IPv6 Deployment at clara.net
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Why IPv6?

For us, back in 2002, a number of things were happening…

- Globally, concerns about IPv4 exhaustion propagating (usual FUD)
- Globally, IPv6 deployment was happening around us
- Customers were asking “what are you doing about this?”
- Engineers were asking “what are we doing about this?”
- UK6X (BT Exact IPv6 IX) just formed (2001)
- **insert usual stuff about emerging mobile applications here**
- “One day your fridge will want to talk to your mp3 player” and other silly things
- **More importantly , we already had a customer offering a v6 service…**

IPNG

- **IPNG were a small organisation dedicated to providing IPv6 connectivity to end-users via tunnels.**
- **They had membership of the UK6X and an /48 allocation from UK6X space.**
- **They also had a connection to 6bone and some 6bone space.**
- **End users would be allocated a /64 for connectivity**
- **System was fully automated for end user provisioning and change requests.**
- **At its peak it had 4000 users sustaining 2Mbit/Second of traffic.**

Getting ClaraNET on the Native IPv6 Internet - So where to start?

- Well, firstly one should obtain an IPv6 allocation from one's RIR.
- In 2002, RIPE NCC had the following requirements for obtaining an IPv6 allocation:

To qualify for an initial allocation of IPv6 address space, an organisation must:

a) be an LIR;
b) not be an end site;
c) plan to provide IPv6 connectivity to organisations to which it will
assign /48s, by advertising that connectivity through its single
aggregated address allocation; and
d) have a plan for making at least 200 /48 assignments to other
organisations within two years.

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From: hostmaster@clara.net
Date: 05/08/02
To: hostmaster@ripe.net

Dear hostmaster,

Can we please have some IPv6 Space.

We would like a /35 for our customer IPNG , some /48s for customers and believe that we will be allocating around 100 /48s a year, making our two year target of 200 /48s.

Lots of Love

Claranet.

clara.net

From: hostmaster@ripe.net
Date: 06/08/02
To: hostmaster@clara.net

Dear Claranet,

 You can have 2001:0db8::/32

 Lots of Love

 RIPE NCC.

So where to start?

- Well, of course it wasn't quite as simple as this. Having looked back at the original hostmaster ticket, there were 35 emails exchanged between our hostmaster and RIPE NCC!

- Since then the policy has changed somewhat:

5.1. Initial allocation
5.1.1. Initial allocation criteria

To qualify for an initial allocation of IPv6 address space, an organisation must:

a. be an LIR;
b. advertise the allocation that they will receive as a single prefix if the prefix is to be used on the Internet;
c. have a plan for making sub-allocations to other organisations and/or End Site assignments within two years.

5.1.2. Initial allocation size

Organisations that meet the initial allocation criteria are eligible to receive a minimum allocation of /32.

Organisations may qualify for an initial allocation greater than /32 by submitting documentation that reasonably justifies the request. If so, the allocation size will be based on the number of existing users and the extent of the organisation's infrastructure.

Source: http://www.ripe.net/ripe/docs/ipv6policy.html#initial_allocation

So what next?

Well, the /32 needed to be added to our IP provisioning and management systems.

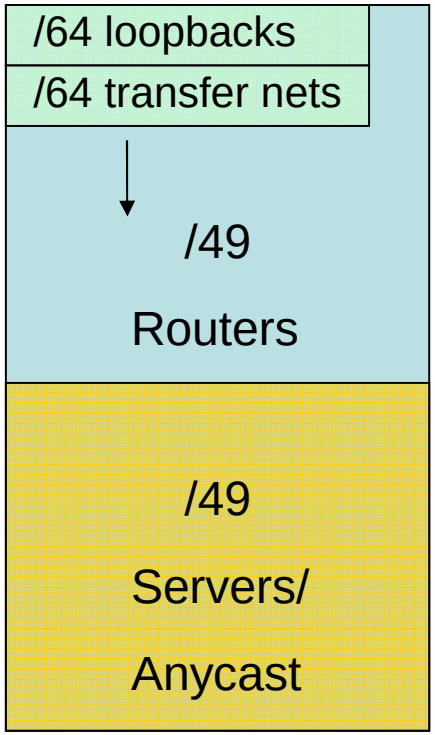
We hadn’t at this point thought of the development work involved in changing the code for this such to support IPv6 addressing and subnetting so it lived in a text file for a while ☺

Carving it up

- A /32 gave us 8 /35s
- We chose the first /35 to be our own
- We allocated the next to IPNG as promised
- From our first /35, we designated the first /48 as infrastructure
- The following /48s would be allocated to customers.

Carving it up

- So, our first infrastructure /48, how did we carve that one up?



- Two /49s, one for routers the other for servers or anycast IPv6 addresses
- Router /49 split into /64s, with the first reserved for loopbacks, the rest for transfer networks

Carving it up

- Why /64 router transfer networks?

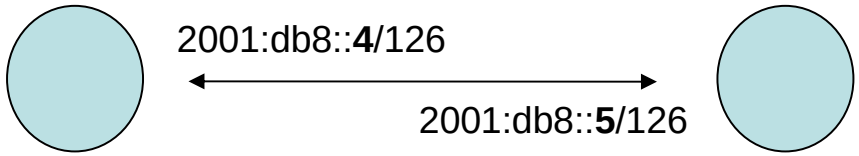
- Well, /64 is minimum for stateless autoconfiguration
- Why would you want autoconfiguration between routers?
- We opted for /126 size subnets for point-to-point transfer networks and /64s for shared LAN segments (ex IPv4 broadcast domains)
- But what should I use?

