Internet Exchange Point Design

ISP/IXP Workshops

IXP Design

- Background
- Why set up an IXP?
- Layer 2 Exchange Point
- Design Considerations
- Route Collectors & Servers
- What can go wrong?

A bit of history

Where did the IX concept come from?

A Bit of History…

- NSFnet – one major backbone
  - US "National Science Foundation" funded
  - Connected academic & research institutions
  - Also connected "private company" networks, with acceptable use policy
    - **AUP: No commercial activity**
  - Three Network Access Points (NAPs): Chicago, New York, San Francisco
- Private companies needed to interconnect their networks
  - Requirement to send "commercial traffic"
  - Could not cross NSFnet
  - Resulted in the early "commercial Internet Exchanges"

More History…

- Early Internet Exchanges created in early 90s
  - CIX-West – west coast USA
  - MAE-East – east coast USA
  - D-GIX – Stockholm
- End of the NSFnet in 1995:
  - Meant move towards commercial Internet
  - Private companies selling their bandwidth
  - ANS (operator of the late NSFnet) had to join IXes
- Routing Arbiter project helped with coordination of routing exchange between providers
  - Traffic from ISP A needs to get to ISP B

More History still…

- The NAPs established late in NSFnet life were some of the original "exchange points"
  - NAP operators supported commercial activities as well
  - (Sprint: NY, PacBell: SF, Ameritech: Chicago, MFS: Vienna/VA)
- The NAPs replaced by IXPs:
  - NAPs didn't succeed (operated by ISPs), replaced by more neutral IXPs
  - E.g. Virginia NAP replaced by MAE-East (by MFS)
- Mid 90s saw rapid Internet growth, with major providers connecting…

Even more History

- D-GIX formed in Stockholm in 1992
  - Three major ISPs interconnected
  - Latency reduction, performance gains
  - Local traffic stays local
- LINX formed in London in 1994
  - Five UK operators interconnected
  - Latency reduction, performance gains
  - Local traffic stays local
- HKIX formed in Hong Kong in 1995
  - Vibrant Internet community, many small operators
  - Latency, performance, and local traffic benefits
- Also AMS-IX in Amsterdam in 1994
  - Same reasons as others

Internet Exchange Point

- What:
  - **A neutral location where network operators freely interconnect their networks to exchange traffic**
- What is the physical IX:
  - An ethernet switch in a neutral location
- How does it work:
  - IX Operator provides the switch and rack space
  - Network Operators bring routers, and interconnect them via the IX fabric
- Very simple concept – any place where providers meet to exchange traffic

Internet Exchange Point

- Layer 2 exchange point
  - Ethernet (100Gbps/10Gbps/1Gbps/100Mbps)
  - Older technologies used in the past included ATM, Frame Relay, SRP, FDDI and SMDS
- Layer 3 exchange point
  - Has historical status now
  - Router based
    - Best known example was CIX-West
    - Router very quickly overwhelmed by the rapid growth of the Internet

Why an Internet Exchange Point?

Saving money, improving QoS,
Generating a local Internet economy

Internet Exchange Point
Why peer?

- Consider a region with one ISP
  - They provide internet connectivity to their customers
  - They have one or two international connections
- Internet grows, another ISP sets up in competition
  - They provide internet connectivity to their customers
  - They have one or two international connections
- How does traffic from customer of one ISP get to customer of the other ISP?
  - Via the international connections

Internet Exchange Point
Why peer?

- Yes, International Connections…
  - If satellite, RTT is around 550ms per hop
  - So local traffic takes over 1s round trip
- International bandwidth
  - Costs significantly more than domestic bandwidth
  - Congested with local traffic
  - Wastes money, harms performance

Internet Exchange Point
Why peer?

- Solution:
  - Two competing ISPs peer with each other
- Result:
  - Both save money
  - Local traffic stays local
  - Better network performance, better QoS,…
  - More international bandwidth for expensive international traffic
  - Everyone is happy

Internet Exchange Point
Why peer?

- A third ISP enters the equation
  - Becomes a significant player in the region
  - Local and international traffic goes over their international connections
- They agree to peer with the two other ISPs
  - To save money
  - To keep local traffic local
  - To improve network performance, QoS,…

Internet Exchange Point
Why peer?

