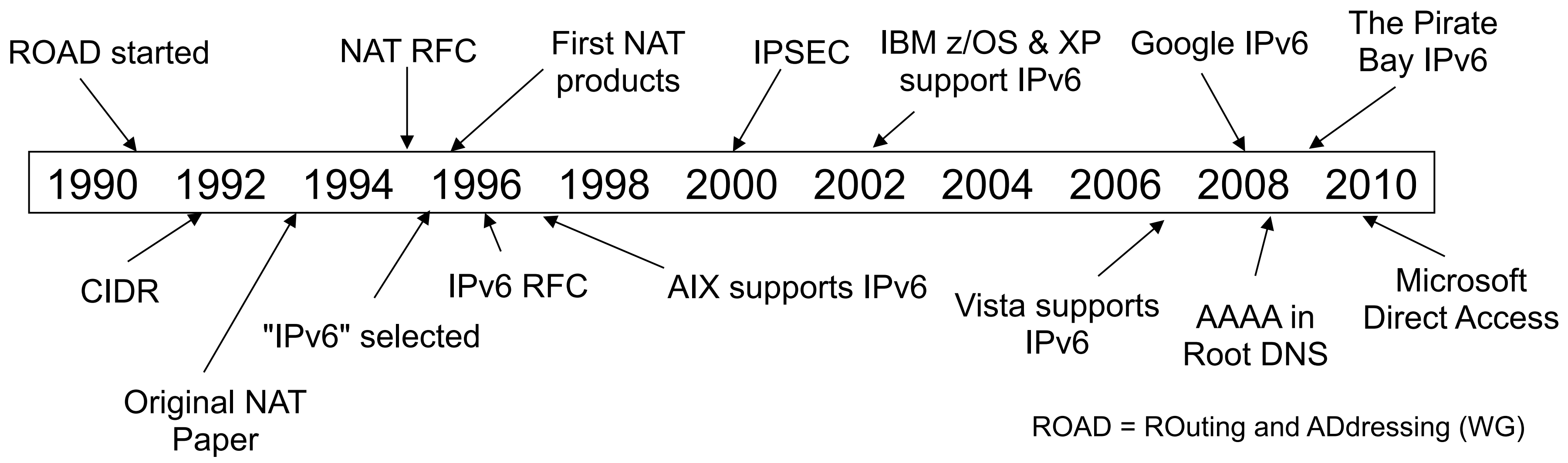
Why IPv6?

- Biggest and actually only advantage: More IP addresses!

- end-to-end, IP-layer authentication & encryption possible (IPSEC)
- for billions of new users (Japan, China, India,.)
- for billions of new devices (mobile phones, cars, appliances,.)
- for always-on access (cable, xDSL, ethernet-to-the-home,.)
- for applications that are difficult, expensive, or impossible to operate through NATs (IP telephony, peer-to-peer gaming, home servers,.)
- to phase out NATs to improve the robustness, security, performance, and manageability of the Internet
- server-less plug-and-play possible
- elimination of “triangle routing” for mobile IP

Compacted IPv6 History

- IPv6 (Internet Protocol version 6)
  - Also called IPng (Internet Protocol Next Generation)
- No IPv5? (RFC1190 : ST Datagram Mode)

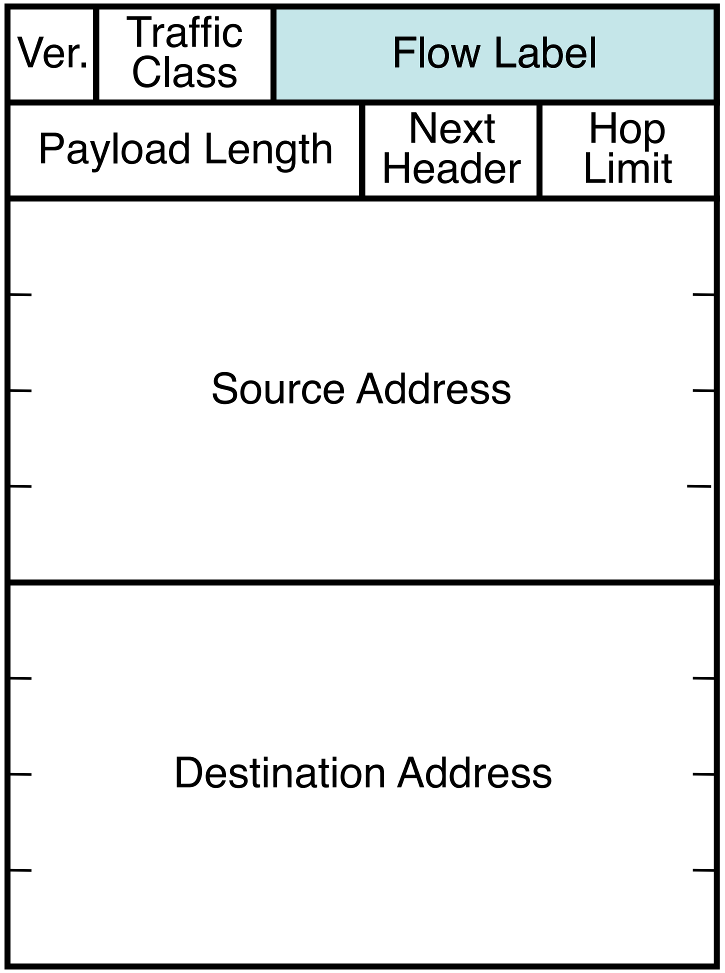


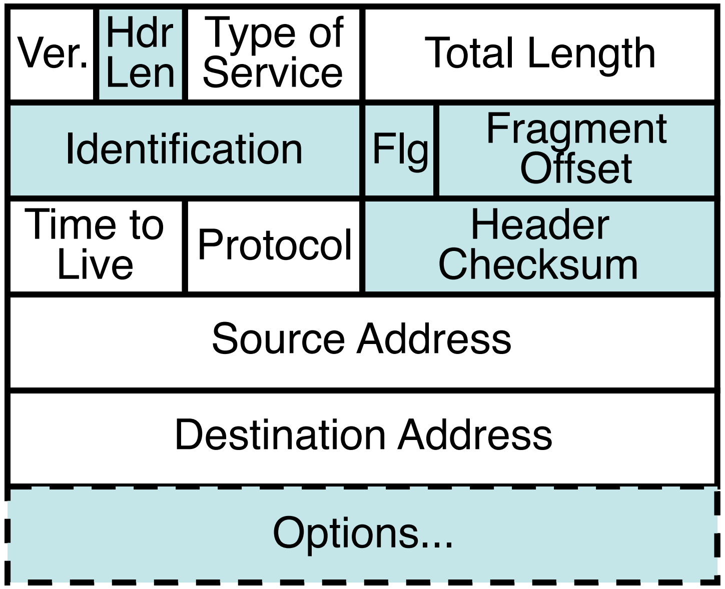
ROAD = ROuting and ADdressing (WG)

CIDR = Classless Internet Domain Routing

NAT = Network Address Translation

Differences between IPv4 and IPv6 header





blue fields have no equivalent in the other version

IPv6 header is twice as long (40 bytes) as IPv4 header without options (20 bytes)

Summary of changes between IPv4 and IPv6

- Revised
  - Addresses increased 32 bits -> 128 bits
  - Time to Live -> Hop Limit
  - Protocol -> Next Header
  - Type of Service -> Traffic Class
  - No more broadcast
- Streamlined
  - Fragmentation fields moved out of base header
  - IP options moved out of base header
  - Header Checksum eliminated
  - Header Length field eliminated
  - Length field excludes IPv6 header
  - Alignment changed from 32 to 64 bits
- Extended
  - Flow Label field added (but still not defined, thus not used)

How to notate an IPv6 address

- Full form:

  2001:0db8:0000:0000:0000:0000:0000:029a
- Compressed:

  2001:db8::29a
- IPv4-embedded:

  0:0:0:0:0:ffff:192.0.2.42

  or compressed:

  ::ffff:192.0.2.42

- Documentation IPv6 Prefix: 2001:db8::/32
- Documentation IPv4 Prefix: 192.0.2.0/24
- Localhost ::1

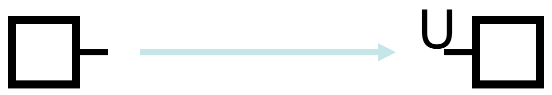
How to note an IPv6 address (#2)

- No more netmasks, only prefixes: 2001:db8::/48
- Scope qualifiers (%) fe80::202:2dff:fe2a:3f78%4
- In URL's: http://[2001:db8::42]:80

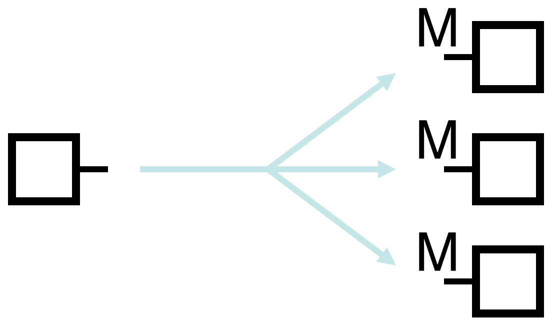
  (square-bracket convention also used anywhere else there's a conflict with address syntax. eg IRC configuration files, SPF records)
- Forward DNS:
  - spaghetti.ch.example.org AAAA 2001:db8:302::202:2dff:fe2a:3f78
- Reverse DNS:
  - 8.7.f.3.a.2.e.f.f.f.d.2.2.0.2.0.0.0.0.0.2.0.3.0.8.b.d.0.1.0.0.2.ip6.arpa. PTR spaghetti.ch.example.org.
- ip6.int and bitstring notation are deprecated.
- A6/DNAME has been marked experimental.

