The Geography and Governance of Internet Addresses
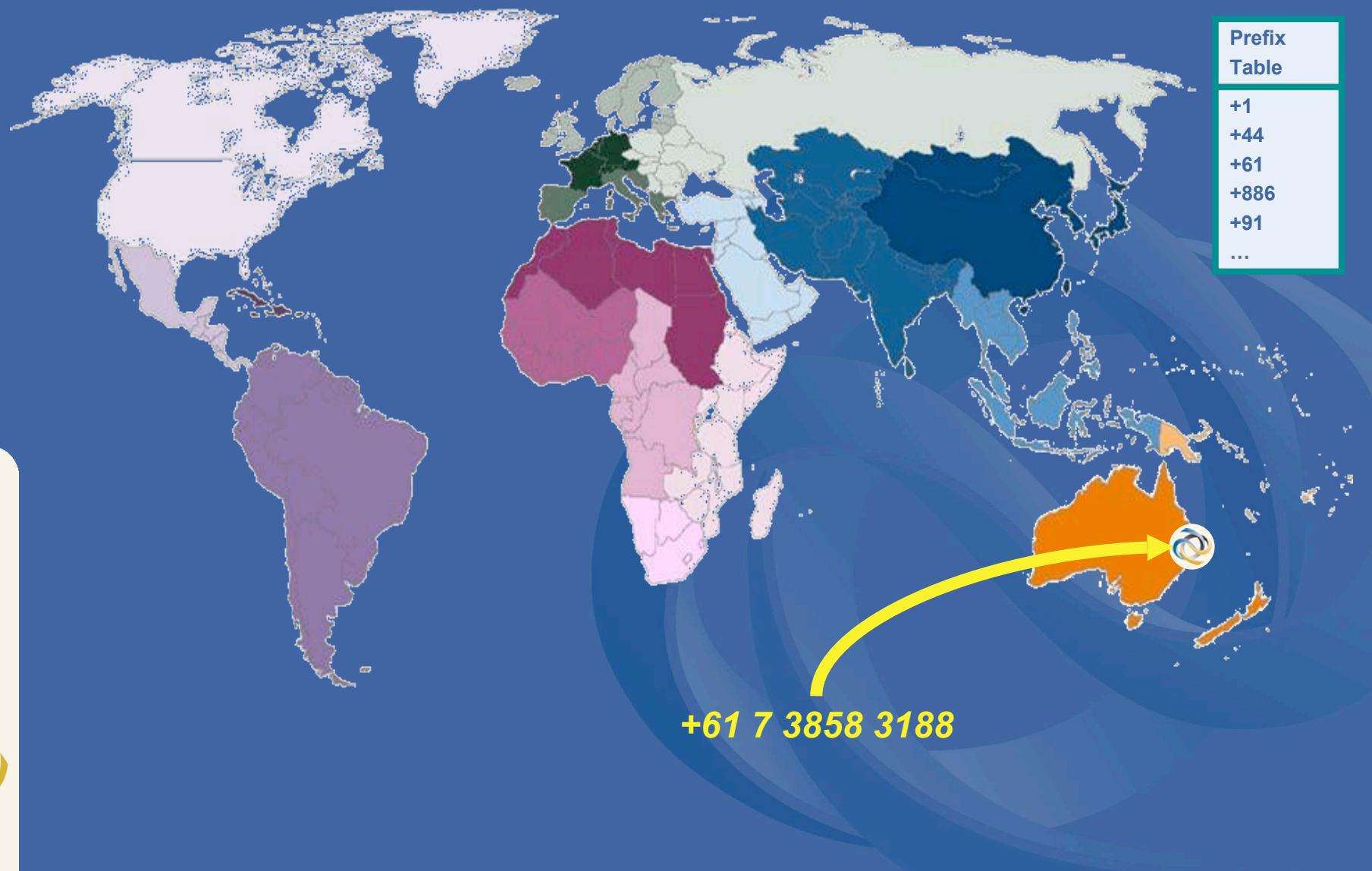
Paul Wilson

APNIC

What is an IP address?
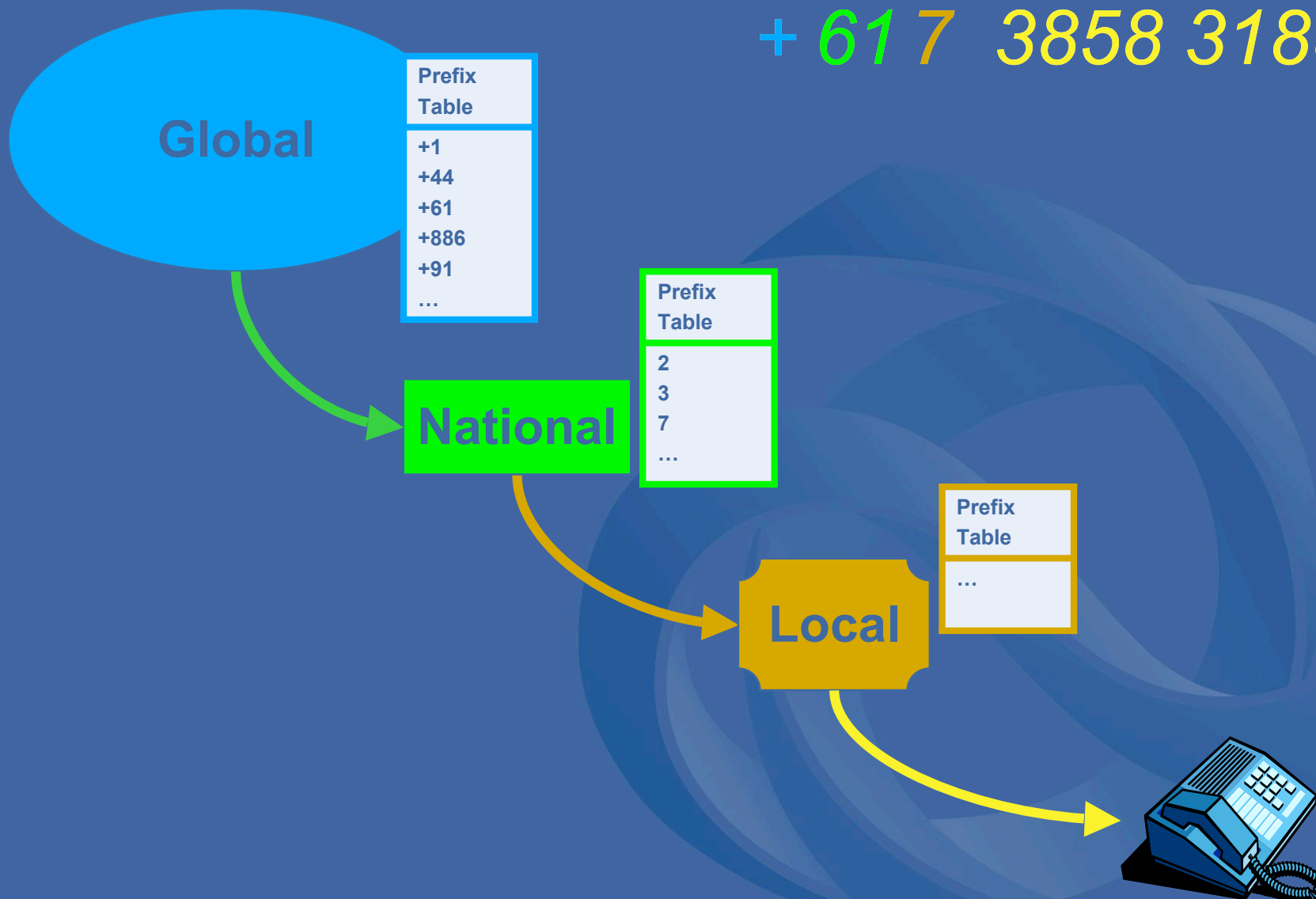
APNIC

What is an address?

- *An identifier which includes information about how to find its subject*
    - (according to some rules of interpretation)
- Normally hierarchical
    - Each part provides more specific detail
- For example…
    - +61 7 3858 3188
    - www.apnic.net
    - pwilson@apnic.net
    - 202.12.29.142

APNIC

Telephone network geography

Prefix Table

+1
+44
+61
+886
+91
…

+61 7 3858 3188

Telephone network routing

$+$ *61 7 3858 3188*

Global

Prefix Table
+1
+44
+61
+886
+91
...

National

Prefix Table
2
3
7
...

Local

Prefix Table
...

What is an IP address?

