Tutorial - IPv6 Address Management

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Tutorial Overview

- Introduction to IP Address Management
- Rationale for IPv6
- IPv6 Addressing
- IPv6 Policies & Procedures
- References

IP Address Management

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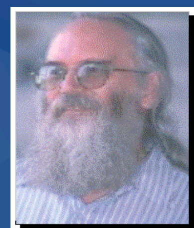
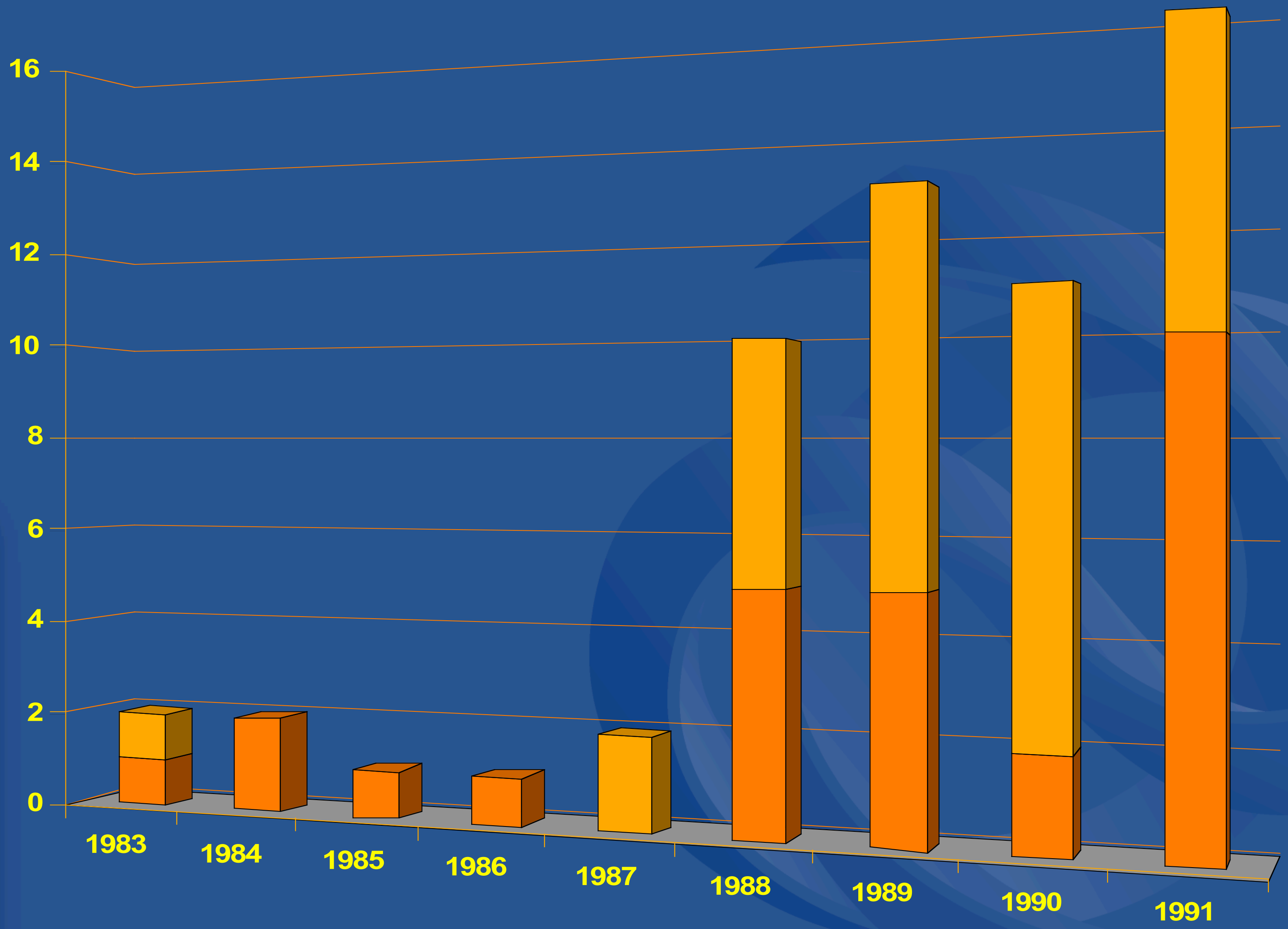
The early years: 1981 – 1992

1981:

"The assignment of numbers is also handled by Jon. If you are developing a protocol or application that will require the use of a link, socket, port, protocol, or network number **please contact Jon to receive a number assignment**." (RFC 790)



IANA Address Consumption



Global Routing Table: ’88 - ’92

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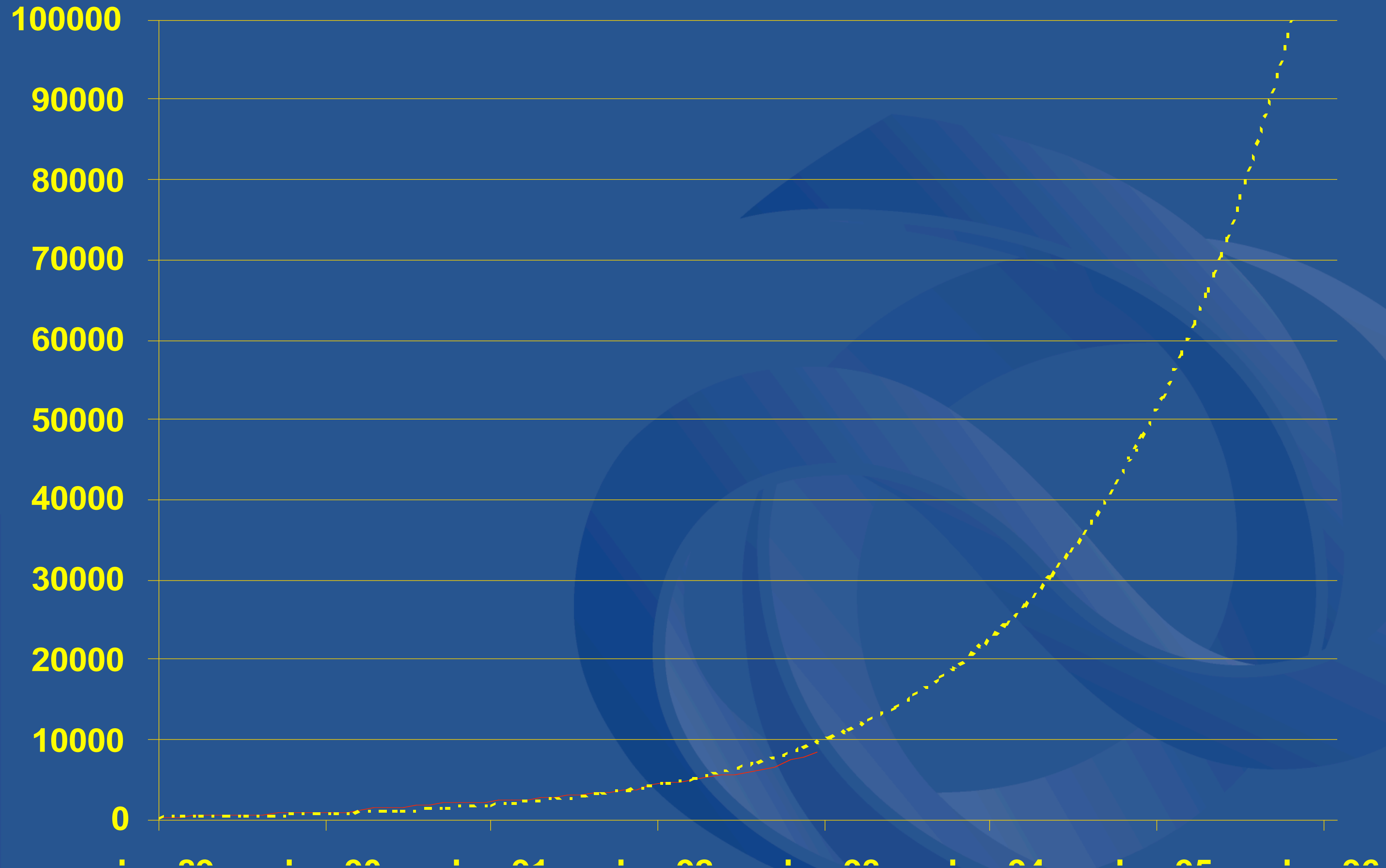

The boom years: 1992 – 2001

1992:

"It has become clear that … these problems are likely to become critical within the next one to three years." (RFC1366)

"…it is [now] desirable to consider delegating the registration function to an organization in each of those geographic areas." (RFC 1338)