- Private peering means that the three ISPs have to buy circuits between each other
  - Works for three ISPs, but adding a fourth or a fifth means this does not scale
- Solution:
  - Internet Exchange Point

Internet Exchange Point

- Every participant has to buy just one whole circuit
  - From their premises to the IXP
- Rather than N-1 half circuits to connect to the N-1 other ISPs
  - 5 ISPs have to buy 4 half circuits = 2 whole circuits → already twice the cost of the IXP connection

Internet Exchange Point

- Solution
  - Every ISP participates in the IXP
  - Cost is minimal – one local circuit covers all domestic traffic
  - International circuits are used for just international traffic – and backing up domestic links in case the IXP fails
- Result:
  - Local traffic stays local
  - QoS considerations for local traffic is not an issue
  - RTTs are typically sub 10ms
  - Customers enjoy the Internet experience
  - Local Internet economy grows rapidly

Who can join an IXP?

- Requirements are very simple: any organisation which operates their own autonomous network, and has:
  - Their own address space
  - Their own AS number
  - Their own transit arrangements
- This often includes:
  - Commercial ISPs
  - Academic & Research networks
  - Internet infrastructure operators (eg Root/ccTLDs)
  - Content Providers & Content Distribution Services
  - Broadcasters and media
  - Government Information networks

When an IXP is not beneficial

- Legislation: When there is one *legislated* monopoly transit provider
  - With all other network operators *legislated* to be customers of this monopoly provider
- Geography: When the local economy is so small that it cannot sustain more than one network operator
  - Very small nations (maybe less than 10000 population?)
  - Sparsely populated / remote areas

When an IXP is not permitted

- This is still the situation in several countries around the world
- Usually it is a Government operated "national telco"
  - ISP licence mandates connecting to "national telco" for Internet services
- Implications:
  - Expensive domestic connectivity
  - Expensive international connectivity
  - Restricted and poor service offerings
  - No domestic Internet economy

