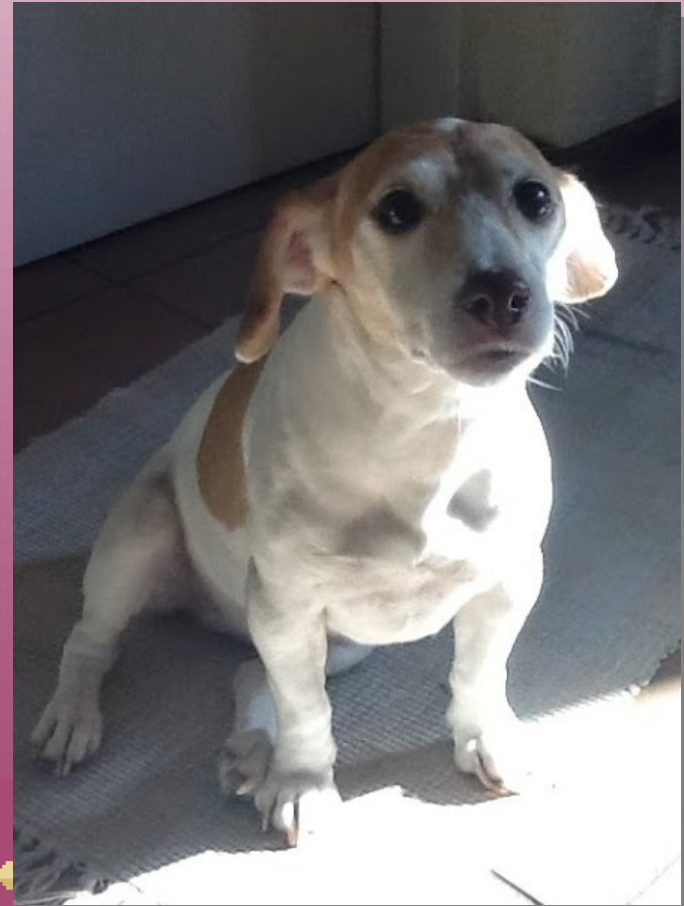


IPv6 & Linux



About Me

- Work at **Jumping Bean**
 - Developer & Trainer
 - Contact Info:
 - Twitter @mxc4
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 - mark@jumpingbean.co.za



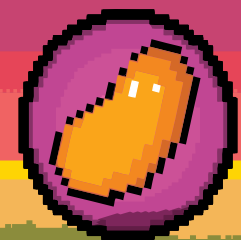
Goals & Motivation

Why?

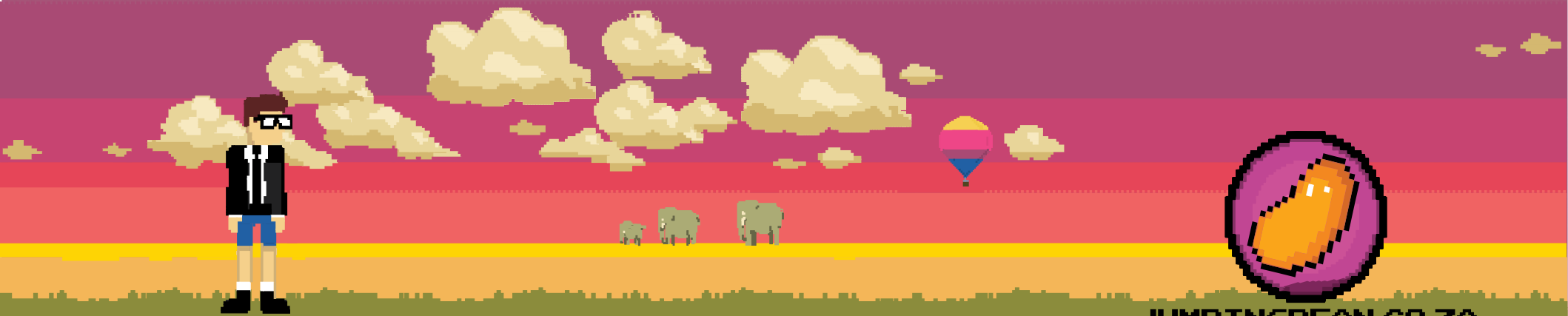
- Why IPv6?
- Why this talk?
 - Information on the internet fragmented and confusing,
 - No single how-to to get hands dirty

What?