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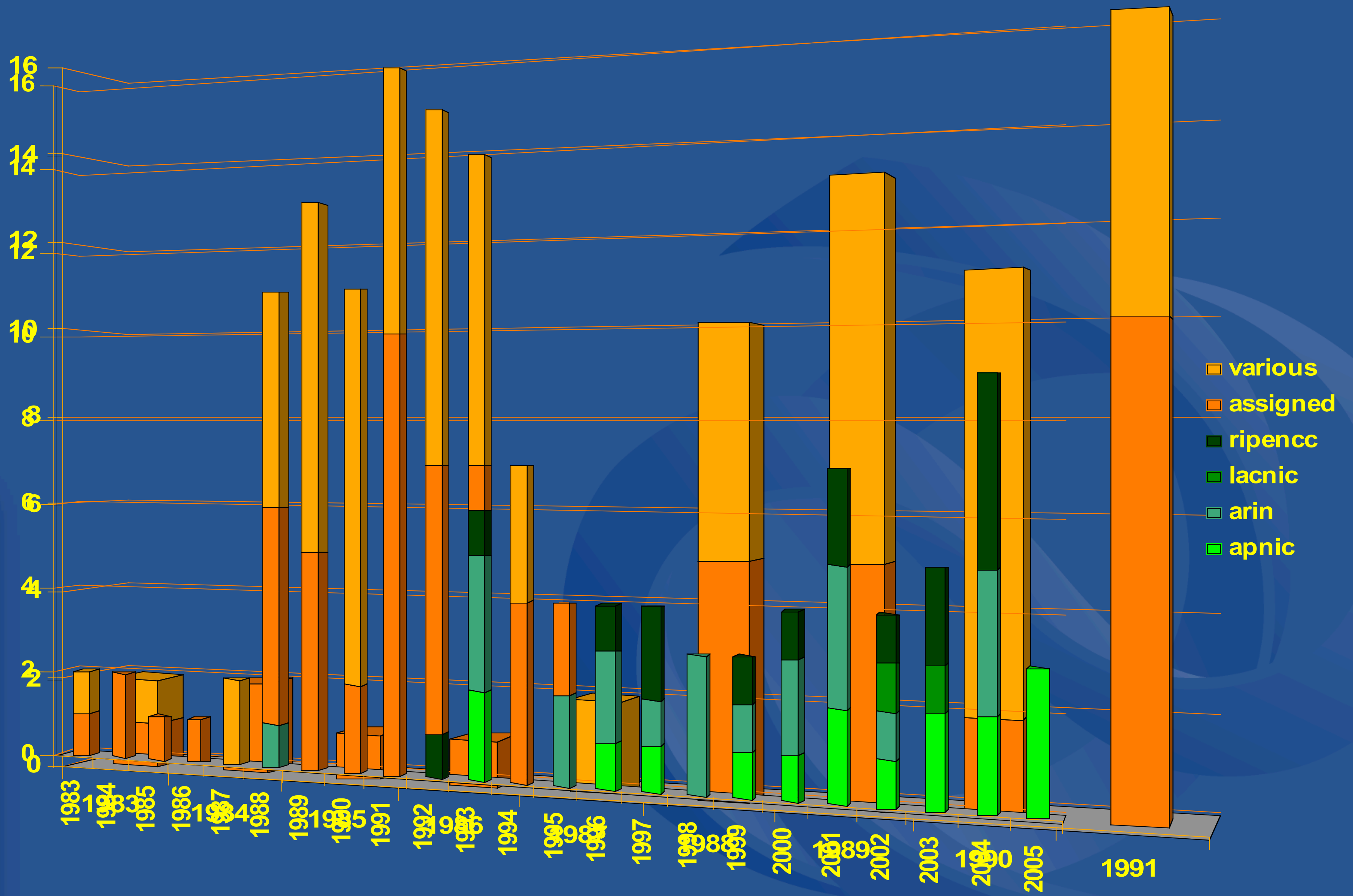
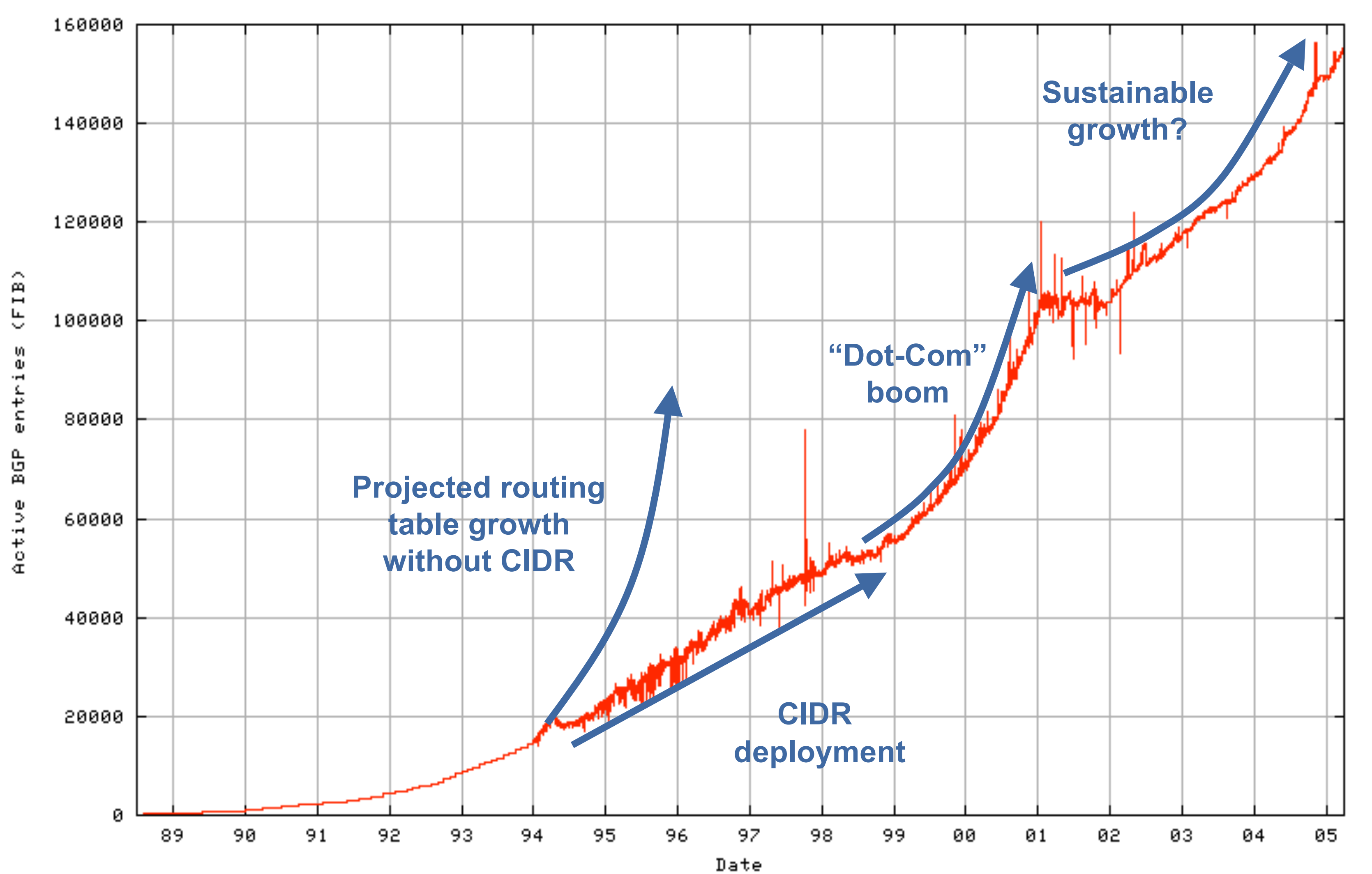
IANA Address Consumption



Global routing table



http://bgp.potaroo.net/as1221/bgp-active.html

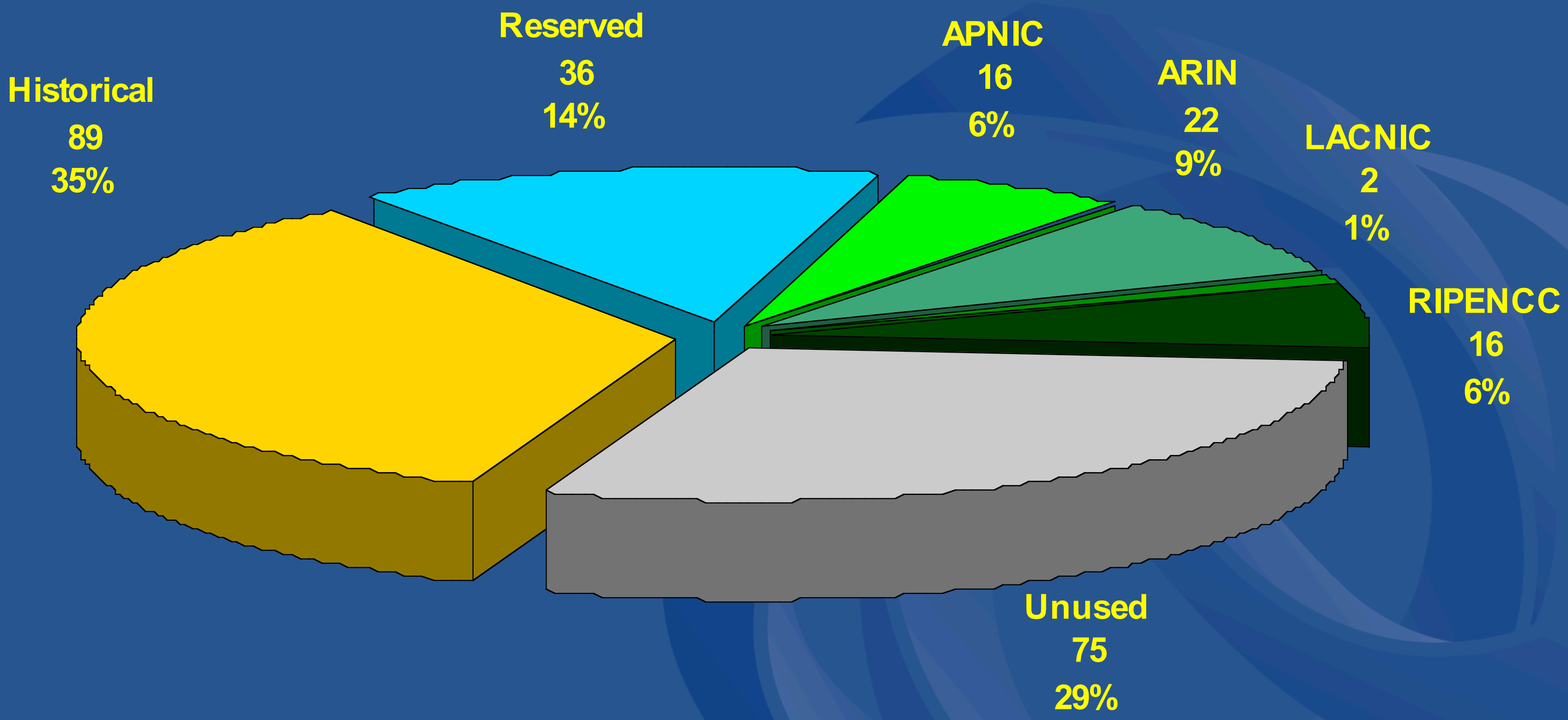
Recent years: 2002 – 2005

2004:

Establishment of the
Number Resource Organisation

NRO

IPv4 Distribution – Global



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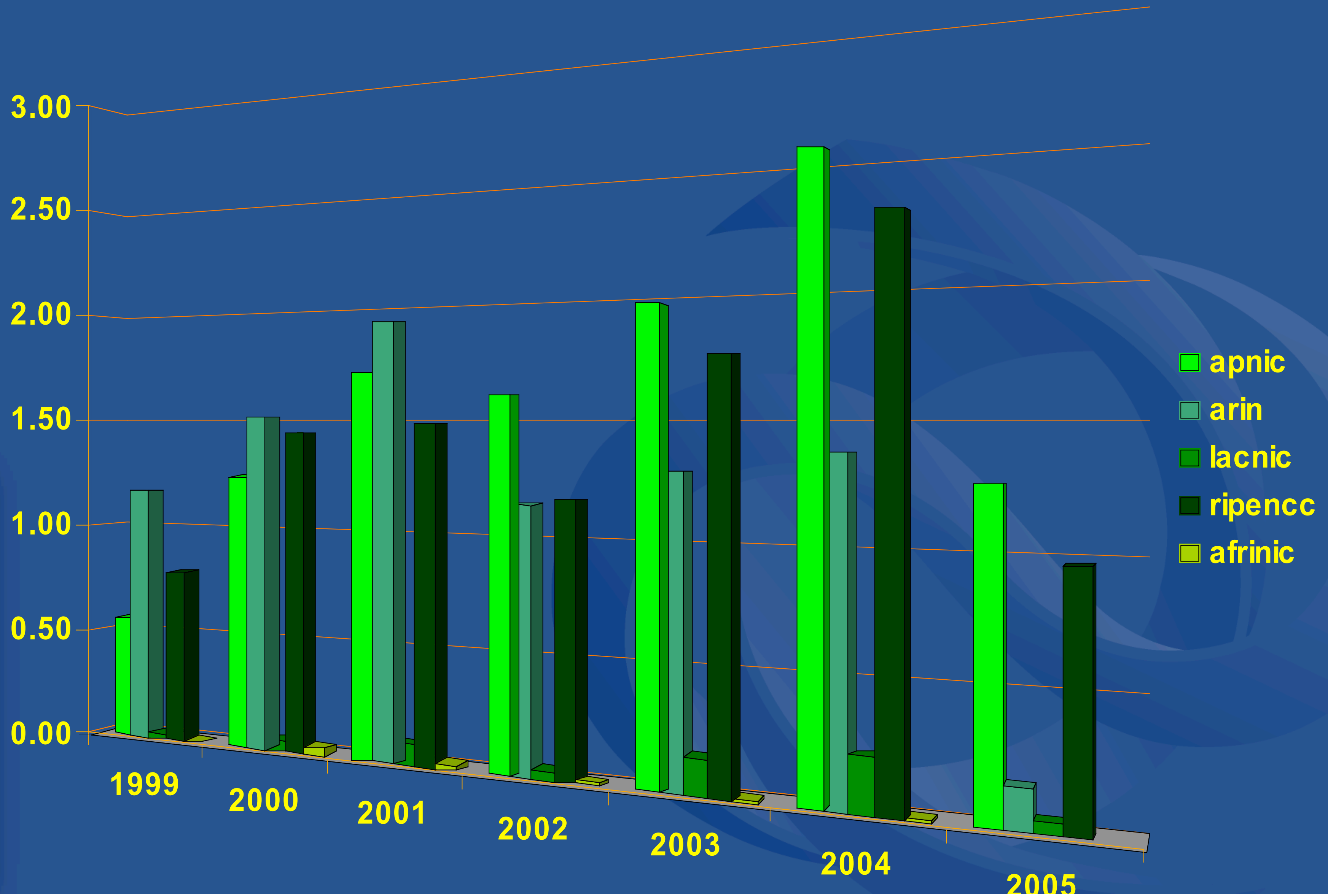
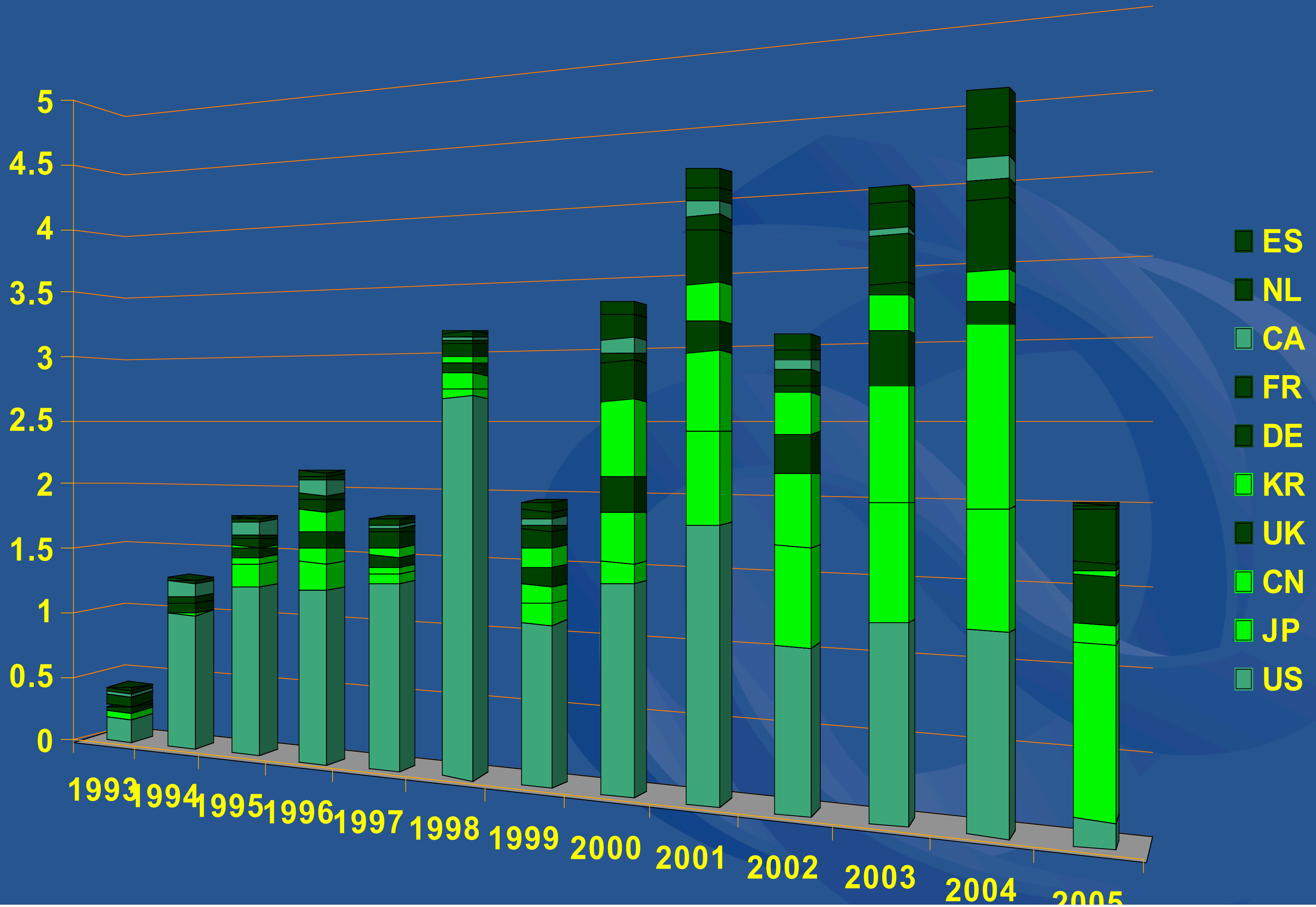
IPv4 Distribution – Regional



