Introduction to The Internet

ITU/APNIC IPv6 Workshop

22nd – 24th October 2018

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Acknowledgements

- This material originated from the Cisco ISP/IXP Workshop Programme developed by Philip Smith & Barry Greene
- Use of these materials is encouraged as long as the source is fully acknowledged and this notice remains in place
- Bug fixes and improvements are welcomed
  - Please email *workshop (at) bgp4all.com*

Philip Smith

Introduction to the Internet

- Topologies and Definitions
- IP Addressing
- Internet Hierarchy
- Gluing it all together

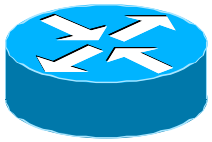
Topologies and Definitions

What does all the jargon mean?

Definitions

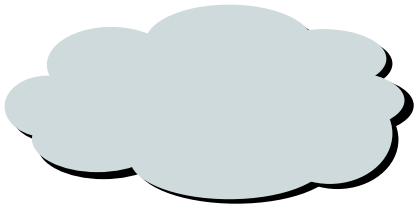
- Network Operator
  - An organisation running an IP backbone
  - Provides access to end users or other network operators
  - Sometimes called a **Service Provider** or a **Network Provider**
- ISP
  - Internet Service Provider
  - Usually commercial, for profit
- REN
  - Research & Education Network
  - Providing access for Universities & Colleges
  - Non-commercial, educational use only

Some Icons…



Router
(layer 3, IP datagram forwarding)

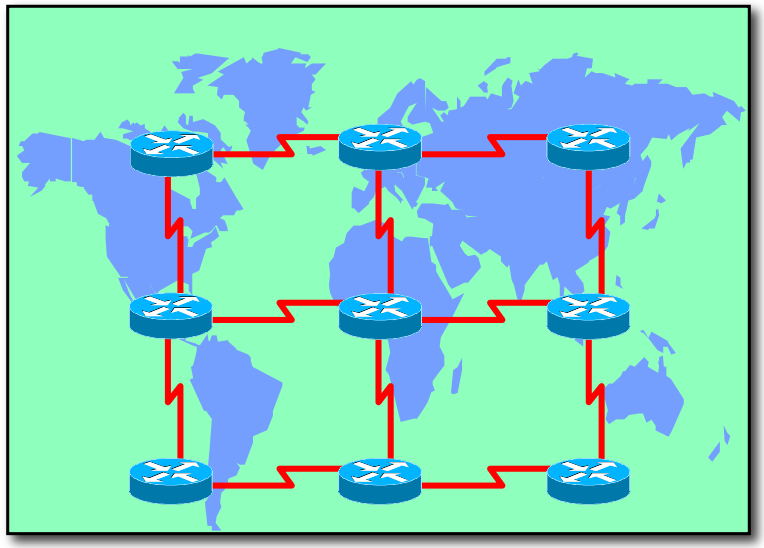
Ethernet switch
(layer 2, packet forwarding)



Network Cloud

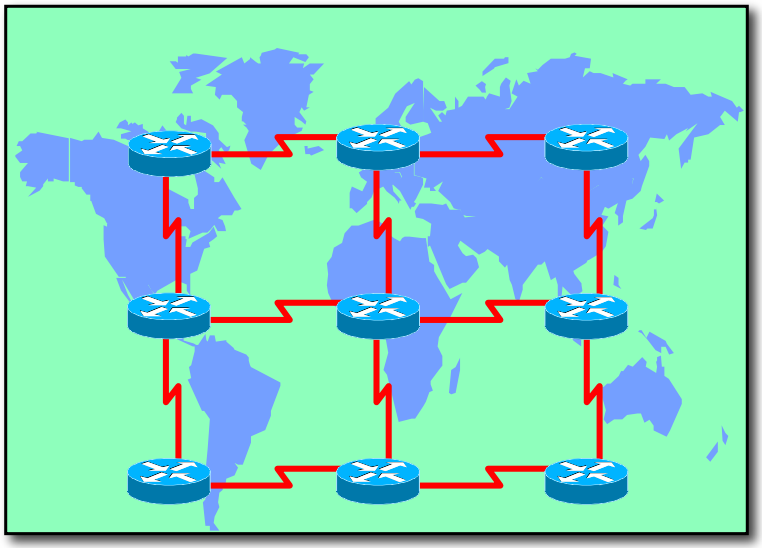
Routed Backbone

- Operators build networks covering regions
  - Regions can cover a country, sub-continent, or even global
  - Each region has points of presence built by the operator
- Routers are the infrastructure
- Physical circuits run between routers
- Easy routing configuration, operation and troubleshooting
- The dominant topology used in the Internet today



MPLS Backbones

- Some operators use Multi Protocol Label Switching (MPLS)
- MPLS is built on top of router infrastructure
  - Replaces old ATM technology
  - Tunnelling over IP network
- Main purpose is to provide VPN services
  - Although these can be implemented with other tunnelling technologies such as GRE