- Understanding of IPv6 concepts, protocol vis-a-vis IPv4,
- How to set up a Linux LAN to use IPv6,
 - Part 1 – Setting up your LAN for IPv6
 - Part 2 – Connecting to the Internet with IPv6



Why IPv6?



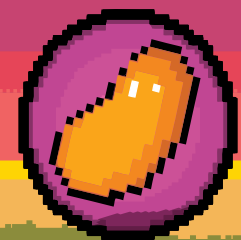
Why IPv6?

- Replacement for IPv4,
- 128 bit IP address
 - IPv4 allowed for 4.3 billion possible addresses,
 - IPv6 allows for 340 undecillion addresses $3.40E38$,
 - $7.9E28$ more than IPv4 addresses,
 - $\sim 4.8 \times 10^{28}$ addresses for every human on earth (7 billion people).
 - $1E32$ – number of stars in the universe (estimated)
 - $1E82$ – number of atoms in the universe (estimated)



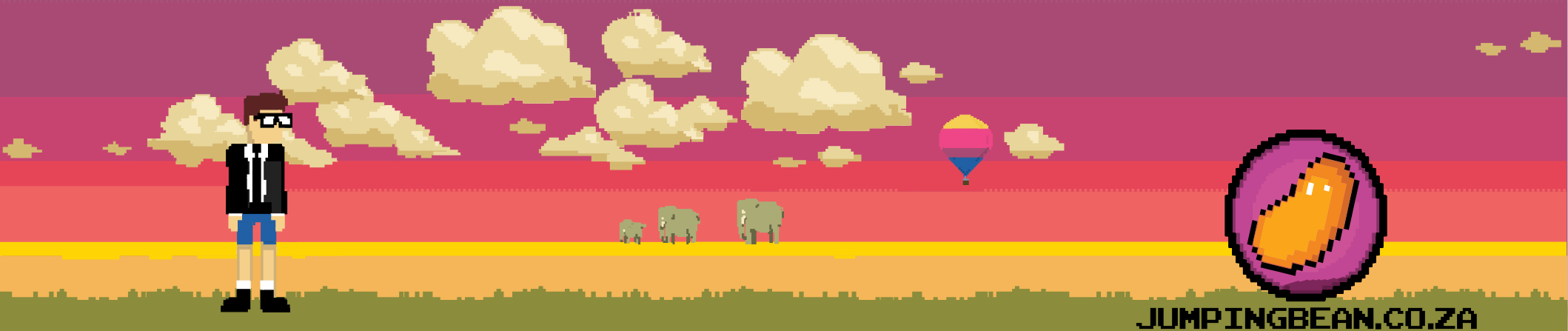
IPv6 Benefits

- No need for NAT,
 - Unique, publicly routable, address per device,
- Devices can have more than one address,
- Eliminates network address collision when merging networks,
- “Simplified” auto-configuration,
- Better handling for mobile devices,
- Better multicast support,
- IPSec was mandatory, now optional,
- Simplified router processing
 - No support for router fragmentation,
 - Packet header processing more efficient
- No broadcast traffic



IPv6 History

- RFC 791 (IPv4) published 1981
- RFC 2460 (IPv6) published 1998
- A long time ago ...
- Not backwardly compatible with IPv4



IPv6 Addresses



IPv6 Address Notation

- 128 bit address written in hexadecimal,
 - Written as 8 groups of 16 bits separated by a colon:
 - 2001:0db8:85a3:0000:0000:8a2e:0370:7334
- Abbreviation rules:
 - Drop leading zeros in 16 bit group,
 - If 16 bits all zero replace with empty string “::”
 - If there are sequential groups of 0 replaced by empty string then collapse into a single double colon ::
 - 2001:db8:85a3::8a2e:370:7334