IPv4 Allocations – Global top 10



Regional Internet Registries

What are RIRs?

- Regional Internet Registries
- Service organisations
  - Industry self-regulatory structures
  - Non-profit, neutral and independent
  - Open membership-based bodies
  - Representative of ISPs globally
- First established in early 1990's
  - Voluntarily by consensus of community
  - To satisfy emerging technical/admin needs
- In the "Internet Tradition"
  - Consensus-based, open and transparent

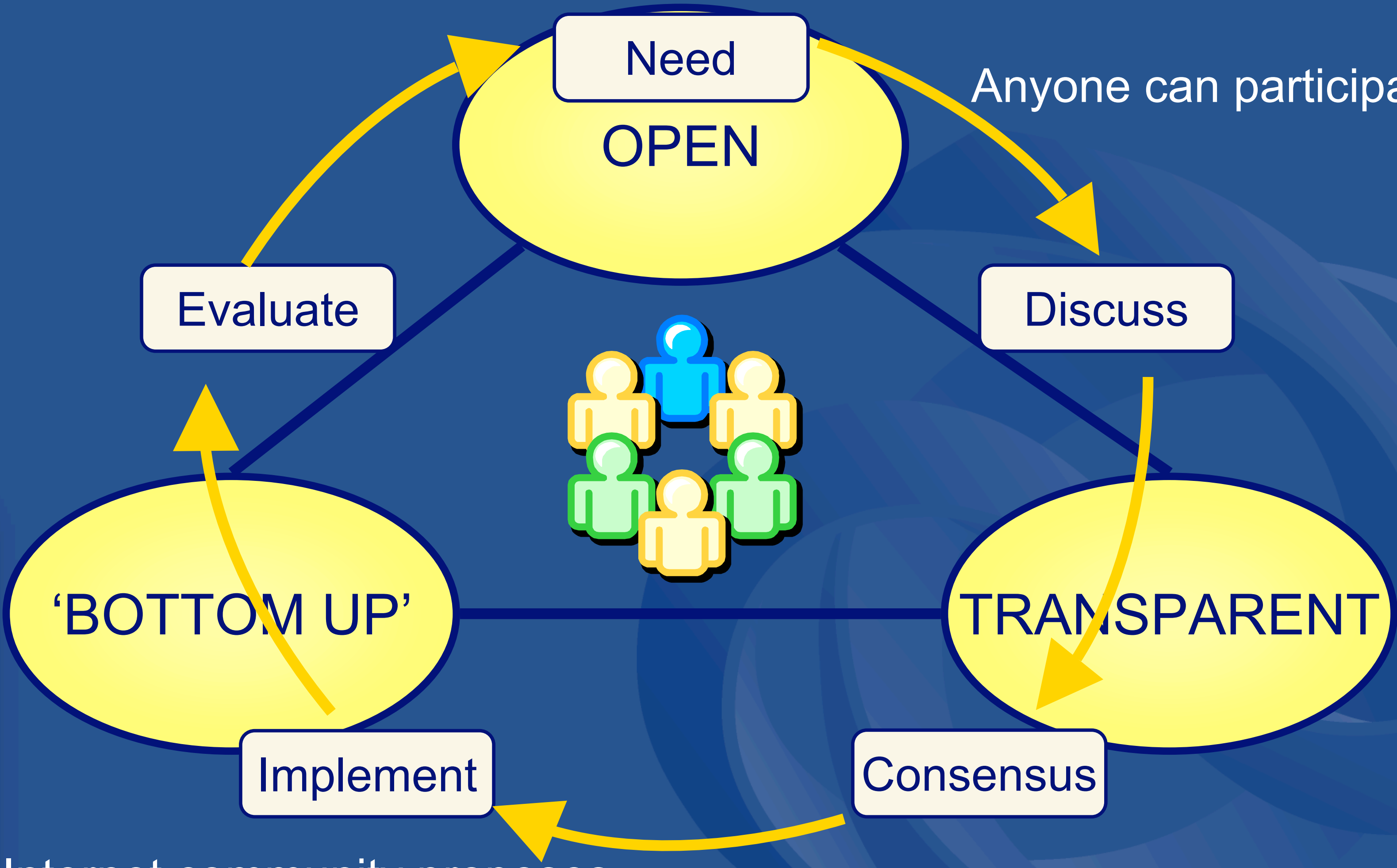
What do RIRs do?

- Internet resource allocation
  - Primarily, IP addresses – IPv4 and IPv6
  - Receive resources from IANA/ICANN, and redistribute to ISPs on a regional basis
  - Registration services ("whois")
- Policy development and coordination
  - Open Policy Meetings and processes
- Training and outreach
  - Training courses, seminars, conferences…
  - Liaison: IETF, ITU, APT, PITA, APEC…
- Publications
  - Newsletters, reports, web site…

How do RIRs do it?

- Open and transparent processes
  - Decision-making
  - Policy development
- Open participation
  - Democratic, bottom-up processes
- Membership structure
  - 100% self-funded through membership fees
  - National Internet Registries (APNIC)
- Community support (APNIC)
  - Training
  - R&D fund
  - Fellowships – funding received and given
  - Open source software contribution (GPL)

