

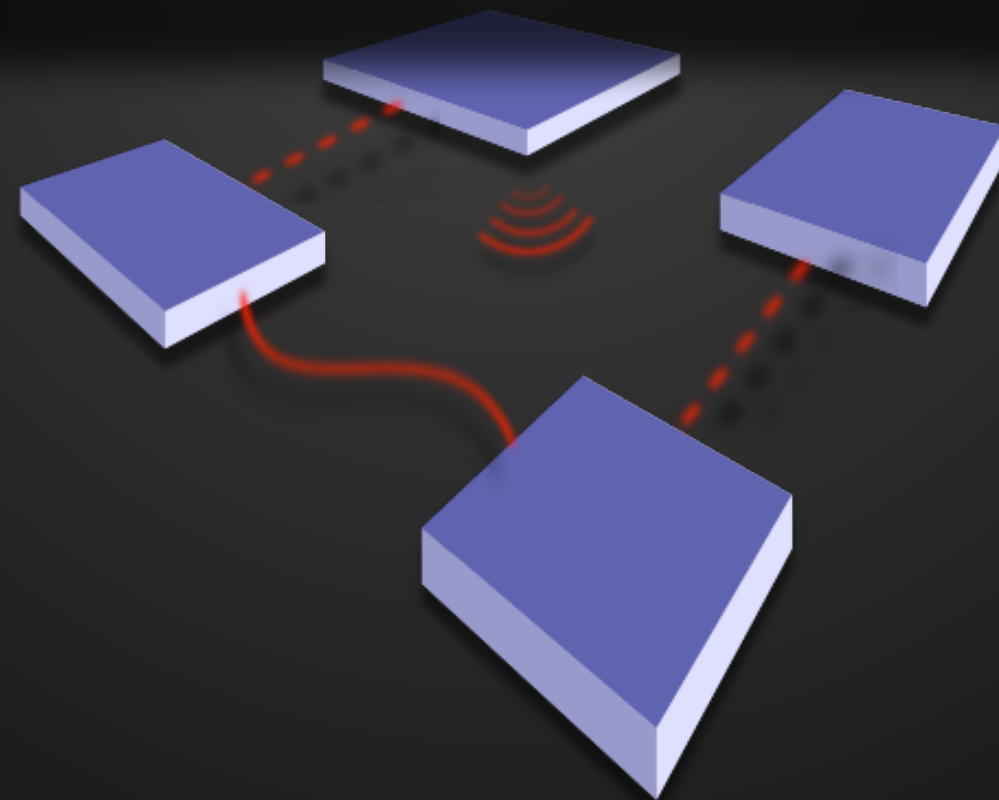
CS-435

spring semester 2025

Network Technology & Programming Laboratory

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Computer Science Department

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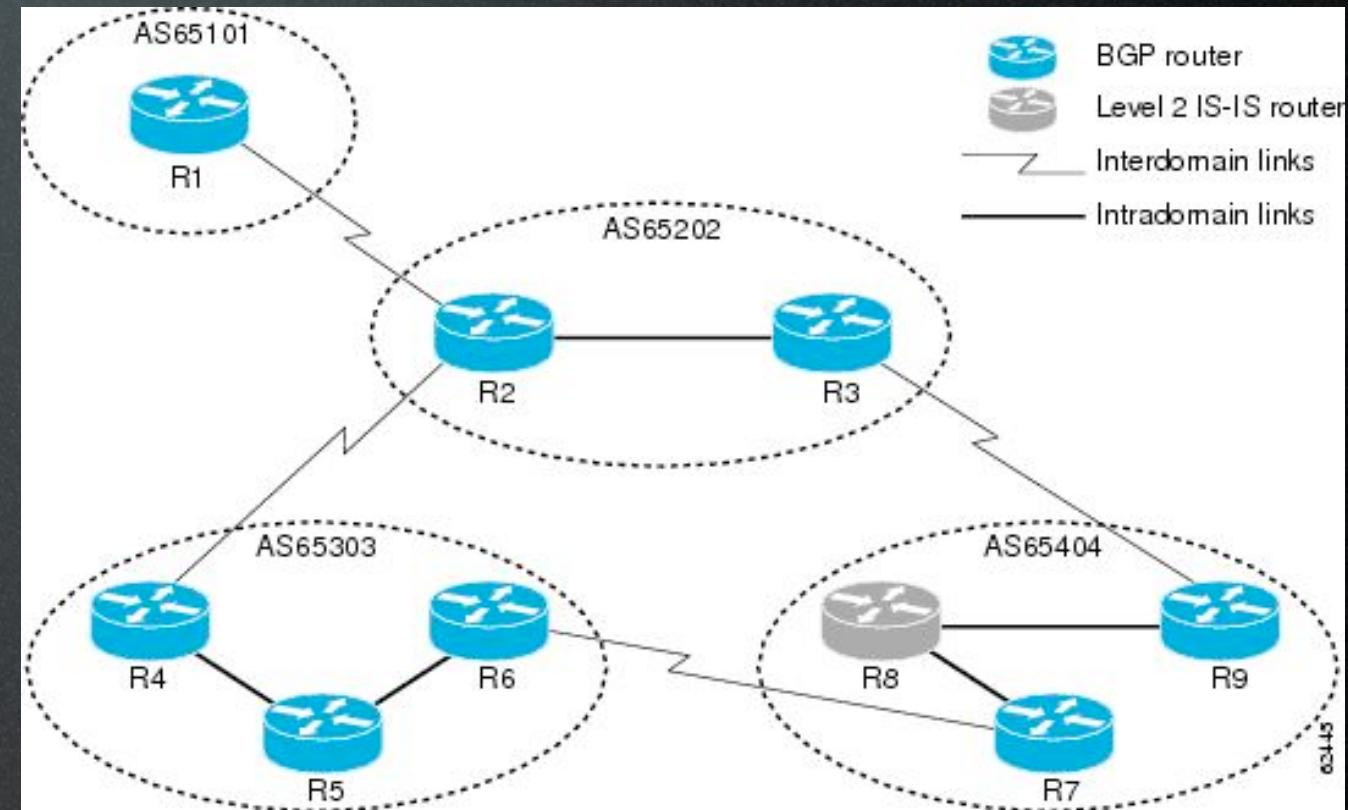
CS-435

Lecture #09 preview

- Dynamic Routing Protocols
- IGPs
- EGPs

Autonomous Systems

- Collection of IP routing prefixes
- Common routing policy to the Internet
- One or more network operators
- Acronym: AS



Autonomous Systems

- Internet Assigned Numbers Authority (IANA)
 - Regional Internet Registries (RIRs)
- Autonomous System Number (ASN)
- Unique ASN allocated to each AS (network ID)
- ASN
 - old: 16bit
 - new: 32bit
 - 0.y y=16bit same as old
 - 1.y reserved

Autonomous System Number

16bit ASN

- 0 reserved - may be used to identify non-routed networks
- 58368-64495 reserved by the IANA
- 64496-64511 reserved for documentation and sample code
- 64512-65534 designated for private use (allocated to the IANA)
- 65535 reserved

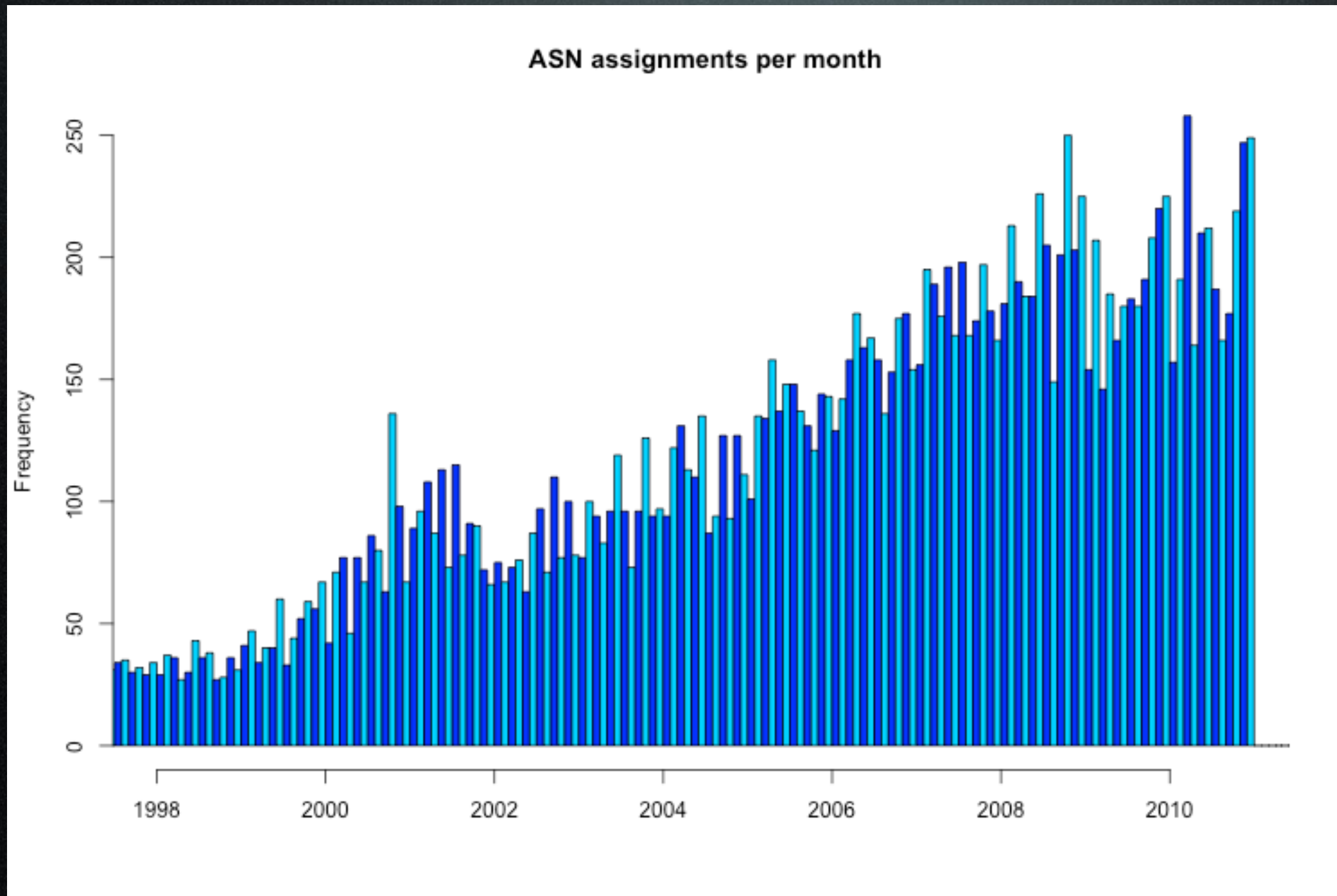
32bit ASN

- 0-65535 same as in 16bit
- 65536-65551 reserved for documentation and sample code
- 65552-131071 reserved
- 4294967295 reserved