- *Internet identifier including information about how to reach a network location*
  - (via the Internet routing system)
- Also a hierarchical identifier
  - Network part and Host part
  - Host part can be subdivided (subnetting)

Fixed address length

Network address	Host address

Variable prefix length
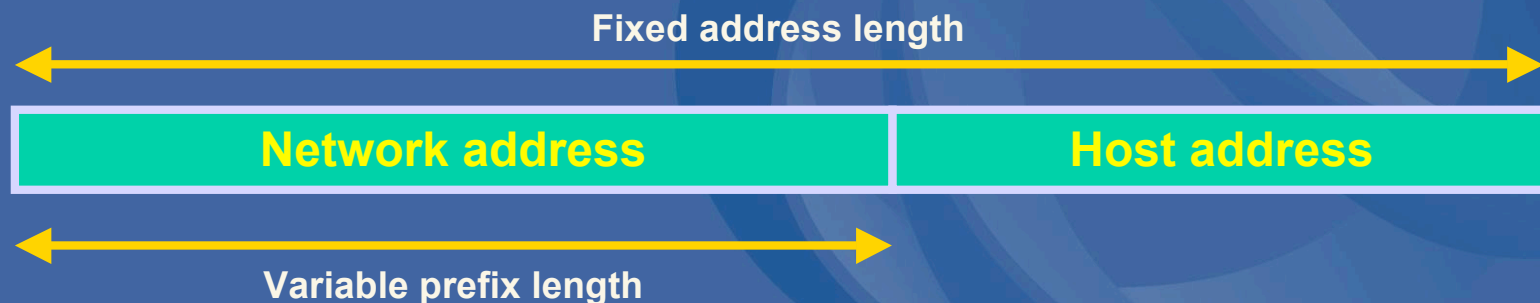
What is an IP address?

IPv4: 32 bits

2^{32} = 4,294,967,296 addresses

= 4 billion addresses

e.g. 202.12.29/24 (network address)

202.12.29.142 (host address)

IPv6: 128 bits

2^{128} = 340,282,366,920,938,463,463,374,607,431,770,000,000

= 340 billion billion billion billion addresses ?

e.g. 2001:0400::/32 (network address)

2001:0400:3c00:af92:: (host address)

APNIC

Internet address routing

The Internet

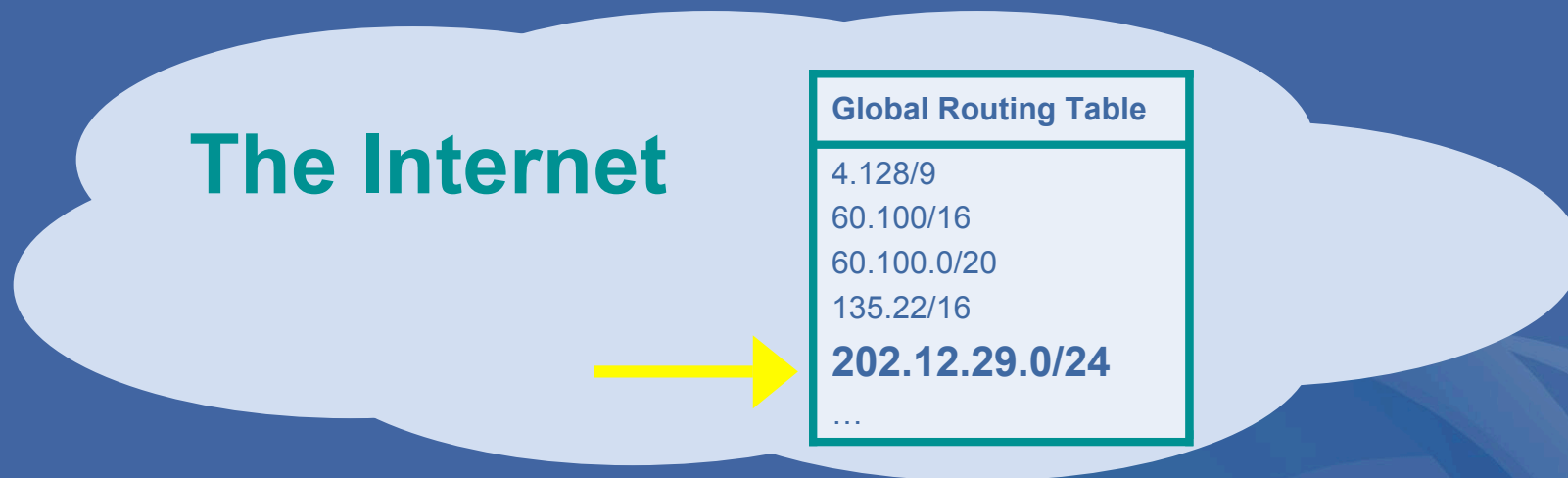**Global Routing Table**

4.128/9
60.100/16
60.100.0/20
135.22/16
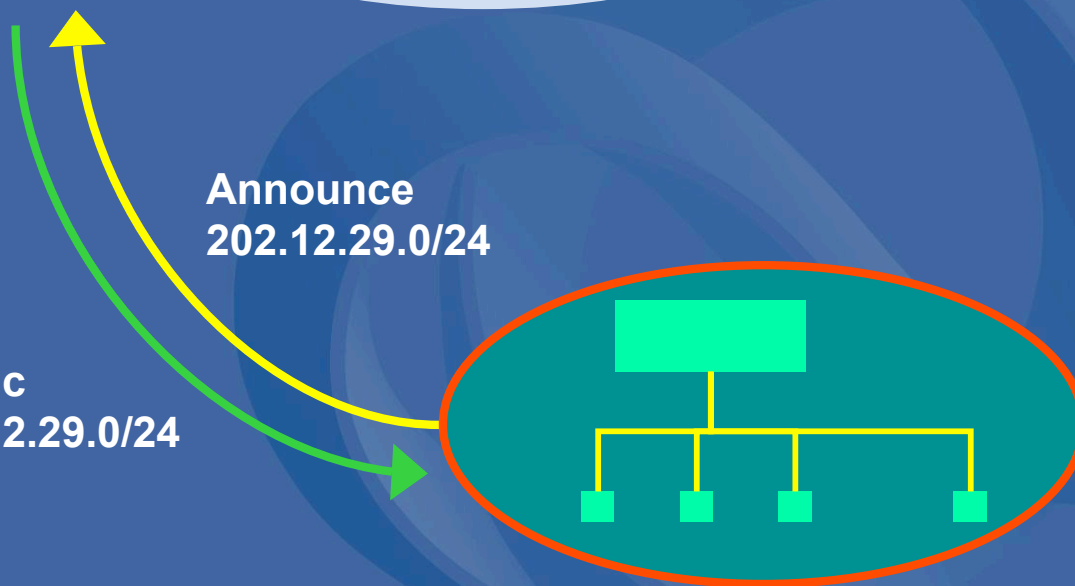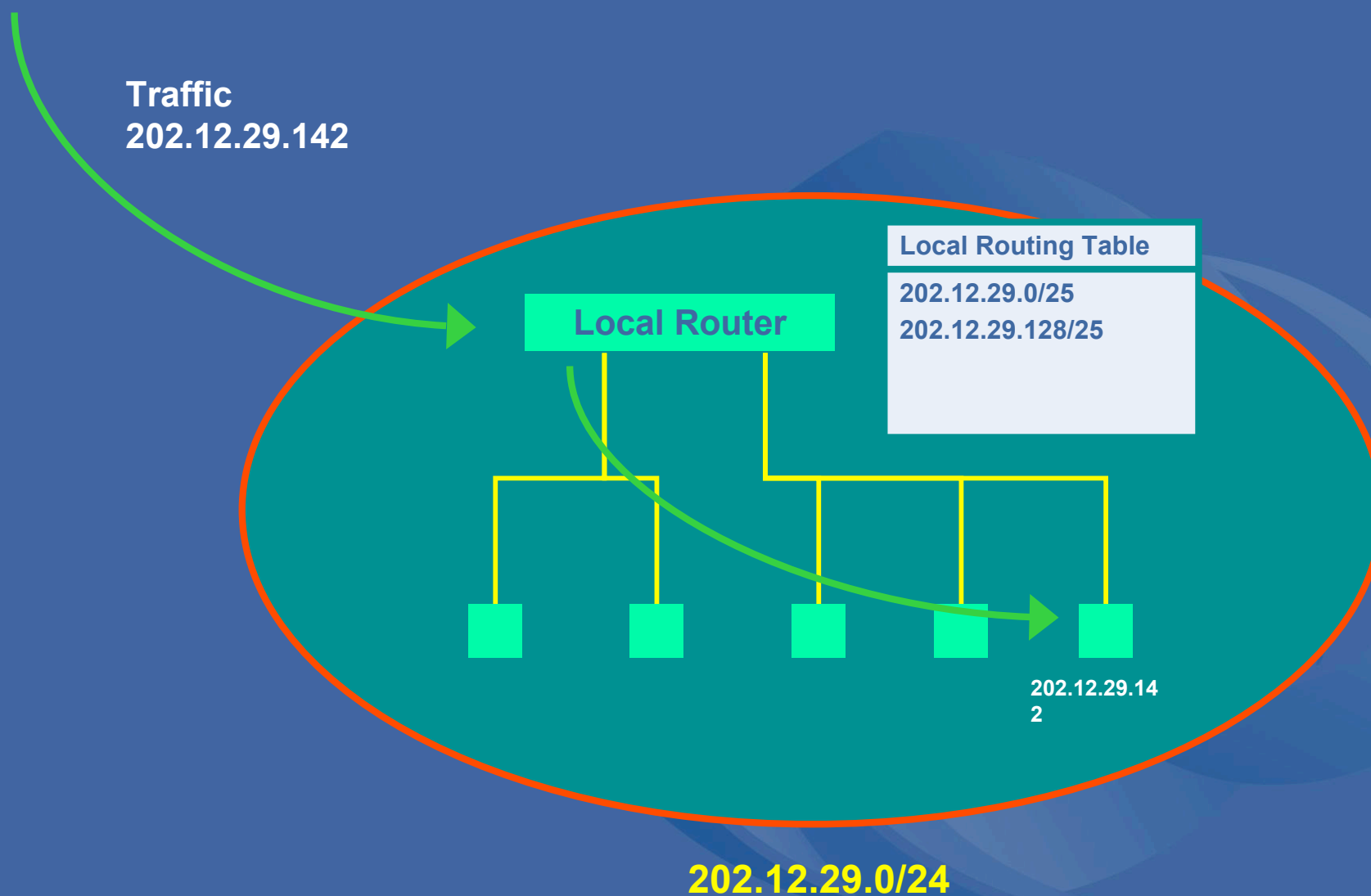**202.12.29.0/24**
…