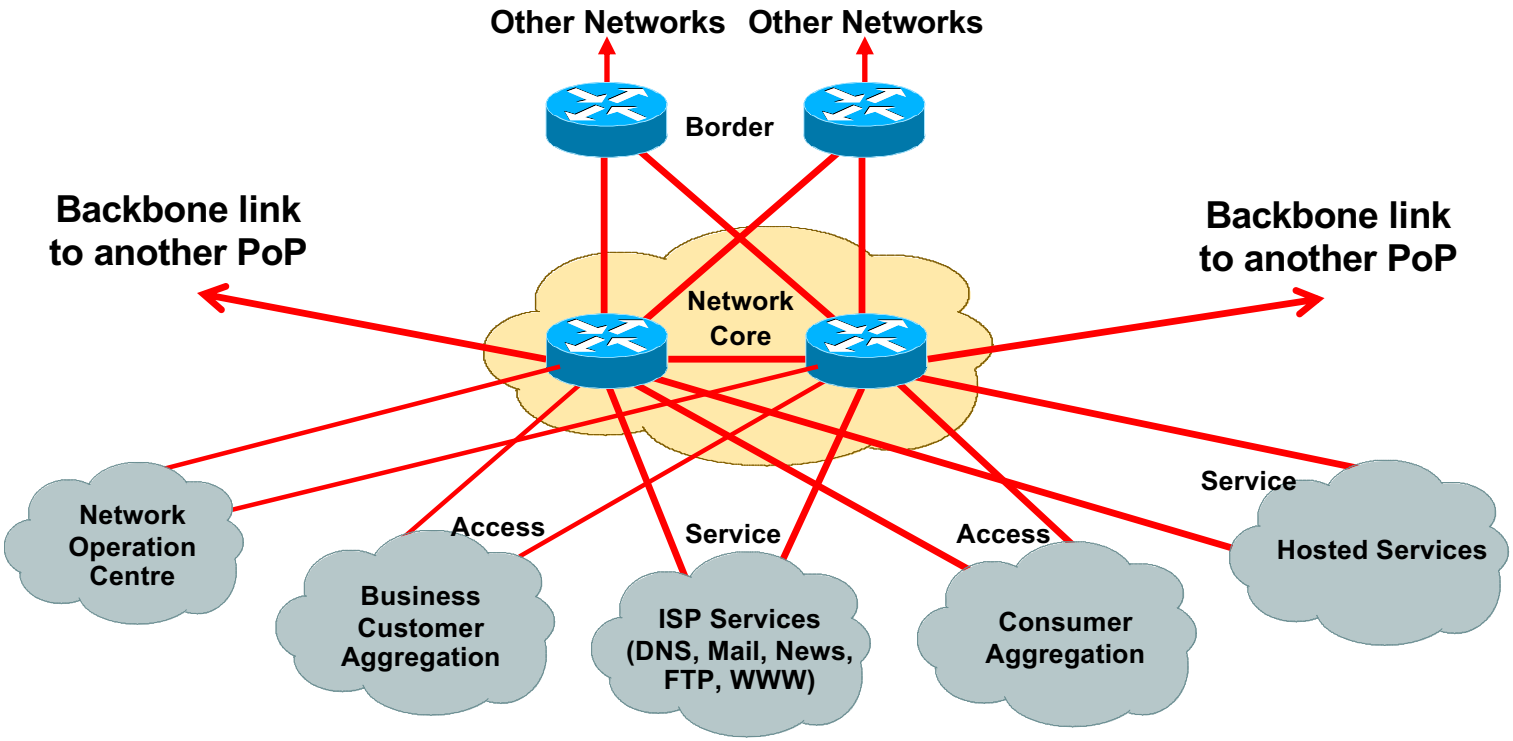
Points of Presence

- PoP – Point of Presence
  - Physical location of operator's equipment
  - Sometimes called a "node"
- vPoP – virtual PoP
  - To the end user, it looks like an operator's location
  - In reality a back hauled access point
  - Used mainly for consumer access networks
- Hub/SuperPoP – large central PoP
  - Links to many PoPs

PoP Topologies

- Core routers
  - high speed trunk connections
- Distribution routers
  - higher port density, aggregating network edge to the network core
- Access routers
  - high port density, connecting the end users to the network
- Border routers
  - connections to other providers
- Service routers
  - hosting and servers
- Some functions might be handled by a single router