RIR Policy Coordination



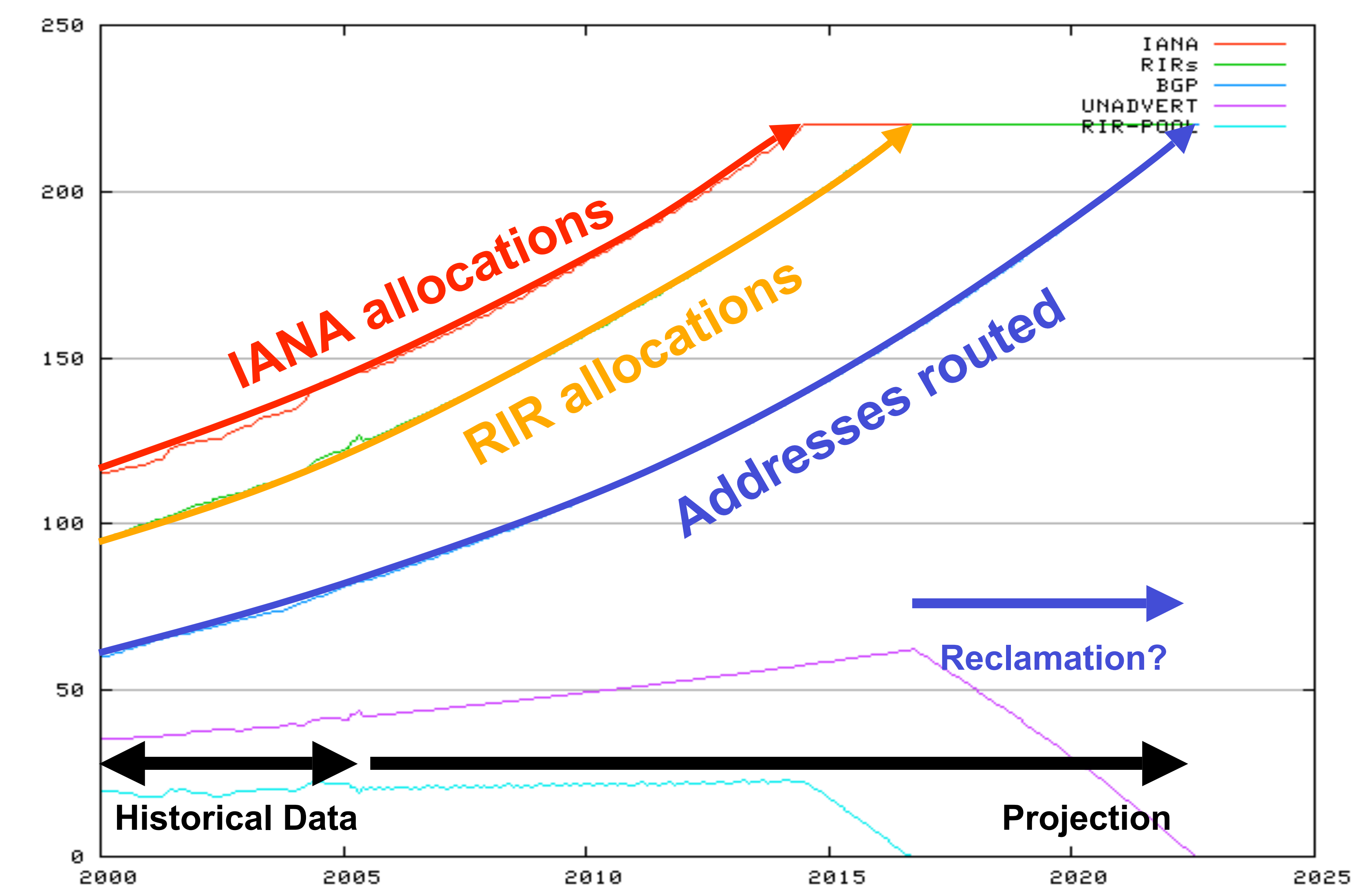
Anyone can participate

Internet community proposes and approves policy

All decisions & policies documented & freely available to anyone

Rationale for IPv6

IPv4 Lifetime

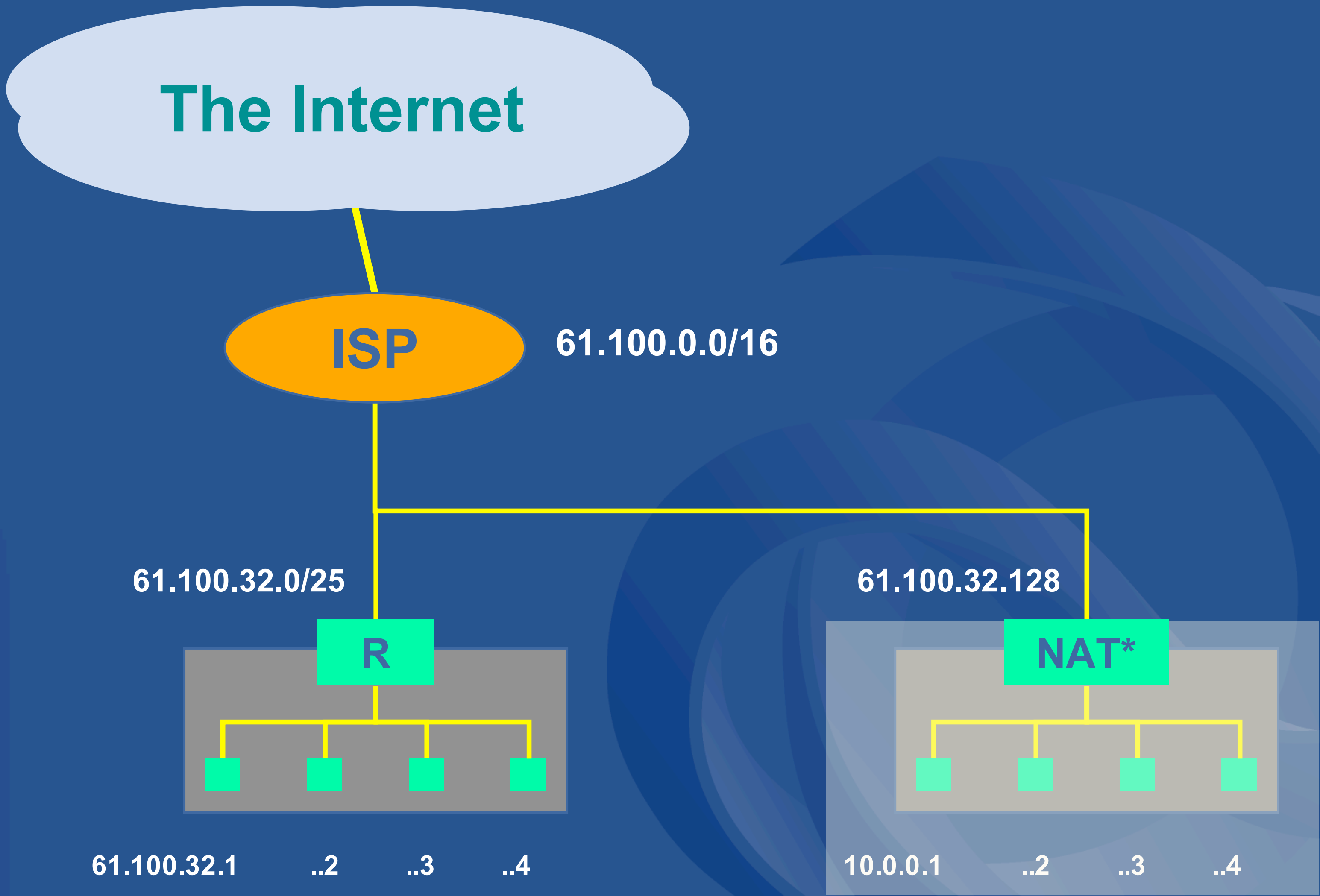


http://bgp.potaroo.net/ipv4

Rationale for IPv6

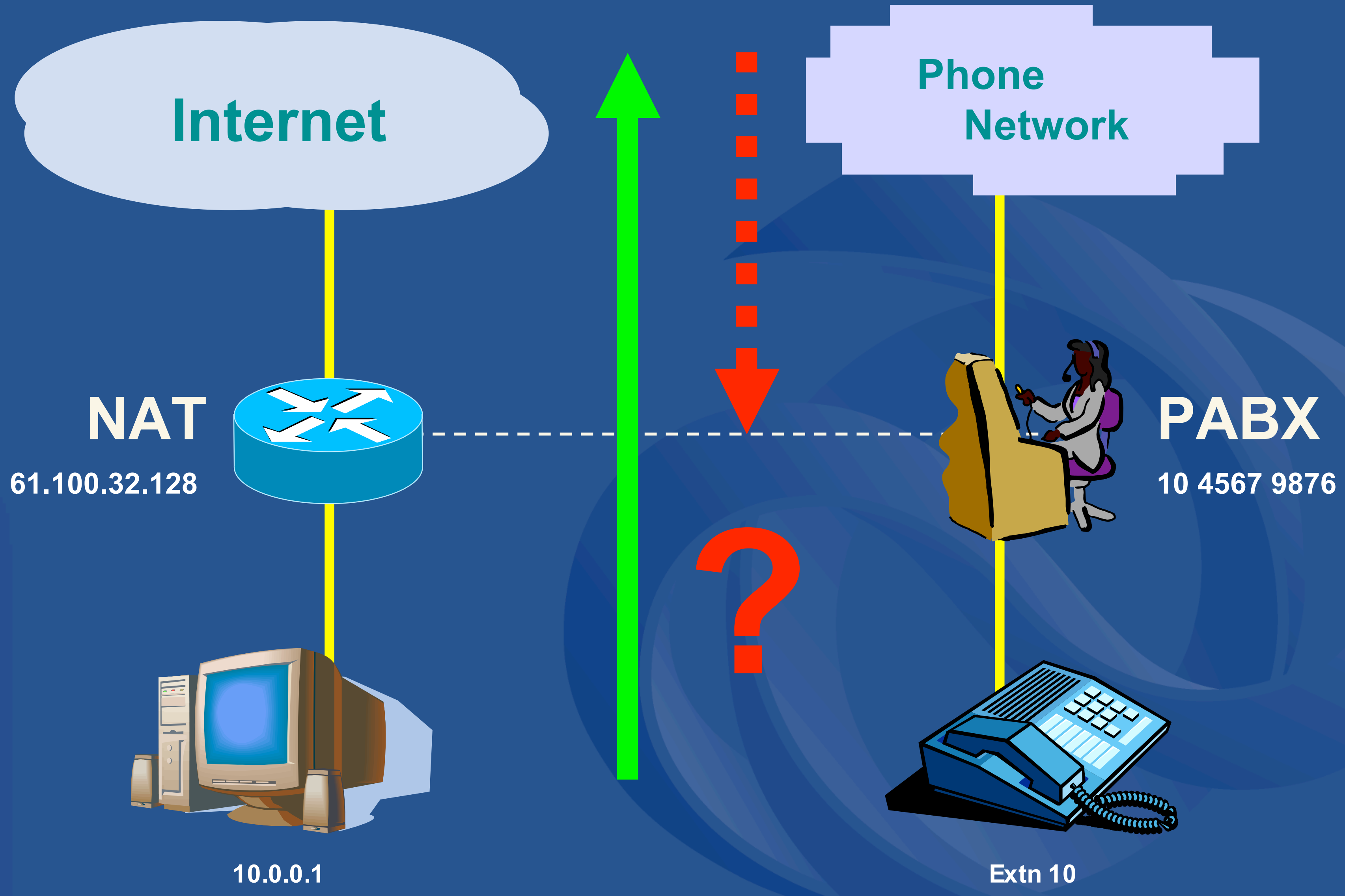
- IPv4 address space consumption
  - Now ~10 years free space remaining
  - Up to 17 if unused addresses reclaimed
  - These are today's projections – reality will be different
- Loss of "end to end" connectivity
  - Widespread use of NAT due to ISP policies and marketing
  - Additional complexity and performance degradation

The NAT "Problem"



*AKA home router, ICS, firewall

The NAT "Problem"



NAT implications

- Breaks end-to-end network model
  - Some applications cannot work through NATs
  - Breaks end-end security (IPsec)
- Requires application-level gateway (ALG)
  - When new application is not NAT-aware, ALG device must be upgraded
  - ALGs are slow and do not scale
- Merging of separate private networks is difficult
  - Due to address clashes
- See RFC2993
  - Architectural Implications of NAT

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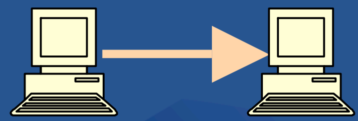
Features of IPv6

IPv6 feature summary

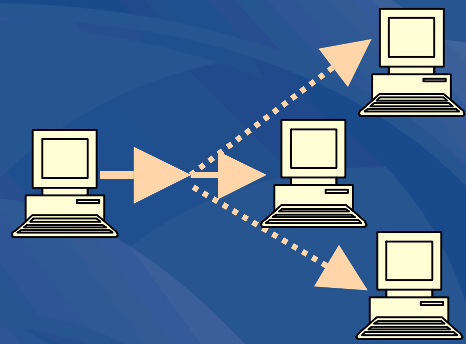
- Increased size of address space
- Header simplification
- Autoconfiguration
  - Stateless (RFC 2462) or stateful (DHCPv6)
  - Facilitates renumbering
- QoS
  - Integrated services (int-serv), Differentiated services (diff-serv and RFC2998)
  - RFC 3697
- IPSec
  - As for IPv4
- Transition techniques
  - Dual stack
  - Tunnelling

IPv6 addressing model

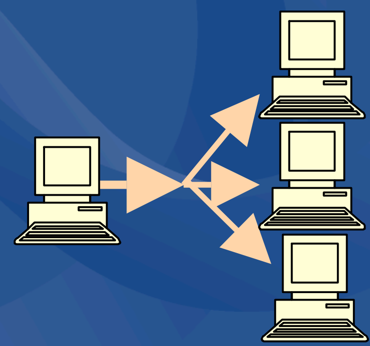
- Unicast
  - Single interface



- Anycast
  - Any one of several



- Multicast
  - All of a group of interfaces
  - Replaces IPv4 “broadcast”



- See RFC 3513

IPv4 vs IPv6

IPv4: 32 bits

- 2^{32} addresses

  = 4,294,967,296 addresses

  = 4 billion addresses

IPv6: 128 bits

- 2^{128} addresses?

  = 340,282,366,920,938,463,463,374,607,431,770,000,000

  = 340 billion billion billion billion addresses?