Autonomous System Number

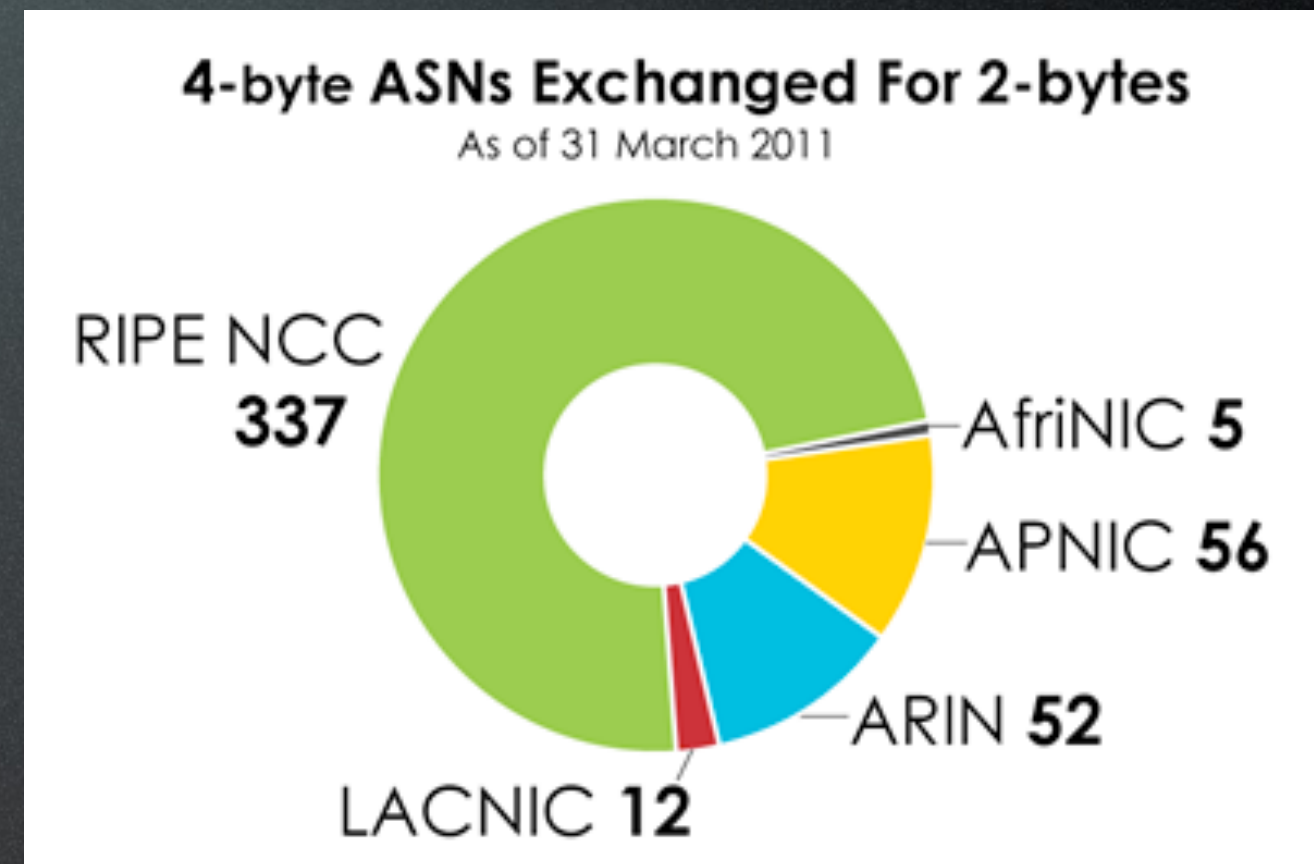
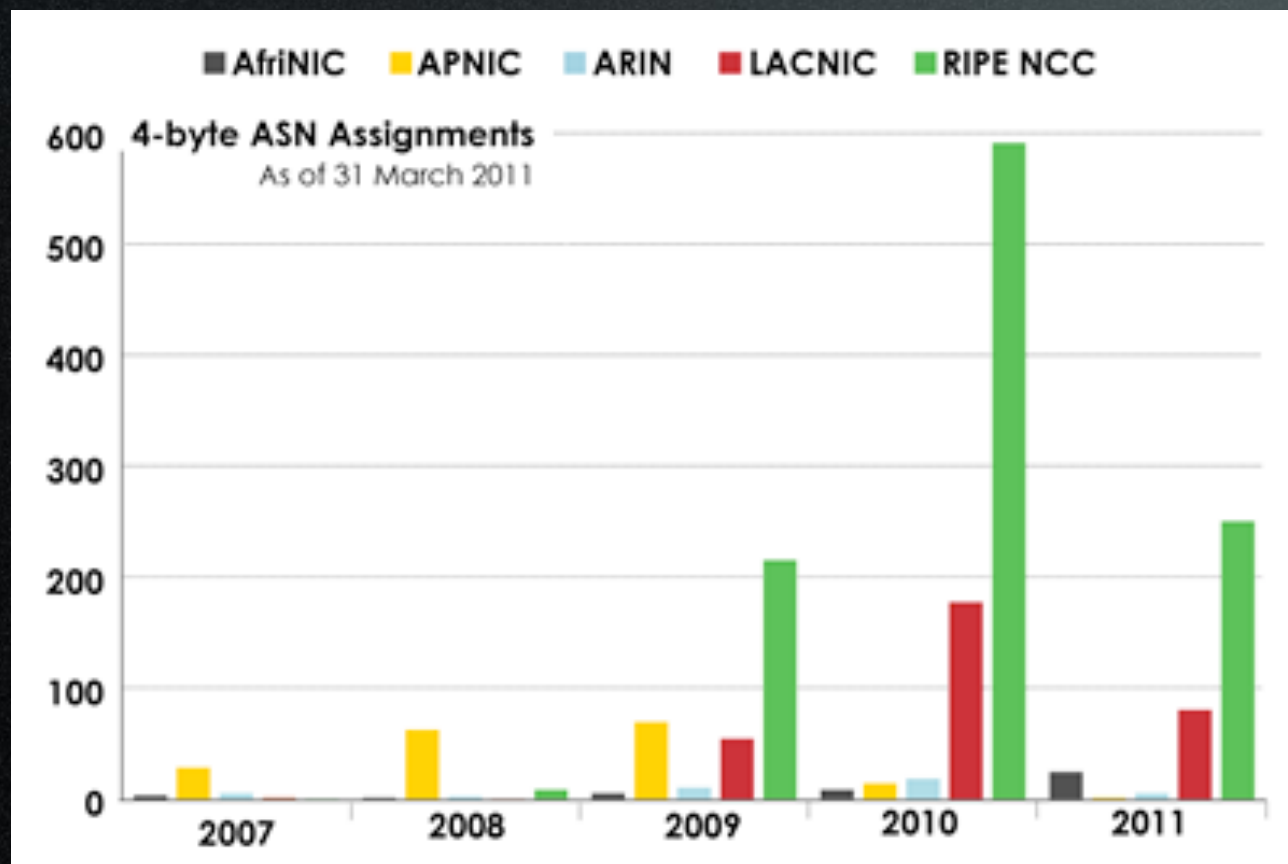
- RIPE NCC (total numbers on 1/1/2011):
 - 21025 ASNs
 - 810 are 32bit
- assigned in 2010: 2437 ASNs
 - 1854 16bit
 - 583 32bit

Autonomous System Number



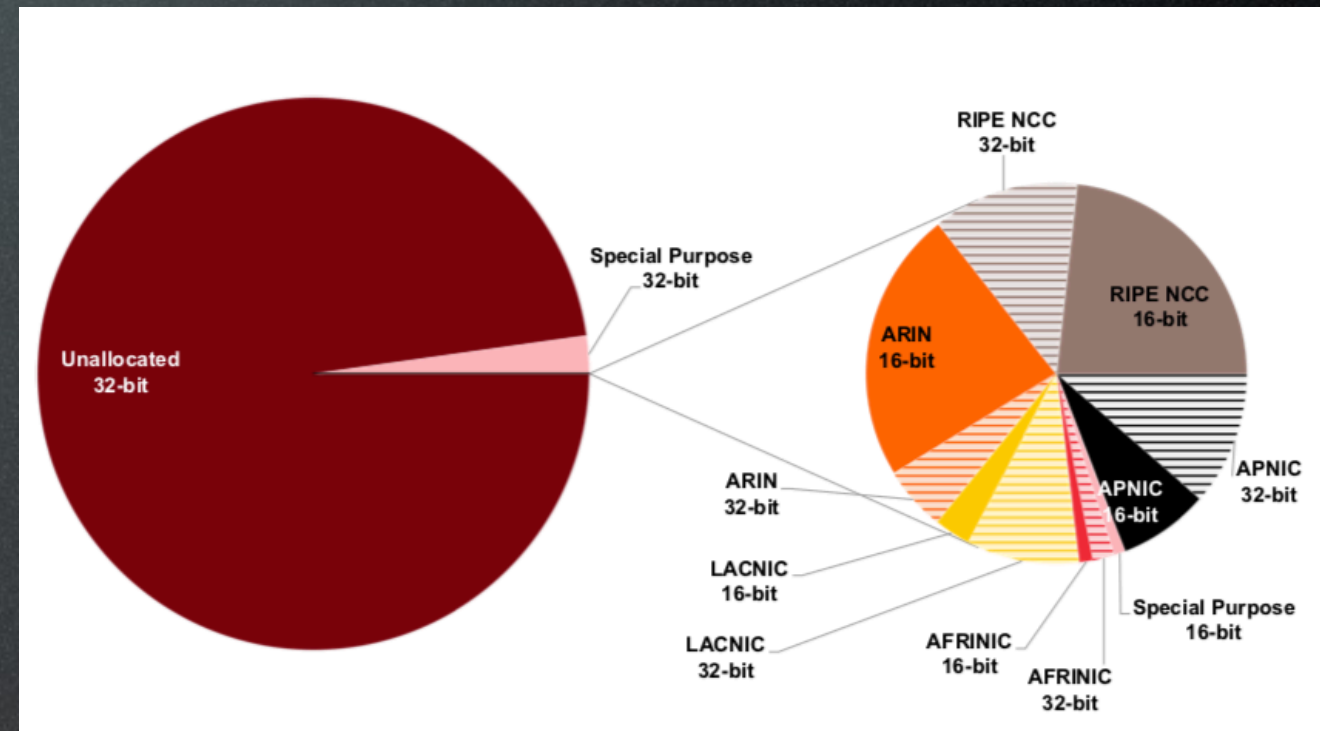
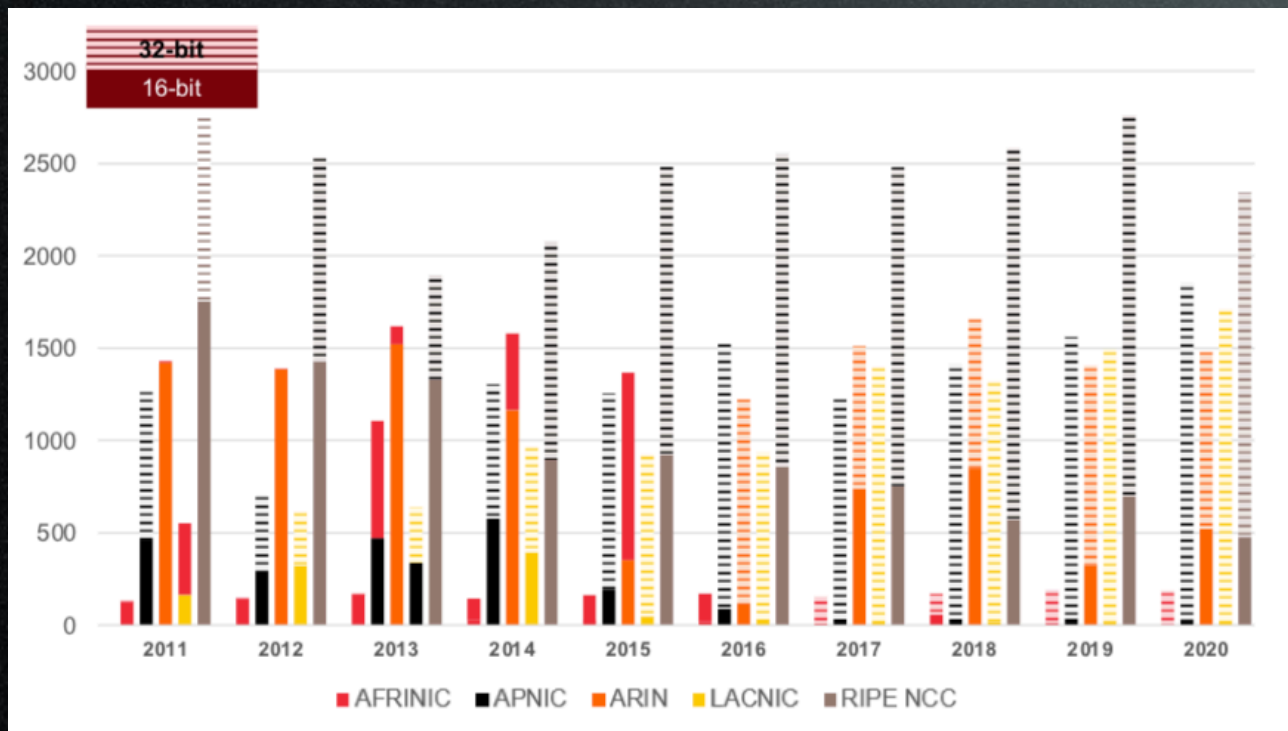
RIPE NCC