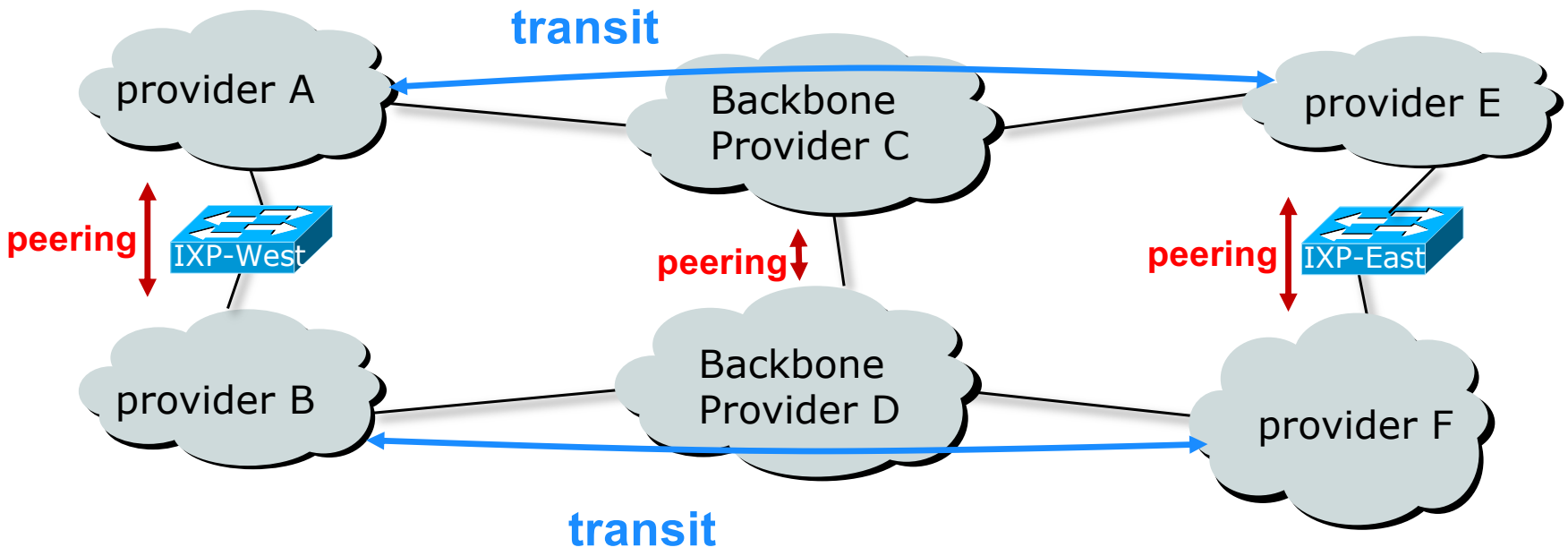
Typical PoP Design



More Definitions

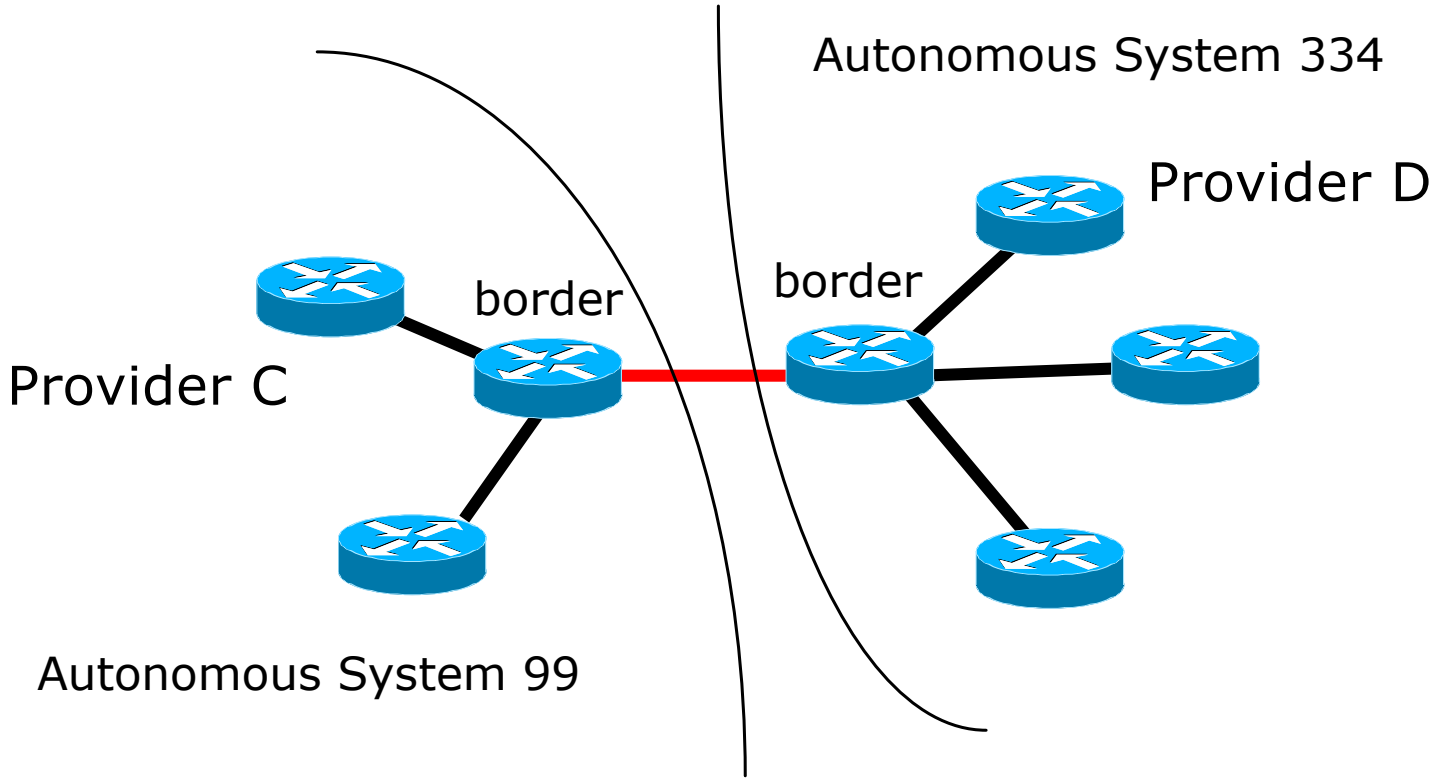
- Transit
  - Carrying traffic across a network
  - Usually **for a fee**
- Peering
  - Exchanging routing information and traffic
  - Usually **for no fee**
  - Sometimes called **settlement free peering**
- Default
  - Where to send traffic when there is no explicit match in the routing table

Peering and Transit example



A and B peer for free, but need transit arrangements with C and D to get packets to/from E and F

Private Interconnect



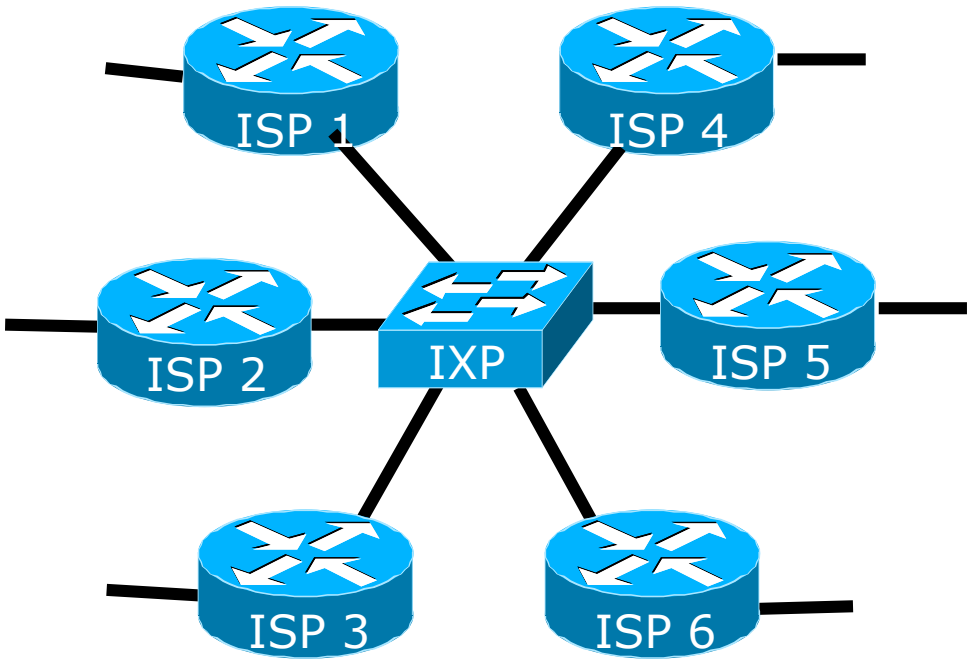
Public Interconnect

- A location or facility where several network operators are present and connect to each other over a common shared media
- Why?
  - To save money, reduce latency, improve performance
- IXP – Internet eXchange Point
- NAP – Network Access Point