/126 (2 bit networks)

- With /126 we closely mirror the /30 IPv4 model.
- 4 usable addresses per subnet

```
$ sipcalc 2001:db8::/64 --v6split=126 | head -13
-[ipv6 : 2001:db8::/64] - 0

[Split network]
Network                 - 2001:0db8:0000:0000:0000:0000:0000:0000 -
                          2001:0db8:0000:0000:0000:0000:0000:0003
Network                 - 2001:0db8:0000:0000:0000:0000:0000:0004 -
                          2001:0db8:0000:0000:0000:0000:0000:0007
Network                 - 2001:0db8:0000:0000:0000:0000:0000:0008 -
                          2001:0db8:0000:0000:0000:0000:0000:000b
Network                 - 2001:0db8:0000:0000:0000:0000:0000:000c -
                          2001:0db8:0000:0000:0000:0000:0000:000f
Network                 - 2001:0db8:0000:0000:0000:0000:0000:0010 -
                          2001:0db8:0000:0000:0000:0000:0000:0013
```



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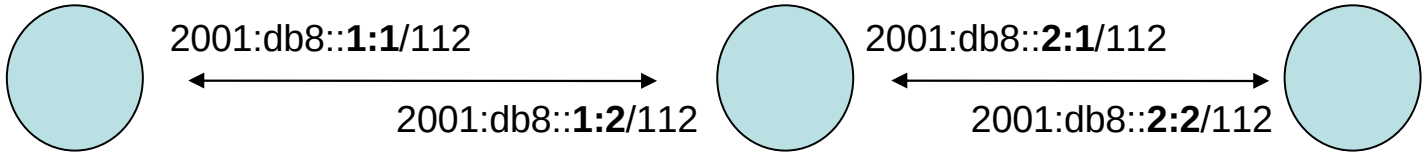
/112 (16 bit networks)

- /112 is another one of these, a /112 occupies from ::0000 to ::FFFF so is perhaps easier to look at

```
$ sipcalc 2001:db8::/64 --v6split=112 | head -13
-[ipv6 : 2001:db8::/64] - 0

[Split network]
Network                 - 2001:0db8:0000:0000:0000:0000:0000:0000 -
                          2001:0db8:0000:0000:0000:0000:0000:ffff
Network                 - 2001:0db8:0000:0000:0000:0000:0001:0000 -
                          2001:0db8:0000:0000:0000:0000:0001:ffff
Network                 - 2001:0db8:0000:0000:0000:0000:0002:0000 -
                          2001:0db8:0000:0000:0000:0000:0002:ffff
Network                 - 2001:0db8:0000:0000:0000:0000:0003:0000 -
                          2001:0db8:0000:0000:0000:0000:0003:ffff
Network                 - 2001:0db8:0000:0000:0000:0000:0004:0000 -
                          2001:0db8:0000:0000:0000:0000:0004:ffff
```



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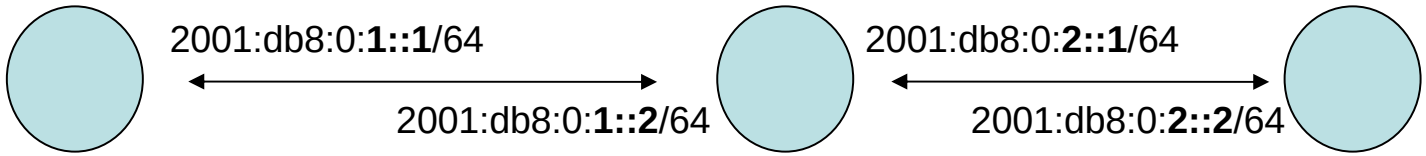
/64 (64 bit networks)

- /64 is the accepted normal, occupying from :: to ::FFFF:FFFF:FFFF:FFFF

If you are unsure as to which scheme to use then my personal recommendation would be to use /64 link addresses as it will simplify your life greatly.

```
$ sipcalc 2001:db8::/48 --v6split=64 | head -13
-[ipv6 : 2001:db8::/48] - 0

[Split network]
Network                 - 2001:0db8:0000:0000:0000:0000:0000:0000 -
                          2001:0db8:0000:0000:ffff:ffff:ffff:ffff
Network                 - 2001:0db8:0000:0001:0000:0000:0000:0000 -
                          2001:0db8:0000:0001:ffff:ffff:ffff:ffff
Network                 - 2001:0db8:0000:0002:0000:0000:0000:0000 -
                          2001:0db8:0000:0002:ffff:ffff:ffff:ffff
Network                 - 2001:0db8:0000:0003:0000:0000:0000:0000 -
                          2001:0db8:0000:0003:ffff:ffff:ffff:ffff
Network                 - 2001:0db8:0000:0004:0000:0000:0000:0000 -
                          2001:0db8:0000:0004:ffff:ffff:ffff:ffff
```



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Assignments to customers

- We opted to assign using the following guidelines:
  - Access (Dial/DSL) assigned /64 by default
  - Everybody else assigned /48 by default
  - **All /48 and bigger assignments require end-user documentation and are recorded in IRR**.
- No IPv6 PI available (yet) in the RIPE NCC region due to internal RIPE NCC politics
  - Providers in this region should assign out of their PA space, encourage customers to become an LIR or ask customers to seek resources elsewhere (if they are entitled) and have the need for PI.

Rolling it out – The routers

- From 2002, the point of conception, to present, we are an almost entirely Cisco powered network

- Four basic models of routers present:
  - 12000 series (GSR)
  - 7500 series (yes, these still exist!)
  - 7200 series
  - 6500 (and 7600 series now)

- IPv6 AND stable IOS required for all!
- No easy task back in 2002 ☹

Rolling it out – The routers

- **No good telling you what worked then, code was buggy and unstable. Best talk about what works now:**

➢ 12000 series

GSRs limited to 12.0(S) and now newer 12.0(SY) and 12.0(33)S

All are the only 12.0 code trains to have IPv6 support, chances are you are running a supported release, but check for bugs first if its not recent.

IPv6 support on Engine 0 and Engine 1 linecards exists but performance is terrible. Don't do it.

➢ 7500 series

No 12.0(S) IOS IPv6 support. **12.3 Mainline worked for us** but is not very functional especially when it comes to modern features.

Would not suggest deploying IPv6 code to 75xx series unless you really have to

It will consume RAM and flash that you probably don't have and won't want to buy.

➢ 7200 series

Late 12.2SB or **12.2SRC** are the current recommendations. Again YMMV

Don't even *think* about trying this on anything less than NPE-400,

there is no official support for it.

➢ 6500/7600 series

12.2 SX (6500) and 12.2SR (7600) are the current favourites, would recommend minimum SupervisorII if you have old 6500 chassis

As with all of these **READ THE RELEASE NOTES FIRST**,

I can't stress how important this is!!!