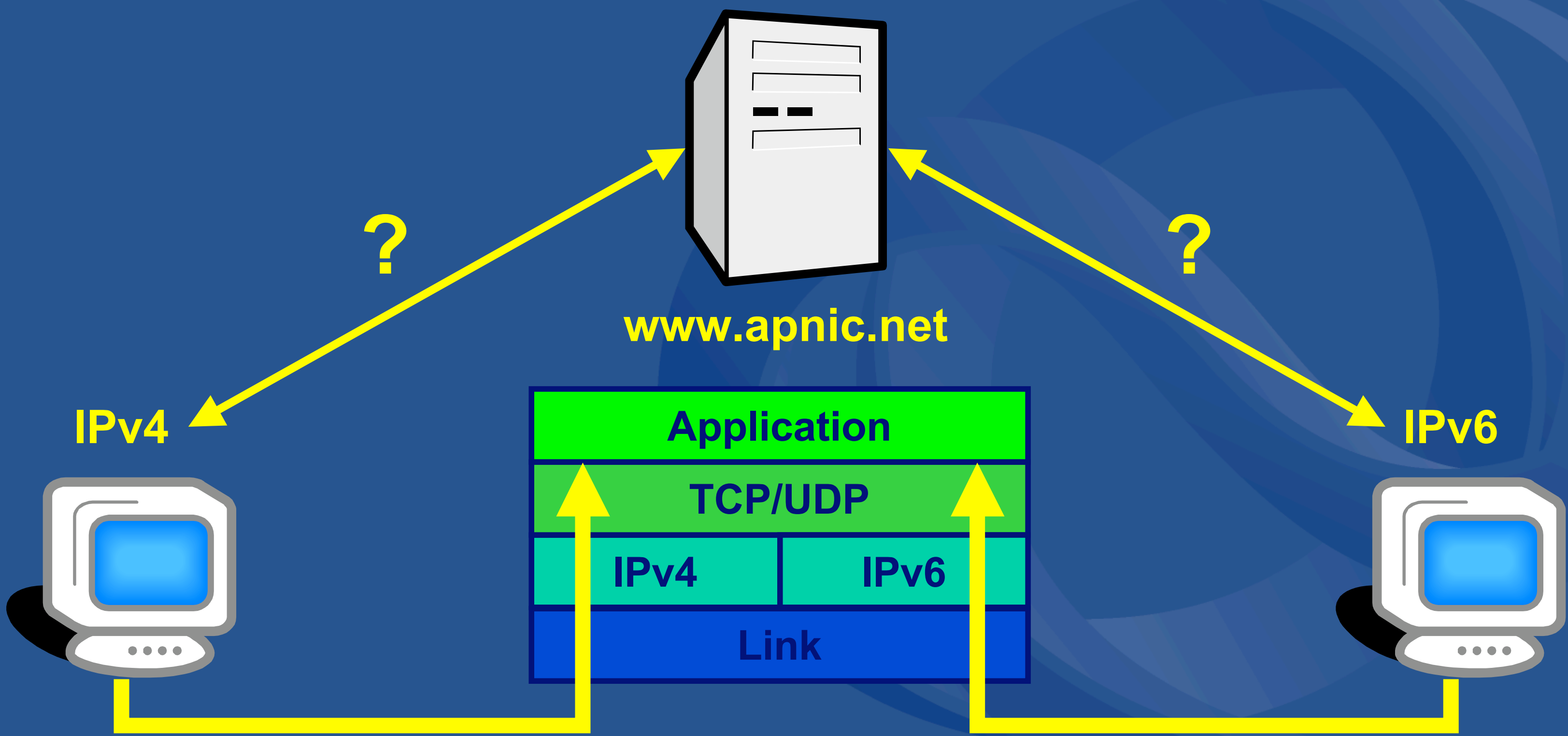
- No, due to IPv6 address structure…

IPv6 header

- IPv6 header is simpler than IPv4
  - IPv4: 14 fields, variable length (20 bytes +)
  - IPv6: 8 fields, fixed length (40 bytes)
- Header fields eliminated in IPv6
  - Header Length
  - Identification
  - Flag
  - Fragmentation Offset
  - Checksum
- Header fields enhanced in IPv6
  - Traffic Class
  - Flow Label

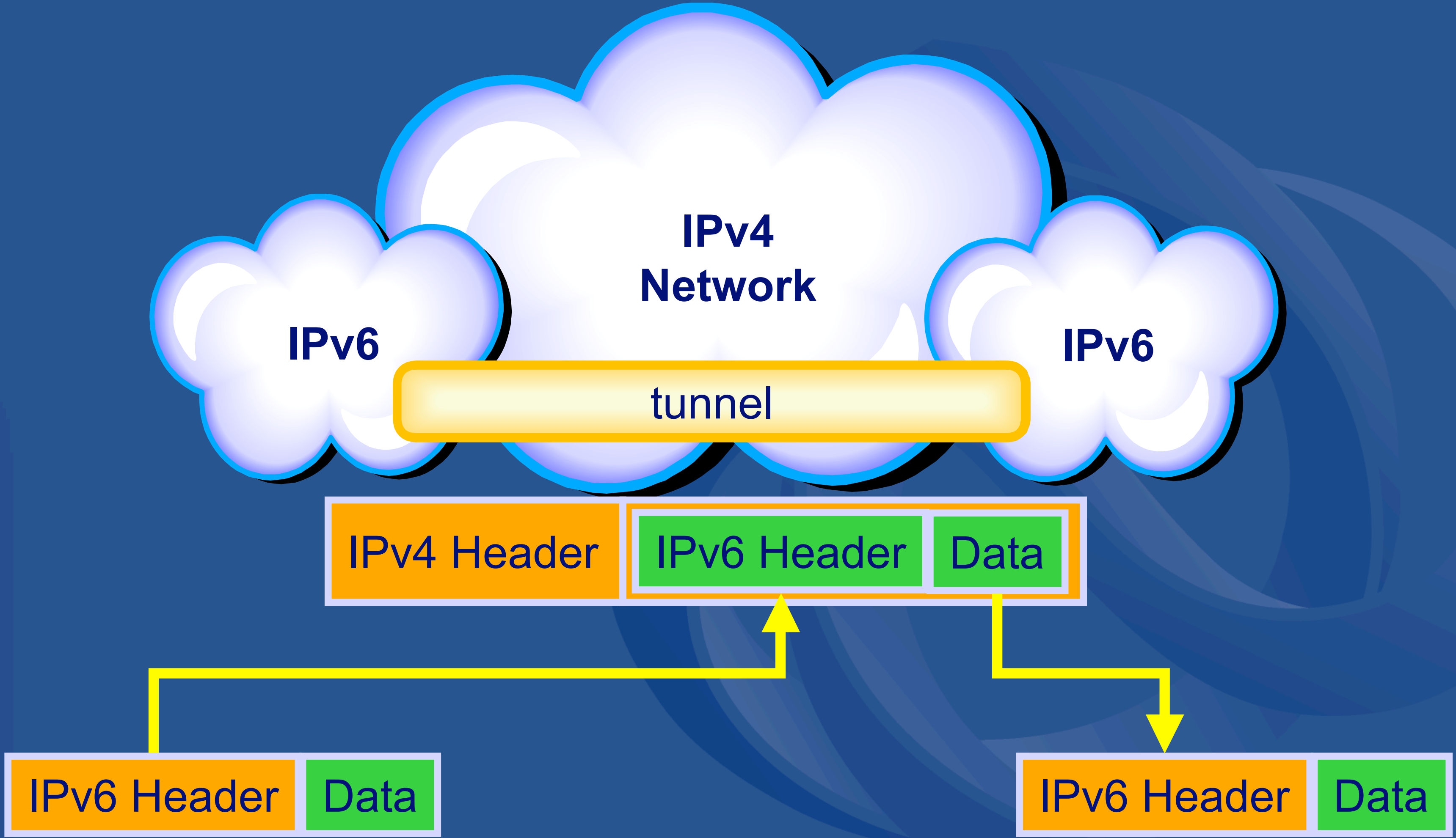
IPv6 transition

- Dual stack hosts
  - Two TCP/IP stacks co-exists on one host
  - Supporting IPv4 and IPv6
  - Client uses whichever protocol it wishes



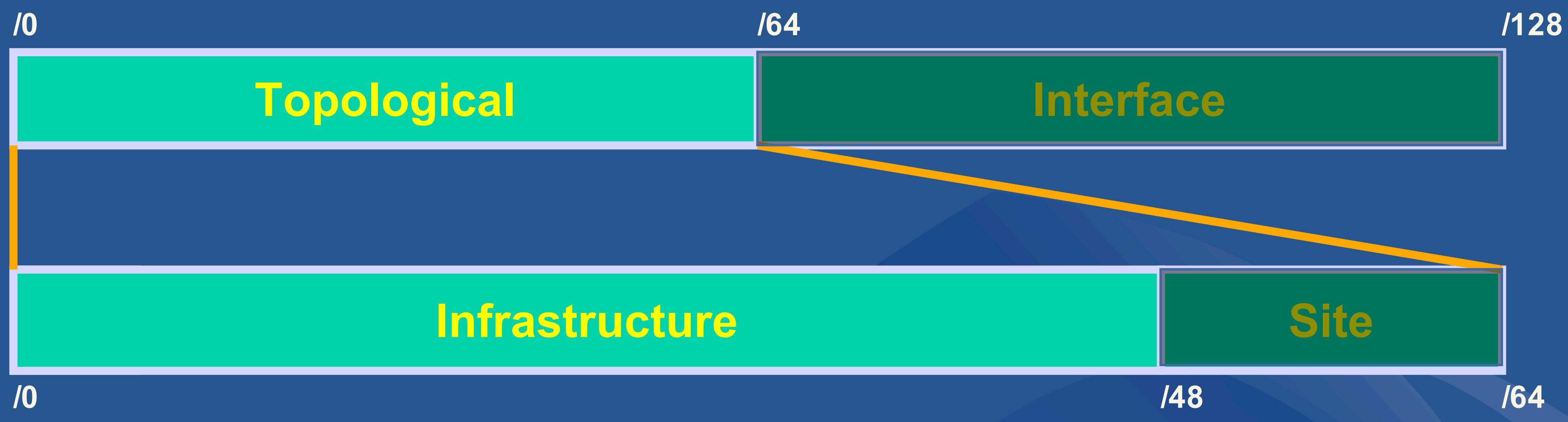
IPv6 transition

- IPv6 tunnel over IPv4



IPv6 Addressing

How much IPv6?



- 2^{64} “subnet” addresses

  = 18,446,744,073,709,551,616

  = 18 billion billion subnet addresses

- 2^{48} site addresses

  = 281,474,976,710,656

  = 281 thousand billion site addresses

IPv6 address format

2001:0DA8:E800:0000:0260:3EFF:FE47:0001

- 8 groups of 4 hexadecimal digits
  - Each group represents 16 bits
  - Separator is ":"
  - Case-independent