Public Interconnect

- Centralised (in one facility)
- Distributed (connected via WAN links)
- Switched interconnect
  - Ethernet (Layer 2)
  - Technologies such as SRP, FDDI, ATM, Frame Relay, SMDS and even routers have been used in the past
- Each provider establishes **peering** relationship with other providers at IXP
  - Provider border router peers with all other provider border routers

Public Interconnect

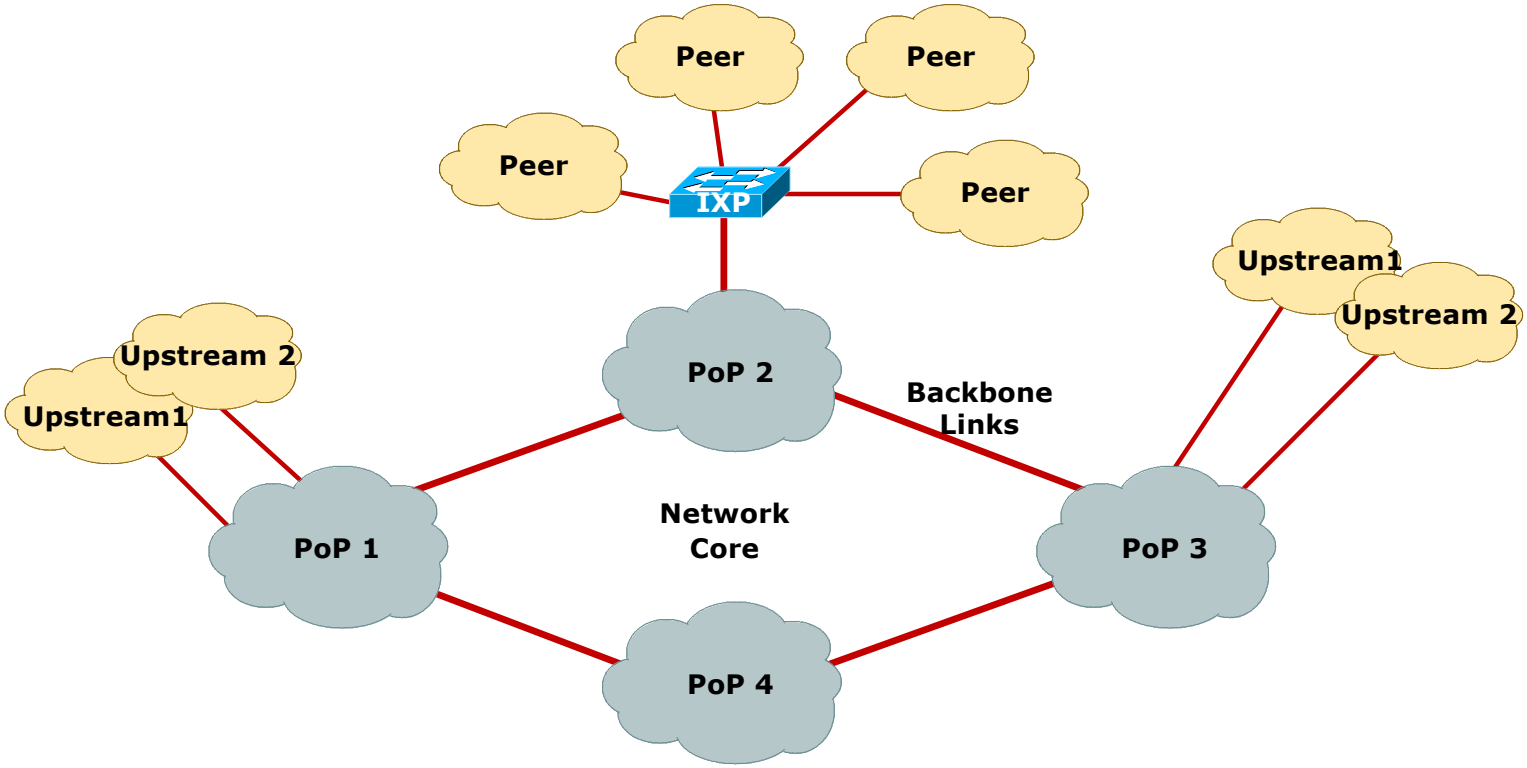


Each of these represents a border router in a different autonomous system

Operators participating in Internet

- Bringing all pieces together, Network Operators:
  - Build multiple PoPs in a distributed network
  - Build redundant backbones
  - Have redundant external connectivity
  - Obtain transit from upstream providers
  - Get free peering from local providers at IXPs

Example Backbone Design



IP Addressing

Where to get address space and who from

IP Addressing Basics

- Internet uses two types of addressing:
  - IPv6 – the new IP protocol
  - IPv4 – legacy IP protocol
- Internet uses classless routing
  - Routers must be CIDR capable
    - **C**lassless **I**nter**D**omain **R**outing
  - No routing assumptions made based on the address block
  - Engineers talk in terms of prefix length
  - For example: 158.43/16 and 2001:DB8::/32