Addressing Types

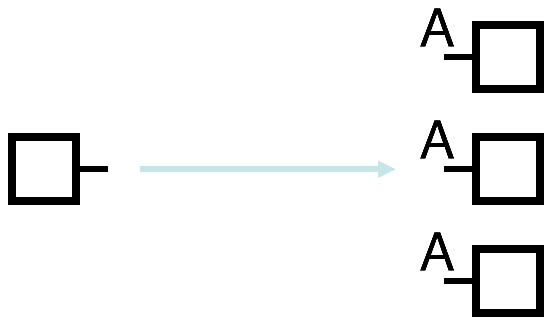
- Unicast
  One on one



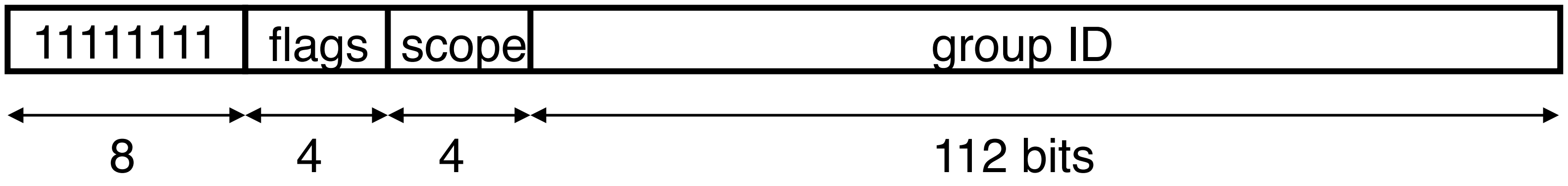
- Multicast
  One to many



- Anycast
  One to any



Multicast addresses



- low-order flag indicates permanent / transient group; three other flags reserved
- scope field:

– 1 - interface-local	(for multicast loopback)
– 2 - link-local	(same as unicast link-local)
– 3 - subnet-local	
– 4 - admin-local	
– 5 - site-local	(same as unicast site-local)
– 8 - organization-local	
– B - community-local	
– E - global	(same as unicast global)

(all other values reserved)

- Per /48 automatically a globally unique Multicast prefix:

  2001:db8:29a::/48 -> ff3e:30:2001:db8:29a::/96

Special Multicast addresses

- ff02::1 = all hosts
- ff02::2 = all routers

- As such, when you want to hack into a network, the moment you are into your first host you can find out all other hosts on the network by justing pinging ff02::1. Some “secure” Operating Systems thus turn that feature off. Finding the first host is of course a lot of fun, but one can easily go through web/mail/etc access logs to find out where they are.

Subnet anycast address

- When one has 2001:db8::/64, then 2001:db8::/128 is the subnet anycast address, which is effectively always ‘localhost’.
- Problem when you get 2001:db8::/127, as then you have 2001:db8::/128 or the subnet anycast address and 2001:db8::1, but nothing else.
- This is the reason why one can’t use /127’s for Point-2-Point tunnels.
- General consensus: use 2x /128, or easier a /64.

- For allocations, ISPs tend to take one /64 for Point-2-Point connections, eg connections to end-users, and then their router is <prefix>::1, while the customer becomes <prefix>::2. When the customer wants more than 1 address, they route them a /64 or /48 to ::2

Address Type Prefixes

• Unspecified	0000 .... 0000 (::/128)
– used when there is no address	
• Loopback	0000 .... 0001 (::1/128)
• Link Local Unicast	1111 1110 1000 0000 .... (fe80::/16)
• Multicast	1111 1111 .... (ffxx::/8)
• Unicast + Anycast	The rest, 2000::/3, which is 1/8th of total IPv6 space
– hierarchical	2001::/16 = RIRs
– /13 - /32 to LIR's (ISP's)	2001::/32 = Teredo
– /48 or /56 to endusers / sites	2002::/16 = 6to4
	3ffe::/16 = 6bone*
– “Site Local” used to exist (fec0::/10) but this has been deprecated in favor of ULA.	fd00::/8 = ULA