IPv6 address format

2001:0DA8:E800:0000:0260:3EFF:FE47:0001

↓

2001:DA8:E800:0:260:3EFF:FE47:1

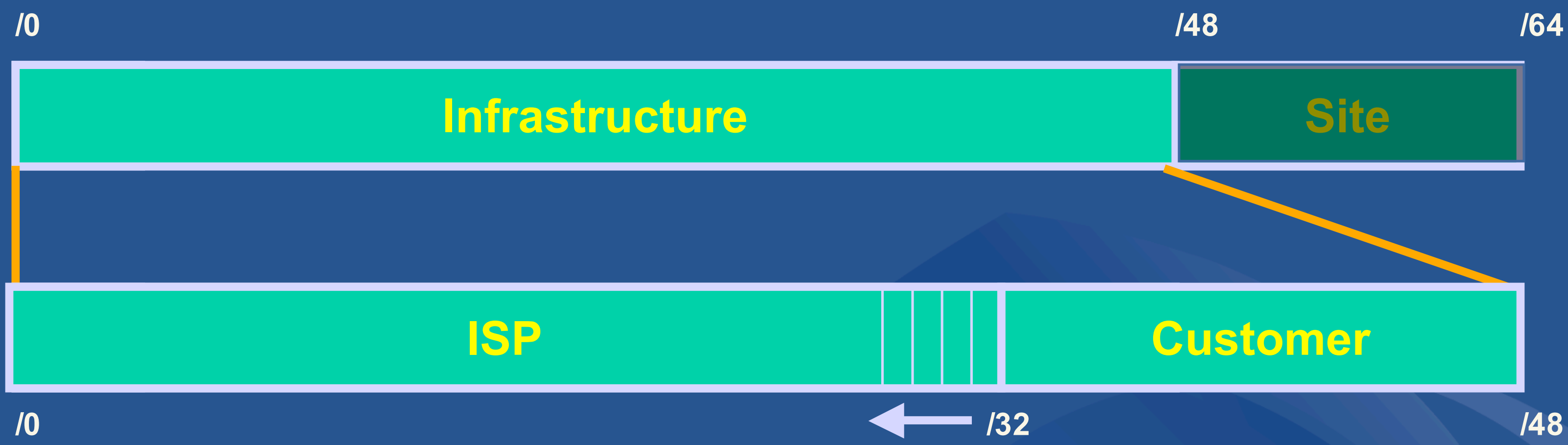
2001:0DA8:E800:0000:0000:0000:0000:0001

↓

2001:DA8:E800::1

IPv6 Address Structure

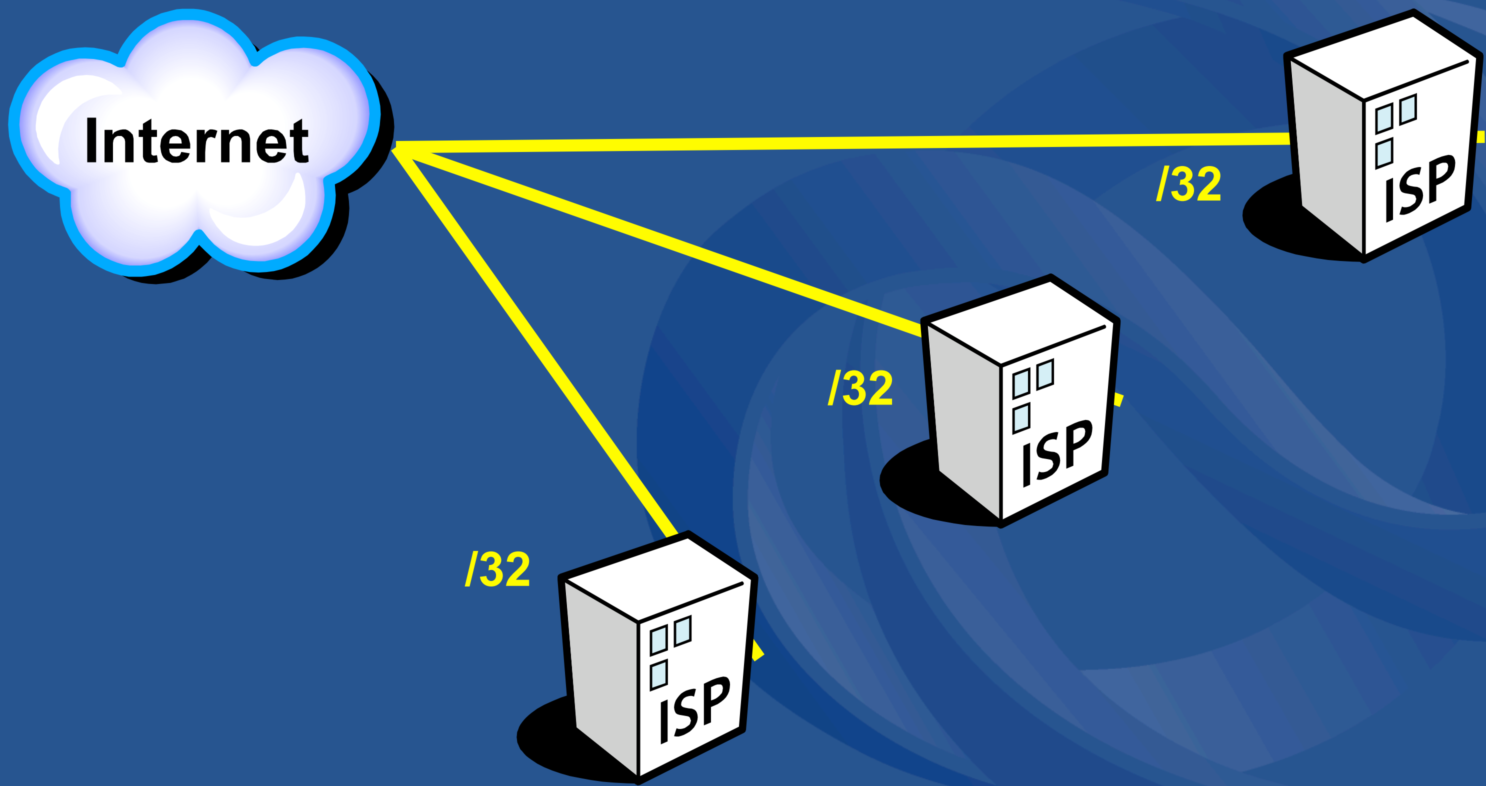
IPv6 address structure



- Current ISP allocation (min) is /32
  - Providing 2^{16} = 65,536 customer site addresses
  - ISP allocation can be larger and can increase
- Each site address is /48
  - Providing 2^{16} = 65,536 subnet addresses

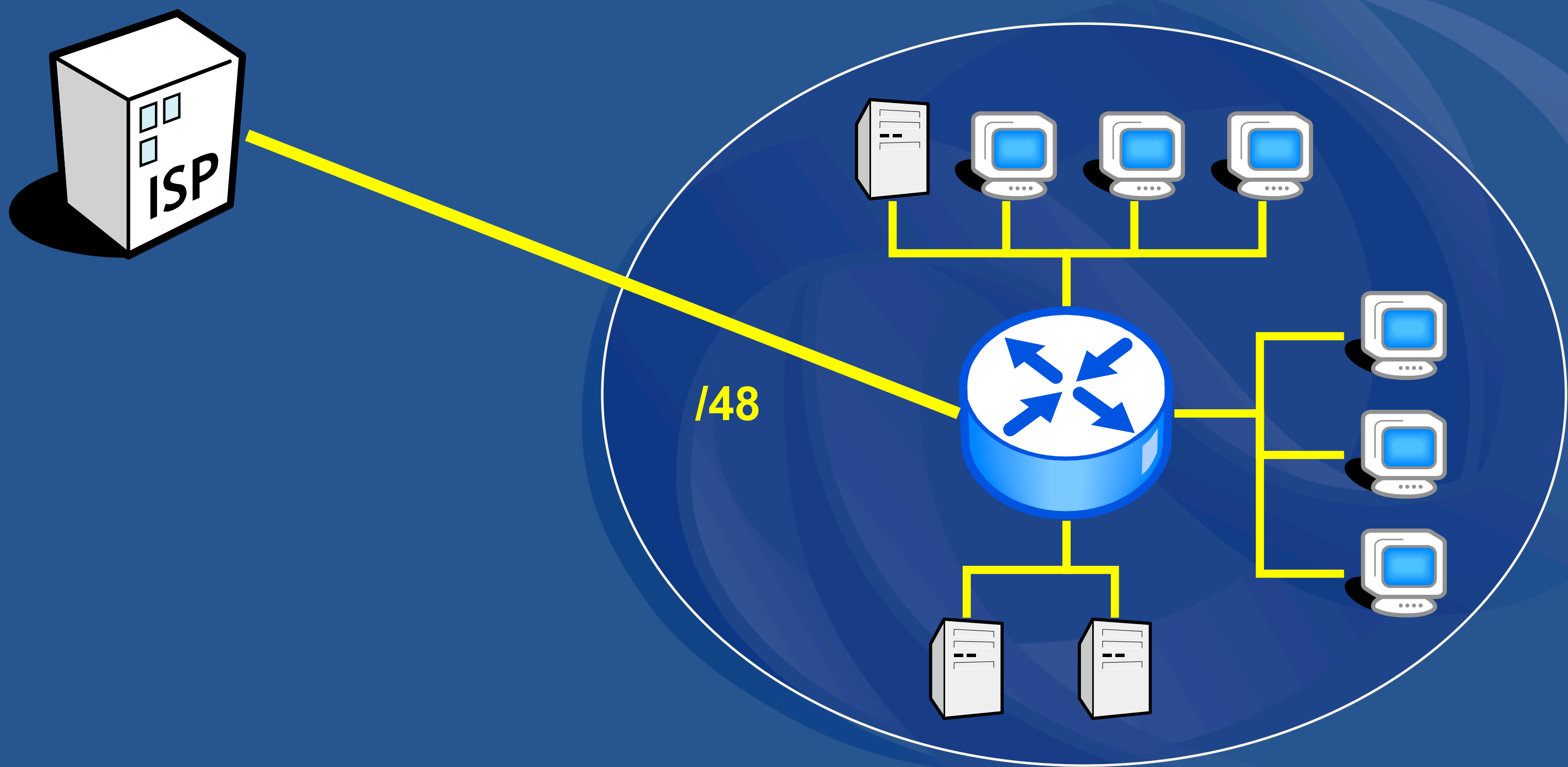
IPv6 – ISP addressing

- Every ISP receives a /32 (or more)
  - Providing 65,536 site addresses (/48)