Autonomous System Number



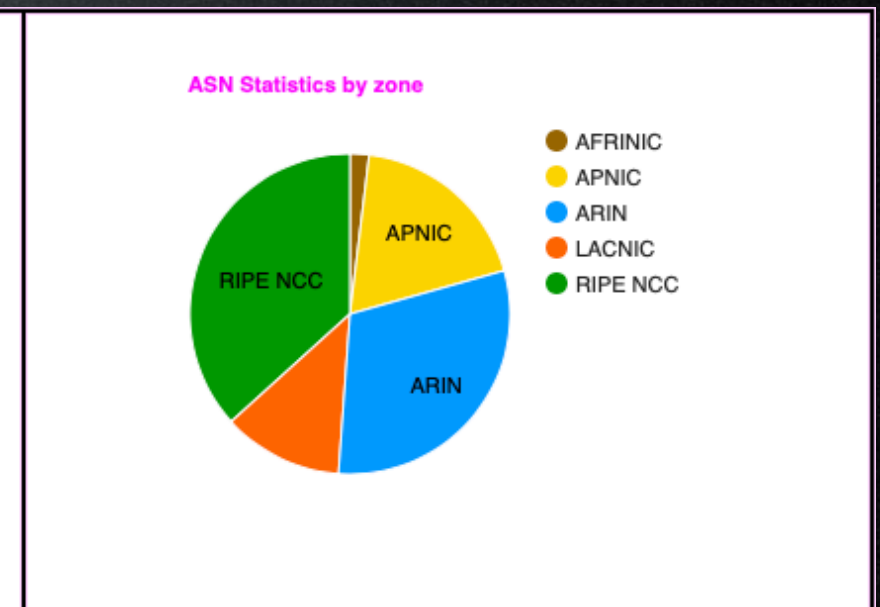
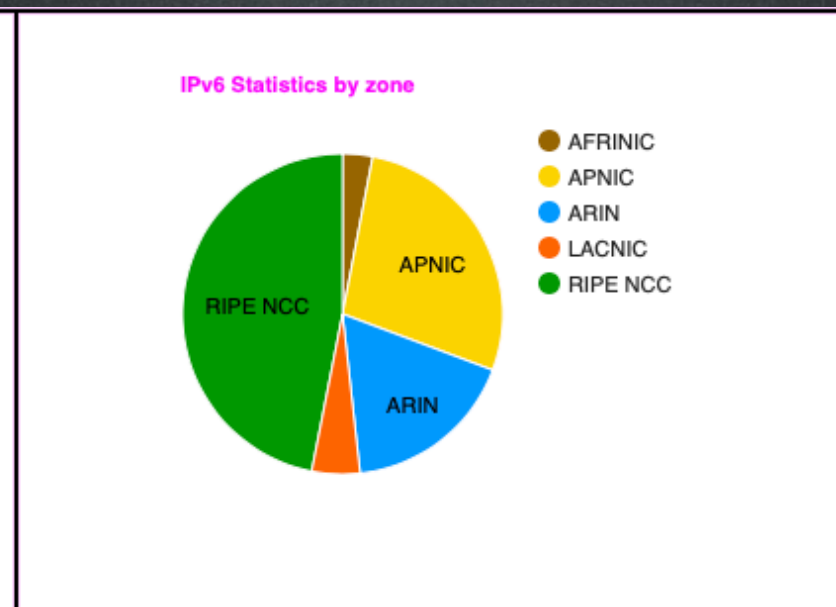
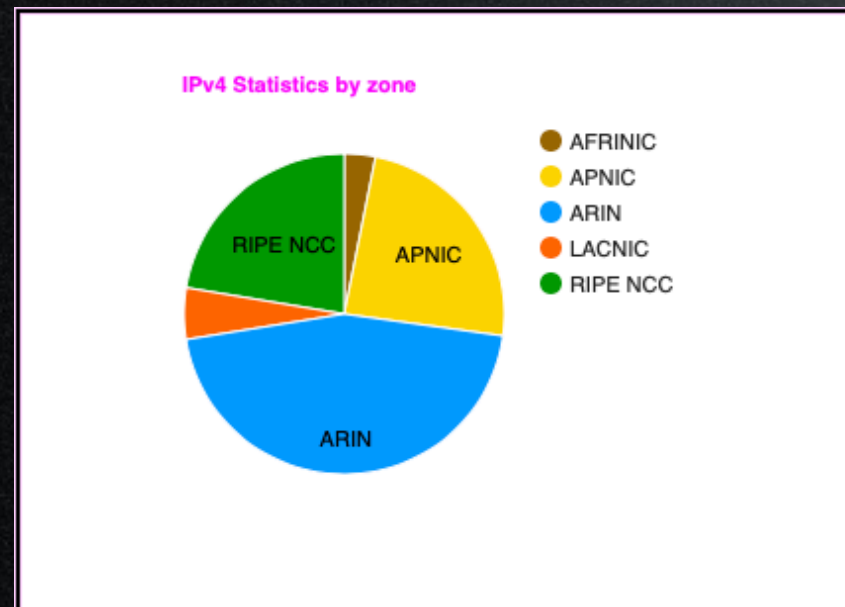
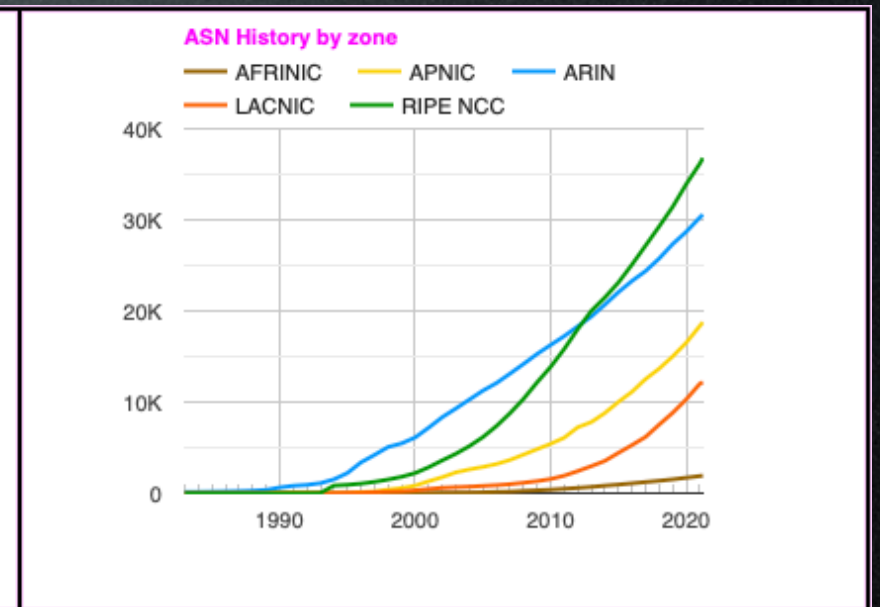
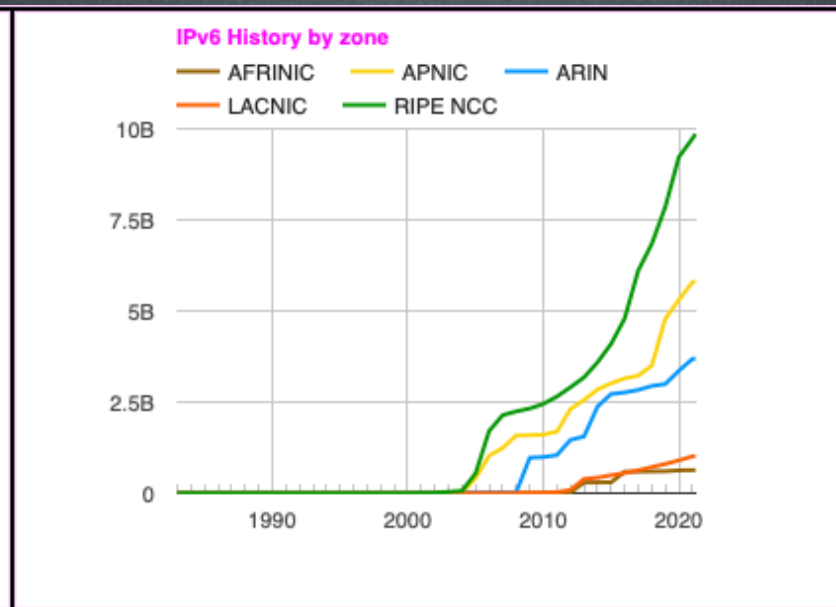
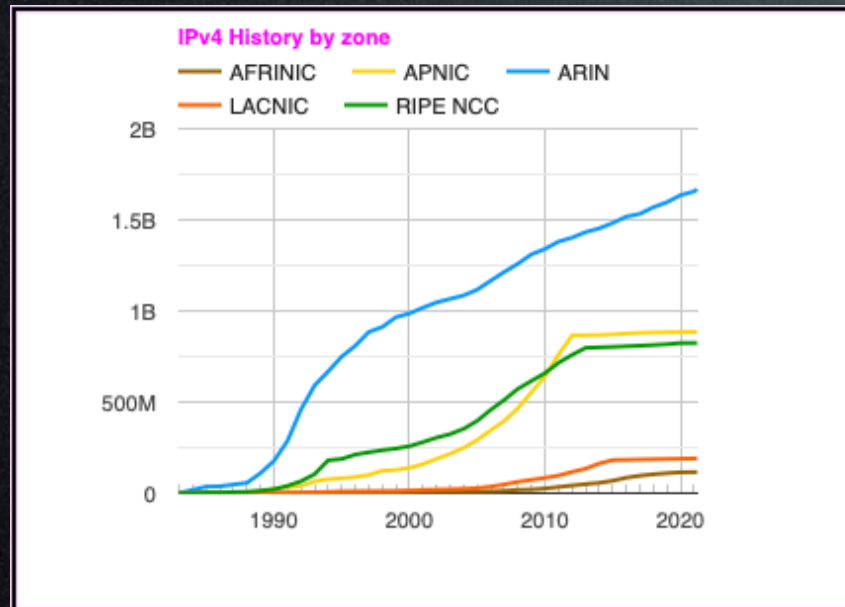
32bit ASN

Autonomous System Number



[late 2020 stats]