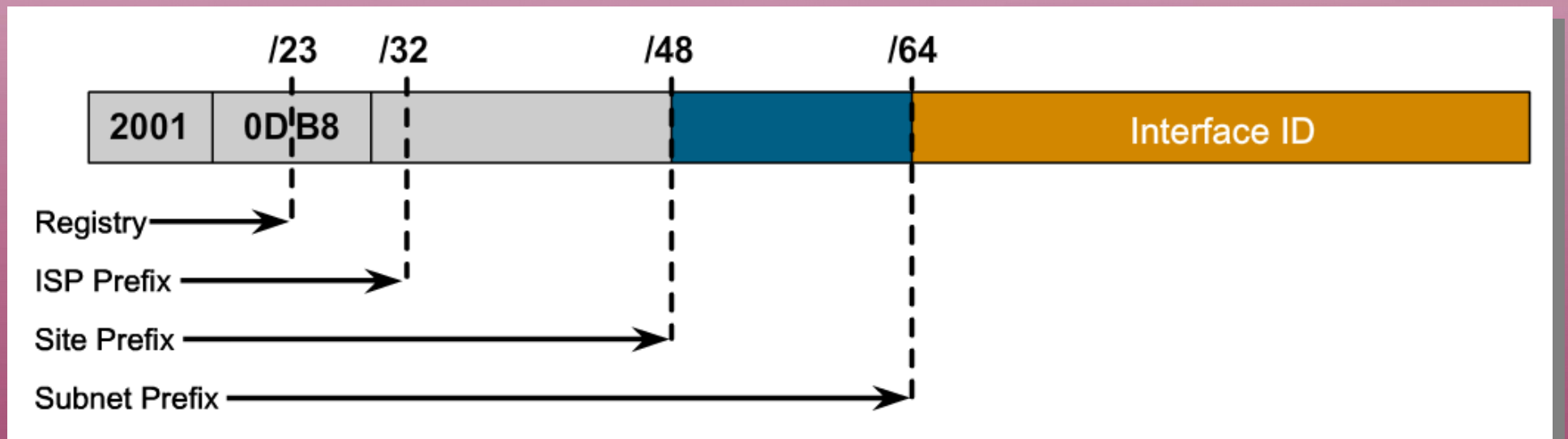


IPv6 Routing Prefix & Interface ID

- “Network mask” is fixed at 64 most significant bits
 - no CIDR,
- Interface identifier (host portion) is fixed at 64 least significant bits
- Common to see IPv6 address with prefix mask that don't match 64 bits,
 - Used in routing,
 - Used in address block assignment,
 - Used in slicing up blocks for special usage

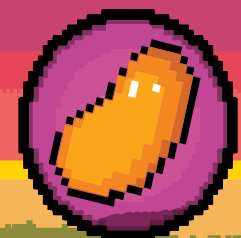


IPv6 Address Prefix/Subnet



IPv6 Address Allocation

- **Internet Assigned Numbers Authority (IANA)** assigned Regional Internet Registrars 23/12 bit blocks,
- **Regional Internet registrars (Afrinic)** assign blocks 19/32 to local Internet registrars,
- **End User** recommended to get a /48 block which means 65335 subnets but now recommended 56 subnet only 256 subnets.