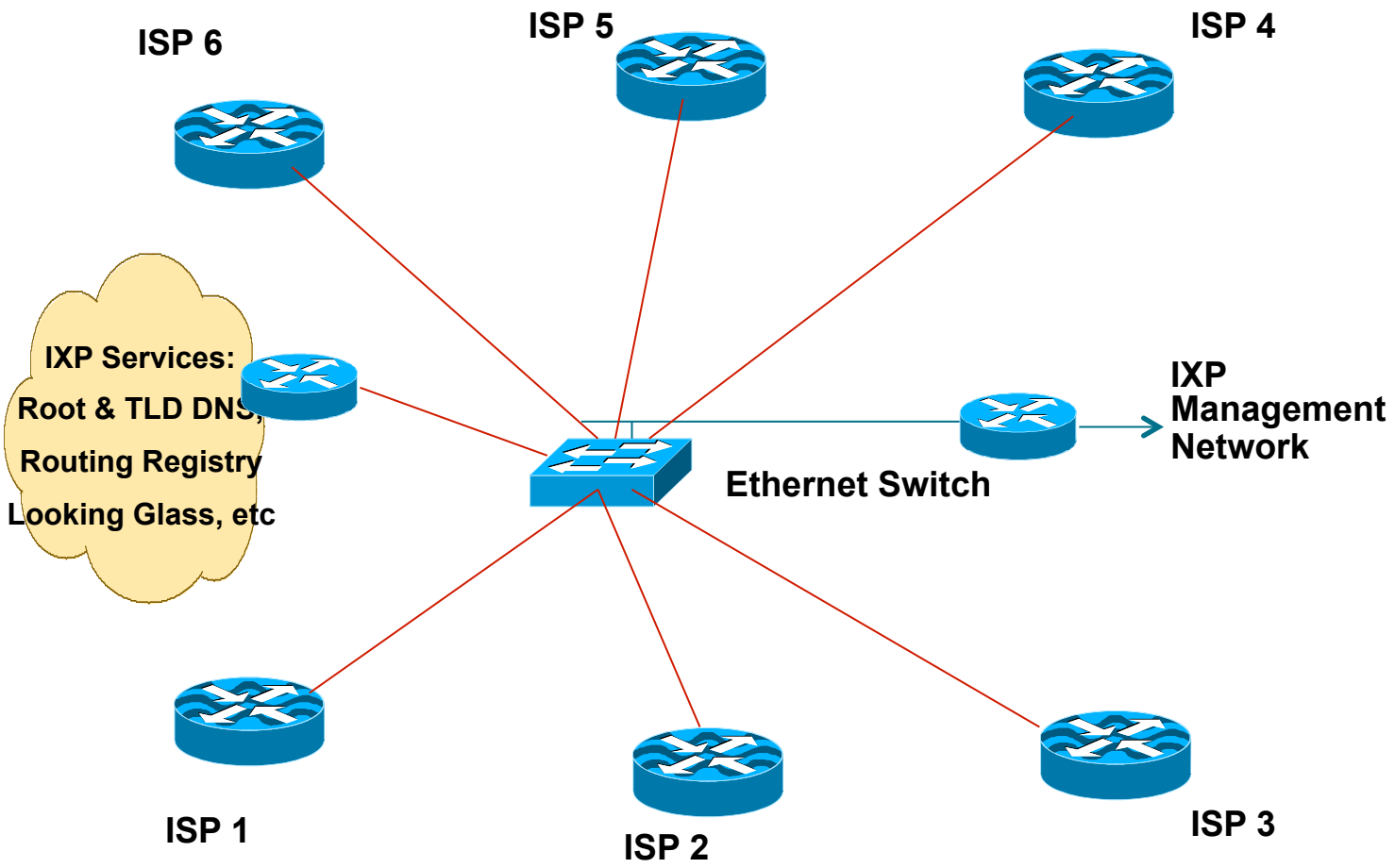
Layer 2 Exchange

The traditional IXP

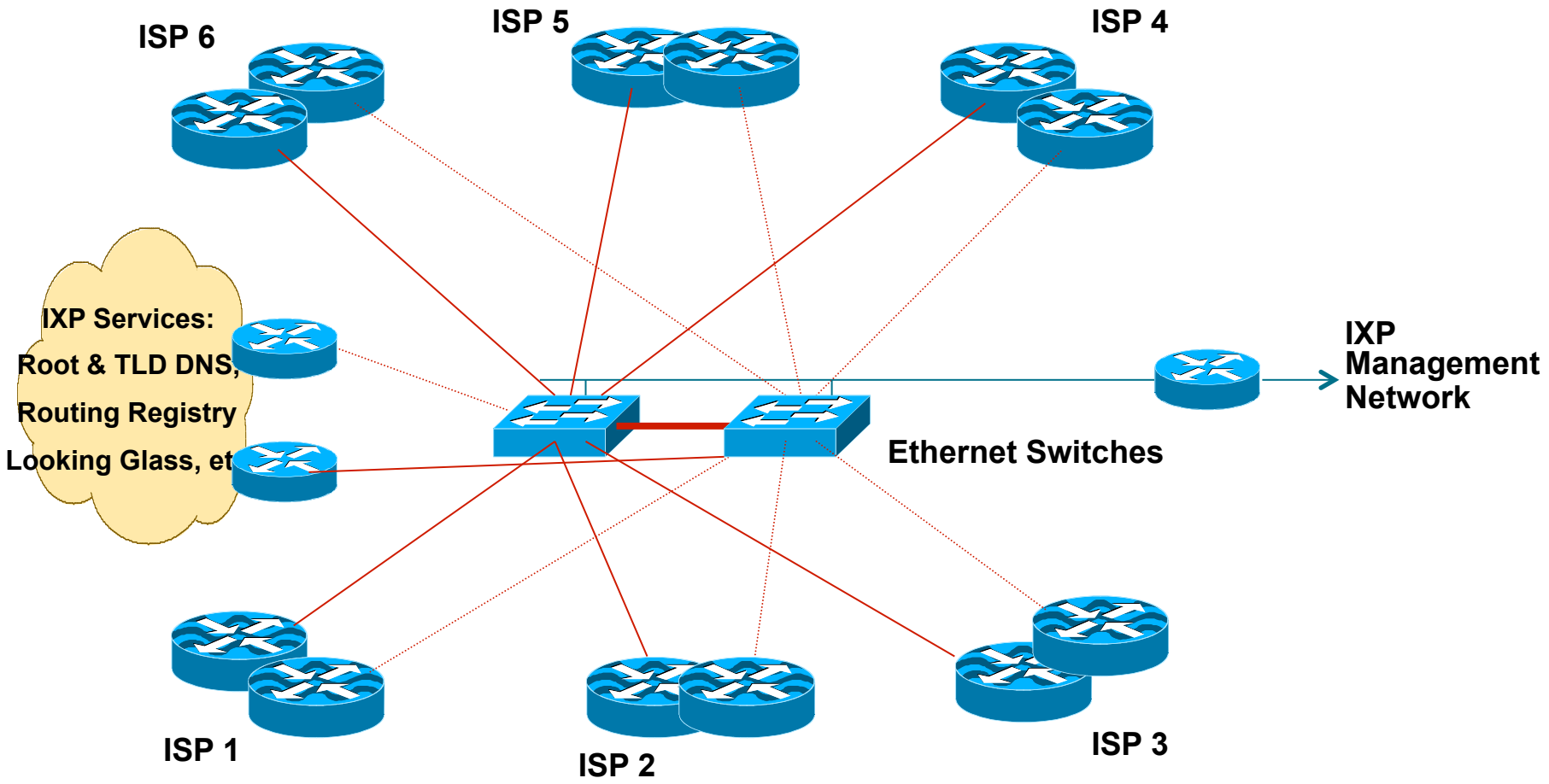
IXP Design

- Very simple concept:
  - Ethernet switch is the interconnection media
    - IXP is one LAN
  - Each ISP brings a router, connects it to the ethernet switch provided at the IXP
  - Each ISP peers with other participants at the IXP using BGP
- Scaling this simple concept is the challenge for the larger IXPs

Layer 2 Exchange



Layer 2 Exchange



Layer 2 Exchange

- Two switches for redundancy
- ISPs use dual routers for redundancy or loadsharing
- Offer services for the “common good”
  - Internet portals and search engines
  - DNS Root & TLDs, NTP servers
  - Routing Registry and Looking Glass

Layer 2 Exchange

- Neutral location
  - Anyone can install fibre or other connectivity media to access the IXP
    - Without cost or regulations imposed by location
- Secure location
  - Thorough security, like any other network data centre
- Accessible location
  - Easy/convenient for all participants to access
- Expandable location
  - IXPs result in Internet growth, and increasing space requirements

Layer 2 Exchange

- Operation:
  - Requires neutral IXP management
  - "Consortium"
    - Representing all participants
    - "Management Board" etc
- Funding:
  - All costs agreed and covered equally by IXP participants
  - Hosting location often contributes – the IXP brings them more business
- Availability:
  - 24x7 cover provided by hosting location
    - Managed by the consortium