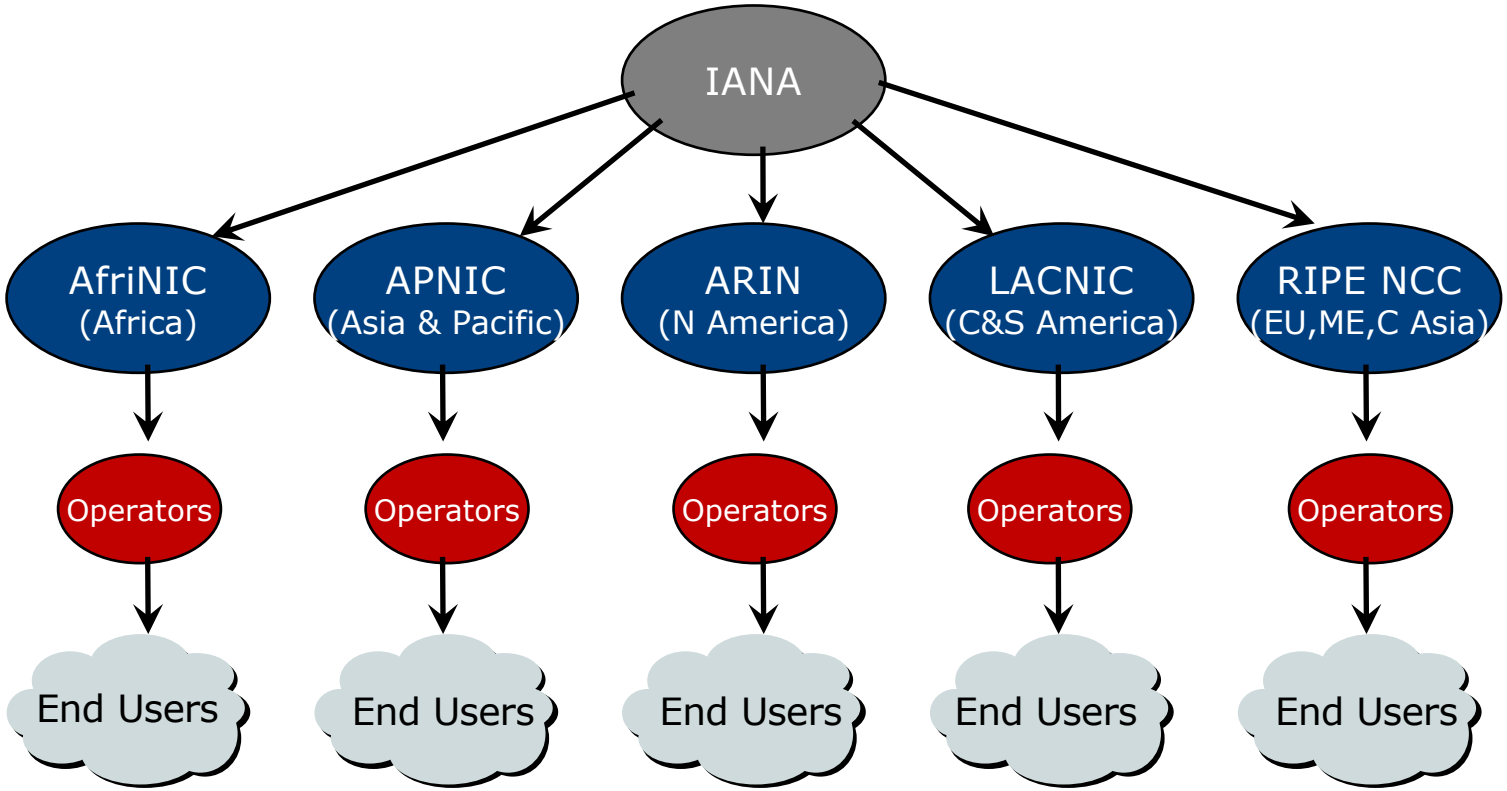
History of IP Addressing

- Pre-CIDR (before 1994)
  - Big networks got a class A
  - Medium networks got a class B
  - Small networks got a class C
- The CIDR IPv4 years (1994 to 2010)
  - Sizes of IPv4 allocations/assignments made according to demonstrated need – **CLASSLESS**
- **IPv6 adoption (from 2011)**
  - Network Operators get at least one /32
  - End Sites get /48
  - IANA's free pool is depleted (February 2011) – the size of IPv4 address allocations and assignments is now very limited

IP Addressing

- IP Address space is a resource shared amongst all Internet users
  - Regional Internet Registries delegated allocation responsibility by the Internet Assigned Numbers Authority (IANA)
  - AfriNIC, APNIC, ARIN, LACNIC & RIPE NCC are the five RIRs
  - RIRs **allocate** address space to Network Operators/Local Internet Registries
  - Operators/LIRs **assign** address space to end customers or other Operators
- RIRs address distribution:
  - IPv6 is plentiful
  - IPv4 is very limited

Address delegation hierarchy



Non-portable Address Space

- "Provider Aggregatable" or "PA Space"
  - Customer uses RIR member's address space while connected to Internet
  - Customer has to renumber to change provider
  - Aids control of size of Internet routing table
  - Need to fragment provider block when multihoming
- PA space is allocated to the RIR member
  - All assignments made by the RIR member to end sites are announced as an aggregate to the rest of the Internet