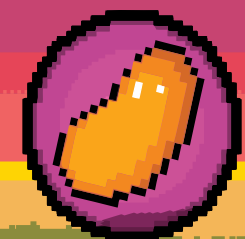
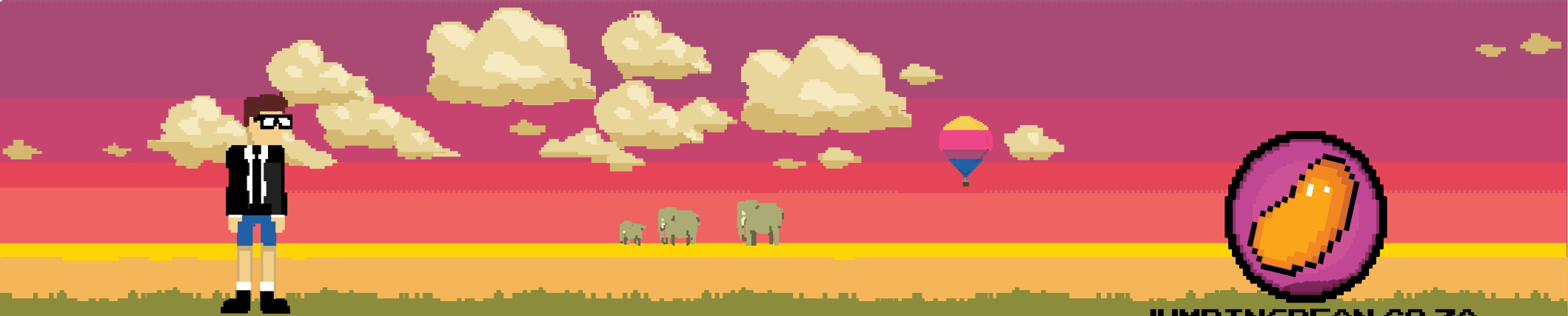


IPv6 Address Allocation

- Entities can apply for own, **provider independent**, IPv6 address block with Regional registrar
- Great for ISP independence,
- Why such large allocations?
 - IPv4 routing tables size (current) - 545K,
 - IPv6 routing table size (current) - 22K,
 - Generous allocation policy to avoid routing table explosion



LAN Configuration



IPv6 How it Works

- Every interface has a **link-local** address,
 - Network segment only,
- Additional address obtain via
 - Manual configuration, or
 - Automatic configuration,
 - SLAAC
 - DHCP
- Other addresses
 - **Unique local address (ULA)** - site routable,
 - **Global address** – internet routable,



IPv6 Link Local

- Each interface auto-assigned a link-local ip address – fe80::/10,
 - Actual assigned link local is fe80::/64
 - replaces layer 2 arp protocols with layer 3,
 - Neighbourhood discovery → map IP to Mac via Neighbour solicitation ,
 - Unique only on local network segment,
 - Used to boot strap other IPv6 protocols and addresses
 - Interface prefix is generated from mac address on ethernet NICs using EUI64:
 - Mac address is 48 bits long,
 - Interface identifier is 64 bits long
 - Not forwarded by routers



Unique Local Address/Global Addresses

- **Stateless Automatic Address Configuration** - allows IPv6 networks to auto-configure themselves via ICMPv6 packets
- **Link-Local address** allows for
 - the issuing of router solicitation packets,
 - Receipt of router advertisement packets,
- **Routers**
 - Receive solicitation packets,
 - Send advertisement packets
 - Provide node with one or more network prefix and router address
 - Network prefix can be a ULA or global address
 - Client does duplicate address detection (DAD)



IPv6 - Configurations

- **SLAAC** can be used in a number of ways:
 - Stateless without DHCPv6,
 - Stateless with DHCPv6
 - Stateful with DHCPv6
- **Stateless** -
 - Router/DHCP server does not track ip address,
 - Simply provides network prefix,
 - Node not guaranteed to get same IPv6 address,
 - Node configures host identifier,
- **Stateful** -
 - DHCP server keeps track of addresses handed out (leases),
 - DHCP can assign same IPv6 address to returning node (DUID),



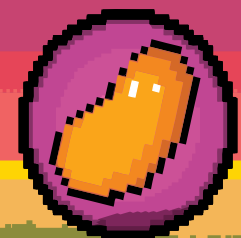
IPv6 - SLAAC

- **Pros**

- Automatic configurations,
- No configuration required by client,

- **Cons**

- No updating of DNS for nodes, fixed with RFC6106,
- Limited set of configurations options for auto configuration of nodes



IPv6 – ULA/Global Configurations

- **Without DHCP** - Router can also send
 - DNS server information,
 - Router IPv6 address (default gateway),
 - Flags
- **With DHCP** – Node can obtain
 - Fixed IP address,
 - Additional configuration information
 - **DUID** – device unique id,
 - DHCPv6 does not use mac address for unique identification,
 - Each address assigned based on DUID and interface Association identifier,
 - Designed to prevent updating DHCP server when network card changes
 - DUID is created by OS or DHCPClient,
 - IAID – from mac