Endless stats

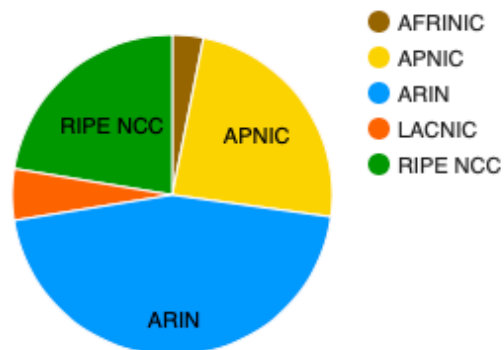


[late 2020 stats]

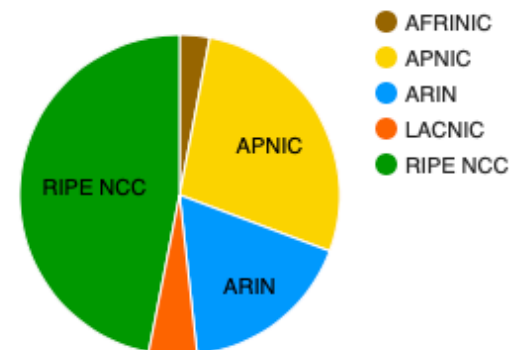
Endless stats

Zone	IPv4 addresses		IPv6 addresses (in /48 blocks)		ASN numbers	
AFRINIC	115 582 208	3.14 %	634 001 658	3.02 %	1 924	1.92 %
APNIC	885 566 720	24.04 %	5 814 956 808	27.67 %	18 760	18.72 %
ARIN	1 667 627 264	45.27 %	3 690 246 419	17.56 %	30 576	30.51 %
LACNIC	190 565 120	5.17 %	1 019 046 047	4.85 %	12 177	12.15 %
RIPE NCC	824 289 952	22.38 %	9 855 962 822	46.90 %	36 788	36.71 %
World	3 683 631 264	100.00 %	21 014 213 754	100.00 %	100 225	100.00 %

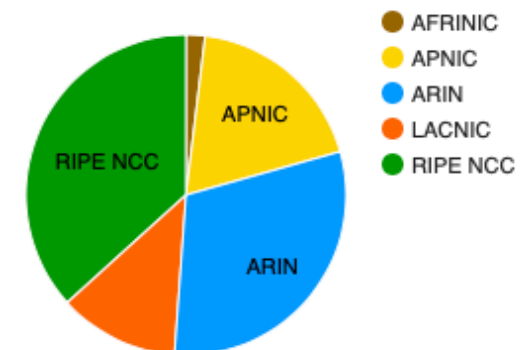
IPv4 Statistics by zone



IPv6 Statistics by zone



ASN Statistics by zone

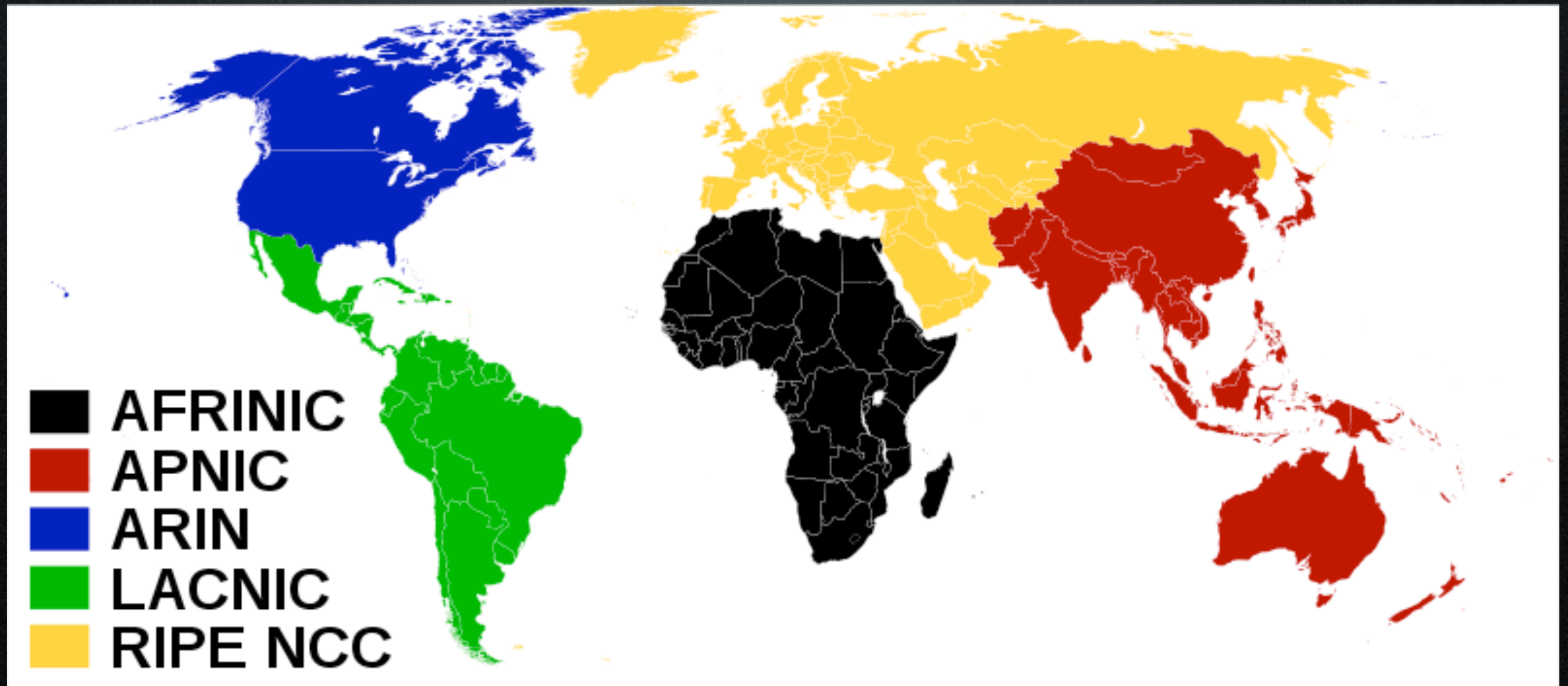


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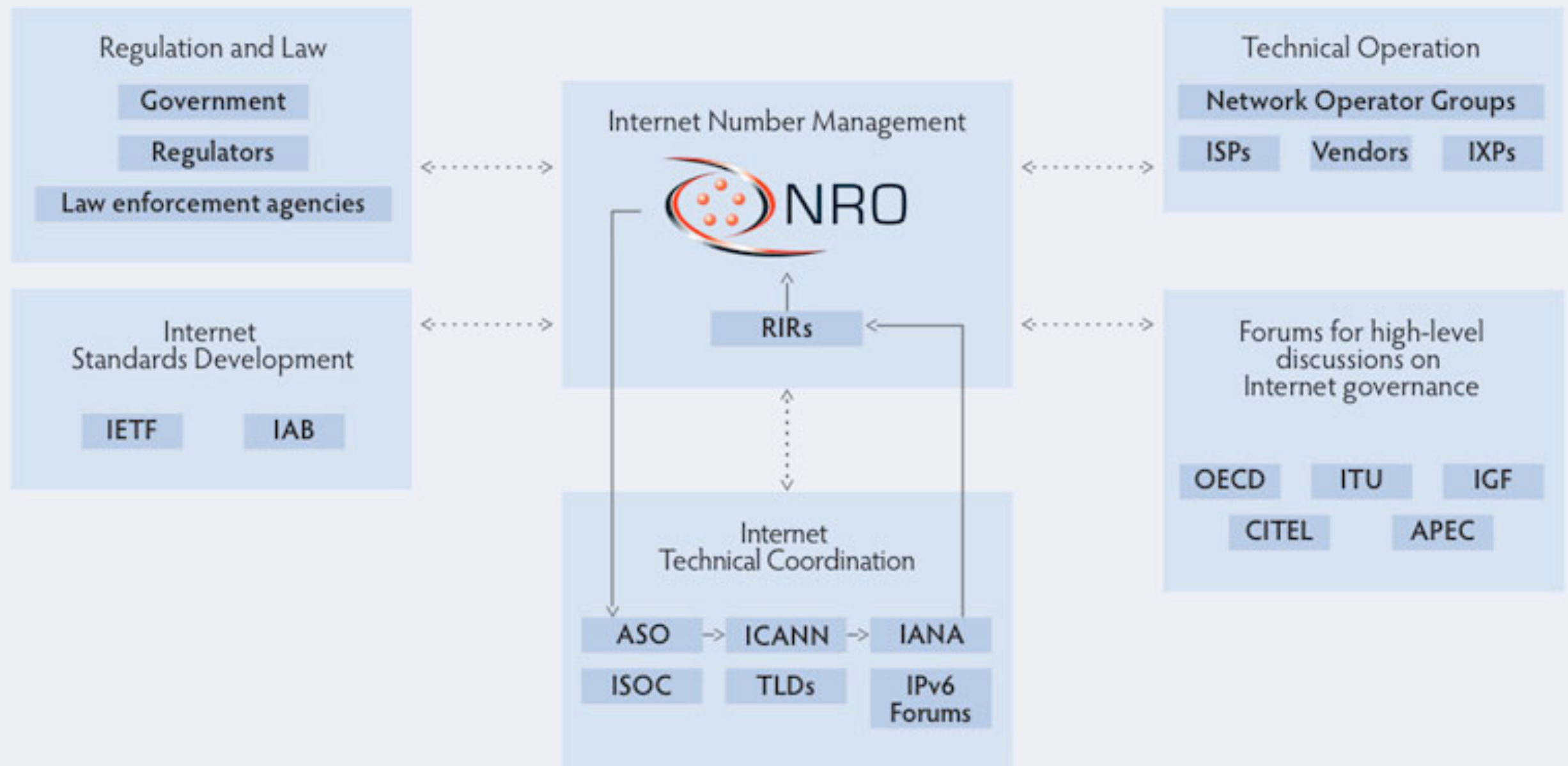
Regional Internet Registries

- RIR organization manages allocation & registration of:
 - IP addresses
 - ASNs
- 5 RIRs:
 - African Network Information Centre (AfriNIC)
 - American Registry for Internet Numbers (ARIN)
 - Asia-Pacific Network Information Centre (APNIC)
 - Latin America and Caribbean Network Information Centre (LACNIC)
 - Réseaux IP Européens Network Coordination Centre (RIPE)