Rolling it out – The routers

We assumed, from day one, that all IPv6 routers would run IPv6 CEF, there would be no reason not to other than bugs and in such case we would attempt to find a stable release:

```
!
ipv6 unicast-routing
ipv6 cef (distributed)
!
```

Finding a stable release actually proved quite hard, we were using 12.2S at the time which had newly introduced CEF code which was quite buggy and the CEF consistency checker became a vital feature for us at the time, in this day and age code is more stable.

Next to configure a loopback address for routing protocol purposes. We decided that we would overload the IPv6 loopback address over the top of the existing IPv4 loopback interface, such

```
!
interface loopback 0
 ipv6 address 2001:db8::1/128
 ipv6 enable
!
```

Rolling it out – The routers

Now, the problem here is, that for TCP/UDP listeners that the router maintains for management , likely we now have an IPv6 listener socket that exists.

The most important priority should be to secure the router, therefore securing the VTY lines is a good start:

Designate authorised source addresses for management (such as your NOC)

and apply such to protect the VTYs

```
!
ipv6 access-list vty6
 permit ipv6 2001:db8:1234:FFFE::/64 any
!
line vty 0 4
 ipv6 access-class vty6 in
!
```

There are many others, beyond the scope of this presentation, the Cisco document "**Managing IOS applications over IPv6**" lists these and is available at the following URL:

http://www.cisco.com/en/US/docs/ios/12_2t/ipv6/SA_mgev6.html

Rolling it out – The interfaces

So, next we standardised on what an IPv6 interface configuration would look like, which options would be configured or deconfigured and how this would look like from a LAN or Point-to-Point perspective.

We settled on the following configuration:

```
!
interface GigabitEthernet 1/1/2
 ipv6 address 2001:db8:1234::1/126 ← set address
 ipv6 enable  ← enable the IPv6 protocol on the interface
 ipv6 nd suppress-ra ← turn off router advertisements
 no ipv6 redirects ← disallow redirects
!
```

Rolling it out – The routing

- We opted not to use (protocol 41) tunnels between our own routers, even as a migration technique, they would never be removed and the routing would be suboptimal and constrained.
- If you do use tunnels, Cisco routers tend to set the tunnel MTU up to be the egress interface which can be fun where tunnel leaves over 4470 byte POS interface, it of course inherits a 4470 byte MTU which could break things when tunnel travels over a 1500 byte Ethernet interface.
- Remember to watch your tunnel MTU if you do this

Rolling it out – The routing

- Our network has MPLS deployed throughout. It was tempting to use 6PE at one point, negating the need to have IPv6 running on the core (P) routers (since it uses LSPs to communicate) but we considered 6PE to be a bad choice since it would only need ripping out at some stage since the core would remain IPv4.

- We opted to do label switched IPv4 alongside routed IPv6, since there are no native IPv6 label signaling protocols it is not possible to build IPv6 LSPs across pure IPv6 paths, Integrated IPv6 TE is therefore also impossible.

- If MPLS based IPv6 TE is an objective of yours then you should use 6PE which maps IPv6 prefixes to IPv4 FECs.

Rolling it out – The routing

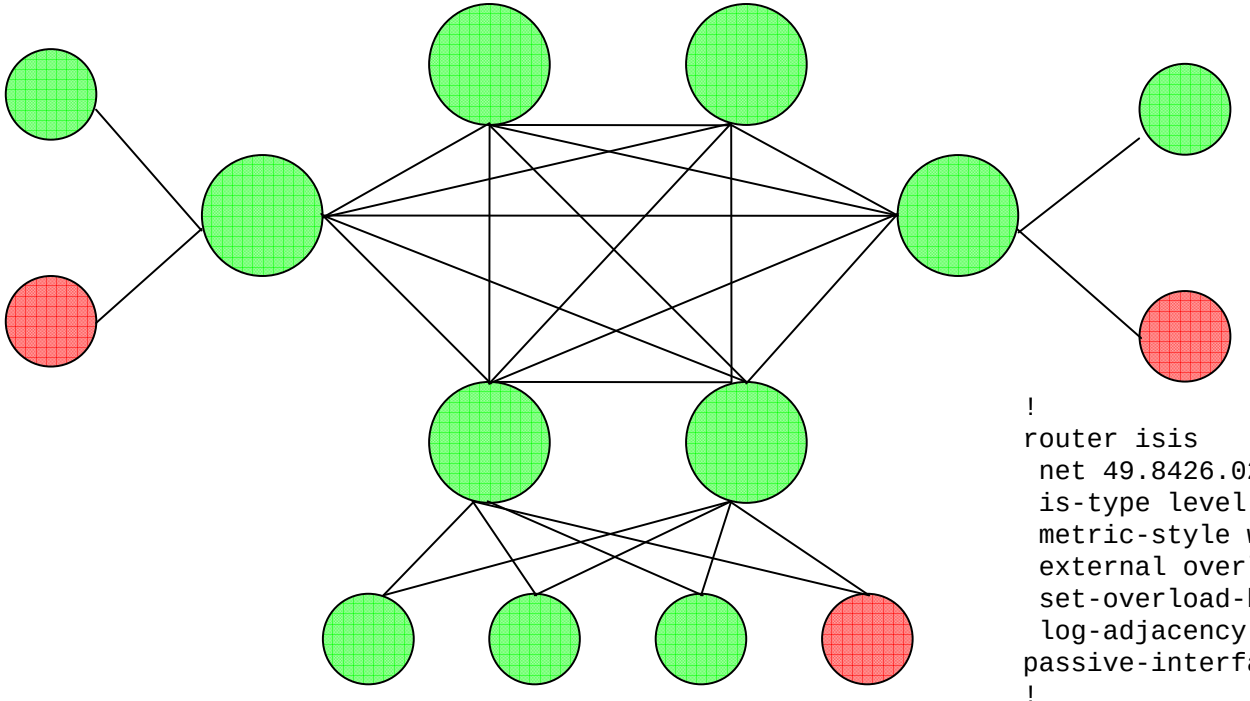
- Our network uses IS-IS as an IGP and iBGP to carry both customer and internet routing.
- We made the decision to deploy multitoplogy IS-IS since integrated IS-IS is TLV based, routers not participating in the migration will ignore the TLVs for the IPv6 topology and it will not affect them
- IPv6 BGP adjacencies are built over the top of IPv4 BGP adjacencies, with the same topology and routing policy
- Multitopology IS-IS is **NOT SUPPORTED** in Cisco 7200 12.2SRC without the Advanced IP Services license (ADVIPSERVICES), if you are migrating to SRC do not get bitten by this, quite why this isn't in SP-SERVICES is beyond me!