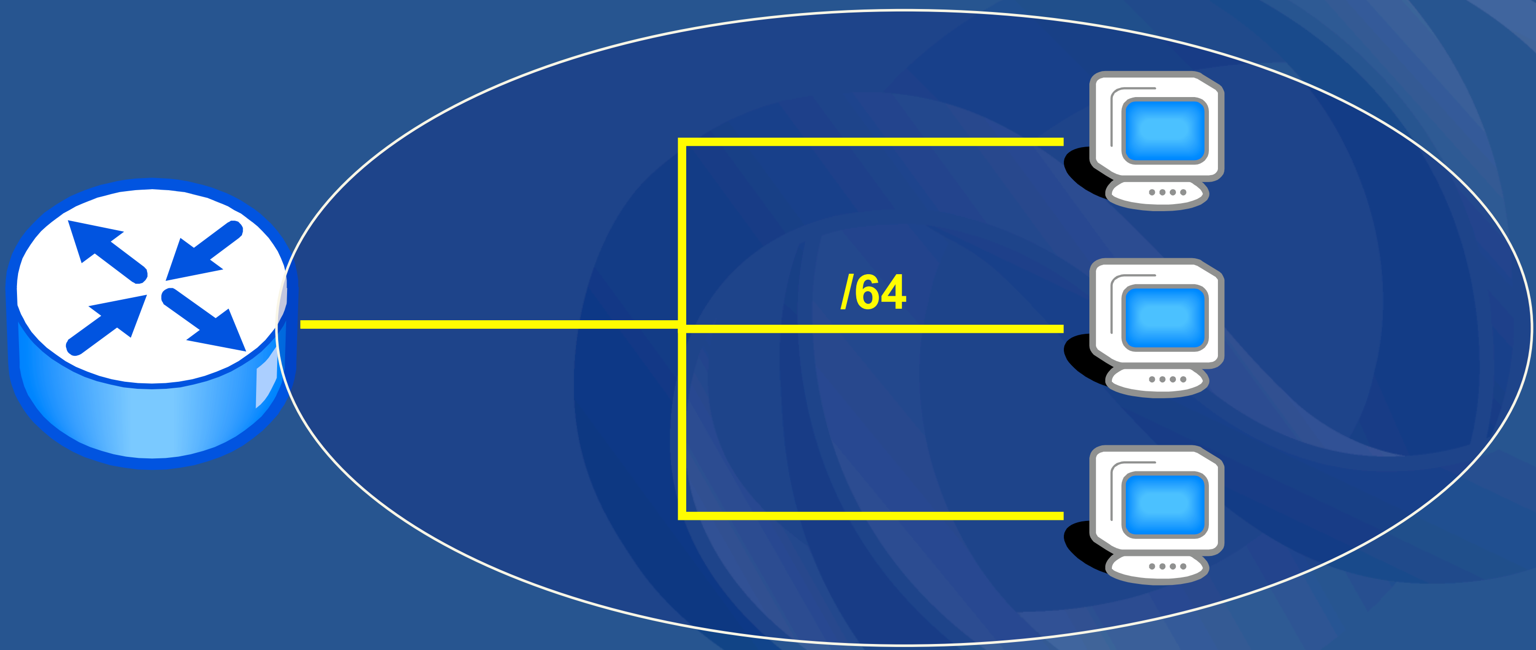
IPv6 – Site addressing

- Every "site" receives a /48
  - Providing 65,536 /64 (LAN) addresses



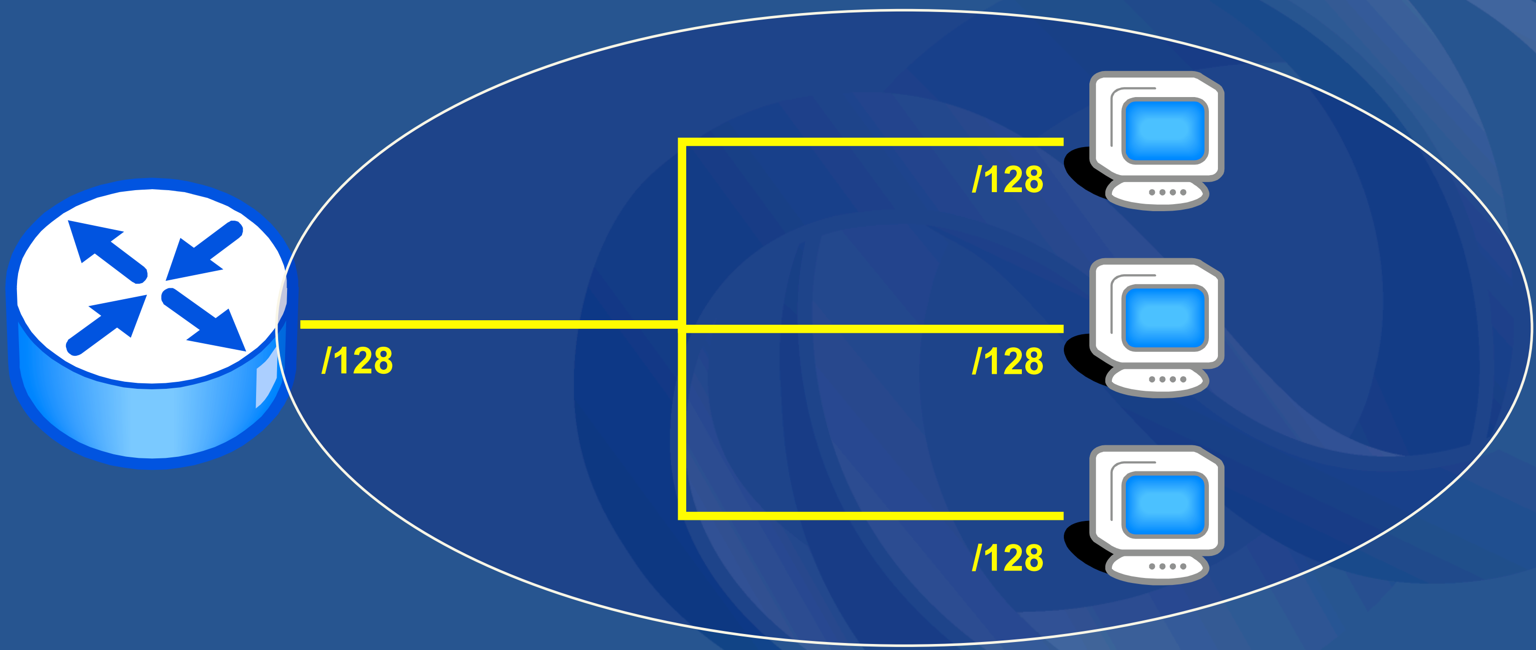
IPv6 – LAN addressing

- Every LAN segment receives a /64
  - Providing 2^{64} interface addresses per LAN



IPv6 – Device addressing

- Every device interface receives a /128
  - May be EUI-64 (derived from interface MAC address), random number (RFC 3041), autoconfiguration, or manual configuration



IPv6 Policy

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IPv6 policy – Overview

- Policy background
- Addressing structure
- IPv6 utilisation – HD ratio
- Initial allocation criteria
- Subsequent allocation criteria
- Address assignment policies
- Other allocation conditions
- Other policies

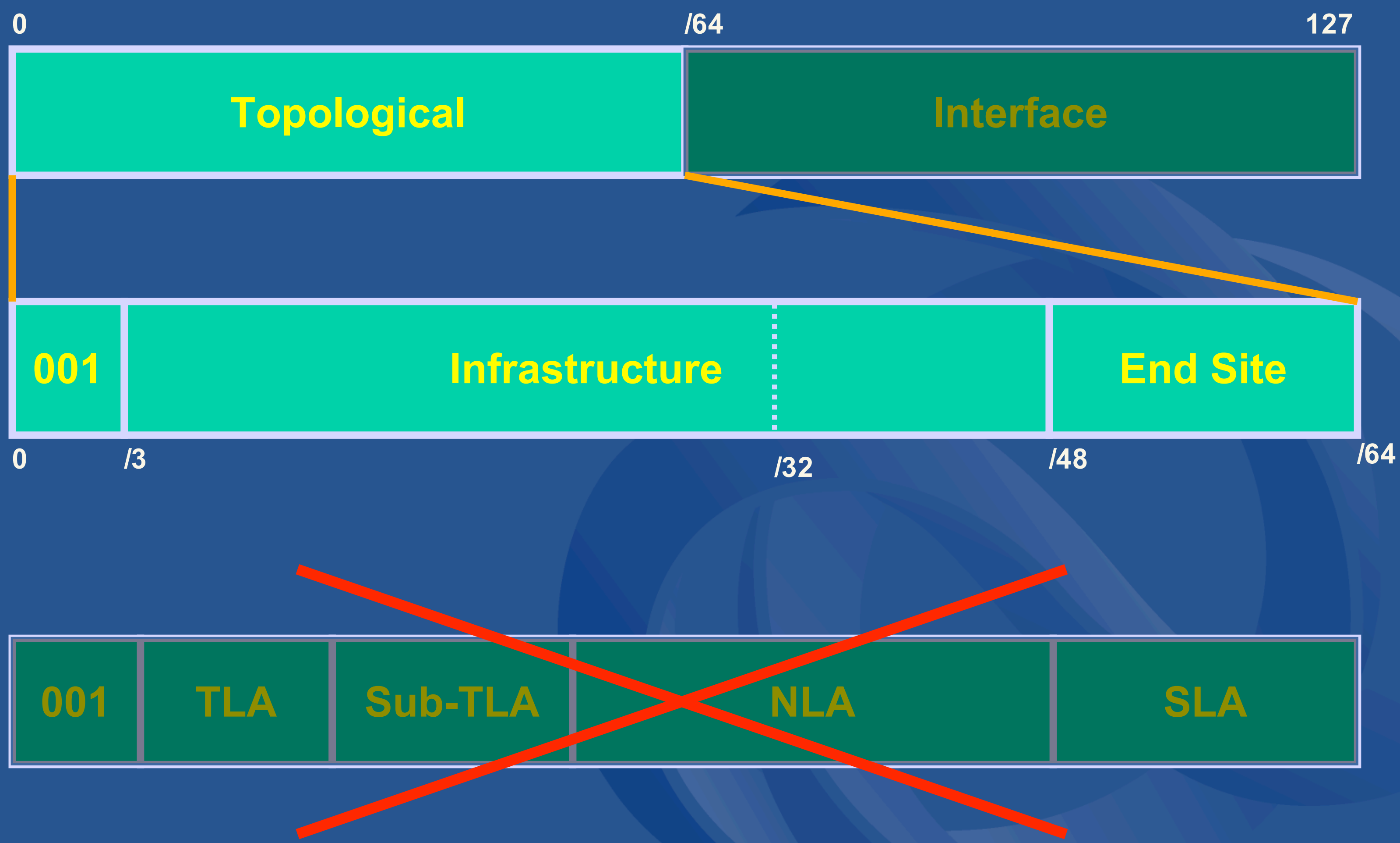
IPv6 policy – History

- IPv6 policy is "Common Policy" of all RIRs
  - The same policy has been adopted by all
  - Regional adjustment is possible
- First policy published in 1999
  - "Provisional IPv6 Policy" adopted by all RIRs
- Policy revised in 2002
  - After extensive review by all RIRs
- Next policy review
  - Currently under discussion
- Public mailing lists and documentation
  - See http://www.apnic.net

IPv6 address space management

- RIR receives allocations from IANA
  - Currently in /23 units (/16 proposed)
- RIR makes allocation to “ISP” (or “LIR”)
  - ISP must demonstrate need for addresses
  - Policies dictate how need can be demonstrated
  - First allocation minimum is /32
  - Subsequent allocations as needed, when current allocation is fully utilised
- ISP makes assignment to customers
  - Including downstream ISPs
- Provider-based addressing
  - ISP should aggregate address announcement
  - Customer addresses are not portable

IPv6 address structure



IPv6 utilisation – HD Ratio

- Under IPv4, address space utilisation measured as simple percentage:

$$Utilisation = \frac{assigned}{available}$$

- IPv4 utilisation requirement is 80%
  - When 80% of address space has been assigned or allocated, LIR may receive more
  - E.g. ISP has assigned 55,000 addresses from /16

$$\frac{assigned}{available} = \frac{55{,}000}{65{,}536} = 84\%$$

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IPv6 utilisation – HD Ratio

- Under new IPv6 policy utilisation is determined by HD-Ratio (RFC 3194):

$$Utilisation_{HD} = \frac{\log(assigned)}{\log(available)}$$

- IPv6 utilisation requirement is HD=0.80
  - Measured according to end-site assignments only (intermediate allocations are ignored)
  - E.g. ISP has assigned 10,000 addresses from /32

$$\frac{\log(assigned)}{\log(available)} = \frac{\log(10{,}000)}{\log(65{,}536)} = 0.83$$

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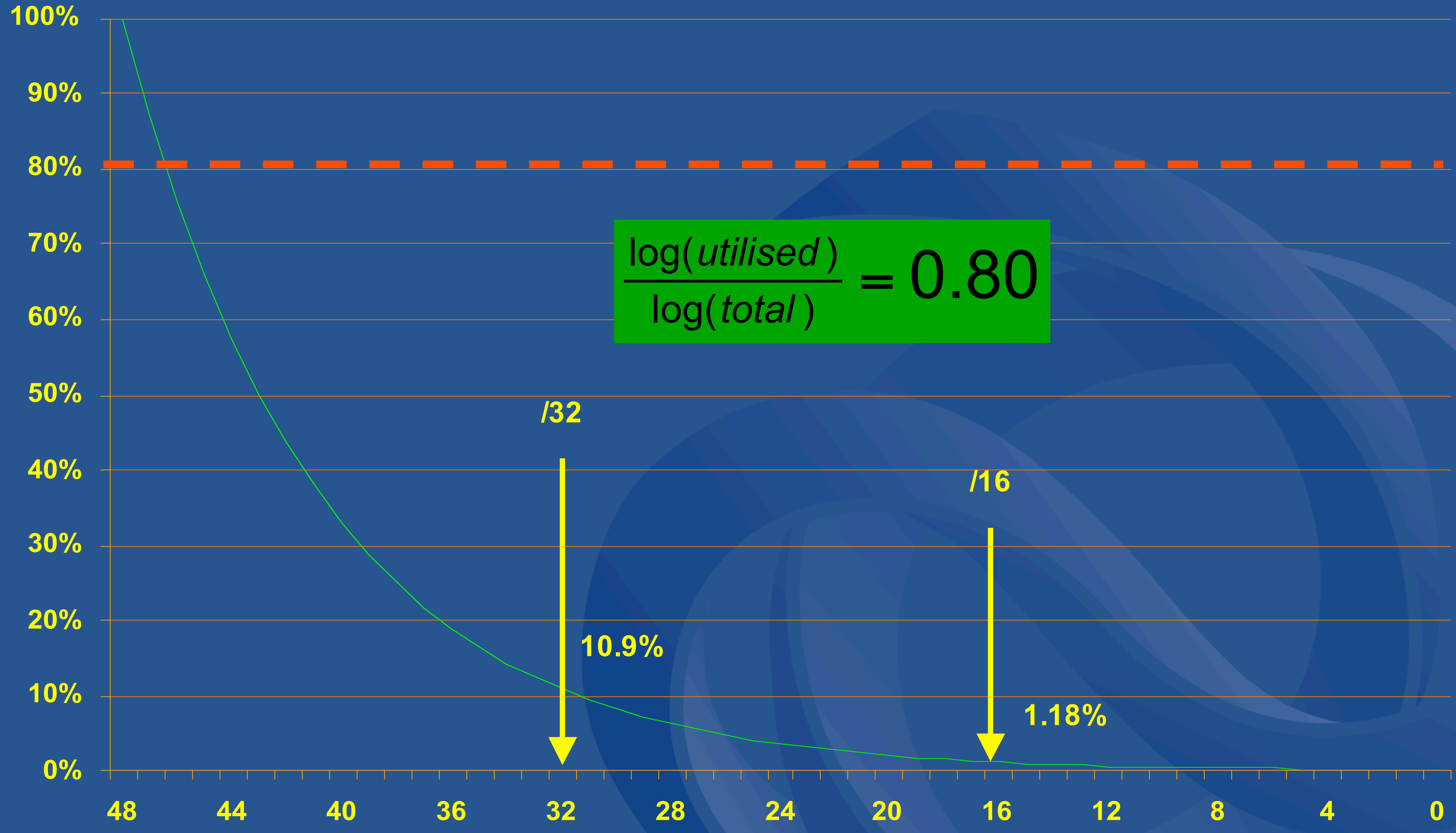
IPv6 utilisation (HD = 0.80)



$$\frac{\log(utilised)}{\log(total)} = 0.80$$

RFC3194 “The Host-Density Ratio for Address Assignment Efficiency”