* = 6bone shut down on 6/6/6

http://www.iana.org/assignments/ipv6-address-space

Prefixes around the world

- 1x /13
- 2x /19
- 6x /20
- 4x /21
- 5x /22
- 1x /23

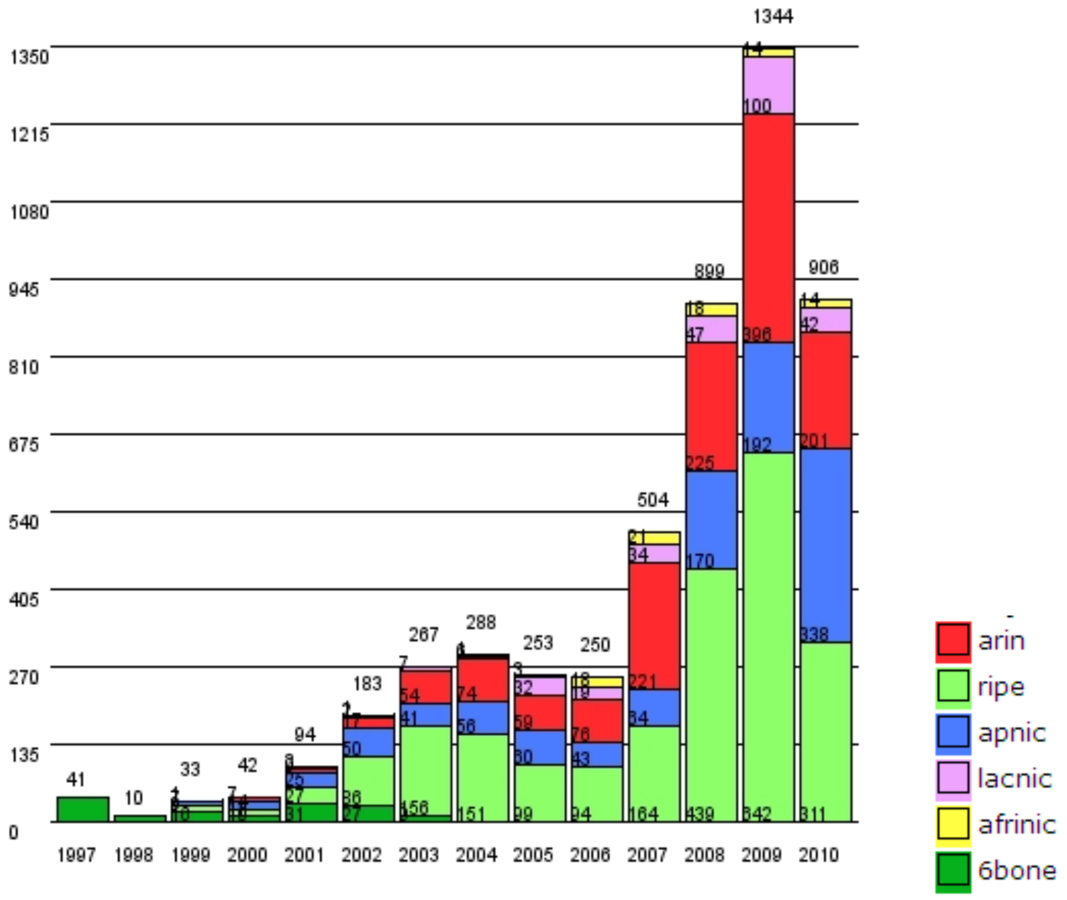
…

- 3922x /32

…

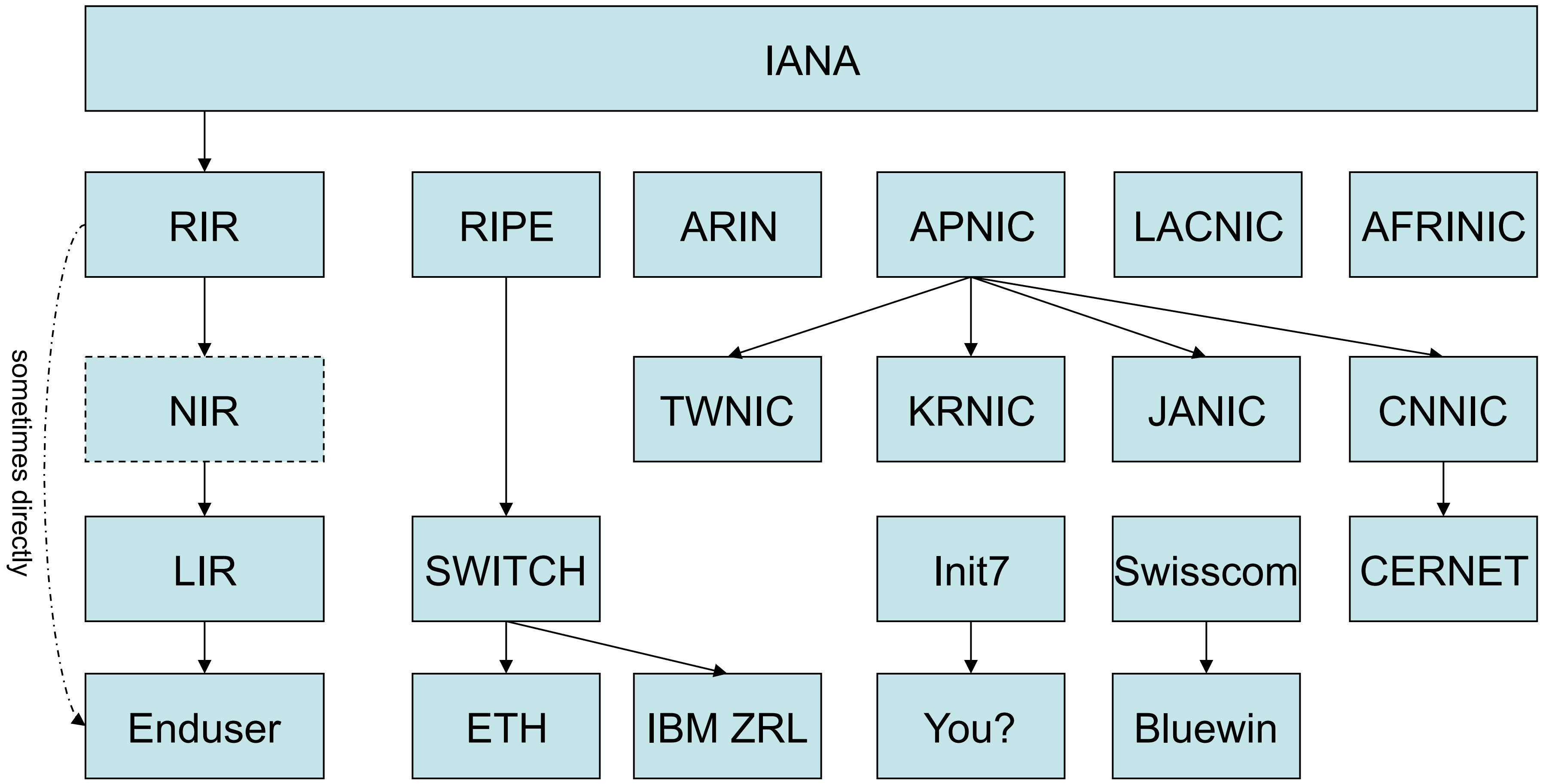
- 12x /44, 1x returned
- 12x /45, 2x returned
- 15x /46
- 22x /47
- 806x /48, 24x returned
- 4x /64, 1x returned

Switzerland: 103 in total, 58 being announce

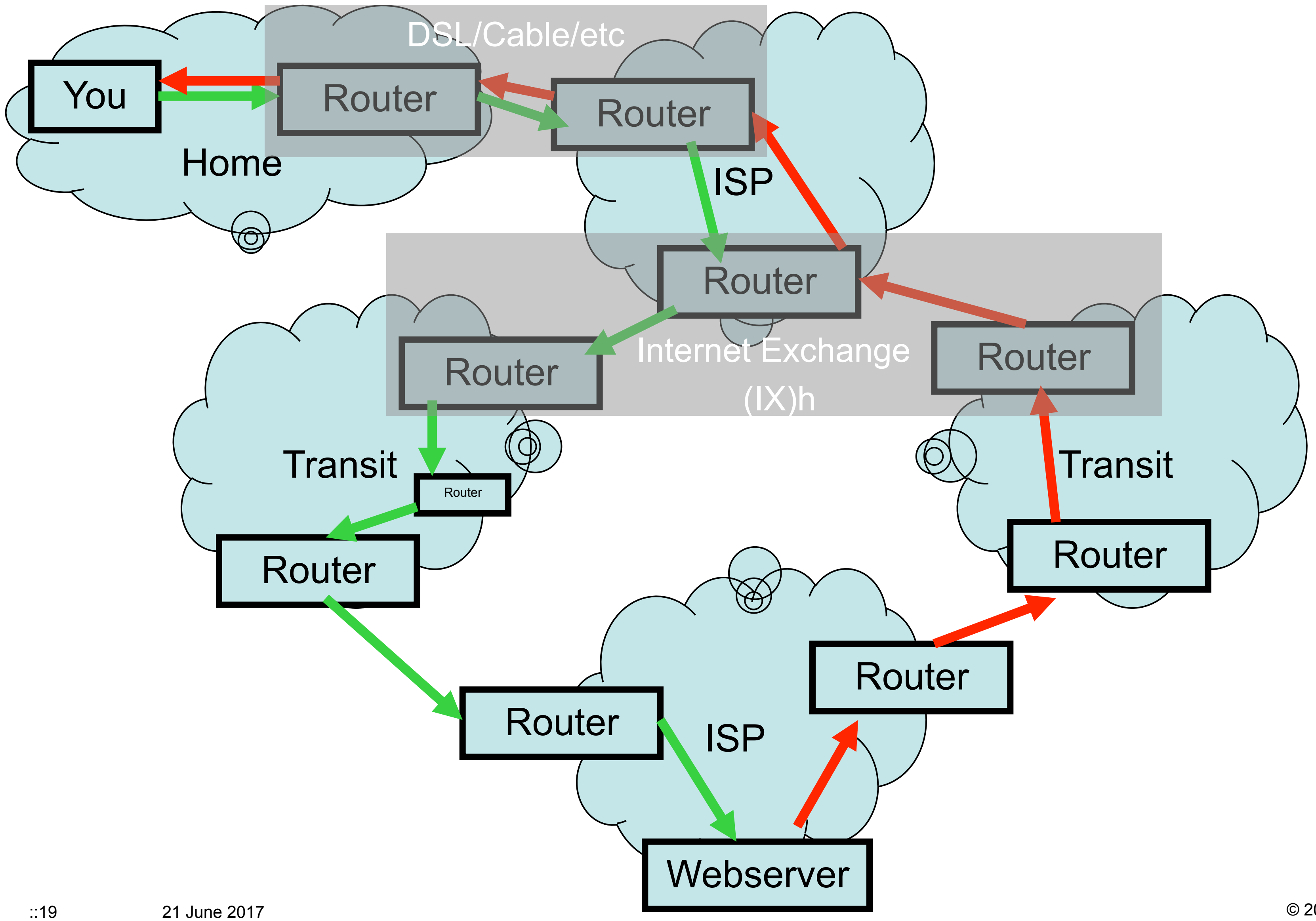


Data Source: http://www.sixxs.net/tools/grh/growth/

Where to get an address?



The Tubes of the Internet



RFC4193 - ULA

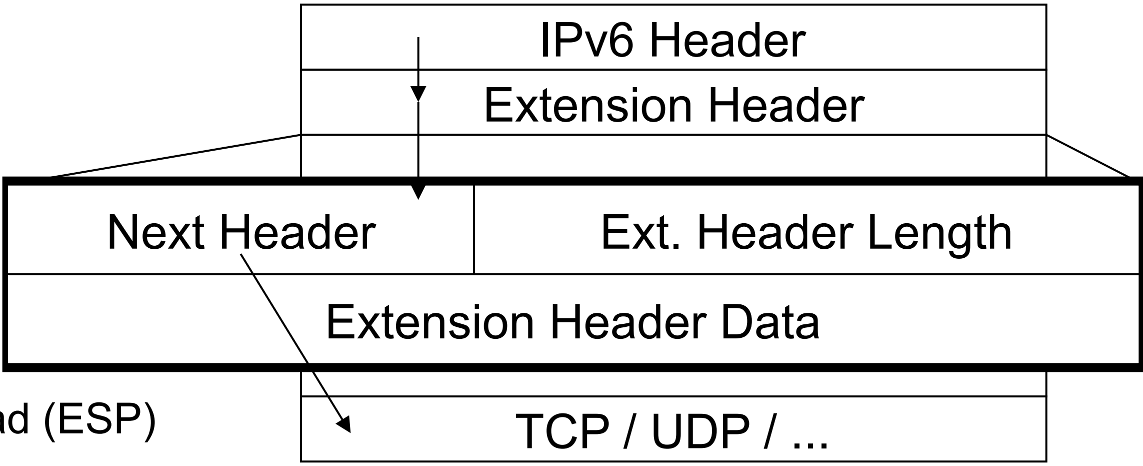
- IPv6 ULA (Unique Local Address)
- RFC4193 Registration
- fd00::/8 ULA Locally Assigned.