Rolling it out – The routing

V6 Participating node

Non-V6 Participating node

Start with standard single topolgy IS-IS



```
!
router isis
 net 49.8426.0200.0801.6800.0015.00
 is-type level-2-only
 metric-style wide
 external overload signalling
 set-overload-bit on-startup wait-for-bgp
 log-adjacency-changes all
passive-interface Loopback0
!
interface gigabitethernet 0/0/0
 ip router isis
 isis metric 100 level-2
!
```

```
#show clns neighbors
System Id      Interface          SNPA               State  HT   Type Protocol
foo            Gi0/0/0            0019.2f8c.dacc     Up     9    L2   IS-IS
bar            Gi1/1/3            0004.8084.d602     Up     29   L2   IS-IS
```

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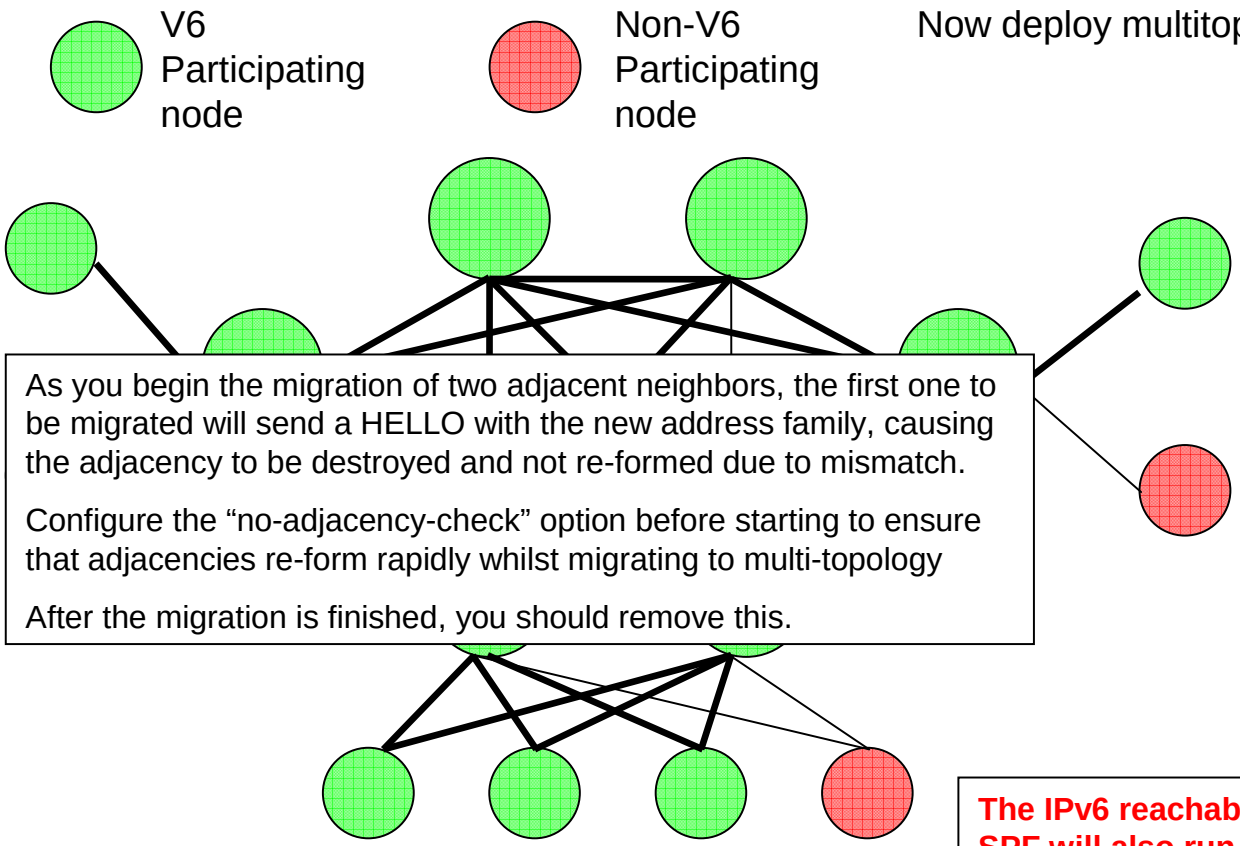
Rolling it out – The routing



As you begin the migration of two adjacent neighbors, the first one to be migrated will send a HELLO with the new address family, causing the adjacency to be destroyed and not re-formed due to mismatch.

Configure the “no-adjacency-check” option before starting to ensure that adjacencies re-form rapidly whilst migrating to multi-topology

After the migration is finished, you should remove this.

Now deploy multitopology on participating boxes

```
!
router isis
 net 49.8426.0200.0801.6800.0015.00
 is-type level-2-only
 metric-style wide
 external overload signalling
 set-overload-bit on-startup
   wait-for-bgp
 log-adjacency-changes all
passive-interface Loopback0
!
 address-family ipv6
  multi-topology
  no adjacency-check
 exit-address-family
!
interface gigabitethernet 0/0/0
 ip router isis
 ipv6 router isis
 isis metric 100 level-2
 isis ipv6 metric 100 level-2
```

The IPv6 reachability TLV will carry its OWN metric, SPF will also run separately to build an IPv6 topology, so remember to configure an IPv6 metric on the interface if an IPv4 one exists and you wish to keep the active topology the same.

```
#show clns neighbors
System Id      Interface          SNPA               State  HT   Type Protocol
foo            Gi0/0/0            0019.2f8c.dacc     Up     9    L2   M-ISIS
bar            Gi1/1/3            0004.8084.d602     Up     29   L2   IS-IS
```