Layer 2 Exchange

- Configuration
  - Public address space for IXP LAN
    - IPv4 (/24) and IPv6 (/64)
  - Private address space for IXP LAN if non-transit and no value add services
  - ISPs require AS, basic IXP does not
- Network Security Considerations
  - LAN switch needs to be securely configured
  - Management routers require TACACS+ authentication, vty security
  - IXP services must be behind router(s) with strong filters

Layer 2 Exchange

- Industry Standards documented by Euro-IX, the European IXP Association
  - Contributed to by the Euro-IX members
  - https://www.euro-ix.net/starting-an-ixp
- IXP BCP
  - General overview of the infrastructure, operations, policies and management of the IXP
  - https://www.euro-ix.net/euro-ix-bcp
- IXP Website BCP
  - https://www.euro-ix.net/website-bcp

“Layer 3 Exchange”

Why this is not an IXP

“Layer 3 IXP”

- Layer 3 IXP today is marketing concept used by Transit ISPs
  - Some incumbent telcos call their domestic or international transit businesses “Exchanges”
- Real Internet Exchange Points are only Layer 2
  - L2 is the accepted International standard

“Layer 3 IXP” – what breaks

- One extra AS hop between peers
  - Makes path via IXP suboptimal/less preferred
  - Path between peers usually remains with upstream transit provider
    - Unless both peers actively implement BGP policies to prefer the L3 IXP
- Members cannot peer with whom they please
  - Mandatory multilateral peering
  - Third party (L3 IXP operator) required to configure peering sessions and peering policy