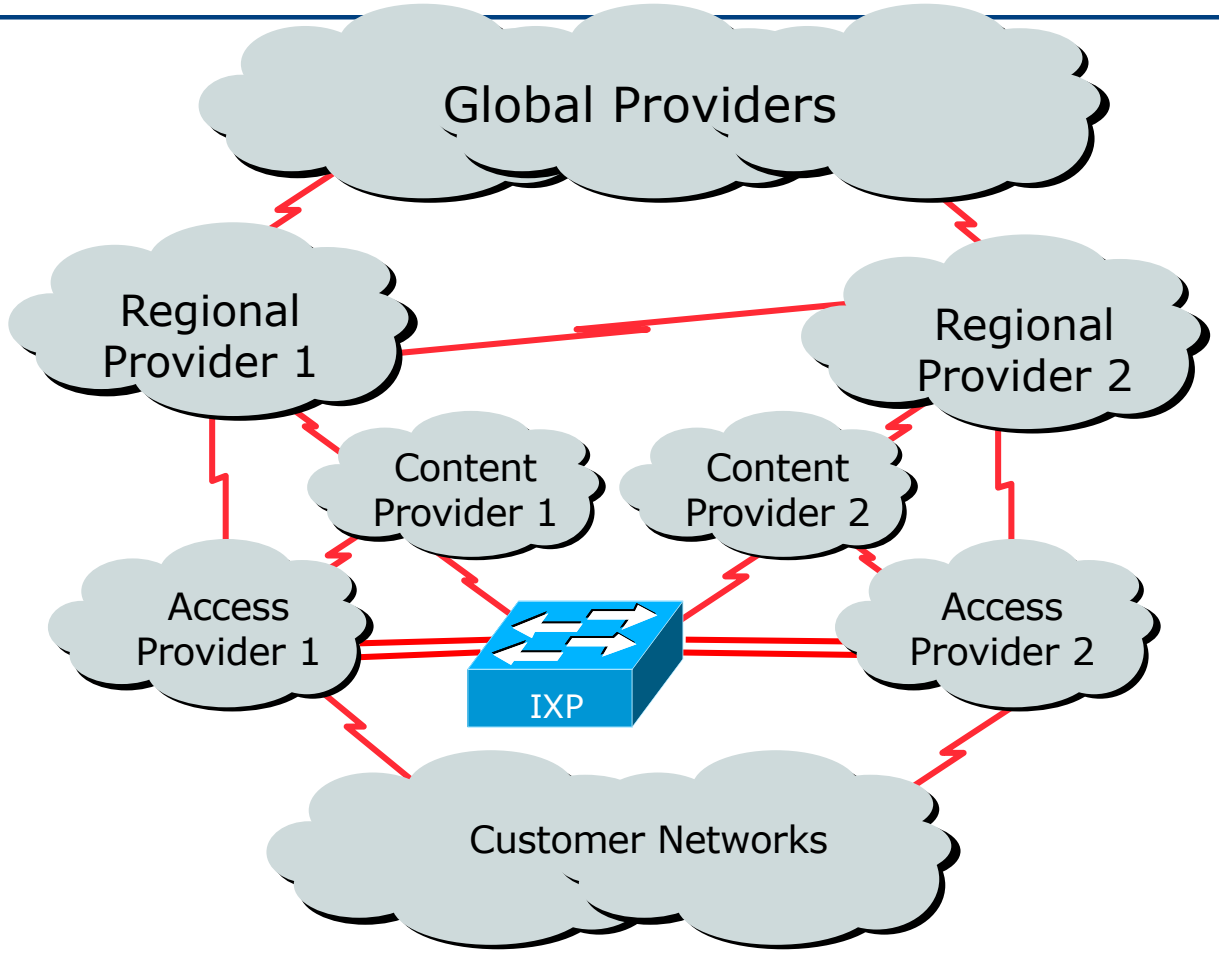
Portable Address Space

- “Provider Independent” or “PI Space”
  - Customer gets or has address space independent of their provider
  - Customer keeps addresses when changing provider
  - Is very bad for size of Internet routing table
  - Is very bad for scalability of the routing system
  - → PI space is rarely distributed by the RIRs