Unique Local Address

- ULA – similar to private addresses in IPv4,
- Can route traffic across network segments,
- Used for company or home lan,
- Should not be routed by gateway devices,
- Network prefix fc00::/7. As 8th bit is always 1 will see fd00 for ula address
- You can create your own ULA or use sites such as <http://unique-local-ipv6.com/>

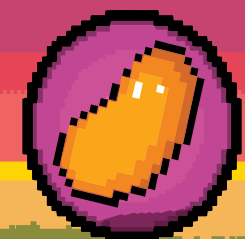
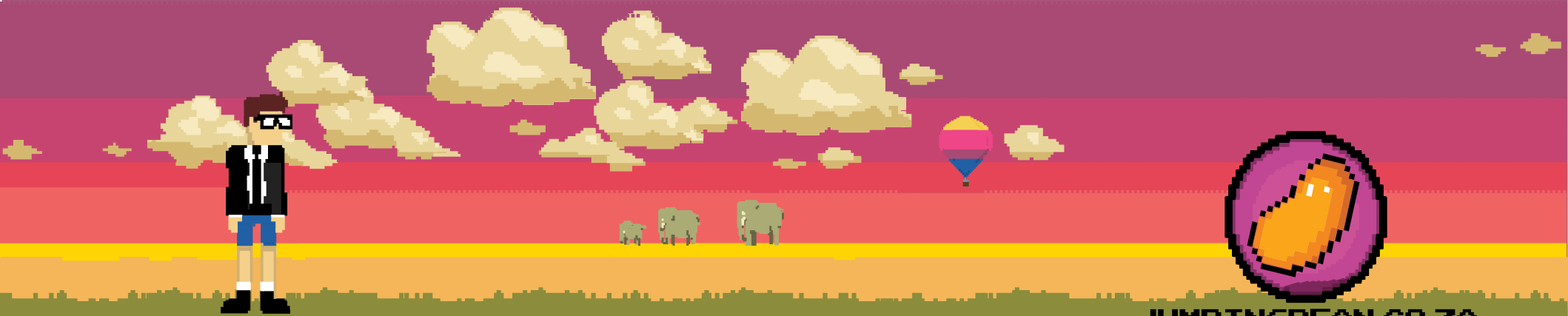


Global Addresses

- Assigned by ISP or Afrinic etc,
- Globally routable,
- Similar to IPv4 public addresses,
- For ISP router will need to receive IPv6 prefix for use in configuring IP addresses for nodes,
- Global addresses currently start with 2001::



How to do this on Linux?



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IPv6 on Linux

- How to set up a basic IPv6 network for lan,
- What we will need:
 - **radvd** – router advertisement daemon,
 - “apt-get install radvd”
 - or a router on your network with a router advertisement daemon running and configured with your DHCP server details,
 - **isc-dhcp-server** – dhcpv6 capable server,
 - “apt-get install isc-dhcp-server”
 - **bind9** – DNS server for Dynamic DNS updates
 - “apt-get install bind9”



IPv6 RADVD Configuration

- Enable Ipv6 forwarding
 - net.ipv6.conf.default.forwarding=1
- Edit /etc/radvd.conf
 - Prefix – the network prefix to advertise, can have more than one,
 - Options
 - **AdvOnLink** – on or off link
 - **AdvAutonomous** – whether this prefix can be used for auto config
 - Enable DHCPv6 lookup
 - **AdvManagementFlag** – use stateful IP assignment
 - **AdvOtherConfigFlag** – get additional config from DHCP server

```
interface eth0
{
    AdvSendAdvert on;
    prefix fd45:2222:0:1::/64
    {
        AdvOnLink on;
        AdvAutonomous on;
    };
};
```

```
interface eth0
{
    AdvSendAdvert on;
    prefix fd45:2222:0:1::/64
    {
        AdvOnLink on;
        AdvAutonomous on;
        AdvManagementFlag on;
        AdvOtherConfigFlag on;
    };
};
```