  It is Unique, but maybe not Unique enough as it has a chance that it is not.
- fc00::/8 ULA “Registered” – but not specified and thus can’t be used.
- Nearly 300 registrations
- Of course not guaranteed, when people don’t check this list it can’t be http://www.sixxs.net/tools/grh/ula/ for a ‘registry’ so that when one registers there and checks before using one at least knows it is quite unique.

- IPv6 PI is available, but costs a bit of money, but is globally unique.

Header Chains

- The Next Header field describes the type of following the IP header which can point to the next header forming a chain.
- Aligned to 64 bits
- Extension headers:
  - Hop by Hop
  - Destination Options
  - Routing Header
  - Fragment Header
  - Authentication Header (AH)
  - Encapsulating Security Payload (ESP)
  - Upper Layer Header
    - TCP/UDP/ICMPv6/SCTP

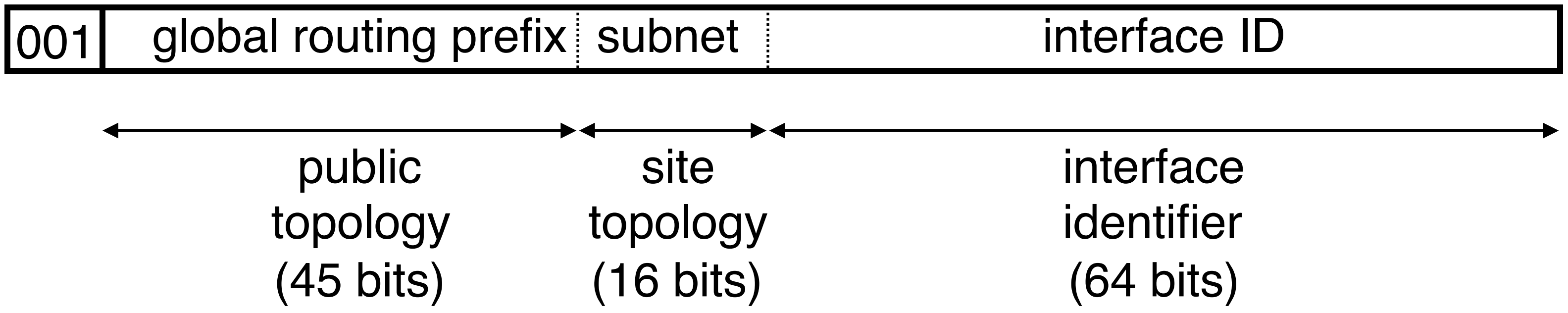


Address Properties

- Multiple addresses per interface
  - Always at least one link-local address
  - One or more unicast prefixes
- Addresses can be marked 'deprecated'
  - they should not be re-used by new outgoing connections
  - old connections will keep working
- Router renumbering protocol, to allow domain-interior routers to learn of prefix introduction / withdrawal

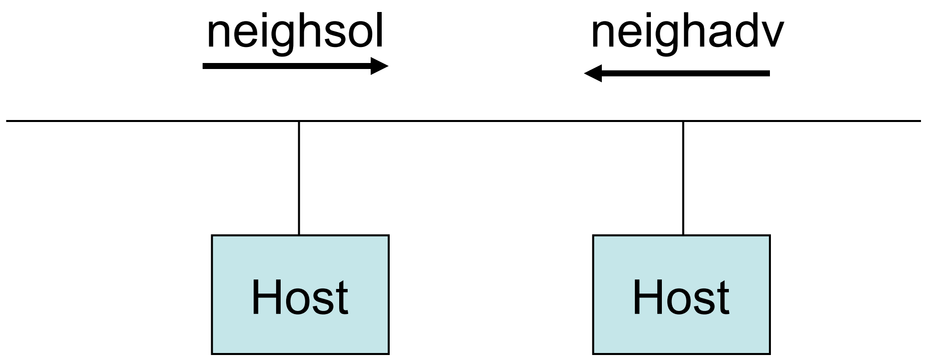
How does a host get an address

- Manual configuration (of interface ID or complete address)
- DHCPv6 (configures complete address + optionally services)
- Automatic derivation from 48-bit IEEE 802 address
  or 64-bit IEEE EUI-64 address as per:
- ::mmMM:MMff:feMM:MMMM (M = Mac address)
- split address in halve, and invert a bit in 'mm'
- Pseudo-random generation for client privacy (RFC3041)
- The latter two choices enable "serverless" or "stateless" autoconfiguration, when combined with high-order part of the address learned via Router Advertisements



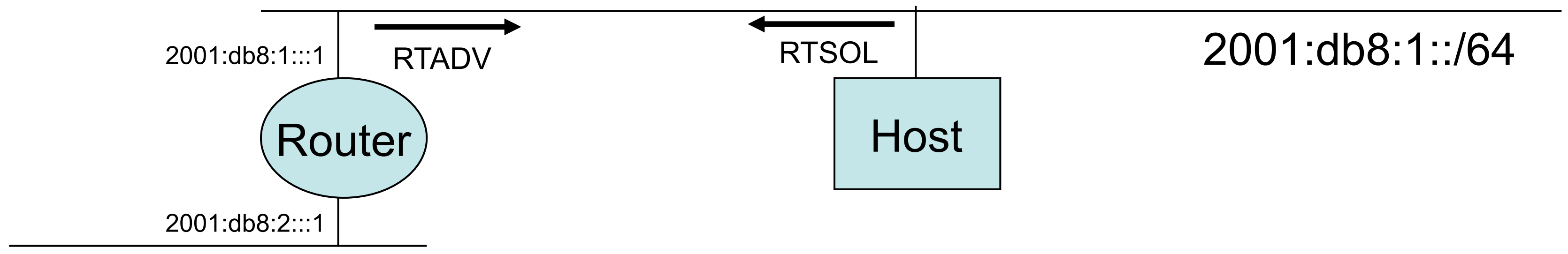
Neighbor Discovery

- Instead of IPv4's ARP
- Determine the addresses that are on the same link
  - Finding routers
  - Finding directly contactable hosts
- Uses ICMPv6.
- Neighbor solicitation for requesting who are neighbors.
- Neighbor advertisement for announcing that you are a neighbor.
- Duplicate Address Detection (DAD)



Router Advertisement (Discovery)

- Router announces periodically which prefix is assigned to the link
- They can learn one or more on-link prefixes
  - Lifetime is included separately for every prefix -> “easy” renumbering
  - Hosts can auto configure themselves using this prefix
- They can learn the router that they can use as a default router
- They can learn if they are required to use stateless or stateful configuration (DHCPv6 for instance)
- Additional information like MTU and hop limit can be learned.



Notes

- No fragmentation in routers
  - Hosts do fragmentation, routers only respond with ICMPv6 Packet Too Big
  - and thus employing Path MTU Discovery.
- Smallest packet size / MTU is 1280 bytes
  - "Layer 2" does the fragmentation when the L3 packets are too big
- Checksums are done usually already by Layer 2, so why repeat doing it in IPv6 where the router has to checksum every packet it would route and thus saving on overhead and calculations.
- IPv4 and IPv6 can coexist, mixing should not be an issue.
- Recommendation to first try IPv6 AAAA's and after that the IPv4 A's when trying to contact a host from an application.