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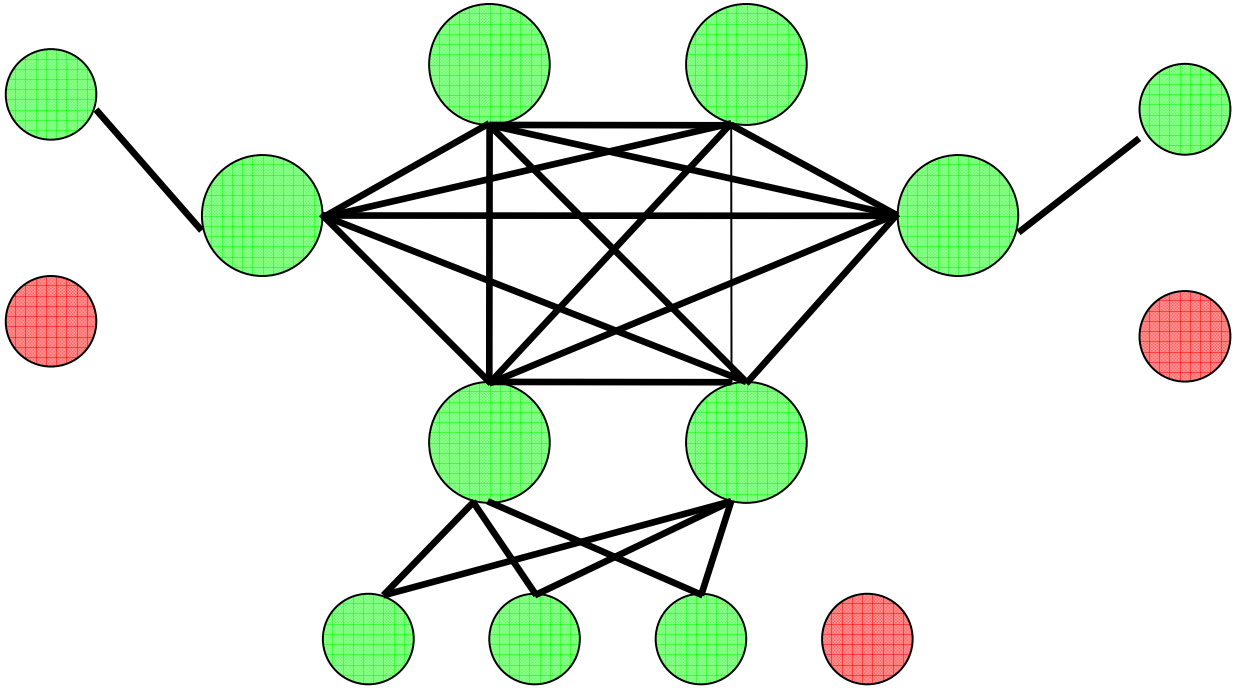
Rolling it out – The routing

V6 Participating node

Non-V6 Participating node

Now deploy additional MP-BGP sessions

Using the same policy



```
!
router bgp 8426
 neighbor 1.2.3.4 description FOO
 neighbor 1.2.3.4 peer-group POP
 neighbor 2001:db8::1 description FOO
 neighbor 2001:db8::1 peer-group POP6
 neighbor POP peer-group
 neighbor POP remote-as 8426
 neighbor POP6 peer-group
 neighbor POP6 remote-as 8426
!
address-family ipv4 unicast
 neighbor POP activate
 neighbor POP remote-as 8426
 neighbor POP send-community
 neighbor POP next-hop-self
 neighbor 1.2.3.4 peer-group POP
 network 1.0.0.0 mask 255.255.255.0
address-family ipv6 unicast
 neighbor POP6 activate
 neighbor POP6 send-community
 neighbor POP6 next-hop-self
 neighbor 2001:db8::1 peer-group POP6
 network 2001:db8::/32
!
```

```
#sh bgp ipv6 summary
BGP router identifier 5.6.7.8, local AS number 8426
2001:db8::1     4  8426 1021453  853089   806576    0    0 1d           1
2001:db8::2     4  8426  437681 1186200   806576    0    0 6d           1
```

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Connecting it to the internet

- We opted for the quickest way to get reachable

Back then, our upstream provider was IPv6 enabled and would give us a dual stack session, we opted for this.

Connecting it to the internet

- Next we attached to the UK6X, an IPv6 only internet exchange set up by British Telecom in 2001 such to facilitate IPv6 internetworking in the UK, we obtained our own dedicated connection alongside IPNG
- UK6X operated a route server model and provided us with a full table
- Full table swaps in this day and age are generally bad news as they create problems later on with regards to routing policy and traffic exchange, we opted on this to get us up and running and moved to a partial (i.e peering model) later on
- We also waited until other exchanges (such as LINX) allowed for IPv6 traffic and began IPv6 peering over these IXPs when the functionality became available
- UK6X no longer exists and has been replaced by a BT commercial product

Connecting it to the internet

- In order to peer or receive transit, we ensured our routing policy was published in the appropriate IRR database, in our case, the RIPEDB, this meant creating a **ROUTE6** object for our /32

route6: 2001:db8::/32
descr: CLARA-IPV6-AGG1
origin: AS8426
mnt-by: AS8426-MNT
source: RIPE

Connecting it to the internet

- The next step was to describe our relationships with IPv6 peers.
- Here we hit a snag.
- The current RPSL language that our

AUT-NUM object was written in did not have the syntax to describe IPv6 adjacencies

RPSL-NG

- We would have to migrate our AUT-NUM object to **RPSL-NG**, the new language designed to represent objects in the database and be forwardly compatible with emerging addressing schemes.
- Unfortunately, this would be a lot of work, not just training but operational support systems which both parse and make changes to the AUT-NUM object would also have to be re-written