Announce
202.12.29.0/24

Traffic
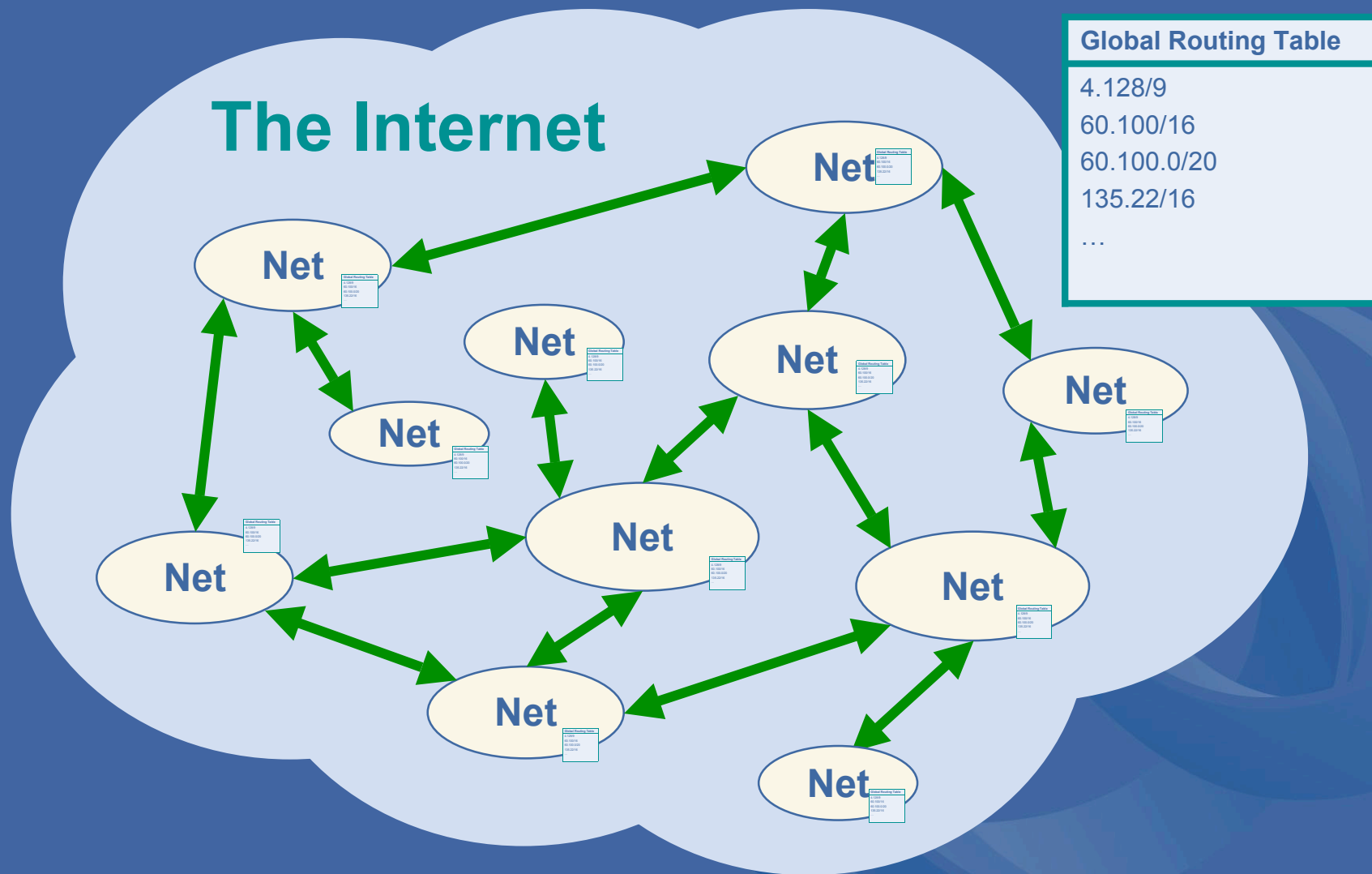**202.12.29.0/24**

202.12.29.0/24

Internet address routing

Traffic
202.12.29.142

Local Router

Local Routing Table

202.12.29.0/25
202.12.29.128/25

202.12.29.14
2

202.12.29.0/24

Global Internet routing

The Internet

Global Routing Table

4.128/9
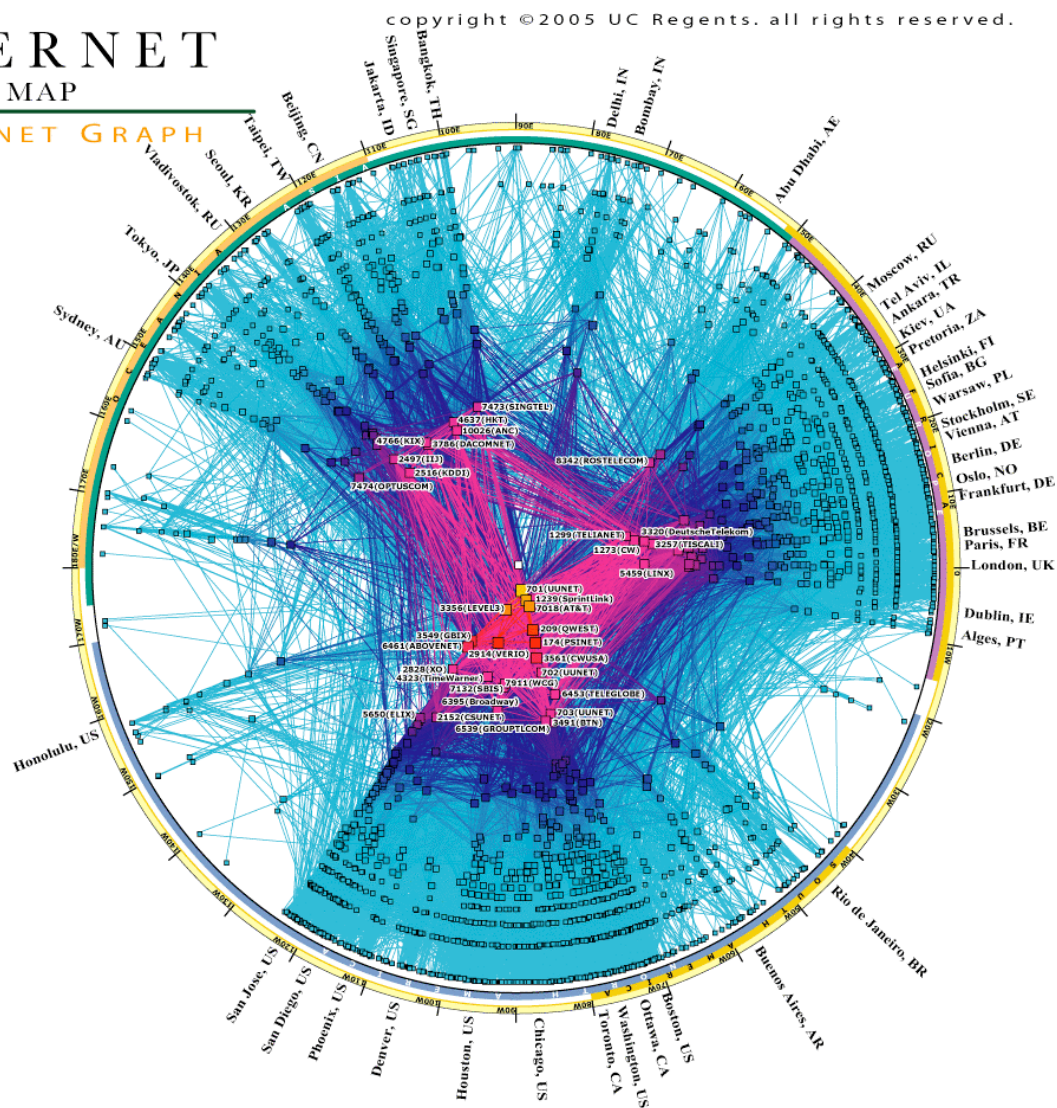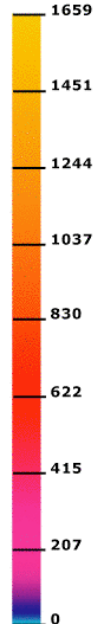60.100/16
60.100.0/20
135.22/16