Fun Notes

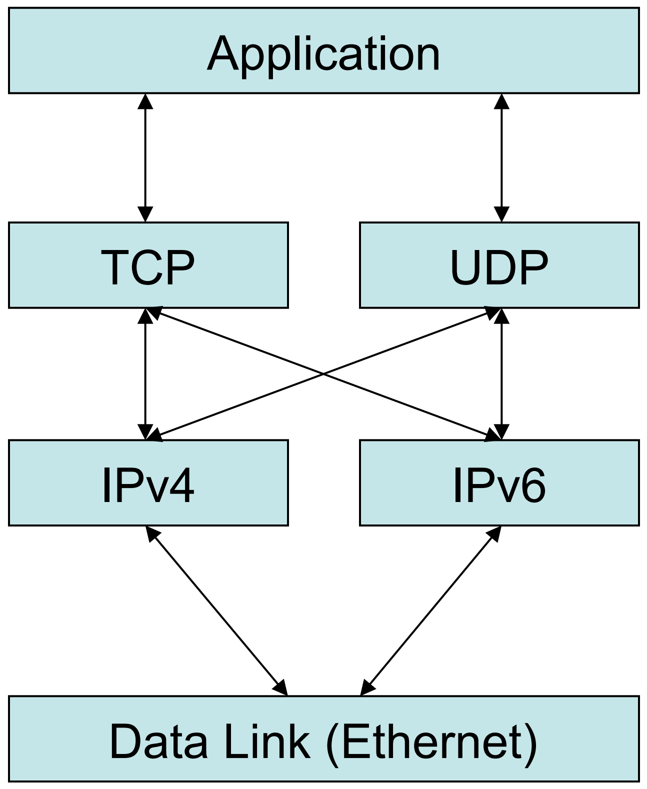
- RFC1888 "OSI NSAPs and IPv6"
  - Defines how to embed an OSI NSAP address inside IPv6
- RFC4048 "RFC 1888 Is Obsolete"
  - Makes RFC1888 historic

- Flow labels are simply not defined at all anywhere
- IPSEC is also available for IPv4, but the problem mostly is the uniqueness of the address space (one will find 192.168.0.0/16, 10.0.0.0/8 or 172.16.0.0/12 at home or in their business?)
- Anycast exists also in IPv4 as it is mostly a routing trick
- RH0 (Routing Header Type 0) – same kind of mistake as in IPv4, one could abuse it to let packets be sent in a loop, oops. This 'feature' is now disabled in most stacks and routers block these packets.

Dual Stack Operation

- Applications can use both IPv4 and IPv6 at the same time, protocols can coexist.
- DNS can contain both IPv4 and IPv6 addresses.
- IPv6 applications can use IPv4-mapped addresses. Though this only is available when the kernel has a mixed IPv4/IPv6 stack. Windows IPv6 implementation doesn't have this for instance.

- Best option: Address Family independency



Address Family (AF) Independency

New functions from RFC2553 and RFC2292:

- getaddrinfo()
  - Getting the addresses belong to a textual identifier
  - Replaces:
  - - gethostbyname()
  - - getservbyname()
  - - inet_pton()
- getnameinfo()
  - Getting a textual representation of an address
  - Replaces:
  - - getservbyaddr()
  - - getservbyport()
  - - inet_pton()

Porting Considerations

- Change socket functions
- Adjust logging function so they can handle larger IP address

  (Don't forget to store both the hostname and the address as changing reverses is as easy as getting a new IP, having two tracking points is better)
- Increase all data member that stores IP addresses in program and in databases/ configuration files
- Adjust keyboard and display interface function so they can handle larger IP addresses.
- RFC2732 states that IPv6 addresses in URIs should be delimited by square brackets [ ] which solves the problem where applications use the colon (:) to distinguish the port from the address

  (eg [2001:db8::1]:80).
- getaddrinfo() returns 0 on succes, !0 on failure unlike most other unix/posix calls.

Server Code Example

Daemons should listen on all possible combinations, as PF_UNSPEC, mostly 2 maximum (IPv4+IPv6)

```
int sockets[10];
int makelisten(char *server, char *service)
{
        int i = 0;
        struct addrinfo hints;
        struct addrinfo *res, *store;
        memset(&hints, 0, sizeof(hints)); /* set-up hints structure */
        hints.ai_family = PF_UNSPEC;
        hints.ai_flags = AI_PASSIVE;
        hints.ai_socktype = SOCK_STREAM;
        if ((error = getaddrinfo(server, service, &hints, &res)))
        {
                perror(gai_strerror(error));
                return -1;
        }
        store = res;
        while (res)
        {
                sockets[i] = socket(res->ai_family, res->ai_socktype, res->ai_protocol);
                if (sockets[i] == -1) continue;
                if (bind(sockets[i], , res->ai_addr, res->ai_addrlen) == 0 &&
                   listen(sockets[i]) == 0) { i++; continue; }
                close(sockets[i]); sockets[i] = -1;
        }
        freeaddrinfo(store);

}

int socket = makelisten(NULL, "80");
```

Client Code Example

Client side program should try to connect to all resolved addresses,

```
int makeconnect(char *server, char *service)
{
        struct addrinfo hints;
        struct addrinfo *res, *store;
        memset(&hints, 0, sizeof(hints)); /* set-up hints structure */
        hints.ai_family = PF_UNSPEC;
        hints.ai_socktype = SOCK_STREAM;
        if ((error = getaddrinfo(server, service, &hints, &res)))
        {
                perror(gai_strerror(error));
                return -1;
        }
        store = res;
        while (res)
        {
                sockfd = socket(res->ai_family, res->ai_socktype, res->ai_protocol);
                if (sockfd == -1) continue;
                if (connect(sockfd, res->ai_addr, res->ai_addrlen) == 0)
                {
                        freeaddrinfo(store);
                        return sockfd;
                }
                close(sockfd);
        }
        freeaddrinfo(store);
        return -1;
}

int socket = makeconnection("www.zurich.ibm.com", "80");
```

RFC3484 – Address Ordering

- Orders addresses:
  - IPv6 native
  - IPv4 native
  - 6to4
  - Teredo

- Configurable
  - Linux: /etc/gai.conf
  - Solaris: ipaddrsel
  - FreeBSD: ip6addrctl
  - Windows: netsh

Use a socket per Address Family

```
tcp6    0    0 :::993          :::*        LISTEN    -
```

Does that listen on IPv6 only? -> Not on Linux, there it is IPv4 and IPv6, applications need to know this as they will see incoming connections on IPv4 as ::ffff:192.0.2.42

```
tcp     0    0 0.0.0.0:993     0.0.0.0:*   LISTEN    -
tcp6    0    0 :::993          :::*        LISTEN    -
```

Debian recently started setting the bindv6only systcl per default so that ”Linux” also behaves like every other Operating System and thus removes this ambiguity.

Porting Applications / Coding new ones

- google(eva ipv6) or http://gsyc.escet.urjc.es/~eva/IPv6-web/ipv6.html
- Contains “Porting applications to IPv6 HowTo“ with great explanation and example code.
- Also serves of course as a rather good example for new programs.

- Implementing AF-independent application document by Jun-ichiro ‘itojun’ Itoh (http://www.kame.net/newsletter/19980604/)
- The document from the master IPv6 Samurai himself.

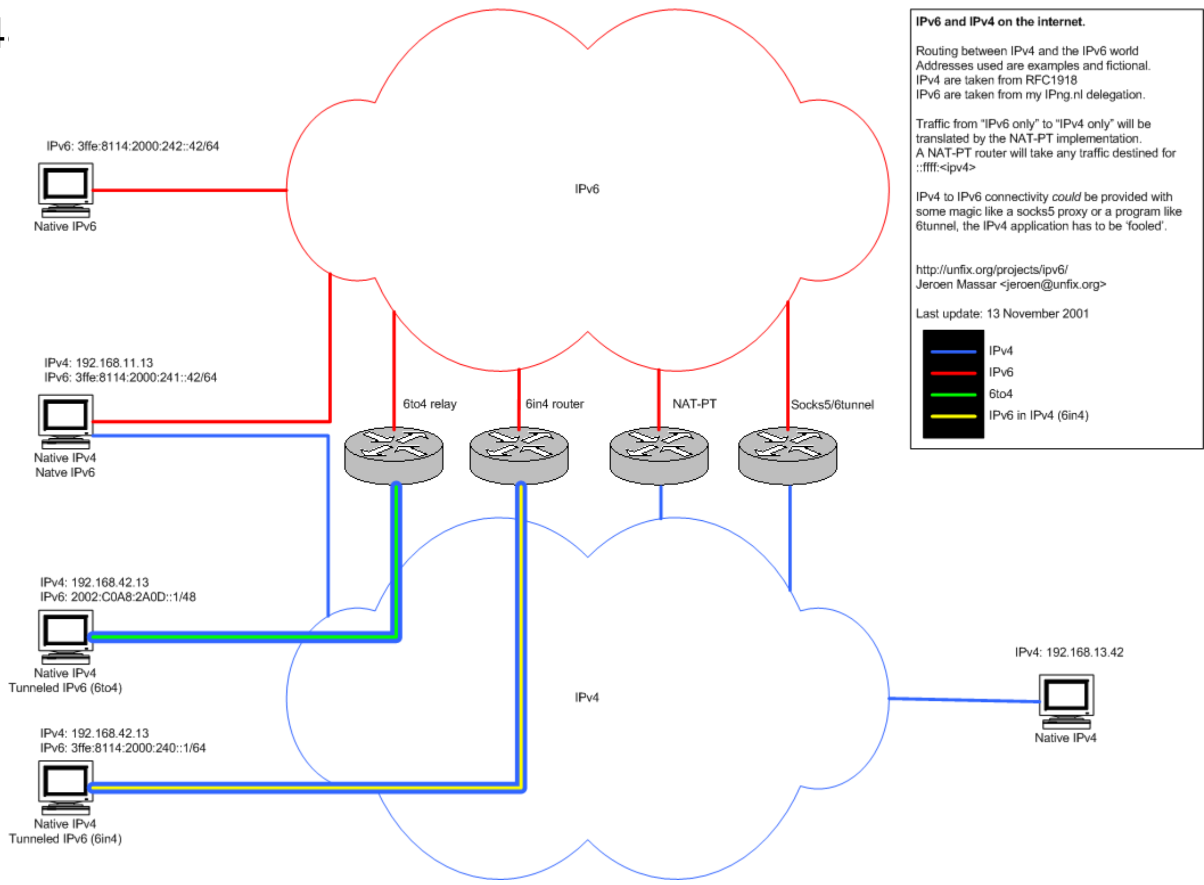
Security Implications

- More diverse devices connected, thus possibly also more vulnerabilities.
- Firewalls should be enabled per default for all incoming connections.
- Scanning of address space is not feasible
  - /64 per link
  - /48 or /56 per 'endsite'
- Currently only BSD has a stateful firewall, Linux since 2.6.[5|6]-USAGI.
- Cisco PIX has it too, but loadbalancing broken.