RPSL-NG

http://www.ripe.net/ripe/meetings/ripe-43/presentations/ripe43-routing-rpslng/

- We opted for a staged migration to an RPSL-NG AUT-NUM object, by embedding the RPSL-NG information in our **remarks** fields, so we could begin to develop new, alongside existing code

```
aut-num:        AS8426
as-name:        CLARANET-AS
descr:          ClaraNET
descr:          UK AS of European ISP
import:         from AS42 action pref=300; community.append(8426:700,8426:799); accept AS42 AND
    {0.0.0.0/0^1-24}
export:         to AS42 announce AS-CLARANET
…
remarks:        Current IPv6 policy, ready for the RPSL-NG object
remarks:        --
remarks:        mp-import:    afi ipv6.unicast
remarks:        {
remarks:        from 2001:db8:0:2::26 at 2001:db8:0:2::25 action pref=1;
    community.append(8426:2000,8426:2030,8426:2998); accept AS29452;
remarks:        from 2001:7F8:4::312:1 at 2001:7F8:4::20EA:1 action pref=300;
    community.append(8426:700,8426:799); accept AS-JANETPLUS;
…
remarks:        }
remarks:
remarks:
remarks:        mp-export:    afi ipv6.unicast
remarks:
remarks:        {
remarks:
remarks:        to 2001:7f8:4::999e:1 at 2001:7F8:4::20EA:1 announce AS-CLARANET;
remarks:        to 2001:7f8:4:1::999e:2 at 2001:7F8:4:1::20EA:1 announce AS-CLARANET;
…
remarks:        }
```

Import for IPv6 peers

Export for IPv6 peers

Remote peer

Us

AS-SET (remains the same)

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RPSL-NG

http://www.ripe.net/ripe/meetings/ripe-43/presentations/ripe43-routing-rpslng/

- Adding new IPv6 peers would mean using specific tools which updated the remarks fields.
- Sadly, RPSL-NG has not been widely adopted. The IRRToolset since v4.8.2 has had support for RPSL-NG , but of course, you need to get it to compile first ☺
- Due to the lack of widespread adoption, we resisted migrating our AUT-NUM object to RPSL-NG until recently.
- **As of this year (2008), our AUT-NUM object is now in RPSL-NG format, see AS8426 in RIPEDB**.

BGP Challenges - IPv6 BOGONS

- Well, as one would have expected, an IPv6 internet does indeed contain bogon networks, i.e networks not to be accepted from peers.
- The list of these is quite extensive at present, I would like to direct your attention to the document titled

  “Packet Filter and Route Filter Recommendation for IPv6 at xSP routers “

  Available here:

  http://www.cymru.com/Bogons/ipv6.txt

- If you just want to get yourself up and running quickly, Gert Döring maintains an up to date list of what should currently be filtered, based on both a relaxed and strict model.

  Available here:

  http://www.space.net/~gert/RIPE/ipv6-filters.html

BGP Challenges – Ghost routes

- Old releases of router software out there in the field have a bug whereby when reachability to destinations becomes lost, a BGP withdrawal is not sent
- This bug is apparent when dealing with V6 prefixes
- IPv6 global table is riddled with these so called “Ghost” routes which end up blackholing traffic to non-existent destinations.
- SixXS have a “Ghost Route Hunter” (GRH) project currently ongoing to monitor these, I would recommend use of the SixXS site as its list of tools for providing information about the V6 Global table are both extensive and useful

  http://www.sixxs.net/tools/grh/

Bad Traffic – Packets we do not accept and neither should you

- Routing Headers
  - RFC5095 (Dec 2007) deprecates use of Routing-Header type 0 (RH0), considered “evil”.
  - Not all platforms support RH filtering, **some only allow complete and not selective RH filtering**.
  - We filter **all** RH for the time being
- 6BONE sourced (3FFE::/16)
- Documentation prefix sourced (2001:DB8::/32)
- Loopback, unspecified, v4-mapped (::/8)
- Site local (FEC0::/10 Deprecated RFC3979)

Potentially Bad Traffic – Packets you can choose to accept

- Transition mechanism anycast relays - 6to4 (2002::/16) and Teredo (2001::/32)
  - In line with your local security policy, this address space represents relayed traffic during the transition phase, (more on these later), blocking it will cause pain and make you unreachable to people using these services **we do not block this and I would advise you not to**
- ULA (FC00::/7)
  - The IPV6 equivalent of RFC1918 operating in the global scope, **we block this traffic.**
  - Some operators may source ICMP messages from ULA space as some operators currently do from RFC1918 space, I personally have no issue blocking this but you may.

Some notes on Bad Traffic

- You could of course opt to only permit allocated space (i.e no special-use space)
- Don’t try and block link-local traffic unless you want to break neighbor discovery ☺
- Saying that however, if you receive tunneled traffic (via 6to4 for instance), be aware of the impact of receiving tunneled link-local.

Netflow / IPFIX

- Back in 2002, no way of accounting for IPv6 traffic, if you wanted to know, you tapped the circuit or applied appropriate debug commands!
- We now have NetflowV9 which is the basis of an emerging IETF standard (IPFIX) to solve this.
- Some open source Netflow projects have NetflowV9 support. Many commercial offerings do as well.
- Switching your exporter to v9 will of course require a v9 collector, ensure your collector supports this.

Non-native users

- Your customers may already have IPv6 via a number of transition mechanisms not provided by yourself.
- These will likely perform less optimally when reaching IPv6 destinations than any sensible native service you can offer.
- Most are dynamic and utilise “Relay” stations, be aware of where these are in relation to your network as their location will influence the customer's IPv6 'experience'.
- Encourage users to move to your own native service as soon as you can

Non-native users via static Protocol 41

- Static protocol 41 tunnels do not easily cross NAT devices
- Require detailed configuration and agreements between users.
- Not a popular method of connecting end users

Non-native users via Teredo

- Provides NAT penetrating access to users by tunnelling over UDP/IPv4
- Teredo client comes as standard with WinXP, Vista, 2K3 etc and is available for *nix (http://www.remlab.net/miredo/), client will negotiate use of a relay when it starts.
- Windows Machines **prefer IPv4 over Teredo**
- Teredo relays anycast **2001::/32**
- Be aware of how far away your nearest relays are (http://www.sixxs.net/tools/grh/lg/?find=2001::/32)
- Running a public relay yourself is indeed possible, requires not much knowledge to set up but a true dedication to run properly.
- If you are interested in running a public relay, contact one of the folks listed in **TEREDO-MNT** in the RIPEDB