…

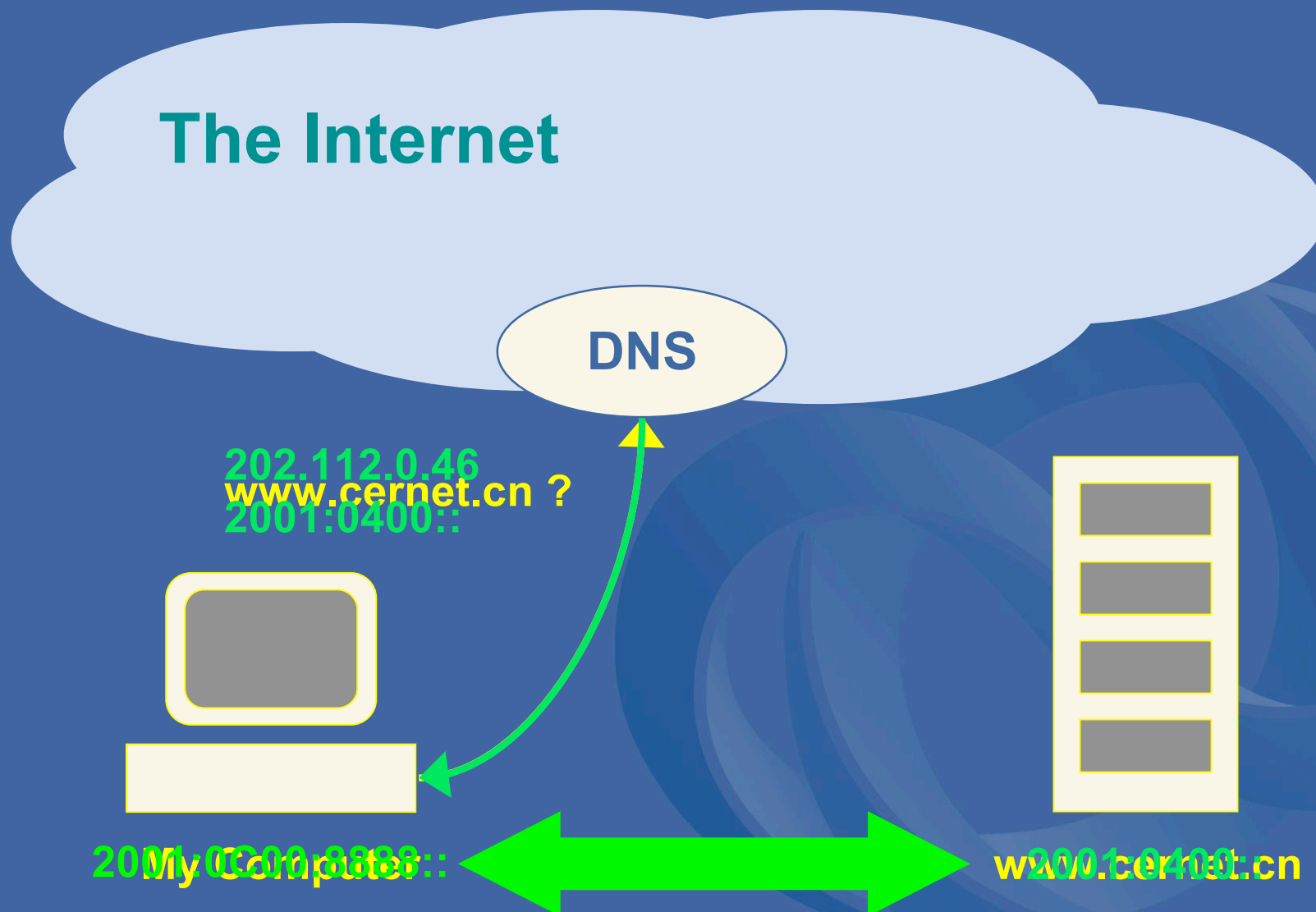# Global Internet routing

IPv4 INTERNET TOPOLOGY MAP
AS-level INTERNET GRAPH

What else is an IP address?

- Internet infrastructure addresses
- Uniquely assigned to infrastructure elements
- Globally visible to the entire Internet
- A finite "Common Resource"
- Never "owned" by address users

- Not dependent upon the DNS

IP addresses are not domain names…

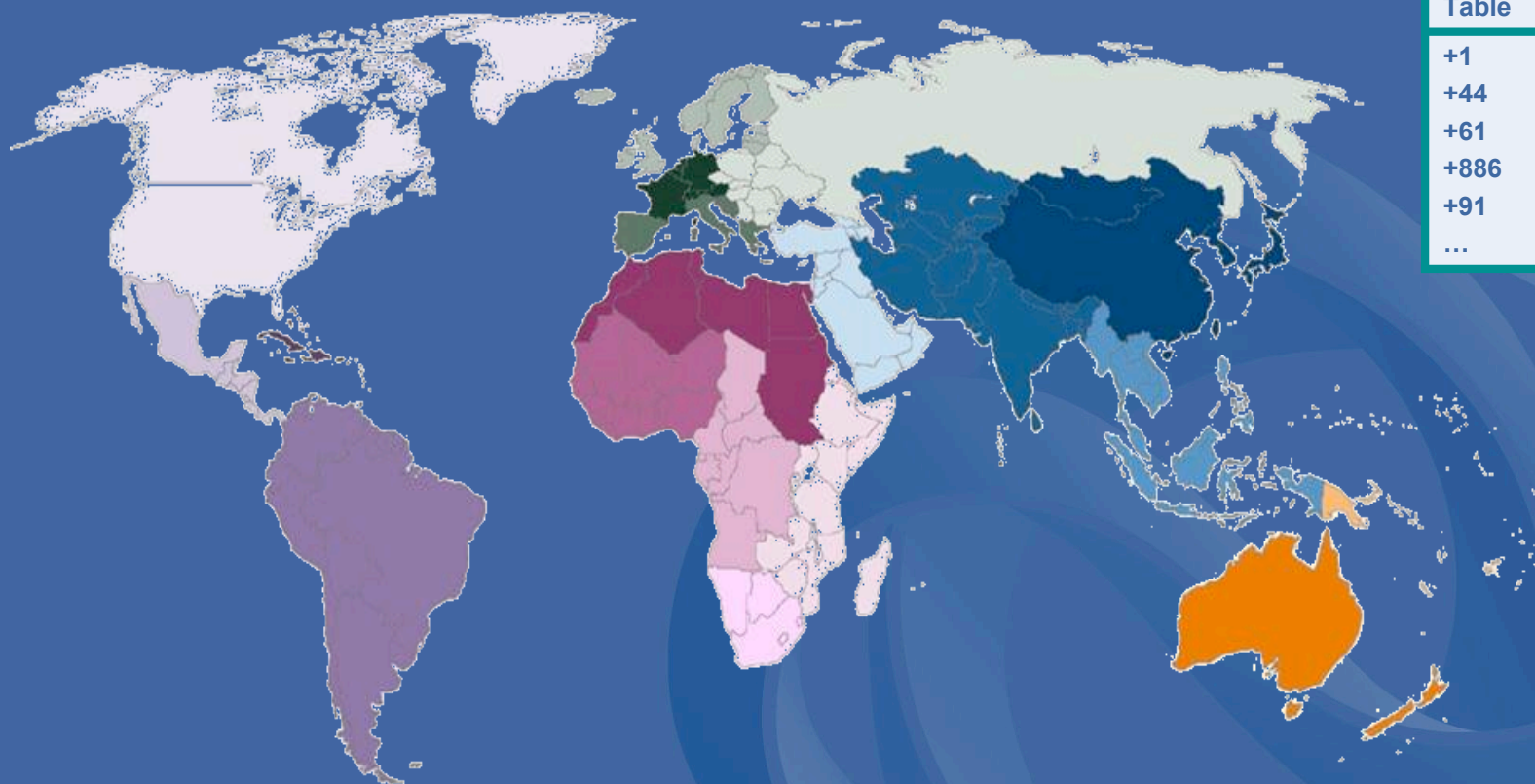The Internet

DNS

202.112.0.46
www.cernet.cn ?
2001:0400::

My Computer
2001:0c00:8888::

www.cernet.cn
2001:0400::