DOCTOR FUN
4 June 2003
W3
OwN
uR
fR1dg3!
3133T
SNAX0rZ
Copyright © 2003 David Farley, d-farley@ibiblio.org
http://ibiblio.org/Dave/drfun.html
This cartoon is made available on the Internet for personal viewing only. Opinions expressed herein are solely those of the author.
The brave new world of IPv6

Transitioning to IPv6

- 6to4
  - 2002:<aabb>:<ccdd>::/4
- Teredo
- ISATAP
  - <64bit prefix>: 0:5efe:<aabb>:<ccdd>
- 6in4 (Proto-41/SIT)
- 6rd
- GRE
- tinc / openvpn /...
- AYiYA
- IPv6 over MPLS/6PE
- DSTM (IPv6 -> IPv4)
- NAT-PT / SIIT
- BIS & BIA
- Faith/TCP-UDP Relay
- Application Proxies
  - (SOCKS / http / smtp/...)



IPv6 and IPv4 on the internet.

Routing between IPv4 and the IPv6 world
Addresses used are examples and fictional.
IPv4 are taken from RFC1918
IPv6 are taken from my IPng.nl delegation.

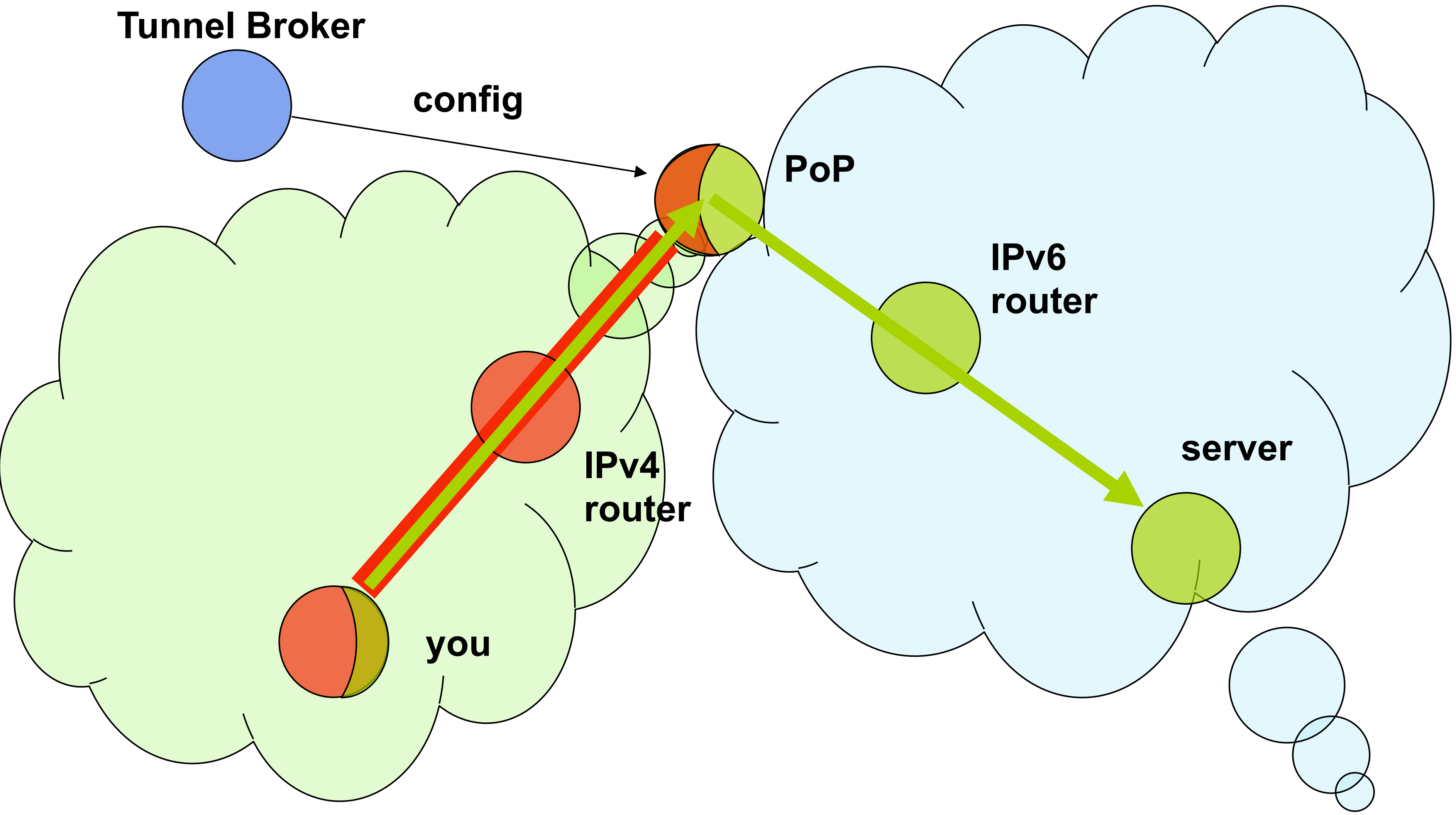
Traffic from "IPv6 only" to "IPv4 only" will be translated by the NAT-PT implementation.
A NAT-PT router will take any traffic destined for ::ffff:<ipv4>

IPv4 to IPv6 connectivity *could* be provided with some magic like a socks5 proxy or a program like 6tunnel, the IPv4 application has to be 'fooled'.

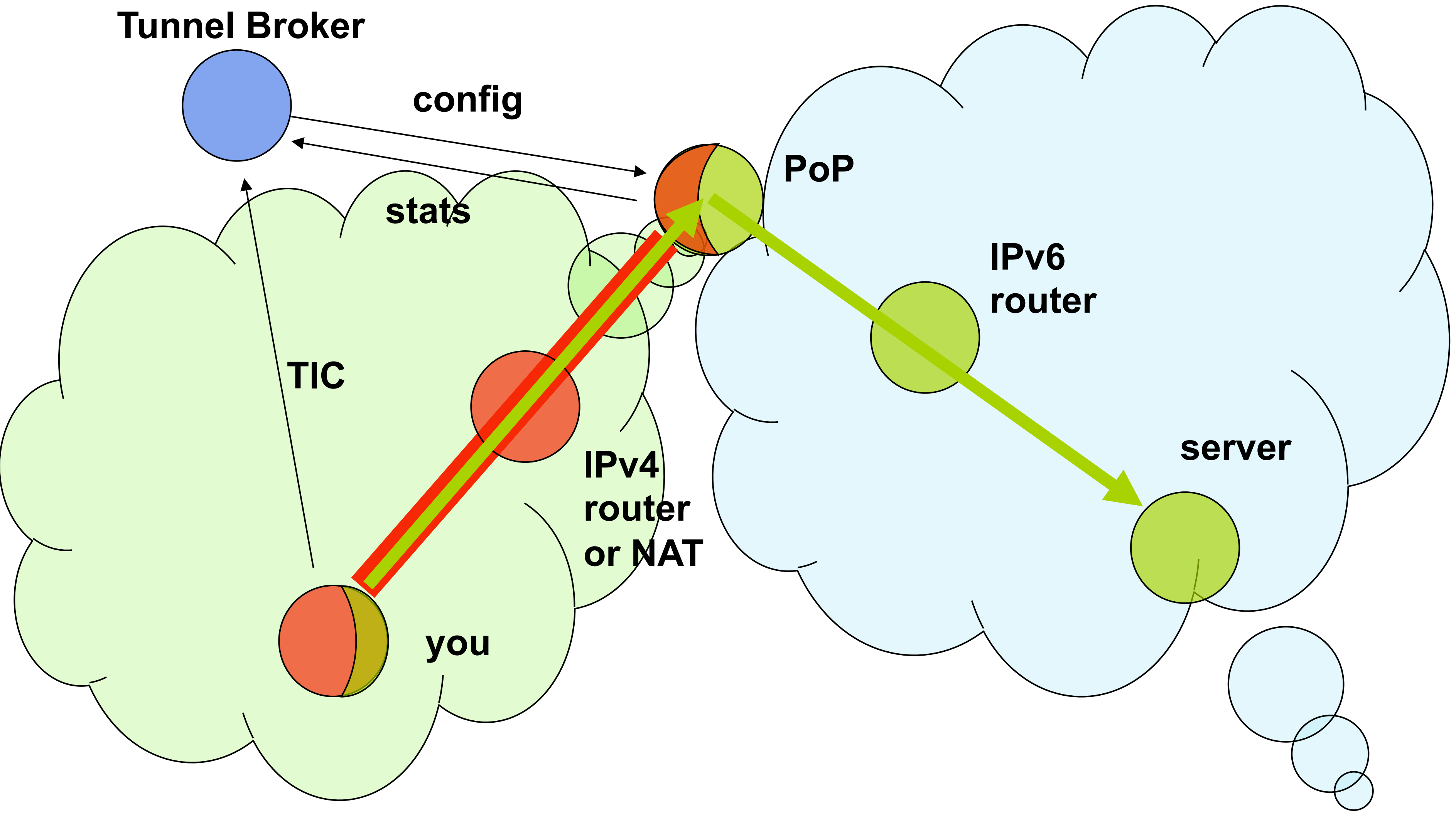
http://unfix.org/projects/ipv6/
Jeroen Massar <jeroen@unfix.org>