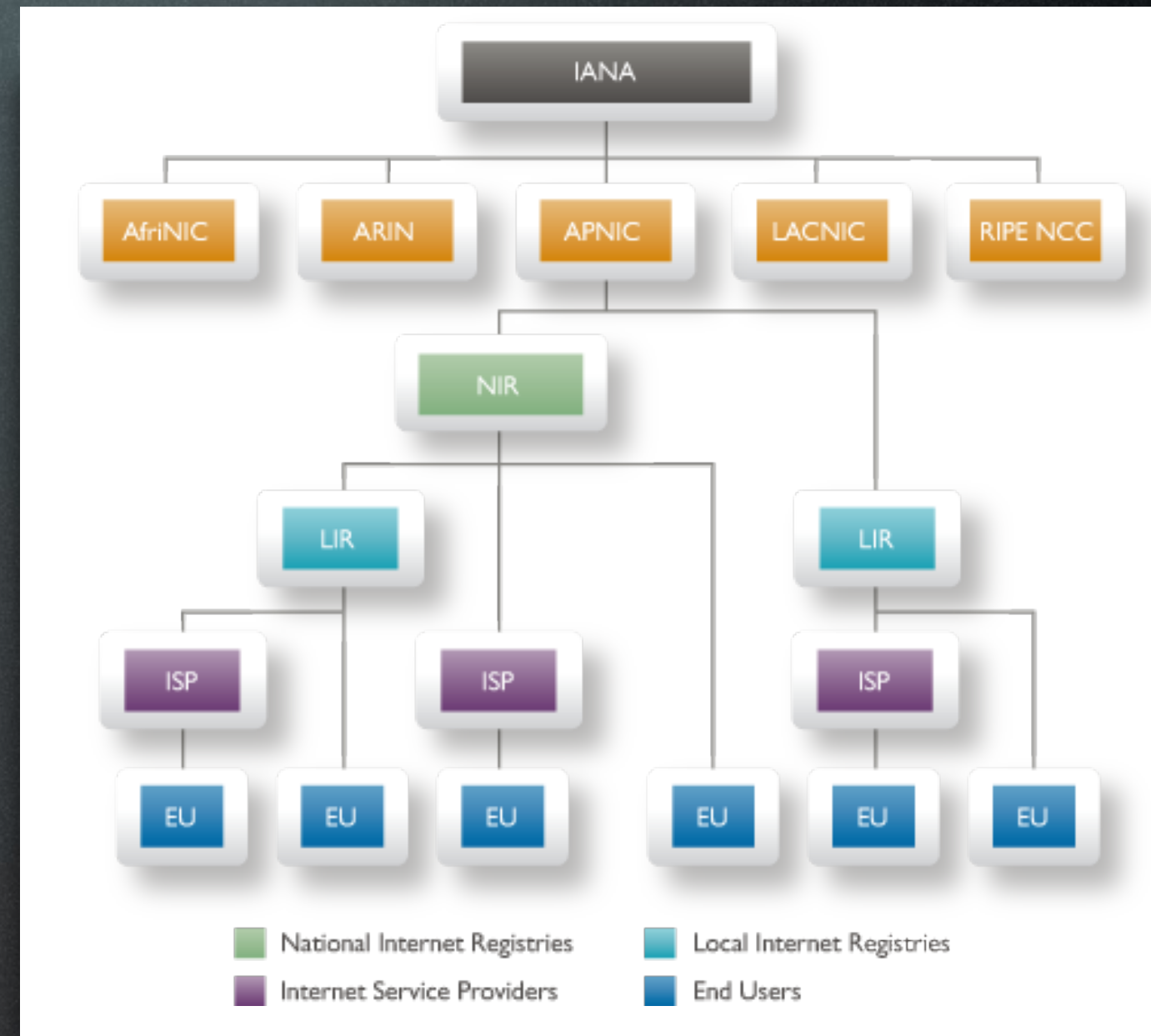
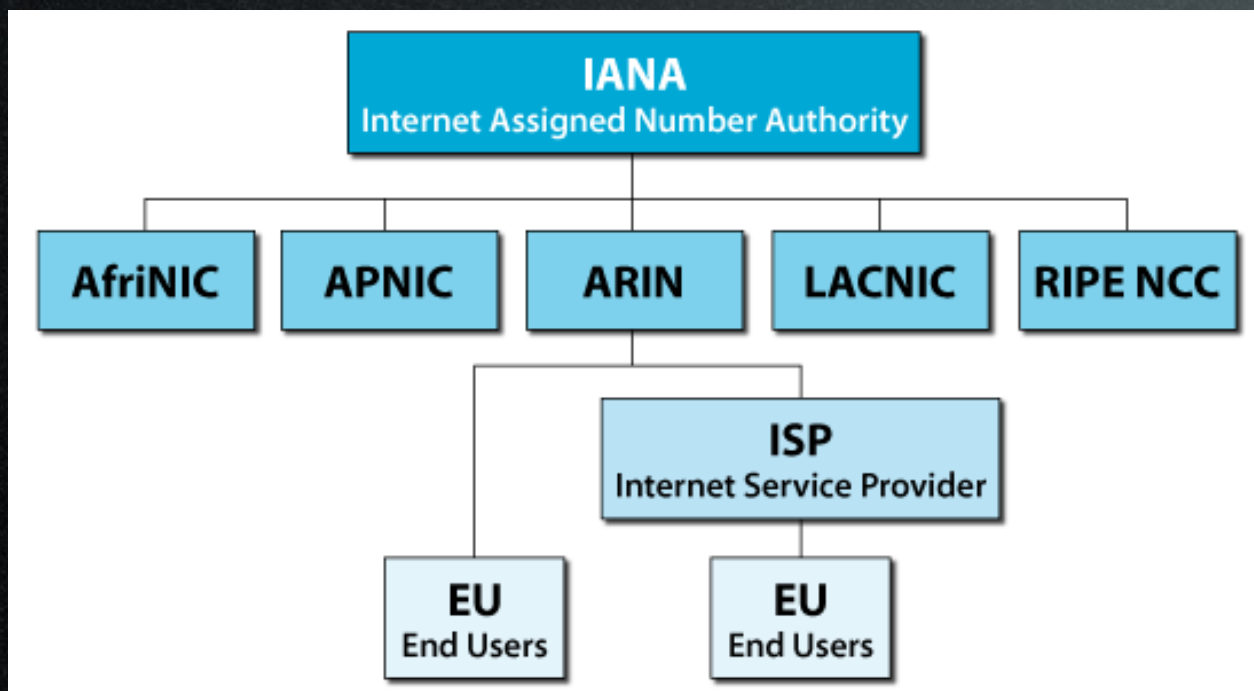
Regional Internet Registries



Number Resource Organization



numbering allocations delegation



IP routing

- Forwarding / Routing Table
- Static routing
 - manual setup of routes
- Dynamic routing
 - automatic setup of routes

Routing

- correct delivery at reasonable level of performance
- paths with no cycles
- functions:
 - topology update
 - route computation
 - switching

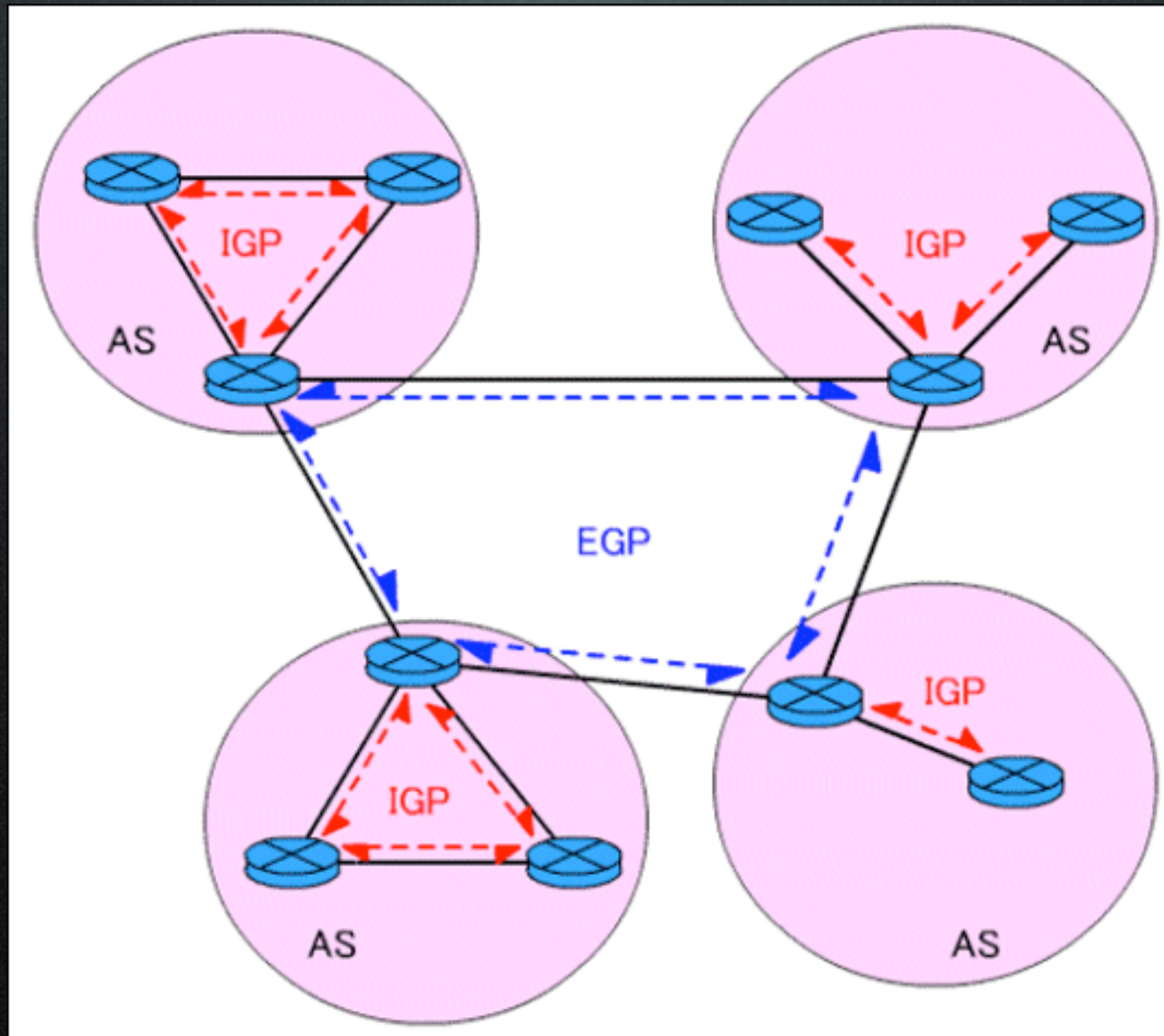
Routing Protocols

- Distance Vector
 - Link cost
 - minimum total cost
 - table exchange
- Link-State
 - Nodes graph
 - shortest path
 - flooding
- Path Vector
 - similar to distance vector
 - table exchange between **speaker** nodes
 - no metrics

Routing Protocols

- Intra-domain / Interior Gateway Protocols (IGPs)
 - routing within an AS
 - ignores the Internet outside
- Inter-domain / Exterior Gateway Protocols (EGPs)
 - routing between ASs
 - assumes that the Internet consists of interconnected ASs