APNIC

Geography of the Internet

APNIC

Geography

Prefix Table
+1
+44
+61
+886
+91
…

APNIC

Internet geography

IPv4 INTERNET
TOPOLOGY MAP
AS-level INTERNET GRAPH
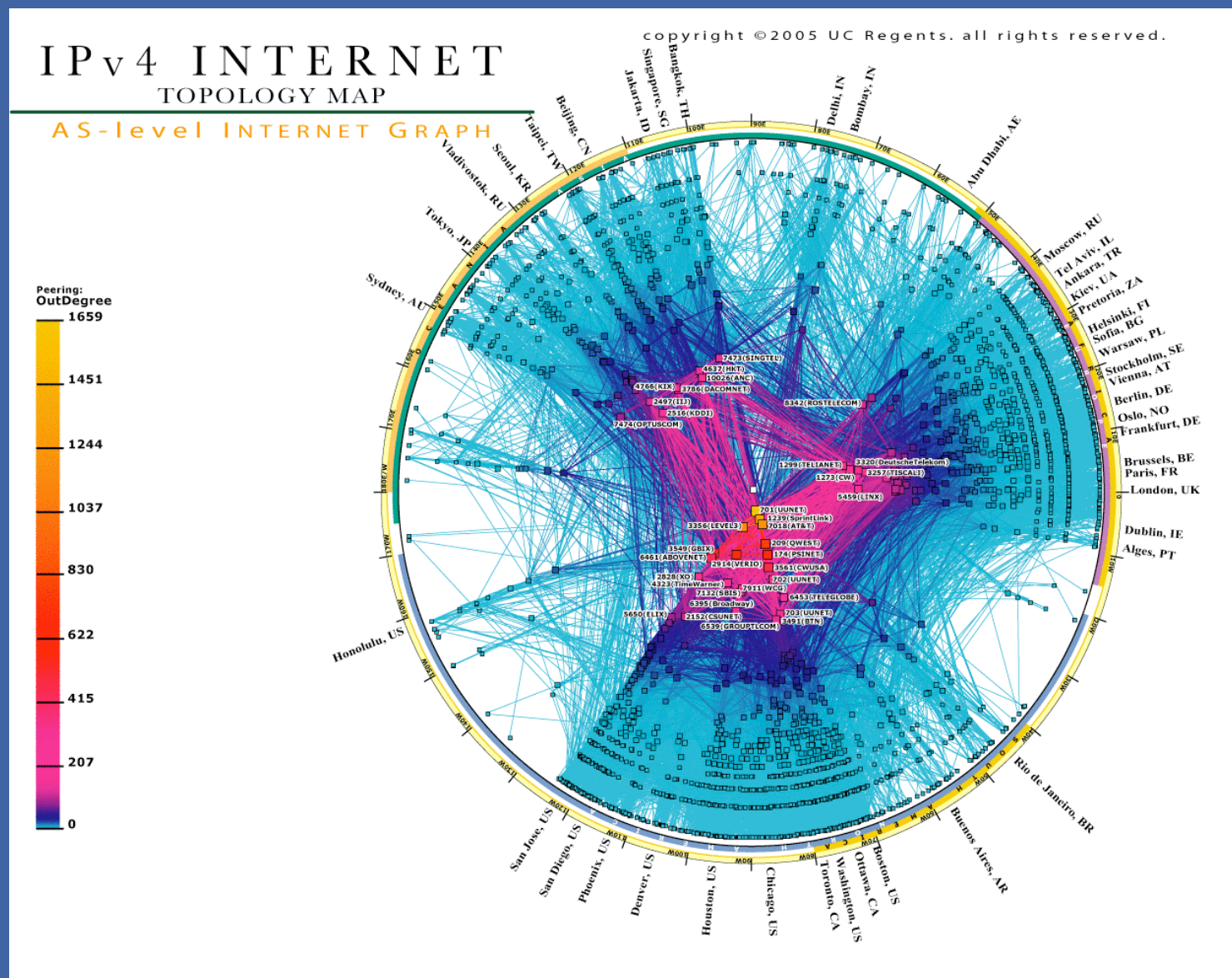
Internet geography

- Internet "Nations" are networks
  - "Frontiers" are their border routers
  - "Treaties" are peerings between them
- It's a very dynamic world…
  - New nations are formed daily
  - New frontiers are established hourly
  - Routing tables change each minute
  - Driven almost entirely by industry
  - No centralised control
- Very different from "traditional" networks
  - Telephony for example

IP Address Management

Where do IP addresses come from?

IETF

↓ **Delegate**

IANA

↓ **Allocate**

RIR / NIR

↓ **Allocate**

Network

↓ **Assign**

User
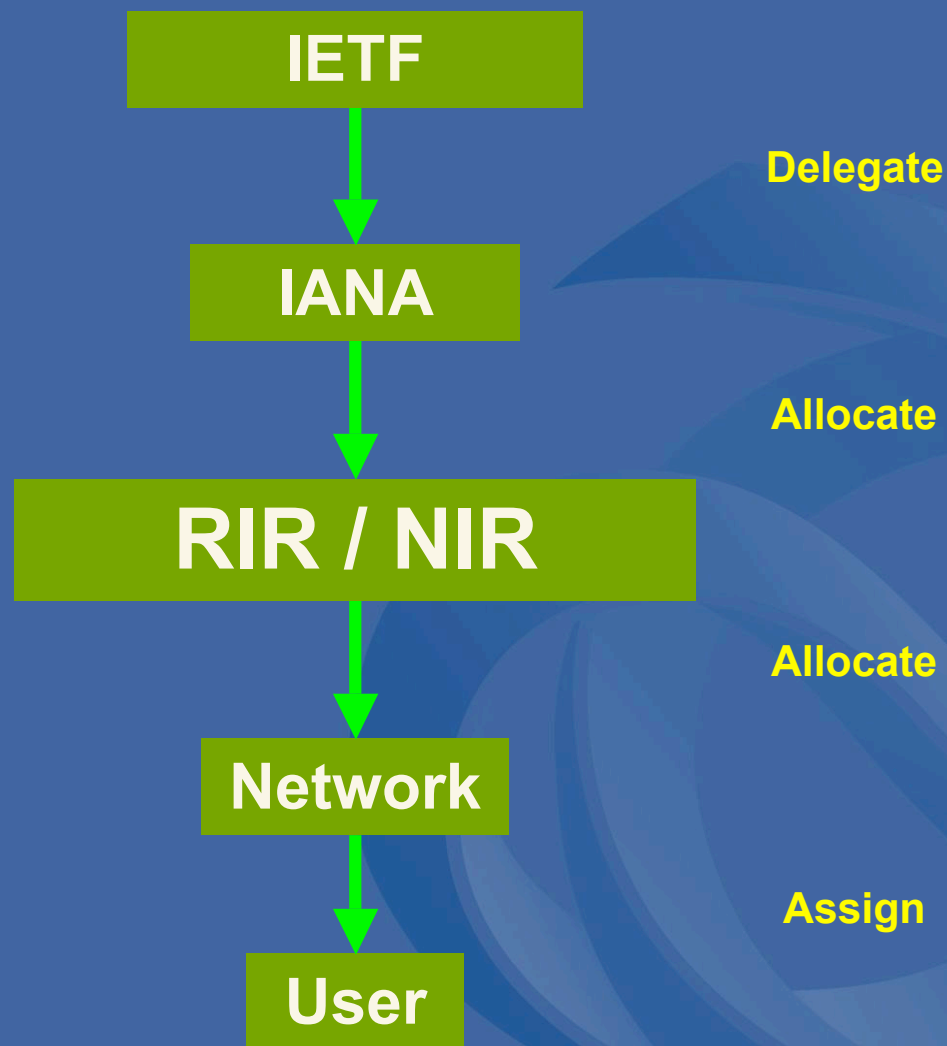
What are RIRs?