Last update: 13 November 2001

RFC3053 – Tunnel Broker



SixXS Tunnel Broker



Protocol 41

- Protocol 41 = IPv6
- It specifies how to put an IPv6 packet inside IPv4.
- Protocol 41 is static only.
- Protocol 41 doesn’t cross NATs.

Version:	IPv4
Src/Dst:	192.0.2.111 -> 192.0.2.222
Protocol:	41 (IPv6)
Version:	IPv6
Src/Dst:	2001:db8::111 -> 2001:db8::222
Protocol:	6 (TCP)
TCP	

6to4

- RFC3056 (6to4) & RFC3068 (6to4 Anycast)
- Uses protocol 41 / static IPv6 tunnels
- 2002:aabb:ccdd::/48 per public IPv4 address (aa.bb.cc.dd)
  - eg 192.0.2.42 => aa = 192 = 0xc0, bb = 0 = 0x00, cc = 0x02, dd = 42 = 0x2a

    Thus: 2002:c000:022a::/48
- Anycast in IPv4 (192.88.99.1/24) though 'private' 6to4 relays exist
- Anycast also in IPv6 as 2002::/16 is only allowed to be announced in BGP as the /16, no more specifics, otherwise one would pollute the IPv6 space with IPv4 routes.

- Due to the double (forward and return path of the packets) anycast in both IPv4 and IPv6, it is very hard to determine the flow of packets as they can be 'pulled' all over the place and this makes it extremely difficult to debug issues with 6to4.

6rd

- RFC5569
- IPv6 Rapid Deployment (RD also from Remi Depres who came up with it)
- Deployed at Free.fr to their 4M user base
- Instead of 2002::/16, uses ISP prefix
  – Eg ISP has existing customers in 192.0.2.0/24 then only 8 bits needed for customers, thus 2001:db8:1100::/40 can be used. The IPv4 address 192.0.2.204 (204 => 0xcc) would then get 2001:db8:11cc::/48.
- Works for Free as they have their own CPE (Cable/DSL modems) and they ‘just’ had to upgrade all of them with this new custom code.

Proto41/Heartbeat

- draft-massar-heartbeat
- Proto-41 is static. The moment the user unplugs / forced DHCP change, another user can get that IPv4 address. That user then gets proto-41 packets and the firewall tool beeps with warnings, which sometimes results in abuse reports because we are attacking them.
- Allows one to move around proto-41 tunnels automatically or enable/disable them on the fly.

Version:	IPv4
Src/Dst:	192.0.2.111 -> 192.0.2.222
Protocol:	41 (IPv6)
Version:	IPv6
Src/Dst:	2001:db8::111 -> 2001:db8::222
Protocol:	6 (TCP)
TCP	

Version:	IPv4
Src/Dst:	192.0.2.111 -> 192.0.2.222
Protocol:	17 (UDP)
UDP	
HEARTBEAT ….	

AVM Fritz!Box has support for this protocol and of course AICCU and several other mini-clients.

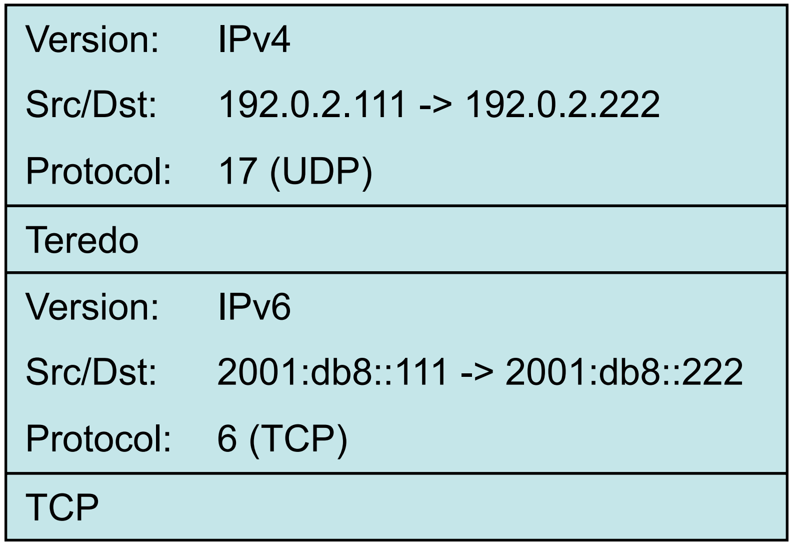
AYIYA – Anything in Anything

- draft-massar-ayiya
- Proto-41 tunnels can’t cross NATs.
- Proto-41 tunnels are not authenticated (read: one can spoof them easily)
- Heartbeat runs next-to the proto-41 tunnel. Heartbeat might work, proto-41 might not.
- AYIYA solves these issues by tunneling IPv6 inside IPv4/UDP and signing these packets. (other options: over HTTP(s), DNS or QoS)

Version:	IPv4
Src/Dst:	192.0.2.111 -> 192.0.2.222
Protocol:	17 (UDP)
AYIYA (id = 2001:db8::111, hash, nxt=41)	
Version:	IPv6
Src/Dst:	2001:db8::111 -> 2001:db8::222
Protocol:	6 (TCP)
TCP	

Teredo

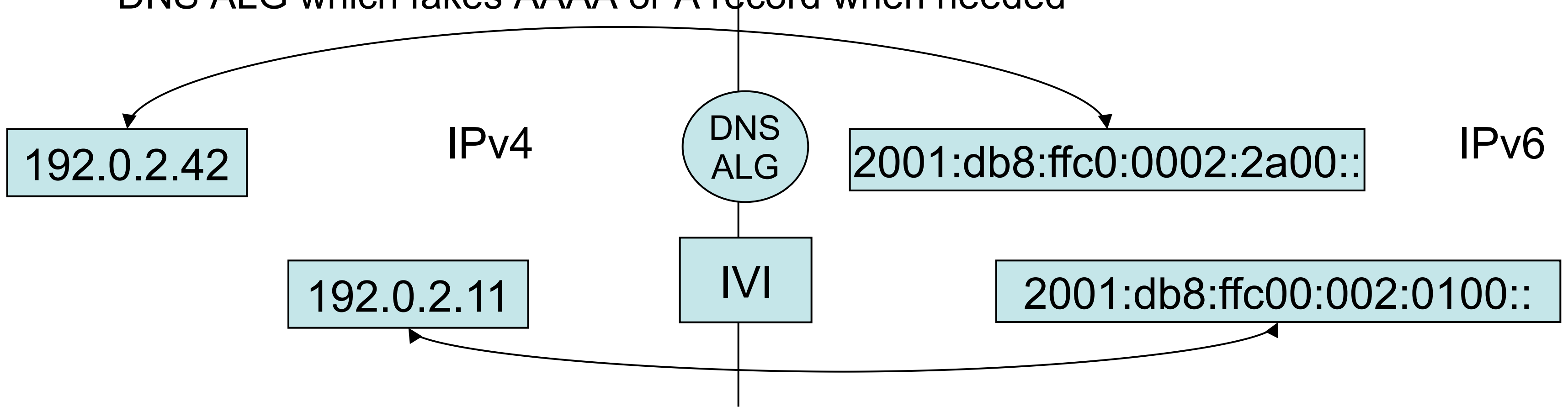
- RFC4830 by Microsofts Christian Huitema
- Proto-41 tunnels and thus 6to4 can’t cross NATs (one can messily do it with some hacks though).
- Meant to give IPv6 connectivity everywhere, as that is what Windows 2008 and up require. Also good for Xbox as it avoids having to solve NAT over and over again.