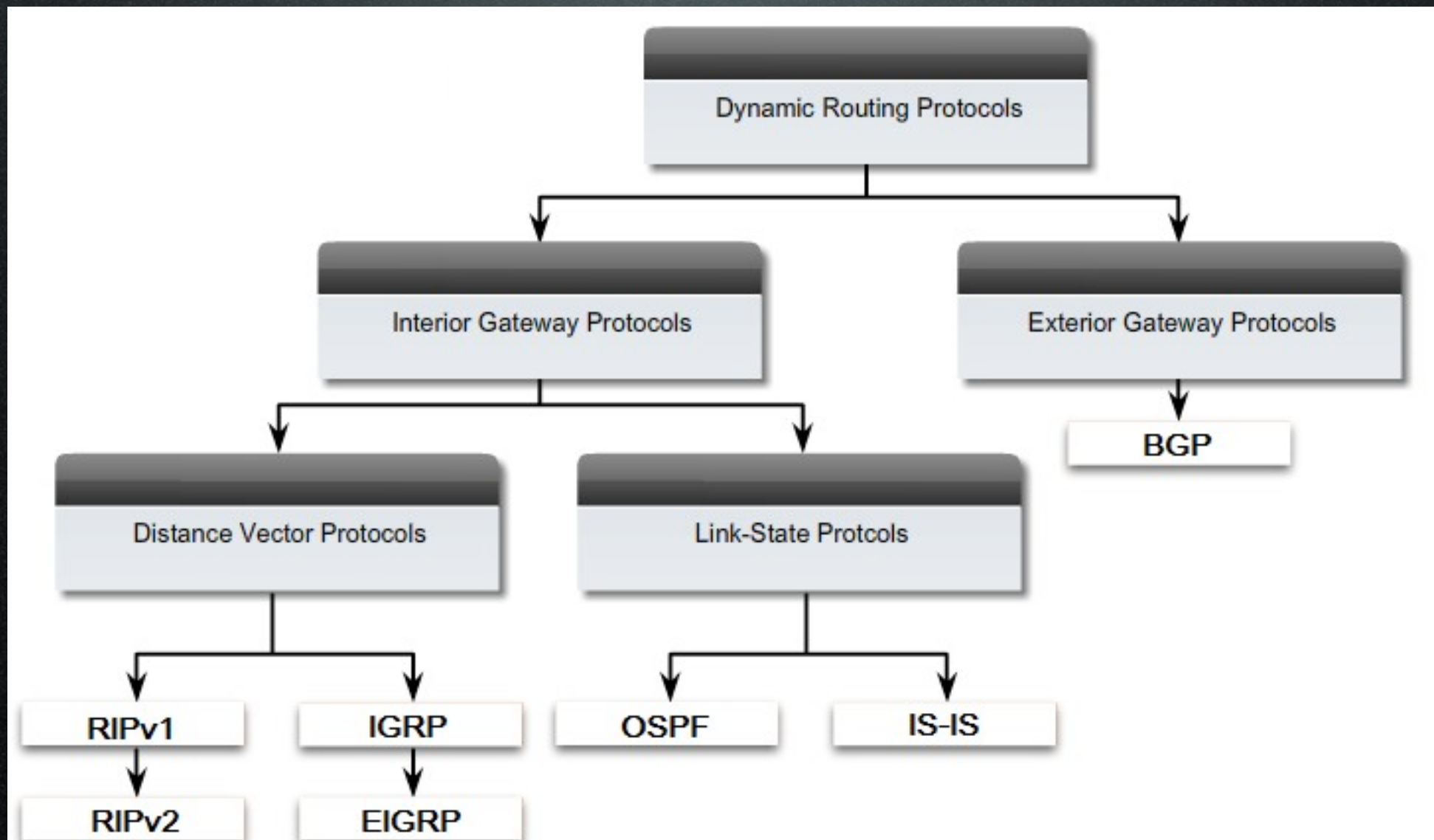
Routing Protocols



Routing Protocols

- Intra-domain / Interior Gateway Protocols (IGPs)
 - RIP
 - IGRP (Cisco)
 - EIGRP (Cisco)
 - OSPF
 - IS-IS
- Inter-domain / Exterior Gateway Protocols (EGPs)
 - BGP
 - EGP3

Dynamic Routing Protocols



Routing Information Protocol

RIP

- distance-vector
- Bellman-Ford algorithm
- metric: hop count
- maximum number of hops: 15
- hop count 16: infinite
- uses UDP

RIP

- RIP version 1
 - classful routing - no variable length subnet masks
 - impossible to have subnets with different sizes
 - broadcast messages
 - maximum 16 hop counts
- RIP version 2
 - CIDR support
 - multicast messages to adjacent routers (224.0.0.9)
 - maximum 16 hop counts
- RIPng
 - IPv6 support
 - maximum 16 hop counts

RIP

- normal routing updates: every 30s
- triggered updates: whenever the metric for a route changes
- after 3 minutes routes are set to 16 (inf) if not updated
- takes a long time to stabilize
- count to infinity problem
- maximum path is 15 hops

RIP vs OSPF

PROPERTIES	RIPv2	OSPFv2
IPv6 version / Update	RIPng	OSPFv3
Developed	1993 (standardized in 1998)	defined in 1998 (v3 in 2008)
Type	Distance Vector	Link-state
Administrative Distance	120	110
Max. Hop Count	15	No limit
Network Size	Small	Small to Large
Algorithm	Bellman-Ford	Dijkstra
Convergence	Slow	Fast
Variable Length Subnet Masks (VLSM)	Yes in v2, not v1	Yes
Routing Updates	Full Table every 30 seconds	LSA generated upon any routing change
Bandwidth Usage	uses more bandwidth	uses less bandwidth
Areas / Boundaries	No	Yes
Metric	Hop Count	Cost

Open Shortest Path First OSPF

- link state routing protocol
- layer 3 protocol, runs on top of IP (IP datagrams protocol #89)
- version 2: IPv4
- version 3: IPv6
- routes packets within a single AS

Open Shortest Path First OSPF

- Dijkstra's algorithm
- shortest path tree
- metric: link RTT, throughput, reliability
- supports CIDR
- Link State Database (LSDB) of entire network
 - tree-image of entire topology
 - refreshed periodically through flooding (multicast to 224.0.0.5 /224.0.0.6)

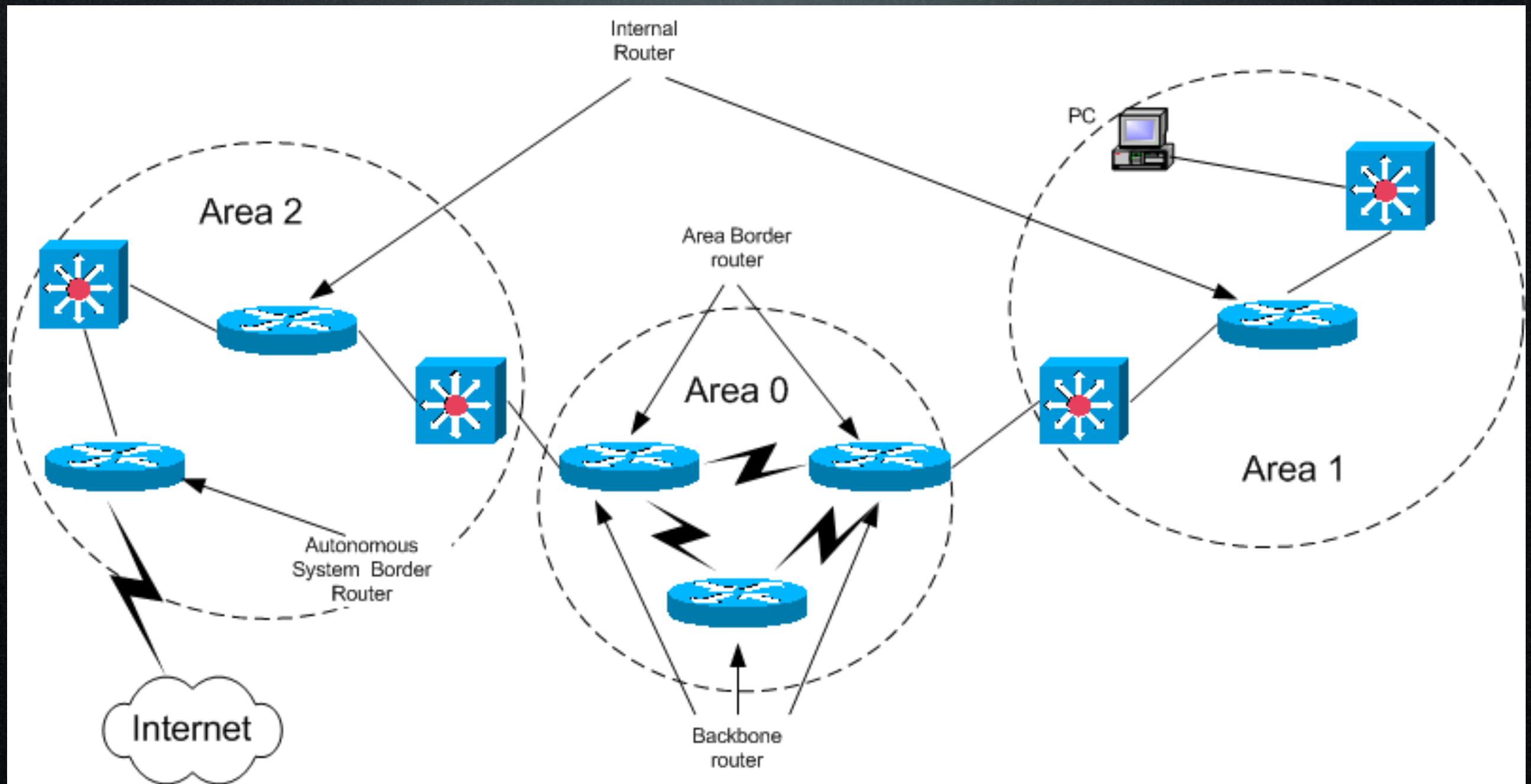
OSPF

- Areas - subdivisions of network
 - maintains a separate link state database
 - connecting router: summarized info towards the rest of the network
 - the topology of an area is unknown outside of the area
- 32bit - dot decimal notation (i.e. 0.0.0.1)
- Area 0: backbone/core area
 - all other areas must connect directly to Area 0
- Area Border Router: connects to backbone

OSPF

- Use of own IP protocol 89 & multicast for flooding
- OSPF router types:
 - Area border router (ABR)
 - Autonomous system boundary router (ASBR)
 - Internal router (IR)
 - Backbone router (BR)