“Layer 3 IXP” – what breaks

- More complicated troubleshooting
  - Troubleshooting peering problems has to involve IXP operator too
- No policy control
  - BGP attributes shared between members gets dropped by IXP router
  - (Examples are BGP communities, MEDs)

“Layer 3 IXP” – what breaks

- CDNs won’t join
  - They have requirements to peer directly with IXP members
- Redundancy problems
  - L3 IXPs with dual sites appear as two separate transit providers between peers
  - Traffic engineering?
- L3 IXP Operator requires strong BGP skills

IXP Design Considerations

Exchange Point Design

- The IXP Core is an Ethernet switch
  - It must be a managed switch
  - It must have reasonable security features
  - https://www.euro-ix.net/ixp-wishlist has more details
- Has superseded all other types of network devices for an IXP
  - From the cheapest and smallest managed 12 or 24 port 10/100 switch
  - To the largest switches now handling high densities of 10GE and 100GE interfaces

Exchange Point Design

- Each ISP participating in the IXP brings a router to the IXP location
  - Note that with increased availability of fibre access, ISPs connect directly to the IXP without provisioning a dedicated router at the IXP location
- Router needs:
  - One Ethernet port to connect to IXP switch
  - One WAN port to connect to the WAN media leading back to the ISP backbone
  - To be able to run BGP

Exchange Point Design

- IXP switch located in one equipment rack dedicated to IXP
  - Also includes other IXP operational equipment
- Routers from participant ISPs located in neighbouring/adjacent rack(s)
- Copper (UTP) connections made for 10Mbps, 100Mbps or 1Gbps connections
- Fibre used for 1Gbps, 10Gbps, 40Gbps or 100Gbps connections

Peering

- Each participant needs to run BGP
  - They need their own AS number
  - **Public** ASN, **NOT** private ASN
- Each participant configures external BGP directly with the other participants in the IXP
  - Peering with all participants

    or
  - Peering with a subset of participants

Peering (more)

- Mandatory Multi-Lateral Peering (MMLP)
  - Each participant is forced to peer with every other participant as part of their IXP membership
  - **Has no history of success** — the practice is strongly discouraged
- Multi-Lateral Peering (MLP)
  - Each participant peers with every other participant (usually via a Route Server)
- Bi-Lateral Peering
  - Participants set up peering with each other according to their own requirements and business relationships
  - This is the most common situation at IXPs today

Types of Operator Peering Policies

- Open Peering
  - Where an ISP publicly states that they will peer with all parties who approach them for peering
  - Commonly found at IXPs where ISP participates via the Route Server
- Selective Peering
  - Where an ISP's peering policy depends on the nature of the operator who requests peering with them
  - At IXPs, operator will not peer with RS but will only peer bilaterally
- Closed Peering
  - Where an ISP decides who its peering partners are, and is generally not approachable to creating peering opportunities

Operators Peering Activities

- The Peering Database documents ISPs peering policies and contact information
  - http://peeringdb.com
- All operators of ASNs should register in the peeringdb
  - All operators who are considering peering or are peering must be in the peeringdb to enhance their peering opportunities
- Participation in peering fora is encouraged too
  - Global Peering Forum (GPF)
  - Regional Peering Fora (European, Middle Eastern, Asian, Caribbean, Latin American)

Routing

- ISP border routers at the IXP must NOT be configured with a default route or carry the full Internet routing table
  - Carrying default or full table means that this router and the ISP network is open to abuse by non-peering IXP members
  - Correct configuration is only to carry routes offered to IXP peers on the IXP peering router
- Note: Some ISPs offer transit across IX fabrics
  - They do so at their own risk – see above

Routing (more)

- ISP border routers at the IXP should not be configured to carry the IXP LAN network within the IGP or iBGP
  - Use next-hop-self BGP concept
- Don't generate ISP prefix aggregates on IXP peering router
  - If connection from backbone to IXP router goes down, normal BGP failover will then be successful