Version: IPv4
Src/Dst: 192.0.2.111 -> 192.0.2.222
Protocol: 17 (UDP)
Teredo
Version: IPv6
Src/Dst: 2001:db8::111 -> 2001:db8::222
Protocol: 6 (TCP)
TCP

Connecting between IPv4 and IPv6 et vice versa: IVI

- Prefix-specific and Stateless Address Mapping (IVI) for IPv4/IPv6 Coexistence and Transition (draft-xli-behave-ivi)
- Xing Li, Maoke Chen, Congxiao Bao, Hong Zhang and Jianping Wu

- Name trick: Roman Numerals: IV = 4, VI = 6 => IVI = 46
- Allows IPv4 to connect to IPv6 and IPv6 to connect to IPv4
- Semi-refresh/combination of NAT-PT and SIIT
- Per-ISP prefix (eg 2001:db8:ff*aa*:*bbcc*:*dd*::)
- DNS ALG which fakes AAAA or A record when needed



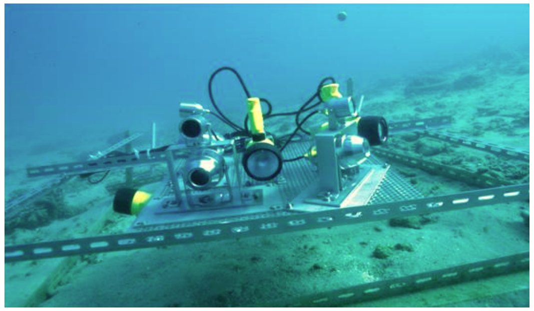
Problems in Transition

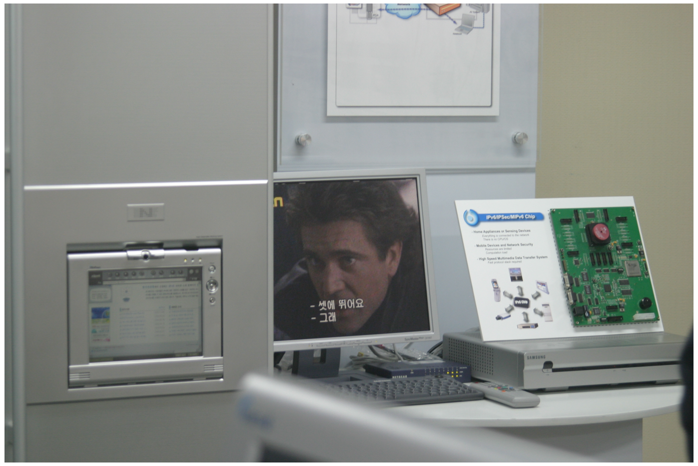
- DNS
  - NAT (DSL/cable modems) routers which handle DNS packets and don't understand AAAA (or DNSSEC).
- Broken connectivity

  => This is the reason there is a Google IPv6 DNS server whitelist.
- Overzealous Firewalls
  - Lots of firewall software does not understand IPv6 and just drop it
- ISP or transit providers which don't support IPv6

IPv6 Toys: Home automation, fridges, sensors, etc

Network Camera
Digital I/O를 활용한 원격 감시
house.6dns.org
[2001:2b8:2:fff3:20a:61ff:fe03:11]



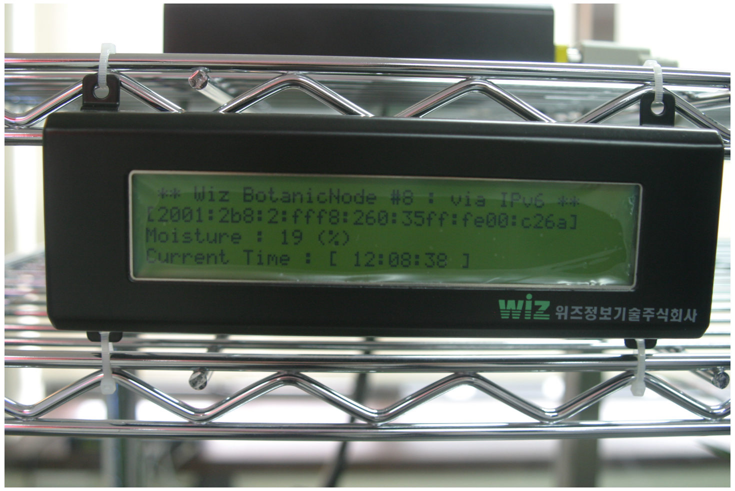


For more:

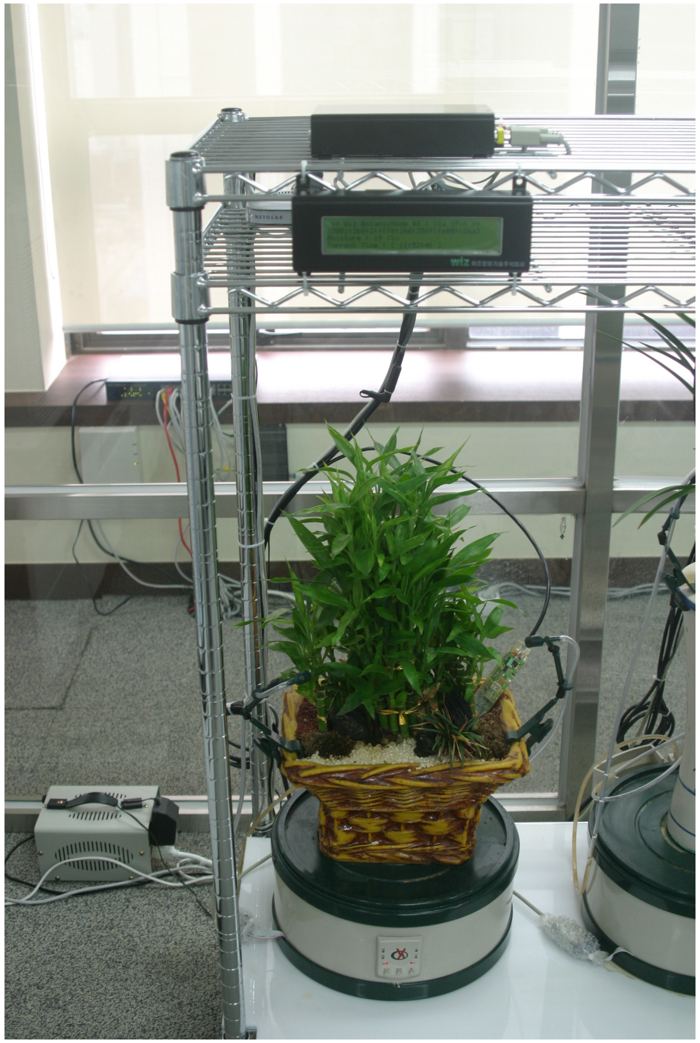
google(IPv6 toys)

google(IPv6 cool)

IPv6 Toys: $ telnet plant



```
 ** Wiz BotanicNode #8 : via IPv6 **
[2001:2b8:2:fff8:260:35ff:fe00:c26a]
Moisture : 19 (%)
Current Time : [ 12:08:38 ]
```



Problems with IPv6 (and thus open research subjects)

- Broken IPv6 implementations, but:
  - http://v6fix.net
  - “Test” function in AICCU (http://www.sixxs.net/tools/aiccu/) to see what breaks and where (coming soon)
- IPv4 will run out before IPv6 is deployed everywhere
  - Carrier Grade NAT (CGN)
  - Tunneling
  - Accessing IPv4 from IPv6 and IPv6 from IPv4
- Routing Table Growth / handling of large amount of prefixes
  - This was already an issue partially in IPv4 but will become a larger problem with IPv6; especially when everybody will wants to do IPv6 PI, which is now available in ARIN and RIPE regions.
  - With IPv6:
    - Every ISP gets at least a /32
    - Every End-site gets a /48 (or /56 for endusers in some regions)
    - A single /32 contains 65536 /48’s; with 10.000 ISPs, that would be 10.000 * 65536 = 655.360.000 routes when de-aggregated: Way more memory in all routers needed, faster CPUs (due to SPF recalculations) etc

“The IPv6 Internet” Today

- Google has a ‘trusted tester program’ (http://www.google.com/ipv6/)
- Wikipedia has a similar signup-first program

  => SixXS is enrolled in both, use our nscaches and voila Google over IPv6

- Various Torrent clients support IPv6 and some (uTorrent) can enable Teredo for you so that it automatically works.

- http://ipv6gate.sixxs.net and http://ipv4gate.sixxs.net for getting to IPv6 content from IPv4 and vice versa.

- 6 Native IPv6 end-user ISPs in Switzerland

  see http://www.sixxs.net/faq/connectivity/?faq=native for all of them
- Your ISP doesn’t do IPv6? Get a tunnel, eg http://www.sixxs.net ☺

Questions?