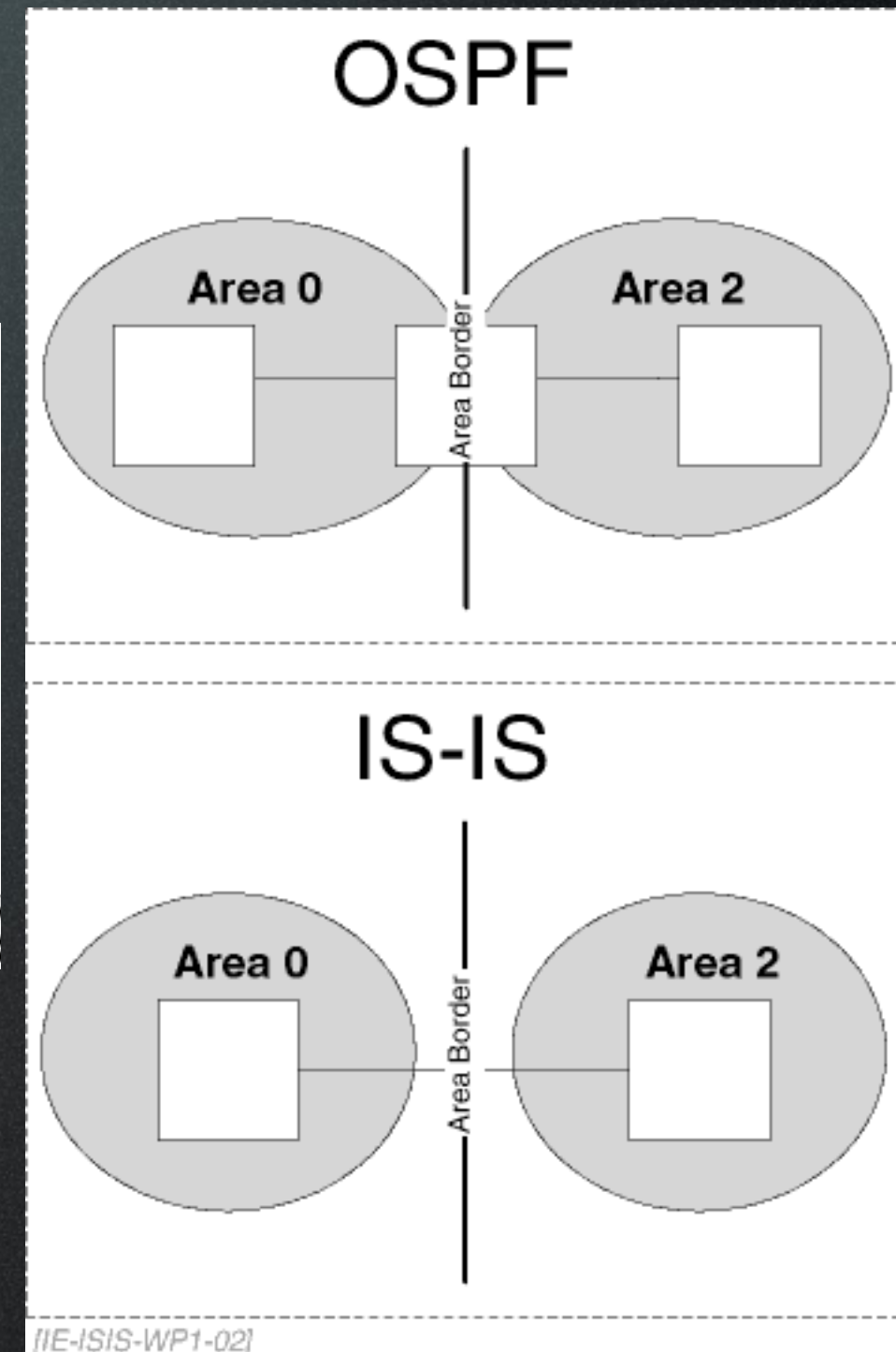
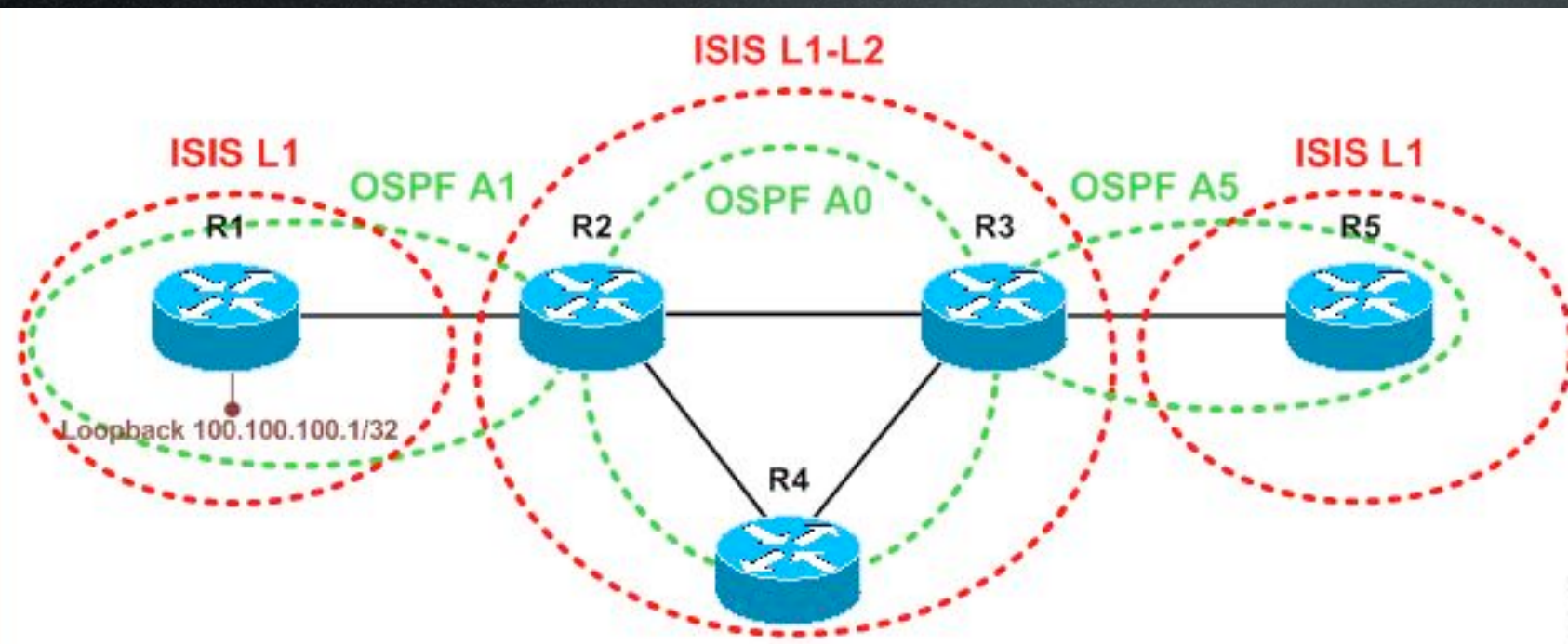
OSPF



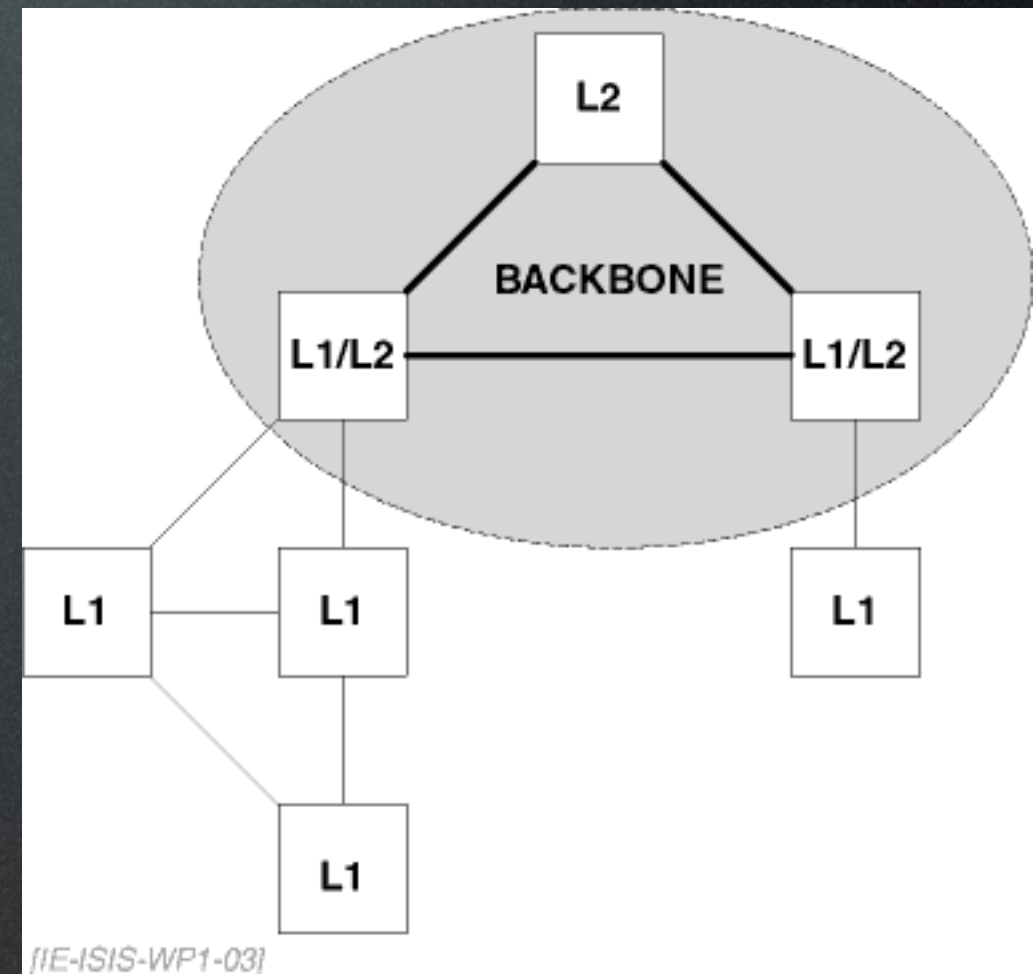
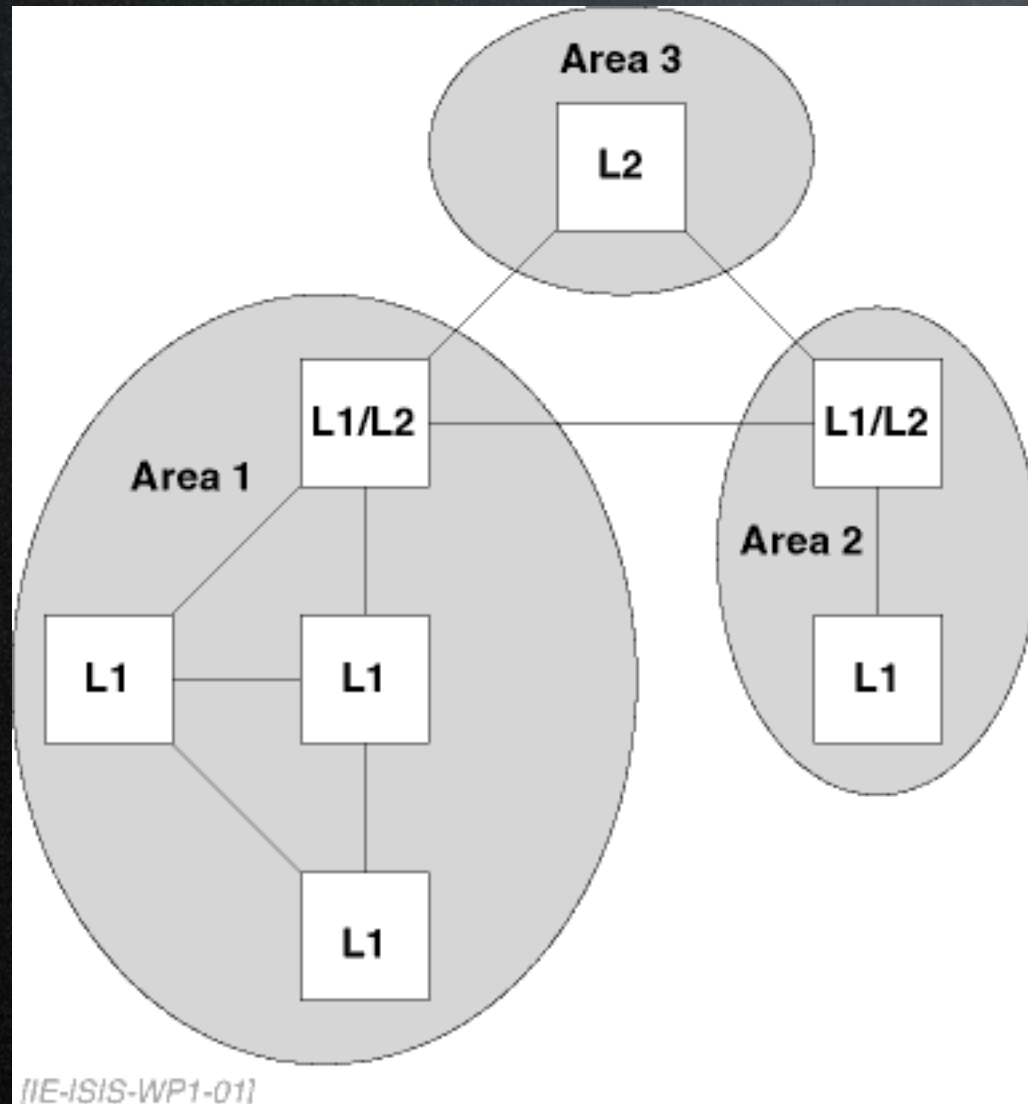
Intermediate System to Intermediate System IS-IS

- the de facto standard for large service provider network backbones
- OSI network layer protocol
- does not use IP
- different usage of “areas” than in OSPF
 - levels: 1(intra area); 2(inter area); 1-2(both)
- lighter than OSPF -> scales better
- routes packets within a single AS

OSPF vs IS-IS



IS-IS



Border Gateway Protocol

BGP

- path vector protocol
- table of IP networks/prefixes
- CIDR
- route aggregation
- most ISPs **must** use BGP
- multihoming:
 - single ISP (multiple access points)
 - multiple ISPs