IPv6 utilisation (HD = 0.80)

- Percentage utilisation calculation

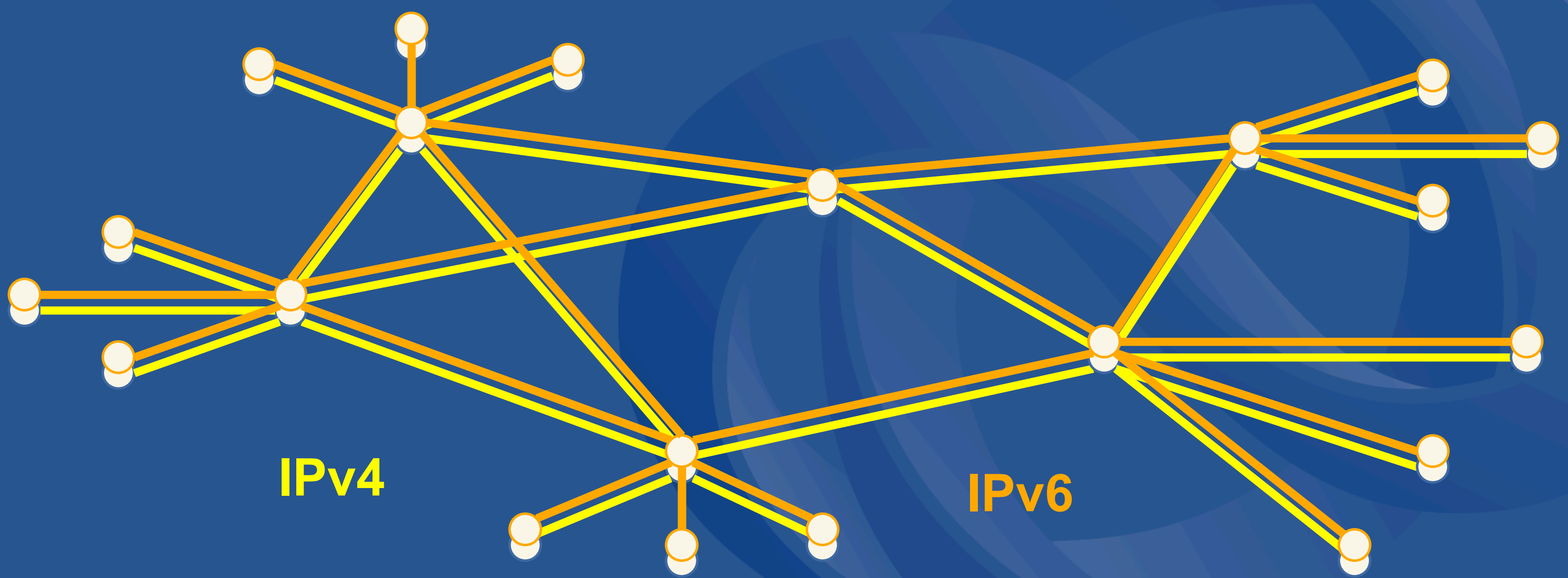
IPv6 Prefix	Site Address Bits	Total site address in /48s	Threshold (HD ratio 0.8)	Utilisation %
/42	6	64	28	43.5 %
/36	12	4096	776	18.9 %
/35	13	8192	1351	16.5 %
/32	16	65536	7132	10.9 %
/29	19	524288	37641	7.3 %
/24	24	16777216	602249	3.6 %
/16	32	4294967296	50859008	1.2 %
/8	40	1099511627776	4294967296	0.4 %
/3	45	35184372088832	68719476736	0.4 %

IPv6 initial allocation criteria

- Initial allocation size is /32
  - Allocated to any IPv6 LIR (ISP) planning to connect 200 End Sites within 2 years
  - Need not be connected to the Internet
  - This is the default initial allocation to "new" ISPs ("slow start" policy)
- Larger initial allocations can be made if justified according to:
  - IPv6 network infrastructure plan
  - Existing IPv4 infrastructure and customer base

IPv6 allocation to existing network

- Existing ISP infrastructure (IPv4)
  - Policy assumes that transition is inevitable
  - Large IPv4 ISPs will receive IPv6 allocations consistent with the scale of existing networks



IPv6 allocation to existing network

- Allocation size calculated from existing IPv4 network infrastructure and customers:
  - 1 IPv6 /48 per customer
  - 1 IPv6 /48 per POP
- Total allocation according to HD-ratio utilisation requirement
  - Eg if 500,000 /48s are required then /24 can be allocated

IPv6 assignments

- Default assignment /48 for all “End Sites”
  - Providing /16 bits of space for subnets
  - Each end site can have 65,536 subnets
- “End Site” defined as an end user of an ISP where:
  - The ISP assigns address space to the end user
  - The ISP provides Internet transit service to the end user
  - The ISP advertises an aggregate prefix route that contains the end user's assignment
  - Multiple subnets are required
- Examples
  - Home, small office, large office, mobile devices?
  - ISP POPs are also defined as End Sites

IPv6 assignments

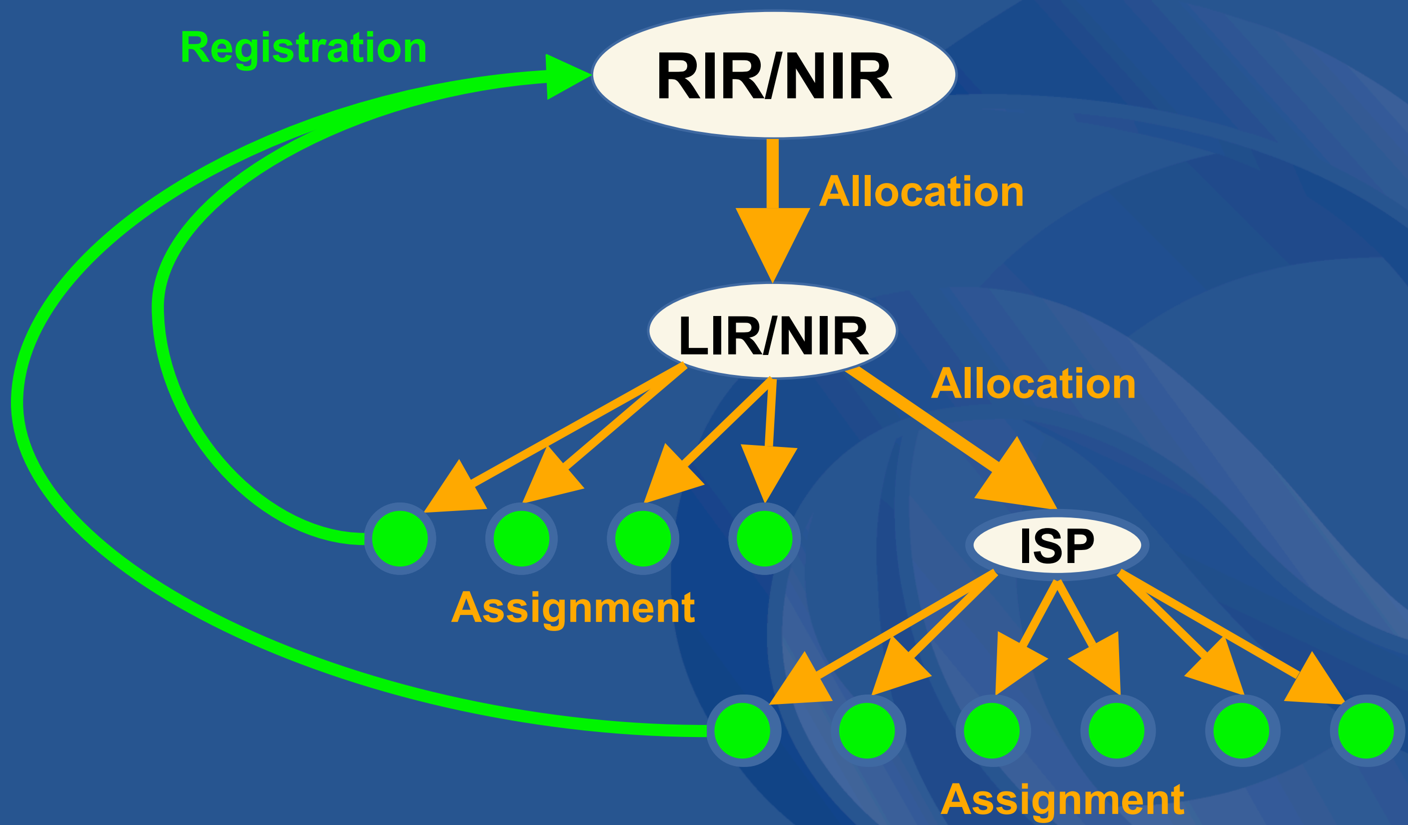
- Larger assignments: Multiple /48s
  - Some end sites will need more than one /48
  - Requests to be reviewed at RIR level
- Smaller assignments: /64
  - Single subnet devices should receive /64 only
  - e.g. simple mobile phone
- Smaller assignments: /128
  - Devices with no subnets should receive /128 only
  - E.g. remote sensor
- See RFC3177 (Sep 2001)

IPv6 assignments

- IPv6 assignments to End Sites are used to determine utilisation of IPv6 address blocks
  - According to HD-Ratio
  - Intermediate allocation hierarchy (ie downstream ISP) not considered
  - All assignments must be registered
  - Utilisation is determined from total number of registrations
- Intermediate allocation and assignment practices are the responsibility of the LIR
  - Downstream ISPs must be carefully managed

IPv6 registration

- LIR is responsible for all registrations



Subsequent IPv6 allocation

- Subsequent allocation can be made when ISP's existing address space reaches required utilisation level
  - i.e. HD >= 0.80
- Other address management policies must also be met
  - Correct registrations
  - Correct assignment practices etc (eg RFC 3177)
- Subsequent allocation size is at least double
  - Resulting IPv6 Prefix is at least 1 bit shorter
  - Or sufficient for at least 2 years requirement

Other allocation conditions

- License model of allocation
  - Allocations are not considered permanent, but always subject to review and reclamation
  - Licenses renewed automatically while addresses in use, consistent with policies
- Existing /35 allocations
  - A number of /35s have been assigned under previous "provisional" IPv6 policy
  - Holders of /35s are eligible to request /32

IPv6 IXP assignments

- Available to Internet Exchange Points as defined
  - Must demonstrate ‘open peering policy’
  - 3 or more peers
- Portable assignment size: /48
  - Not to be announced
  - All other needs should be met through normal processes
  - Previous /64 holders can “upgrade” to /48

IPv6 critical infrastructure

- Available to facilities defined as "critical infrastructure"
  - Root servers
  - RIRs and NIRs
  - ccTLD registries
- Assignment size: /32

IPv6 experimental allocation

- Available for experimental purposes
  - Public experiments only
  - Legitimate experiments documented by RFC, I-D or other formal process
  - APNIC may seek independent expert advice

- Allocation size: /32
  - May be larger if required
  - Address space must be returned after 1 year

IPv6 policy – Current issues

- Size of IANA allocation to RIRs
  - Currently under review
- Size of initial allocation
  - /32 for normal allocations
  - HD-ratio applied for allocation to existing IPv4 infrastructure
- HD-ratio
  - Is 0.8 the appropriate value?
- Assignments under RFC 3177
  - No experience yet
- All issues can be reviewed through APNIC open policy process

IPv6 Policy – Summary

- IPv6 address space is easily available
  - Criteria may be hardened in future
- Policy is subject to review
  - Policies evolve as experience is gained
  - Any member of the community may propose changes, alternatives
- Public mailing lists and documentation
  - http://www.apnic.net/

References

APNIC References

- APNIC website
  - http://www.apnic.net
- APNIC IPv6 Resource Guide
  - http://www.apnic.net/services/ipv6_guide.html
- Includes:
  - Policy documents
  - Request forms
  - FAQs

Other References

- IPv6 Forum
  - http://www.ipv6forum.org
- 6Bone
  - http://www.6bone.net
- “The case for IPv6”
  - http://www.6bone.net/misc/case-for-ipv6.html

Questions?

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