Non-native users via AYIYA

- Like Teredo, provides NAT penetration by tunnelling over UDP/IPv4
- Requires client software (e.g AICCU)
- AYIYA Relays provided by SixXS
- AYIYA Relays operated out of number of involved ISPs
- AYIYA Relays provide IPv6 space from the operators network, getting a list of AYIYA POPs will help you find your nearest relay (http://www.sixxs.net/pops/)

Non-native users via 6to4

- Based on protocol 41, but more dynamic
- Windows Vista comes with 6to4 support
- 6to4 anycasts **2002::/16** for the v6 part of the connectivity and **192.88.99.0/24** for the v4
- Check how far away these prefixes are from you
- Like Teredo, needs dedication to run yourself.
- Contact one of the nice folks in **RFC3068-MNT** if you are interested in running a public 6to4 relay.

IPv6 in the Datacenter

- We deployed /64 server LANs
- No stateless autoconfiguration (disabling router advertisement)
- Don’t forget your security policy!! IPv6 ACLs to be in place **before your boxes go in to a reachable subnet!**
- Neighbor discovery is multicast, keep an eye on your switching infrastructure, especially if you have any special pruning / rate limiting in place.

Managing the “first hop”

- Currently, IOS has an implementation of HSRP6 in 12.4
  - It only supports link-local addressing
    - This means you must advertise the floating address via RA or point static at link-local floating address ☹
- At time of writing, no Cisco implementation of VRRP6, one is planned.
- General Cisco recommendation for First-Hop redundancy is “Use ND + RA + NUD”
- JunOS has had VRRP6 for some time.

Firewalling

- Our internal infrastructure was firewalled using IOS Access-Lists (ACLs).
- Back in 2002 no IPv6 firewall appliance support, preferred solution for many was to use ACLs or open source projects on LAN “gateway” servers. We used ACLs.
- Now most appliance vendors have a commercial IPv6 offering.
- Cisco IOS Firewall now supports V6

uRPF6 at the edge

- uRPF6 generally supported except:
  - At time of writing, the Cisco Policy Feature Card 3 (PFC3) can not perform uRPF for IPv6 in hardware, this restriction applies to the both Supervisor 720 and RSP720 cards in Catalyst 6500 and 7600 router chassis.
  - Using these architectures to perform loose uRPF at the peering edge is therefore not recommended. **We opted not to do so at all.**

Vendor IPv6 Feature Roadmaps

- Cisco: http://www.cisco.com/en/US/docs/ios/ipv6/configuration/guide/ip6-roadmap.html
- Foundry: http://www.foundrynet.com/technology/ipv6/
- Juniper: http://www.juniper.net/techpubs/software/junos/junos91/swref-hierarchy/supported-ipv6-standards.html

DNS

- Next on the list to tackle was the DNS.

For reverse queries, We opted on using IP6.ARPA as IP6.INT was being deprecated in 2006.

For forward queries, AAAA records were used.

Router<->Router Link naming would use the “`ipv6.router.<cc>.clara.net`” domain for the time being, to highlight the new stack was in use.

DNS

If you are a user of bind, tools are available to help you build IPv6 reverse zones:

http://www.fpsn.net/index.cgi?pg=tools&tool=ipv6-inaddr

```
$ cat 2001:db8:0::.rev
$TTL                            18000
@       IN      SOA     ns0.clara.net.          hostmaster.clara.net. (
                                2007060806      ; Serial number
                                28800           ; Refresh every 2 days
                                3600            ; Retry every hour
                                604800          ; Expire every 10 days
                                300 )           ; 5 Minutes

        IN      NS      ns0.clara.net.
        IN      NS      ns1.clara.net.
        IN      NS      ns2.clara.net.

;INSTRUCTION TO MANUAL OPERATORS:
;This whole zone is 2001:db8:0::/48 (the first /48 from our /32)
;Reload using "rndc reload 0.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa"

;2001:db8:0:0::/64 Loopbacks (assign /128s for loopbacks)
$ORIGIN 0.0.0.0.0.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa.
0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0         IN      PTR     routera.ipv6.router.uk.clara.net.
1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0         IN      PTR     routerb.ipv6.router.uk.clara.net.
2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0         IN      PTR     routerc.ipv6.router.uk.clara.net.
…
;2001:db8:0:1::/64 Transfer Networks (assign /126s for transfer networks)
$ORIGIN 1.0.0.0.0.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa.

;2001:db8:0:1::0/126 - Link between routera and routerb
1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0         IN      PTR     g0-0-routera.ipv6.router.uk.clara.net.
2.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0         IN      PTR     g0-0-routerb.ipv6.router.uk.clara.net.
```

Leave instruction to operators

64 Bit origin

64 Bit record

clara.net

DNS

The forward is even simpler….

```
$ cat ipv6.router.uk.clara.net.zone
$TTL                            18000
@       IN      SOA     ns0.clara.net.          hostmaster.clara.net. (
                                2004120604      ; Serial number
                                17280           ; Refresh every 2 days
                                3600            ; Retry every hour
                                1728000         ; Expire every 20 days
                                172800 )        ; Minimum 2 days
                IN      NS      ns0.clara.net.
                IN      NS      ns1.clara.net.
                IN      NS      ns2.clara.net.


routera                   IN      AAAA    2001:db8::1
routerb                   IN      AAAA    2001:db8::2
```

Don’t forget.