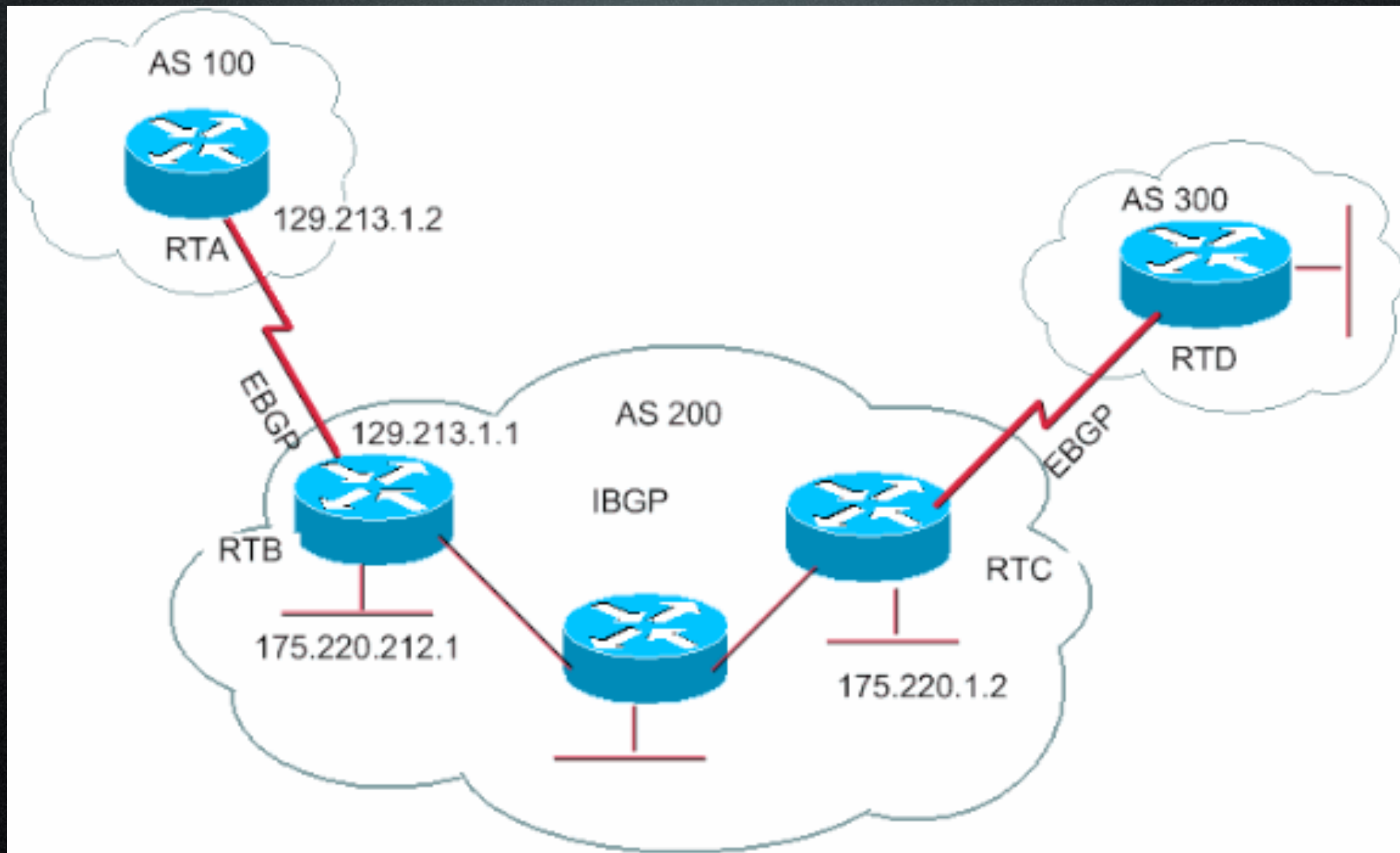
BGP

- manually configured neighbors/peers
- TCP
- 60sec keep alive messages
- hold time before removing peer
- incremental updates
- full table exchange only when (re)establish peering relationship

BGP

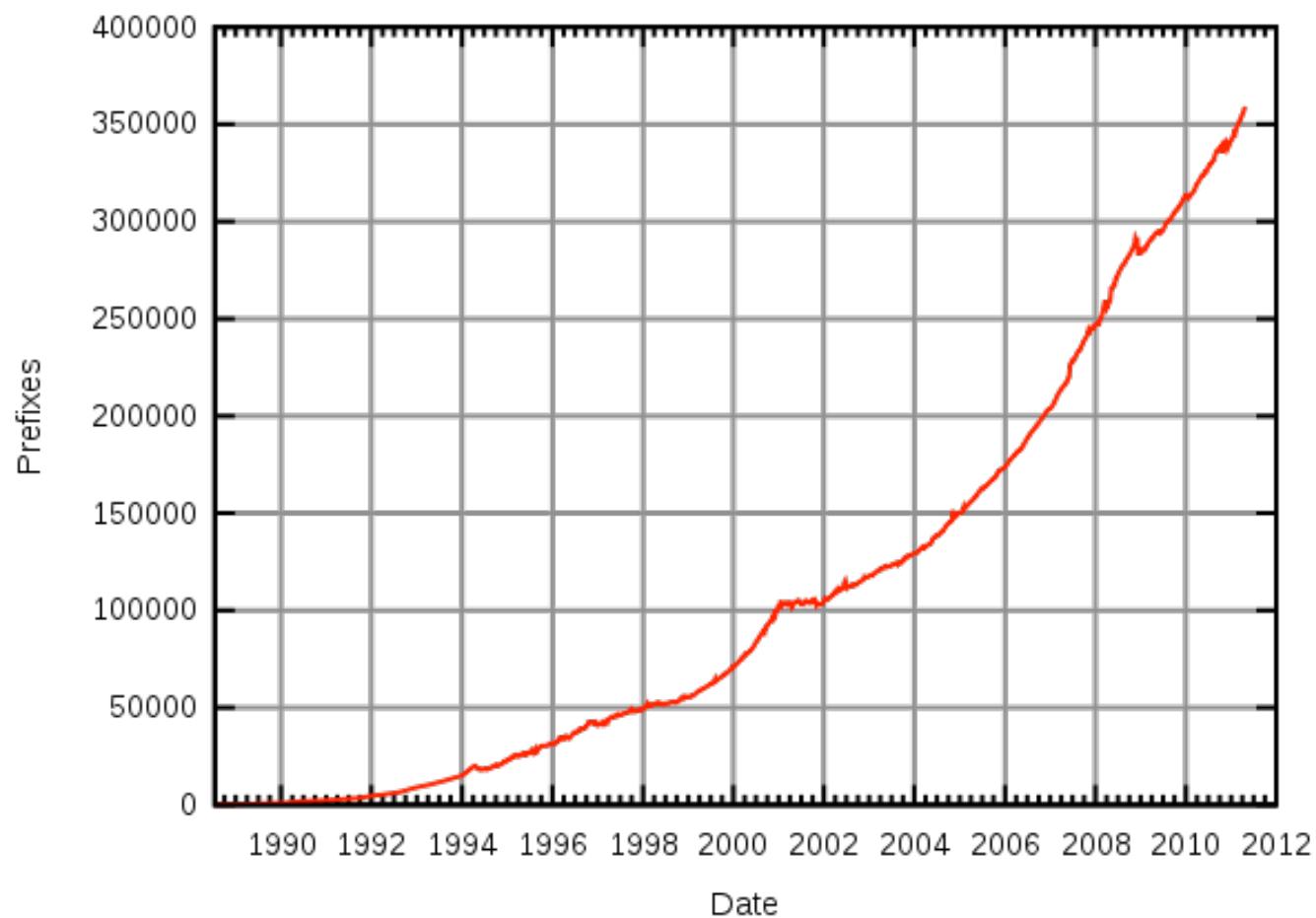
- IBGP (internal/interior BGP inside an AS)
- EBGP (between ASs)
- Border/Edge routers (exchange information between ASs)
- Global routing table - over 300 000 entries

BGP

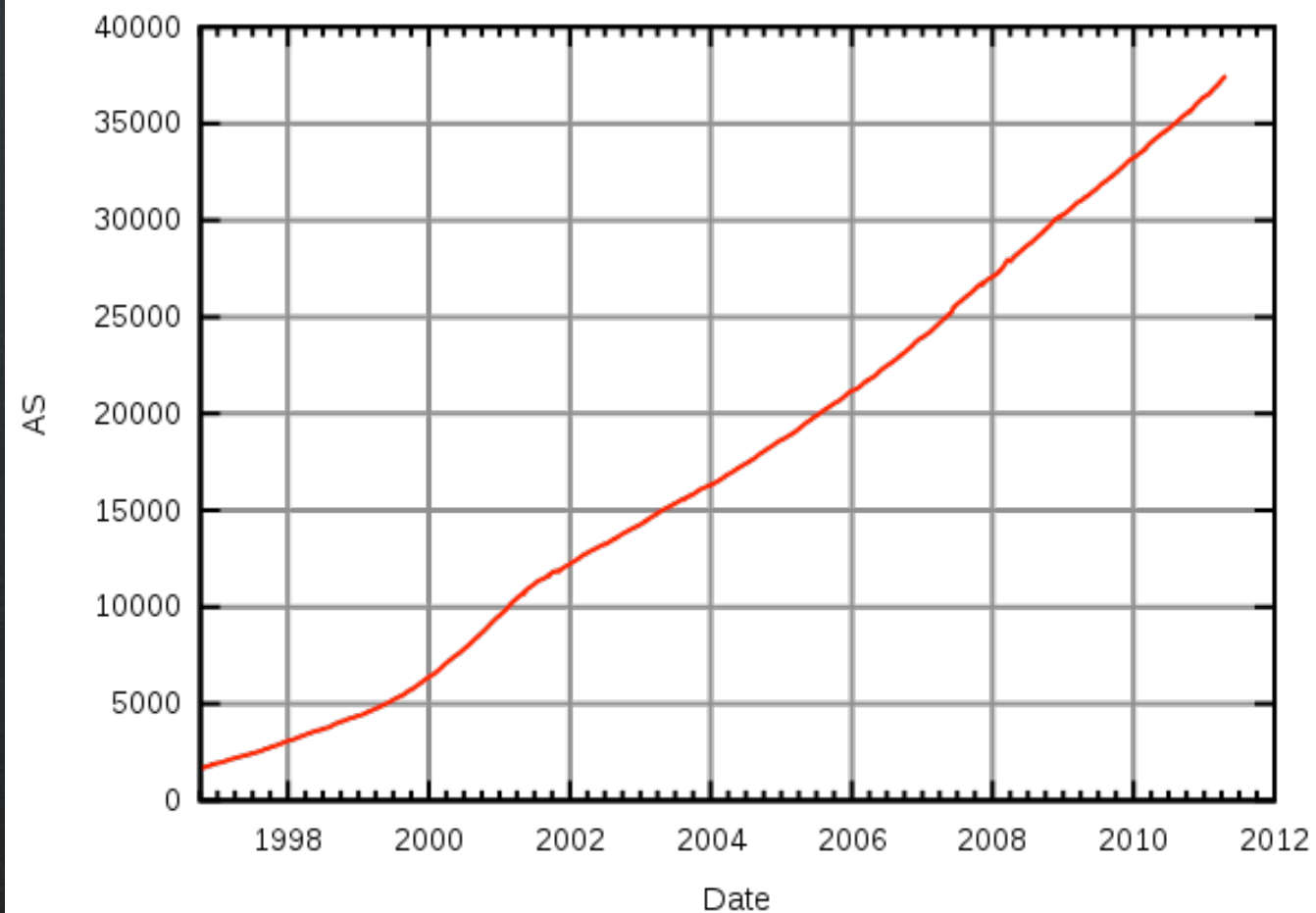


BGP

Prefixes announced
on the Internet



AS announced
on the Internet



BGP multihoming