IPv6 – DHCPv6 Set up

- Isc-dhcp-server can run both IPv4 and IPv6 DHCP services,
- IPv6 DHCP uses different ports to IPv4,
- Most options same as for IPv4 with 6 appended,
 - subnet6, range6
- Use DUID instead of MAC for static address assignment,
- Need to setup keys for dynamic DNS update
- Ubuntu 14.04 – has a bug cannot start dhcp server with “-6” option to enable ipv6.
- Usually edit /etc/default/isc-dhcp-server and add “-6” to options
- Need to add to rc.local for now
 - “sudo dhcpd -6 -cf /etc/dhcp/dhcpd.conf -lf /var/lib/dhcp/dhcpd.leases wlan0”



```
ddns-update-style interim;  
ddns-updates on;
```

```
update-conflict-detection false;  
update-optimization false;
```

```
option domain-name "jozilug.co.za";  
option dhcp6.name-servers fd5d:12c9:2201:1::2;
```

```
default-lease-time 600;  
max-lease-time 7200;  
include "/etc/dhcp/rndc.key";
```

```
zone jozilug.co.za. {  
    primary 127.0.0.1;  
    key rndc-key;  
}
```

```
zone 1.0.0.0.1.0.2.2.c.9.2.1.d.5.d.f {  
    primary 127.0.0.1;  
    key rndc-key;  
}
```

```
subnet6 fd5d:12c9:2201:1::/64 {  
    range6 fd5d:12c9:2201:1::100 fd5d:12c9:2201:1::200;
```



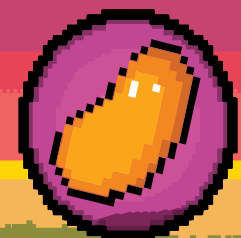
DHCPv6

- Can operate in several modes
 - Stateless mode → router advertisements assign ip address, DHCP provides DNS, time servers etc
 - Stateful mode → DHCP assigns ip addresses and network services,
 - DHCPv6-PD – prefix delegation obtains network prefix from upstream provider
- Router solicitation →
 - O flag → get configuration information,
 - M flag → get IP address



DHCPv6

- Client uses DUID to identify itself (mac address in DHCPv4)
 - DUID – unique per server/client,
 - Should not be changed in products lifetime,
 - Must be globally unique
- IAID – Interface association ID unique per interface and IP address



DUID

- 4 ways to generate DUID
 - Link layer address + time,
 - Vendor assigned unique id based on enterprise number,
 - Link layer address,
 - UUID – used for SIP devices
- Different devices will have different capabilities → e.g. no persistent storage therefore different ways to generate a unique id
- Problem to detect DUIDs → put on label?
- `hexdump -e ""%07.7_ax " 1/2 "%04x" " " 14/1 "%02x:" ""\n""
/var/lib/dhcpv6/dhcp6c_duid`



IPv6 - Bind Set up

- Bind works as for IPv4,
- Bind hosts IPv4 and IPv6 addresses in same zone file,
- Bind will answer queries with the available address. I.e IPv4 host can query for an IPv6 address
- On Ubuntu place zone files in /var/lib/bind otherwise apparmor will prevent updating of zone files



IPv6 - Bind9 Zone File

```
$ORIGIN .
$TTL 604800      ; 1 week
jozilug.co.za    IN SOA jozilug.co.za. admin.jozilug.co.za. (
                    150      ; serial
                    604800   ; refresh (1 week)
                    86400    ; retry (1 day)
                    2419200  ; expire (4 weeks)
                    604800   ; minimum (1 week)
                )
                NS      ns.jozilug.co.za.
                A       127.0.0.1
                AAAA    ::1
$ORIGIN jozilug.co.za.
gateway          AAAA   fd5d:12c9:2201:1::2
ns               AAAA   fd5d:12c9:2201:1::2
```