Internet Hierarchy

The pecking order

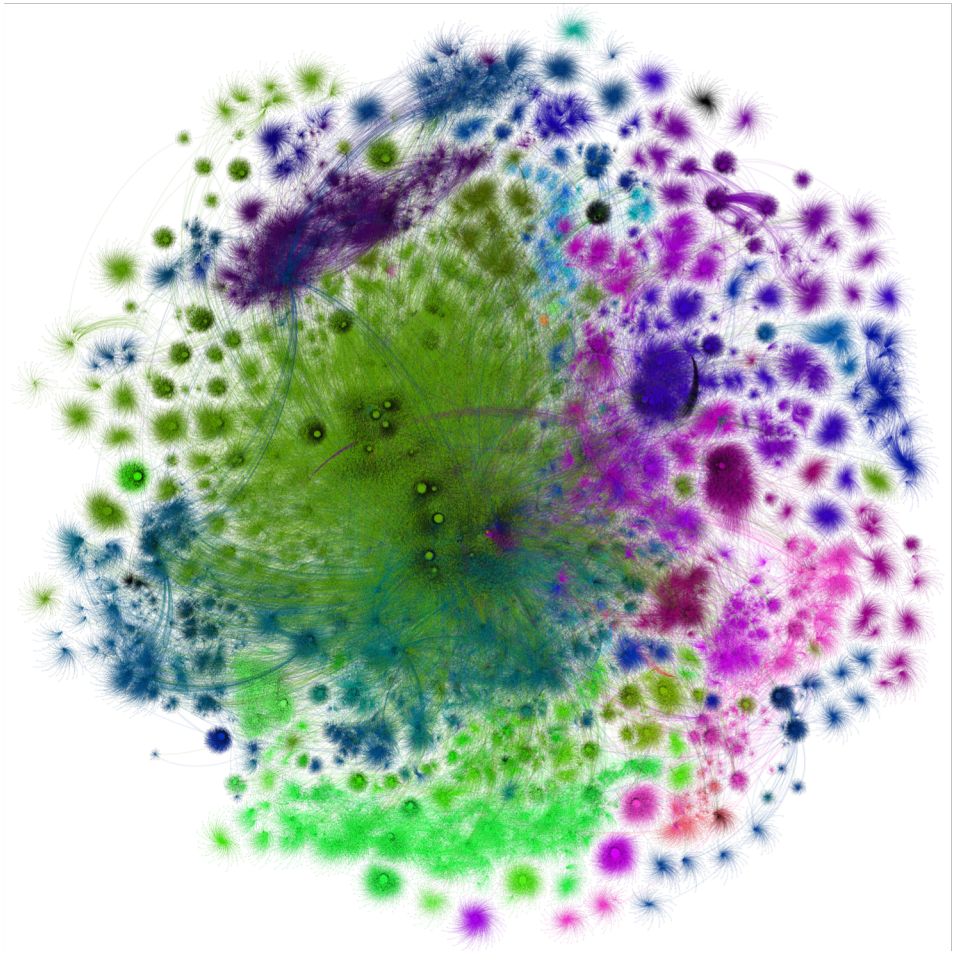
Global Internet: High Level View



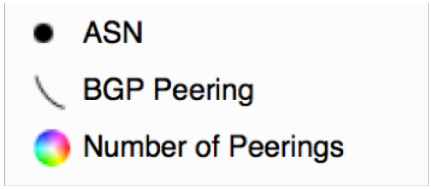
Detailed View of the Global Internet

- Global Transit Providers
  - Connect to each other
  - Provide connectivity to Regional Transit Providers
- Regional Transit Providers
  - Connect to each other
  - Provide connectivity to Content Providers
  - Provide connectivity to Access Providers
- Content Providers
  - Cross-connect to Access Providers
  - Peer at IXPs (free traffic to Access Providers)
- Access Providers
  - Connect to each other across IXPs (free peering)
  - Provide access to the end user

IPv4 Internet by BGP Peerings



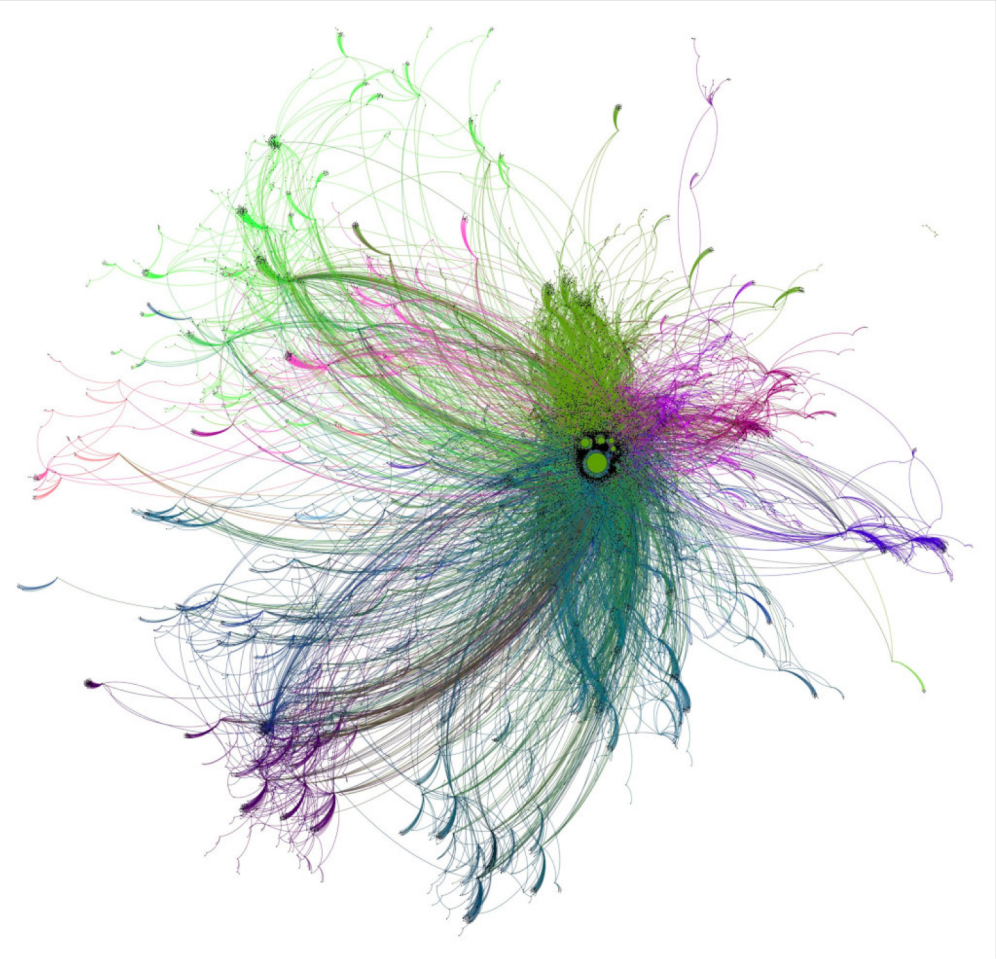
The IPv4 Default Free Zone, June 2016



Credit to Blair Harrison
http://jedi.school.nz/sg2015/
and Dean Pemberton

Also look at
http://thyme.apnic.net/BGP
for regional breakdown and
interactive graphic