Address Space

- Some IXPs use private addresses for the IX LAN
  - Public address space means IXP network could be leaked to Internet which may be undesirable
  - Because most ISPs filter RFC1918 address space, this avoids the problem
- Most IXPs use public addresses for the IX LAN
  - Address space available from the RIRs
  - IXP terms of participation often forbid the IX LAN to be carried in the ISP member backbone
- Typically IXPs now provide both IPv6 and IPv4 support on IX LANs

Autonomous System Numbers

- IXPs by themselves do not require ASNs
  - Ethernet switch is L2 device, and does not run BGP
- Some IXPs have a Route Collector
  - This usually runs in a private ASN
- Some IXPs have a Route Server
  - This usually runs in a public ASN
- Some IXPs have “common good services”
  - These usually require Internet transit
  - Meaning the IXP requires a transit router
    - IXP arranges transit for services with a couple of providers
  - And this transit router requires a Public ASN and Public Address space

Hardware

- Ethernet switch needs to be managed
  - Including CLI access rather than only SNMP
  - Unmanaged switches mean an unmanageable IXP
- Insist that IXP participants connect a router (L3) port to the IXP switch
  - Avoid spanning tree and L2 security issues
  - Run port security or MAC filtering to protect the IX
- Insist that IXP participants bring their own router
  - Moves buffering problem off the IXP switch
  - (Fibre access to IX reduces this requirement)
  - Security of ISP connection is responsibility of the ISP, not the IXP

Charging

- IXPs needs to be run at minimal cost to its member participants
- Common examples:
  - Datacentre hosts IX for free
  - IX operates cost recovery
  - Different pricing for different ports
- IXes do **NOT** charge for traffic crossing the switch fabric
  - They are a peering enabler, encouraging as much traffic as possible between members

Charging: Datacentre hosts IX for free

- Datacentre covers all costs relating to the IX
  - They provide the switch and supporting infrastructure
  - They provide the operator cover
  - They benefit from the business the IX members and their customers bring to the DC
  - They benefit from the "prestige" of hosting the IX and its ancillary services
- The IX does not charge members for anything at all
  - Example: Seattle IX

Charging:
IX Members pay flat fee

- Each member pays a flat annual fee towards their IX membership
- How it works:
  - Cost of switch and ports
  - Cost of operator support
  - Datacentre cost: power, air-conditioning, etc
  - Cost of IX membership association
  - Contingency needed for new equipment and upgrades
- Total annual cost shared equally amongst members
  - The more members, potentially the lower the costs to each

Charging: Differential pricing by port

- IXP Member pays according to the port speed they require
  - One linecard may handle 4 100GE ports
  - Or one linecard may handle 24 10GE ports
  - Or one linecard may handle 96 1GE ports
  - 96 port 1GE card is tenth price of 24 port 10GE card
  - Relative port cost is passed on to participants
  - Plus share in the cost of the switch
  - Plus all the costs mentioned in the flat-fee model
- IX members pay according to the cost of provisioning their port speed
  - Example: Netnod IXes in Sweden

Services Offered

- Services offered should not compete with member ISPs (basic IXP)
  - e.g. web hosting at an IXP is a bad idea unless all members agree to it
- IXP operations should make performance and throughput statistics available to members
  - Use tools such as LibreNMS to produce IX throughput graphs for member (or public) information

Services to Offer

- Root server
  - Anycast instances of F, I and L root nameservers are present at many IXes
- ccTLD DNS
  - The country IXP could host the country's top level DNS
  - e.g. "SE." TLD is hosted at Netnod IXes in Sweden
  - Offer back up of other country ccTLD DNS
- gTLD DNS
  - .com & .net are provided by Verisign at many IXes

Services to Offer

- Route Server
  - Helps scale IXes by providing easier BGP configuration & operation for participants with Open Peering policies
  - Technical detail covered later on
- Looking Glass
  - One way of making the Route Server routes available for global view (e.g. www.traceroute.org)
  - Public or members only access

Services to Offer

- Content Redistribution/Caching
  - Various providers offering content distribution services
  - Broadcast media
- Network Time Protocol
  - Locate a stratum 1 time source (GPS receiver, atomic clock, etc) at IXP
- Routing Registry
  - Used to register the routing policy of the IXP membership (more later)

Introduction to Route Collectors

What routes are available at the IXP?