- Regional Internet Registries
  - Allocation and registration of IP addresses and related "Internet resources"
  - Open policy process
  - Technical services, training and education…
  - No involvement in DNS registration!
- First established in early 1990's
  - Voluntarily by consensus of community
  - To satisfy emerging technical/admin needs
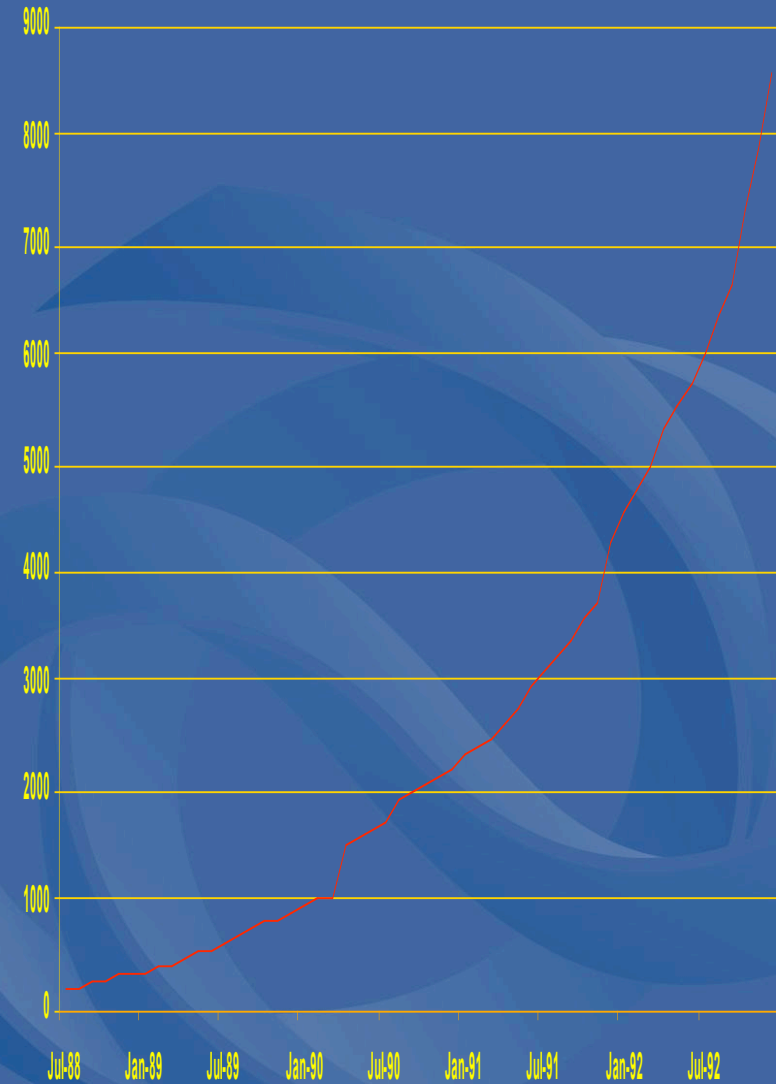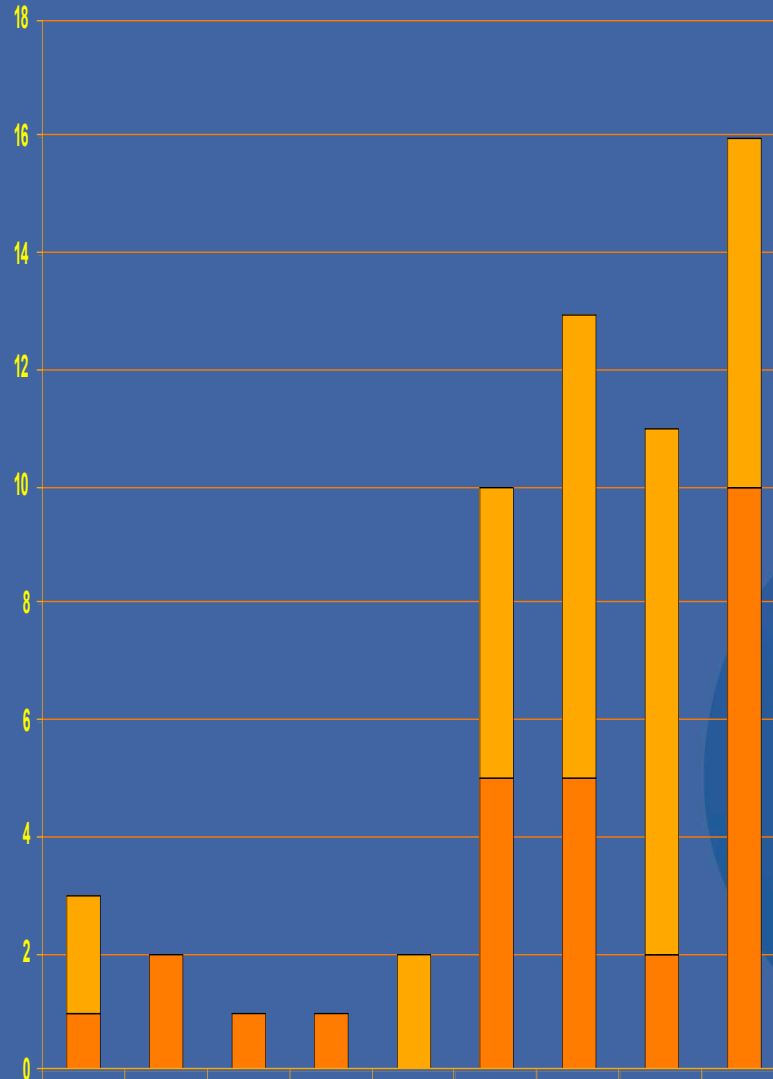
APNIC

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)
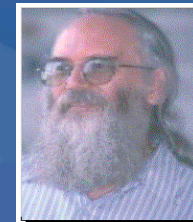
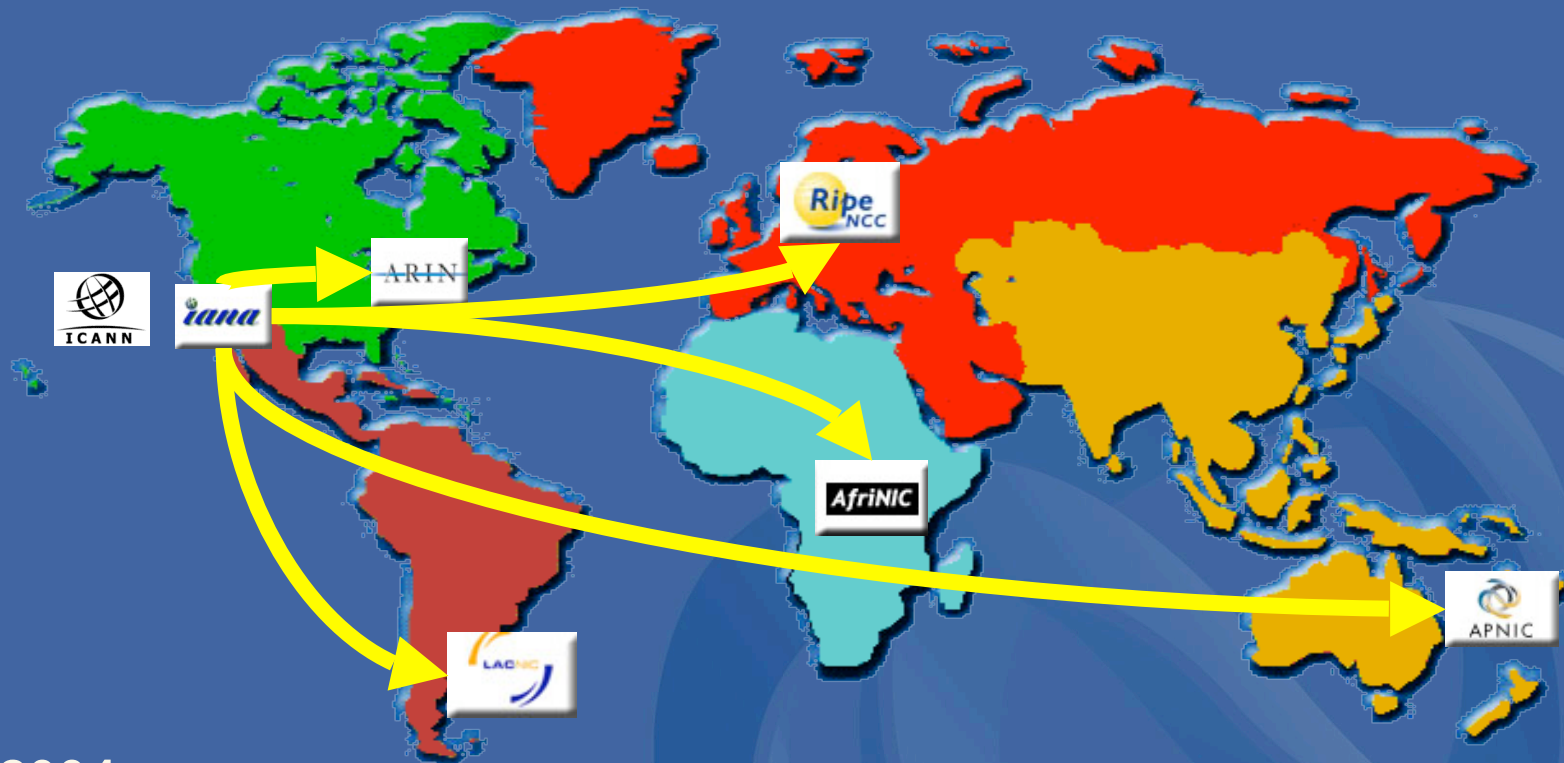# Addresses and Routing: '83 – '91

The Boom: 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)

APNIC

Today: 2002 – 2006

2004:

Number Resource Organisation

What else are RIRs?

- Industry self-regulatory structures
    - Open membership-based bodies
    - Self-funded service organisations
    - Non-profit, neutral and independent
- Participants in the ICANN process
    - Through NRO and ASO
- In the "Internet Tradition"
    - Consensus-based decision making
    - Open and transparent
    - Multi-stakeholder processes