IPv6 Internet by BGP Peerings



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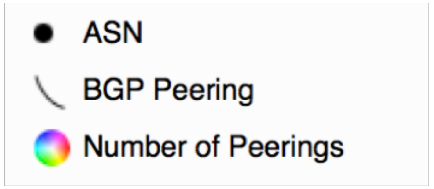
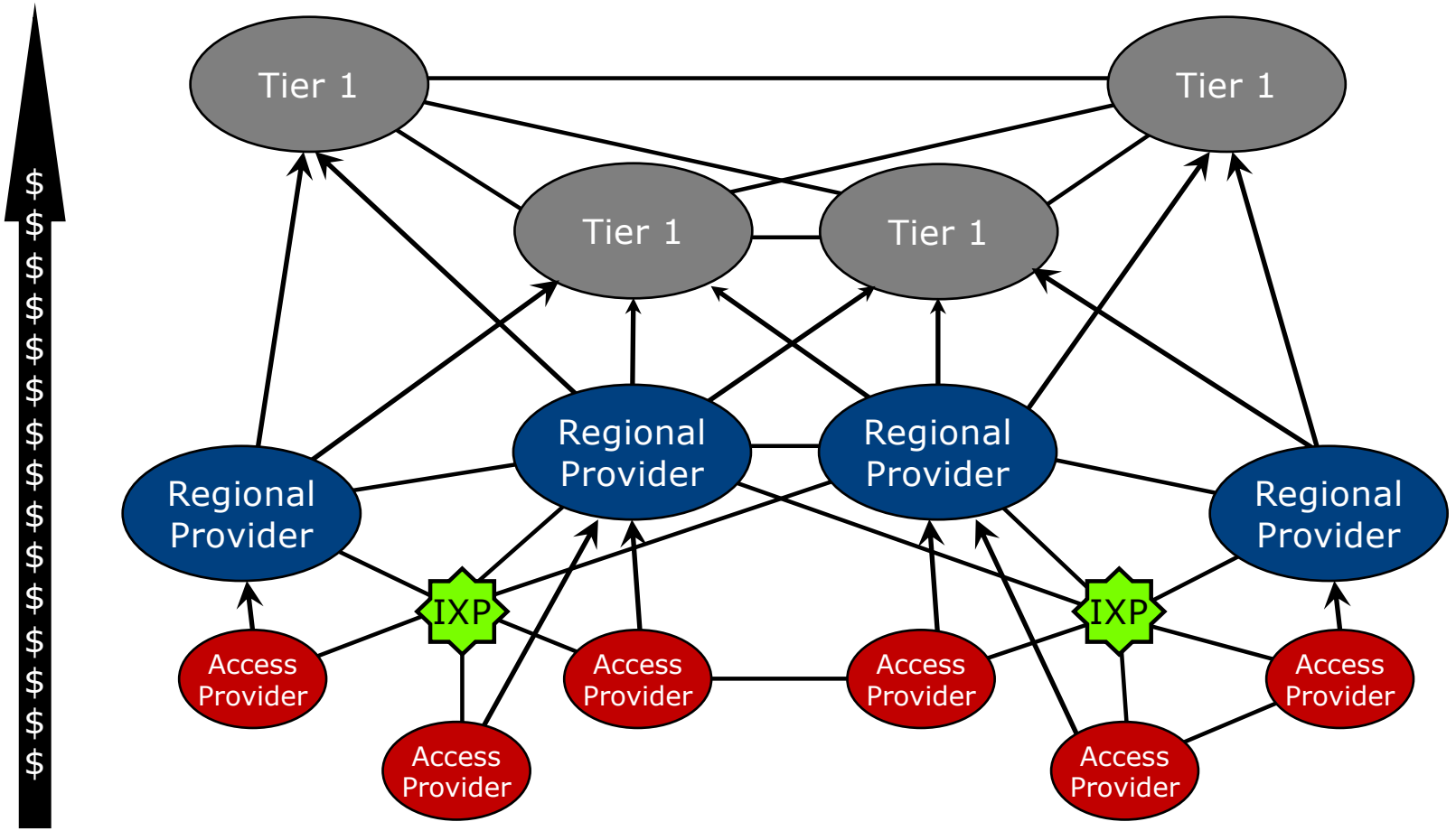


Credit to Blair Harrison http://jedi.school.nz/sg2015-v6/ and Dean Pemberton

Also look at http://thyme.apnic.net/BGP for interactive graphic

Categorising Network Operators



Categorising Network Operators

- Tier-1 – definition:
  - A provider which peers with other Tier-1s and does NOT pay for transit
  - Caveat:
    - Many marketing departments call their service provider a Tier-1 – even though that provider may still pay for transit to some parts of the Internet
- Regional providers often have the reach of Tier-1s but still have to rely on maybe one or two Tier-1s to access the whole Internet
  - They often provide access too, via in country domestic access networks
- Access providers work exclusively in their locale

Inter-provider relationships

- Peering between equivalent sizes of service providers (e.g. Regional to Regional)
  - Shared cost private interconnection, equal traffic flows
  - No cost peering
- Peering across exchange points
  - If convenient, of mutual benefit, technically feasible
- Fee based peering
  - Unequal traffic flows, “market position”

Default Free Zone

The default free zone is made up of Internet routers which have routing information about the whole Internet, and therefore do not need to use a default route

NB: is not related to where a network operator is in the hierarchy

Gluing it together

Gluing it together

- Who runs the Internet?
  - No one
  - (Definitely not ICANN, nor the RIRs, nor the US,…)
- How does it keep working?
  - Inter-provider business relationships and the need for customer reachability ensures that the Internet by and large functions for the common good
- Any facilities to help keep it working?
  - Not really. But…
  - Engineers keep working together!

Engineers keep talking to each other...

- North America
  - NANOG (North American Network Operators Group)
  - NANOG meetings and mailing list
  - www.nanog.org
- Latin America
  - Foro de Redes
  - NAPLA
  - LACNOG – www.lacnog.org
- Middle East
  - MENOG (Middle East Network Operators Group)
  - www.menog.org

Engineers keep talking to each other...

- Asia & Pacific
  - APRICOT annual conference
    - www.apricot.net
  - APOPS mailing list
    - mailman.apnic.net/mailman/listinfo/apops
  - PacNOG (Pacific NOG)
    - mailman.apnic.net/mailman/listinfo/pacnog
  - SANOG (South Asia NOG)
    - lists.sanog.org/mailman/listinfo/sanog

Engineers keep talking to each other...

- Europe
  - RIPE meetings, working groups and mailing lists
  - e.g. Routing WG: www.ripe.net/mailman/listinfo/routing-wg
- Africa
  - AfNOG meetings and mailing list
  - SAFNOG – Southern Africa NOG – www.safnog.org
- Caribbean
  - CaribNOG meetings and mailing list
- And many in-country ISP associations and NOGs
- IETF meetings and mailing lists
  - www.ietf.org

Summary

- Topologies and Definitions
- IP Addressing
  - PA versus PI address space
- Internet Hierarchy
  - Local, Regional, Global Transit Providers
  - IXPs
- Gluing it all together
  - Engineers cooperate, common business interests

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