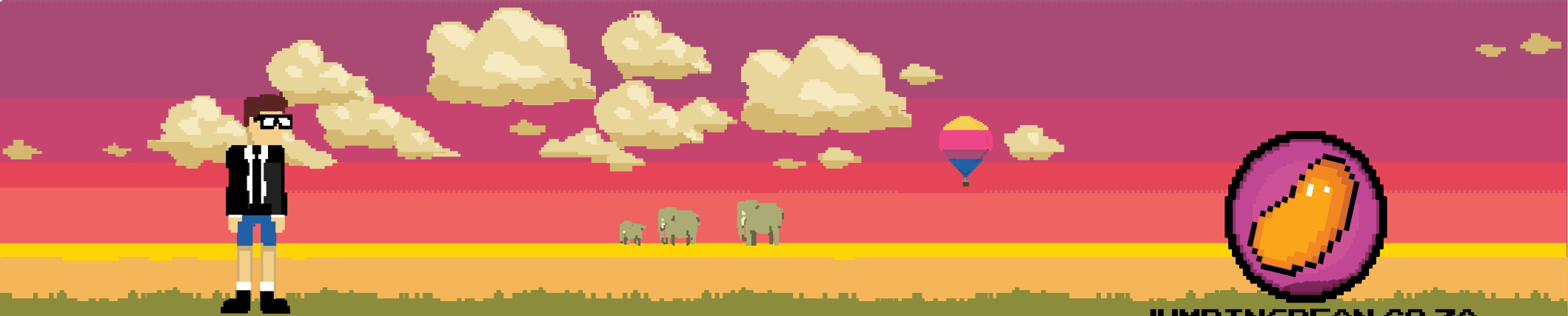


IPv6 – Bind Reverse Zone File

```
;  
; BIND reverse data file for broadcast zone  
;  
$TTL 604800  
@ IN SOA ns.jozilug.co.za. admin.jozilug.co.za (  
    1 ; Serial  
    604800 ; Refresh  
    86400 ; Retry  
    2419200 ; Expire  
    604800 ) ; Negative Cache TTL  
;  
@ IN NS ns.jozilug.co.za.  
  
2.0.0.0.0.0.0.0.0.0.0.0.0.1.0.0.0.1.0.2.2.9.c.2.1.d.5.d.f.ip6.arpa. IN PTR ns.jozilug.co.za
```



Connecting to the Outside World

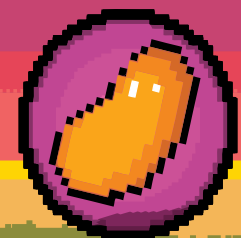


Way too many options

- There are a plethora of “transition mechanisms”
 - IPv4 and IPv6 incompatibility
 - Initially IPv6 over IPv4
 - Then IPv4 over IPv6
- Some are focused on Service provider
 - CG-NAT, NAT444, 464XLAT
- Others for LANS,

- Approaches

- Dual stack
- Encapsulation,
 - Tunnels,
 - A+P,
 - DS-Lite
- Translation,
 - NAT64
 - DNS64,



What to use to connect your LAN?



NAT64/DNS64

- Your ISP gives you an IPv4 address,
- Use only IPv6 internally and use NAT64(**tagya**),
- Configure bind9 to return all IPv4 addresses as “fake” ipv6 addresses,

Bind9 Additions to options

```
dns64 fd5d:12c9:2201:1:1:1::/96 {  
    clients {  
        any;  
    };  
  
    exclude {  
        any;  
    };  
};
```



NAT64/DNS64

- **Pros** – can use Iptables v4 to managed internet connection on Nat64 IPV4 pool,
 - Use only IPv6 internally,
 - Easy to set up
- **Cons** – No access to global IPv6 network. IPv6 only hosts will remain dark
 - Not every type of service is accessible
 - Skype,
 - Web Sockets,
 - SIP



Tunnels 6in4

- Set up DHCPv4 along with DHCPv6,
- Static or automatic tunnels
- Static
 - Create IPV6 SIT tunnel (6in4) to router IPv6 traffic
 - Use a tunnel broker like Hurricane Electric or SixX
- Dynamic
 - Teredo
 - ISATAP