Address Management Policies

Asia Pacific Network Information Centre
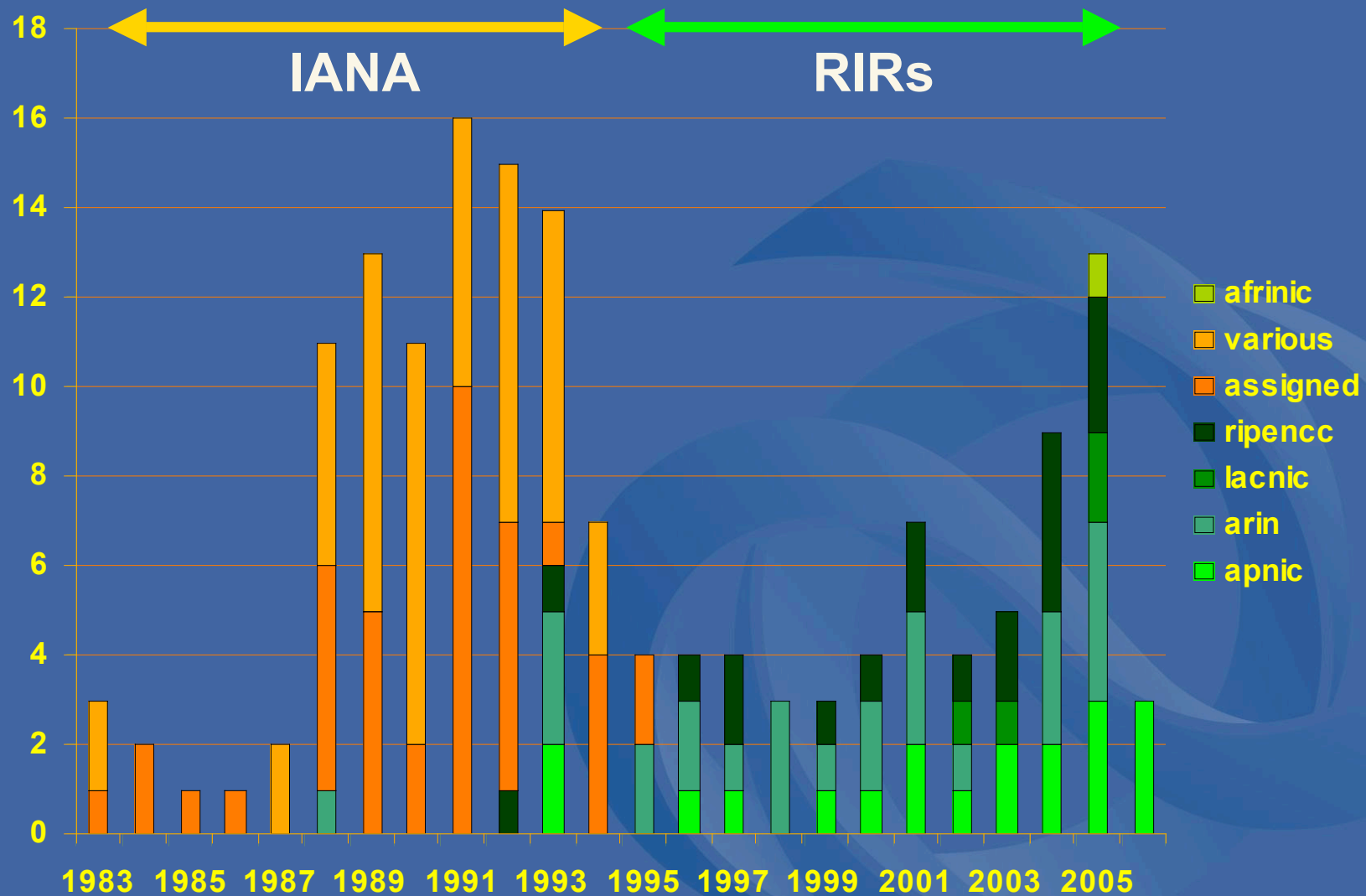
APNIC

Management objectives

- Conservation
  - To ensure ongoing supply of addresses
  - To avoid stockpiling

- Aggregation
  - To avoid fragmentation
  - To allow global routability

- Fairness
  - To treat all users equally
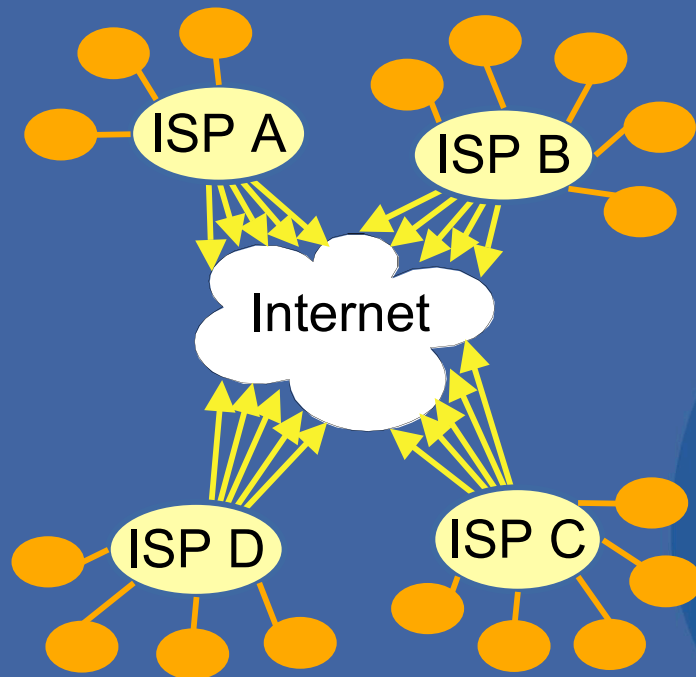 - To allocate according to demonstrated need

IP address conservation

IP address aggregation

Before CIDR

ISP A
ISP B
Internet
ISP D
ISP C

20 routes

CIDR

ISP A
ISP B
Internet
ISP D
ISP C
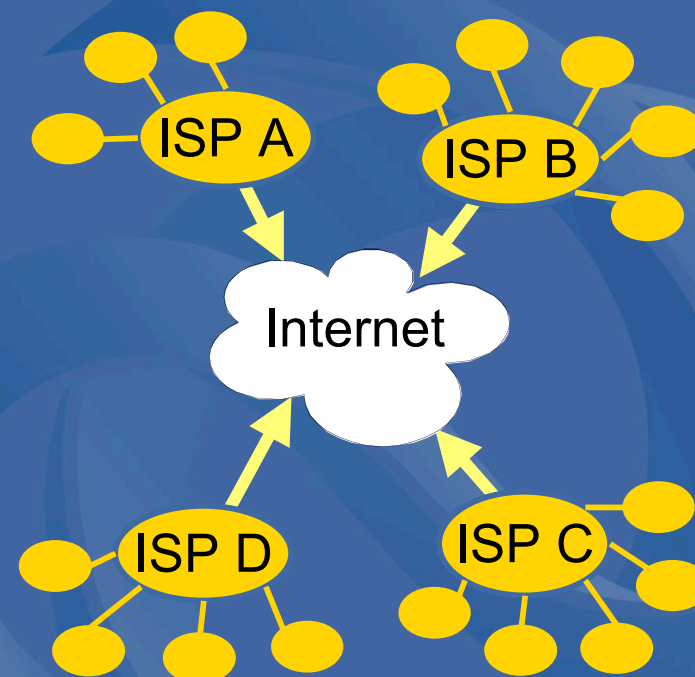
4 routes

IPv4 routing table growth
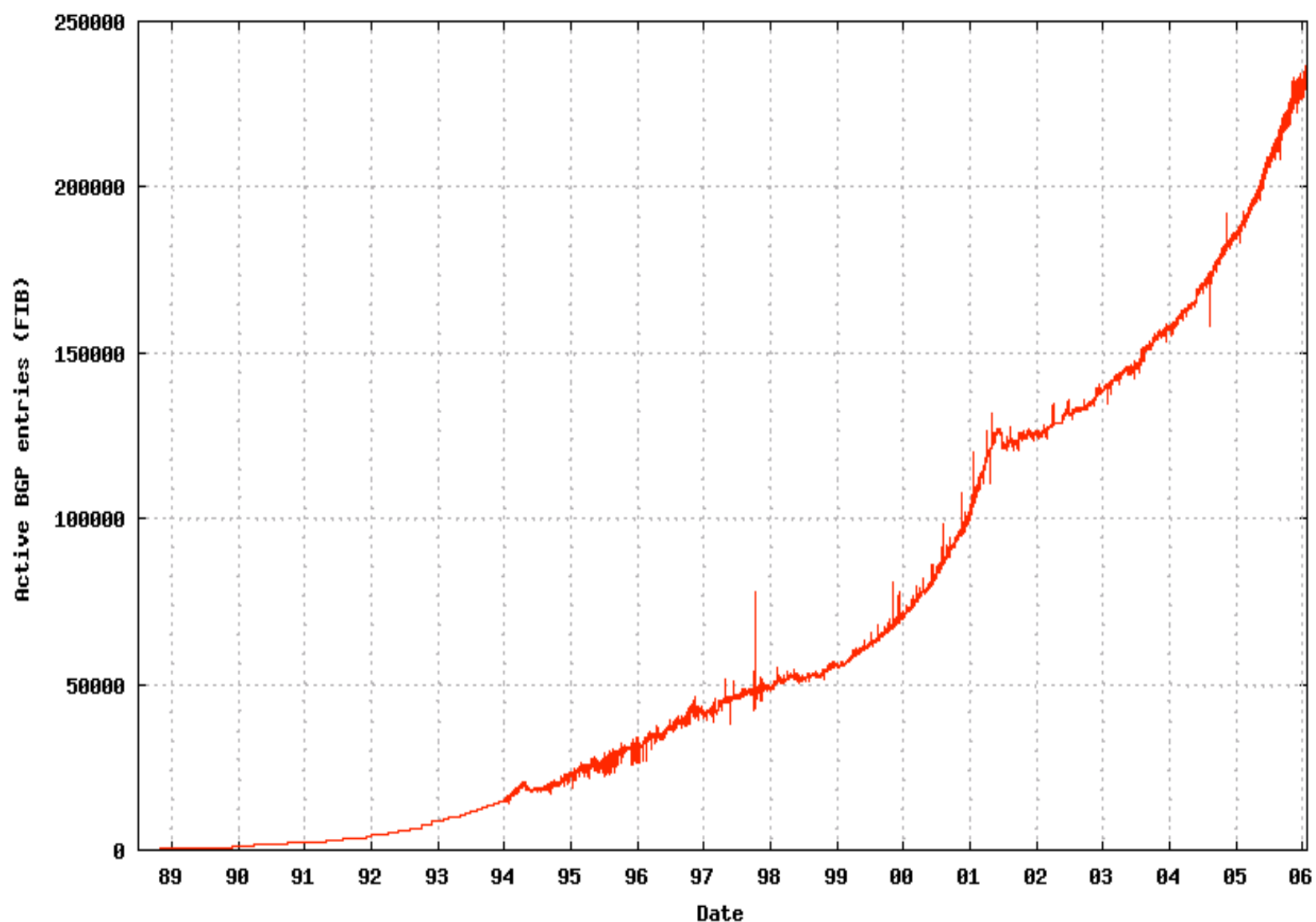
RIR Policy Development Process