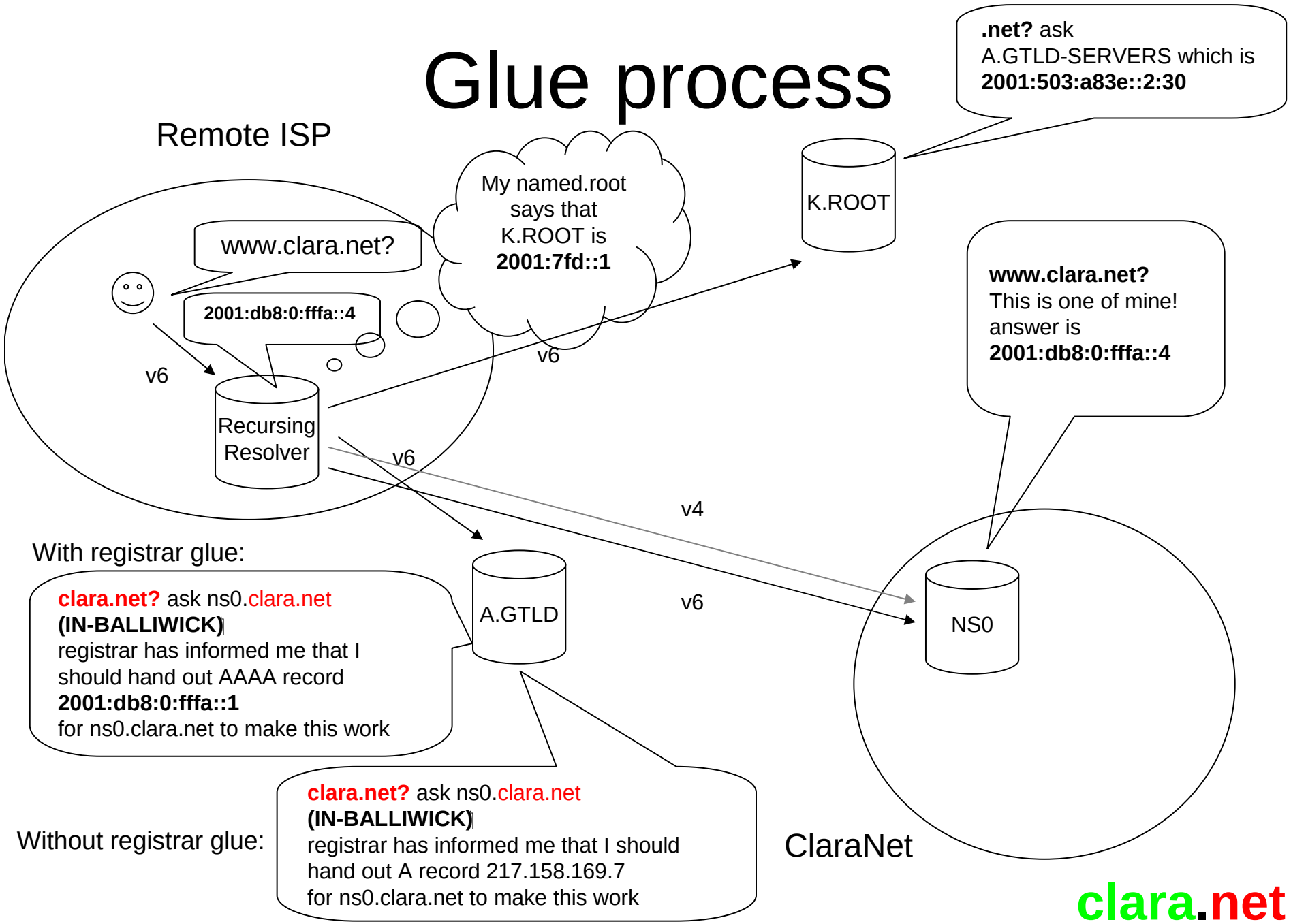
If you want to be authoritative for zones via IPv6 , your DNS servers must have IPv6 reachability – Your named process must have an reachable IPv6 listener

This is common sense!!!

DNS Glue

- As of 04th February 2008, IANA added IPv6 “Glue” to the DNS root zone.
- From this date onward, full end-to-end IPv6 connectivity exists due to DNS lookups no longer needing IPv4 to find your nameservers
- If you operate an authoritative IPv6 DNS platform your nameservers should have IPv6 addresses which are handed out by another system.
- For “In-Bailiwick” you should have “Glue” from your upstream.
- A number of registrars will do this, if you know what to ask for using their own terminology. Others will not (but plan to) and some simply refuse to.

Glue process



clara.net

Other Service Infrastructure

- Speak to your systems administrators. Many modern operating systems have fully featured IPv6 stacks and service applications (such as webservers, mailservers etc..) are now usually built with decent IPv6 operational support.
- The only risks you run if you plan to use older machines running older software that you believe are operationally functional are instability and possible lack of security and/or auditing features you may need.
- Don’t forget, security is everybody's responsibility at the end of the day. When rolling out IPv6 services make sure your network security is adequate, don’t leave it to be a sysadmin problem, provide network security before they move in!

Offering the service to customers :- producing an IPv6 service offering

- **Protocol 41 Tunnels to end users**
  – do this from a dedicated machine (router or *nix box) – NOT FROM YOUR CORE NETWORK!
  - Remember , with tunnels, register the assignments in RIPE
  - Don't forget MTU issues
  - Ensure tunnel is carried along **appropriate routing**, have tunnel path follow infrastructure path.

- **IPv6 access services**
  - It is unlikely that you will have dialup equipment in your network running stable and functional IPv6 code (although possible), look to L2TP to tunnel people to an LNS device
  - Provide IPv6 DSL services to end users if you can, this however will mean changes to your RADIUS and potentially billing and provisioning systems.

- **IPv6 dedicated access services**
  - Provide access to customer's IPv6 assignments over dedicated access lines
  - Provide IPv6 transit or partials

- **IPv6 education**
  - With the advent of **RFC5211** (the transition plan) customers will be asking you questions, be sure you can answer them!

Afterthoughts

- Deploy IPv6 to your office and NOC LANs. (with appropriate security of course), give your staff a taste of working with it, some of them will end up supporting it!

- Many versions of Windows have IPv6 support, but its most mature under Vista / W2K3 server, in fact under Vista its configured and operational by default.

- Don't charge customers for IPv6, make it an additional part of your standard service offering. I wouldn't buy from an upstream that charged extra for this. At the end of the day bandwidth is bandwidth. **Think carefully** before making any service level offerings (if at all) on dedicated IPv6 based services.

- People will ask "Is IPv6 the right way forward?" and scream about the potential FIB size.

  IPv6 is here to stay and quite extensively deployed now, it should now be our job to make it both usable and supportable. See RFC5211

Questions?