DS-Lite

- Used by ISPs
- IPv4 over IPv6 and IPv4 natting
- DS-Lite – Dual Stack light
 - CPE provides private Ipv4 addresses to LAN,
 - CPE encapsulates IPV4 addresses in IPv6,
 - Delivers packet to ISP Carrier Grade Nat (CGN) with public Ipv4 address,
 - Recovers Ipv4 packets,
 - Nat its,
 - Return traffic is mapped to Ipv4 then encapsulated in IPV6 and back to client

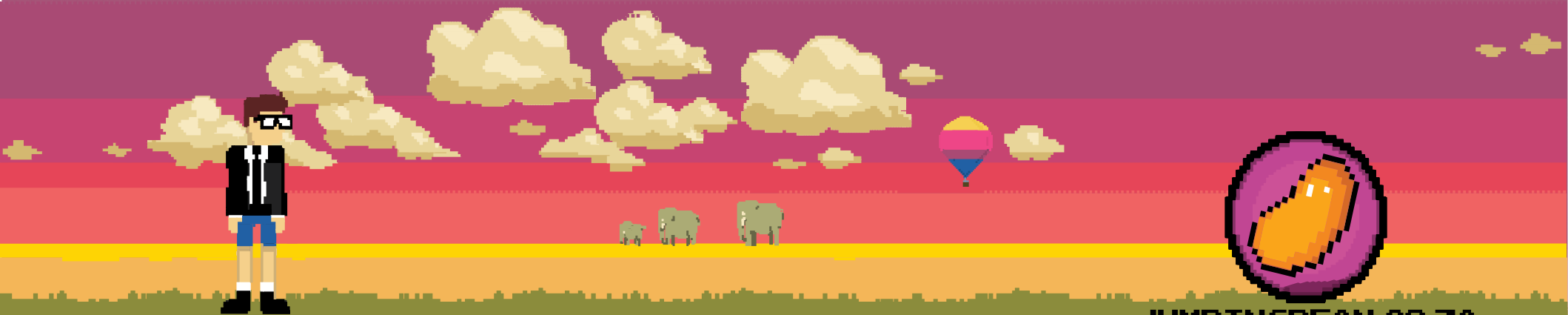


MAP & A+P

- Proposal for ISPs to extend IPv4 address space,
- Address + Port → Single Ipv4 address shared amongst several clients.
 - Client identified by address and port,
 - Each client assigned a port range,
- MAP ->
 - Mapping and Address Port → CISCO Ipv6 transition proposal
 - Combined A+P with tunnelling IPV4 packets over ISP Ipv6 network



Miscellaneous



Privacy Extensions

- RFC 4941 "Privacy Extensions for Stateless Address Autoconfiguration in IPv6".
- Sysctl use_tempaddr=
 - `<= 0` : disable Privacy Extensions
 - `== 1` : enable Privacy Extensions, but prefer public addresses over temporary addresses.
 - `> 1` : enable Privacy Extensions and prefer temporary addresses over public addresses.
- `net.ipv6.conf.eth0.use_tempaddr=2`
→ `/etc/sysctl.conf`
- `net.ipv6.conf.default.use_tempaddr`
→ only sets network addresses assigned after boot up
- `net.ipv6.conf.all.use_tempaddr` → reported bug
- `net.ipv6.conf.all.use_tempaddr = 2`
- `net.ipv6.conf.default.use_tempaddr = 2`
- `net.ipv6.conf.nic0.use_tempaddr = 2`



Disable IPv6

- Remember iptables protects IPv4 addresses only!
- Temporarily disable
 - `sudo sh -c 'echo 1 > /proc/sys/net/ipv6/conf/<interface-name>/disable_ipv6'`
- Edit `/etc/sysctl.conf`
 - `# IPv6 disabled`
 - `net.ipv6.conf.all.disable_ipv6 = 1`
 - `net.ipv6.conf.default.disable_ipv6 = 1`
 - `net.ipv6.conf.lo.disable_ipv6 = 1`
- Edit `/etc/default/grub`
 - `GRUB_CMDLINE_LINUX="ipv6.disable=1"`

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