Need

OPEN

Anyone can participate

Evaluate

Discuss

'BOTTOM UP'

TRANSPARENT

Implement

Consensus

Internet community proposes and approves policy

All decisions & policies documented & freely available to anyone

IPv6

APNIC
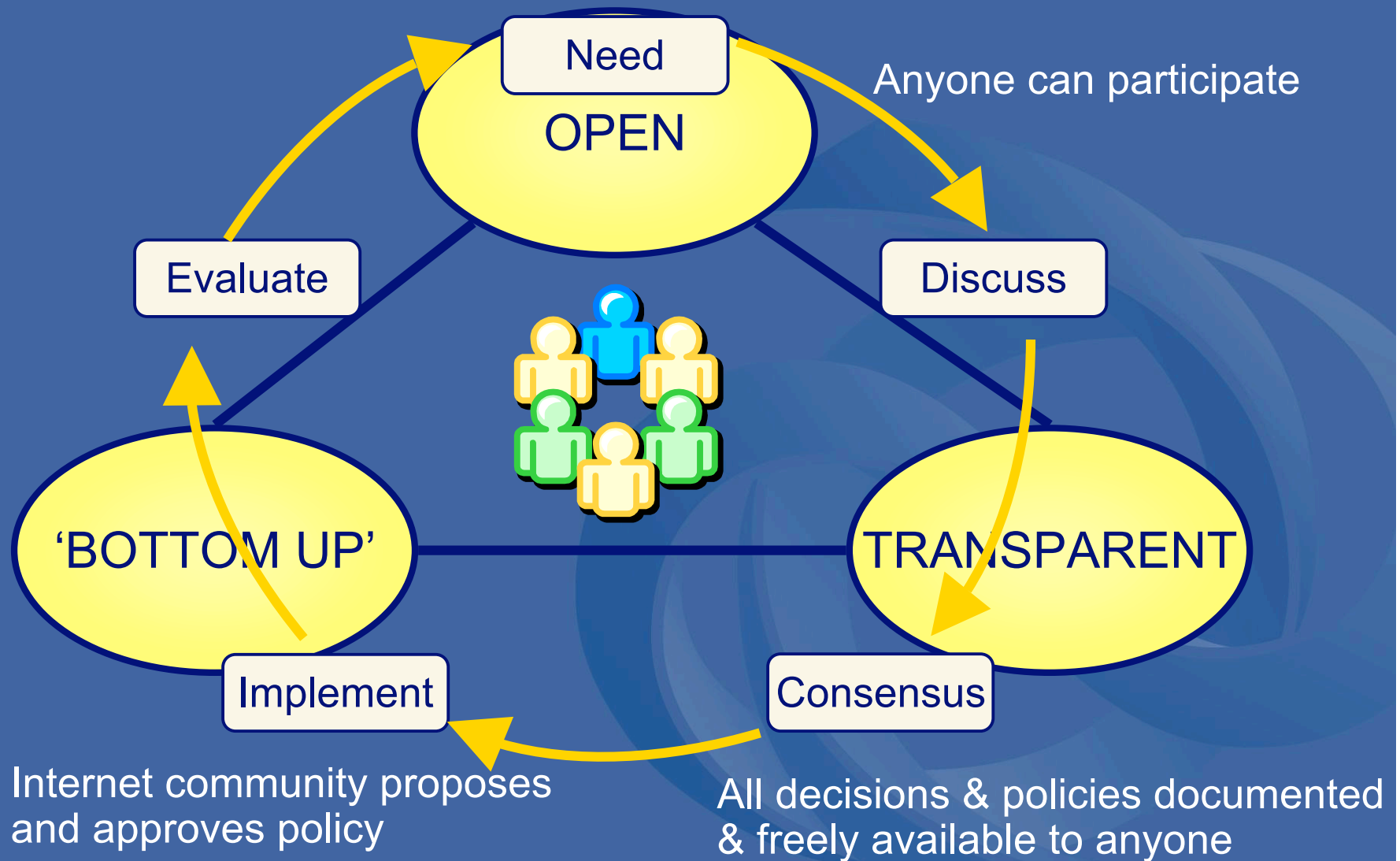
IPv6 – Internet for everything!

IPv6 – why?

- Many "bundled" features
  - Overall protocol simplification
  - Autoconfiguration
  - Quality of Service (QoS)
  - IP Security (IPsec)
  - However all are available in IPv4
- Bigger address space
  - Critical for ongoing Internet growth
  - Critical for new applications
- Otherwise, IPv6 is identical to IPv4

APNIC

IPv6 – how much?

IPv4: 32 bits

e.g. 202.12.29.142   (host address)
      202.12.29/24   (network address)
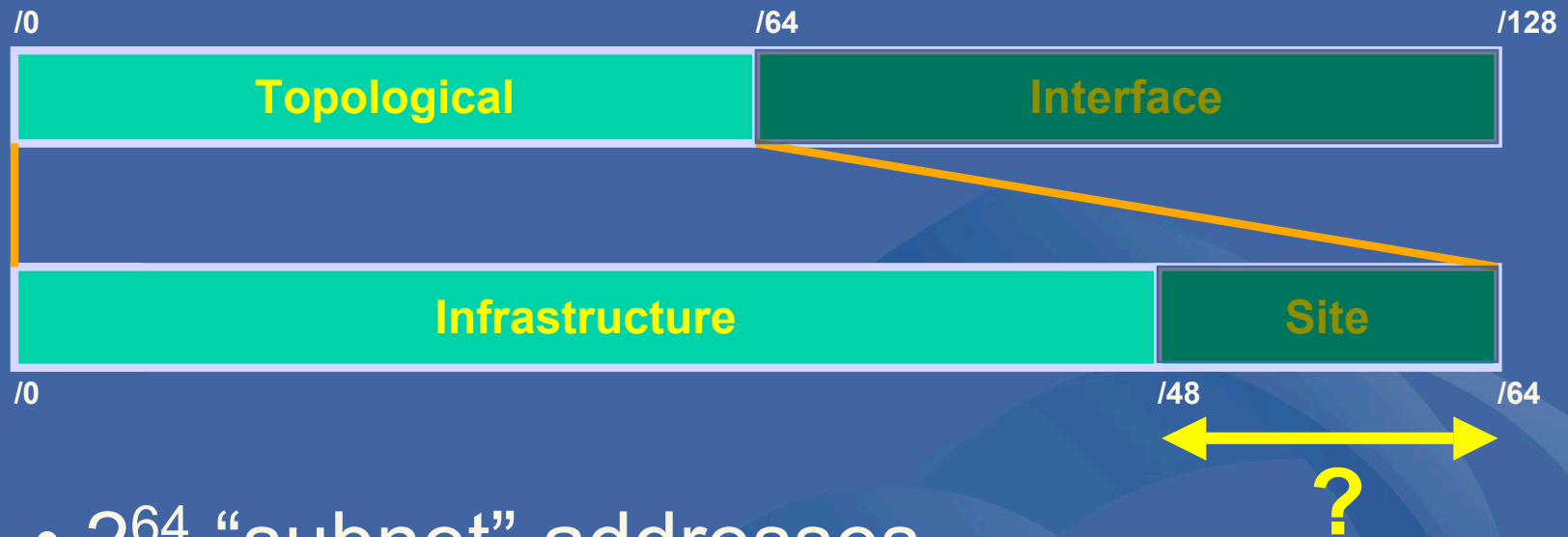

2^{32} = 4,294,967,296 addresses
     = 4 billion addresses

IPv6: 128 bits

e.g. 2001:400:3c00:af92::   (host address)
      2001:0400::/32   (network address)

2^{128} = 340,282,366,920,938,463,463,374,607,431,770,000,000
      = 340 billion billion billion billion addresses ?

IPv6 – how much?

/0	/64	/128
Topological	**Interface**	

/0		/48	/64
Infrastructure		**Site**	

?

- 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 management objectives

- Conservation
    - Different priority due to large address space
    - But how long should IPv6 last?

- Aggregation
    - IPv6 does not solve routing table growth
    - Aggregation is still a crucial goal

- Fairness
    - With IPv6 we can avoid historical problems with IPv4 distribution

Summary

IP addressing

- IP addresses = fundamental Internet infrastructure addresses
  - A **single global network** requires a **single global addressing system**
- IP addresses require careful management
  - **Conservation** for Internet growth
  - **Aggregation** for global routability
- IPv6 operates in the same manner as IPv4

IP address management

- Internet addressing has a 25-year history
  - RIR history is 12 years
  - Driven by the Internet industry
- Current management system has served the Internet well, for over 12 years
  - Massive expansion and the dot-com boom
  - Dynamic and changed by evolution
  - Open policy processes
- Revolutionary changes to this system have unknown consequences

Asia Pacific Network Information Centre

Questions?

pwilson@apnic.net

APNIC