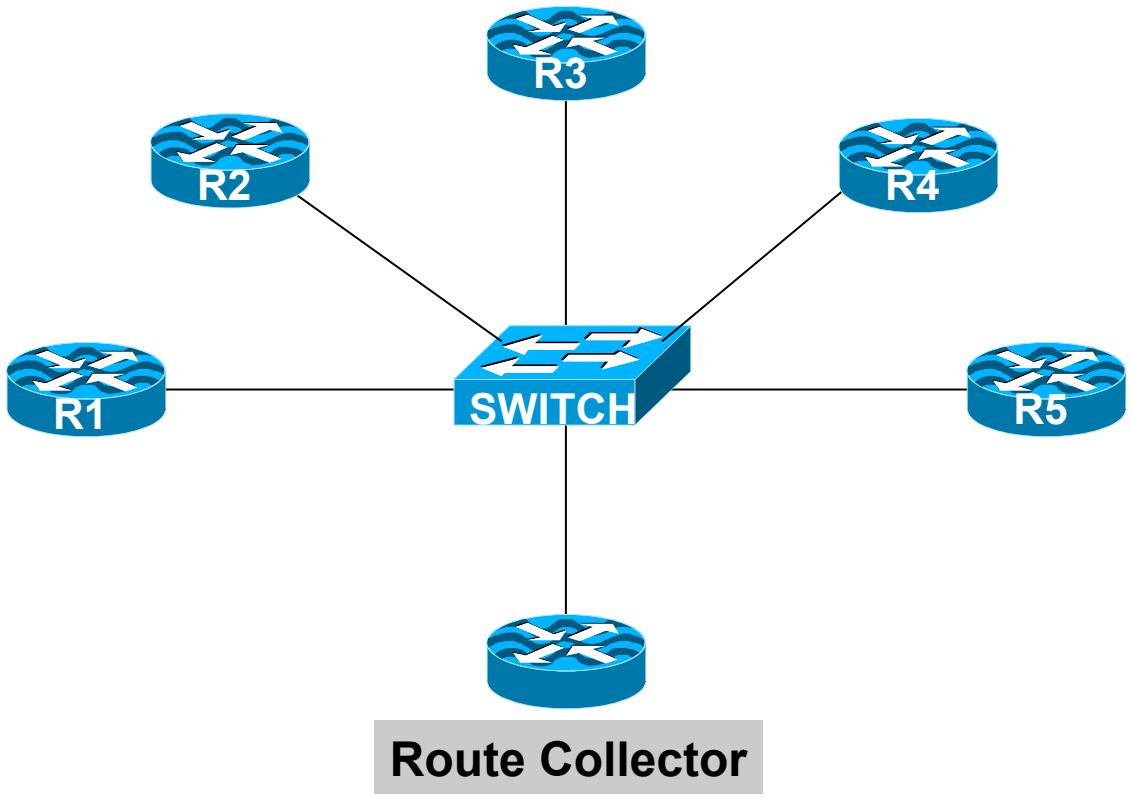
What is a Route Collector?

- Usually a router or Unix system running BGP
- Gathers routing information from service provider routers at an IXP
  - Peers with each ISP using BGP
- Does not forward packets
- Does not announce any prefixes to ISPs

Purpose of a Route Collector

- To provide a public view of the Routing Information available at the IXP
  - Useful for existing members to check functionality of BGP filters
  - Useful for prospective members to check value of joining the IXP
  - Useful for the Internet Operations community for troubleshooting purposes
    - E.g. **www.traceroute.org**

Route Collector at an IXP



Route Collector Requirements

- Router or Unix system running BGP
  - Minimal memory requirements – only holds IXP routes
  - Minimal packet forwarding requirements – doesn't forward any packets
- Peers eBGP with every IXP member
  - Accepts everything; Gives nothing
  - Uses a private ASN
  - Connects to IXP Transit LAN
- "Back end" connection
  - Second Ethernet globally routed
  - Connection to IXP Website for public access

Route Collector Implementation

- Most IXPs now implement some form of Route Collector
  - Usually as a Route Server (see next section)
- Benefits already mentioned
- Great public relations tool
- Unsophisticated requirements
  - Just runs BGP

Introduction to Route Servers

How to scale IXPs

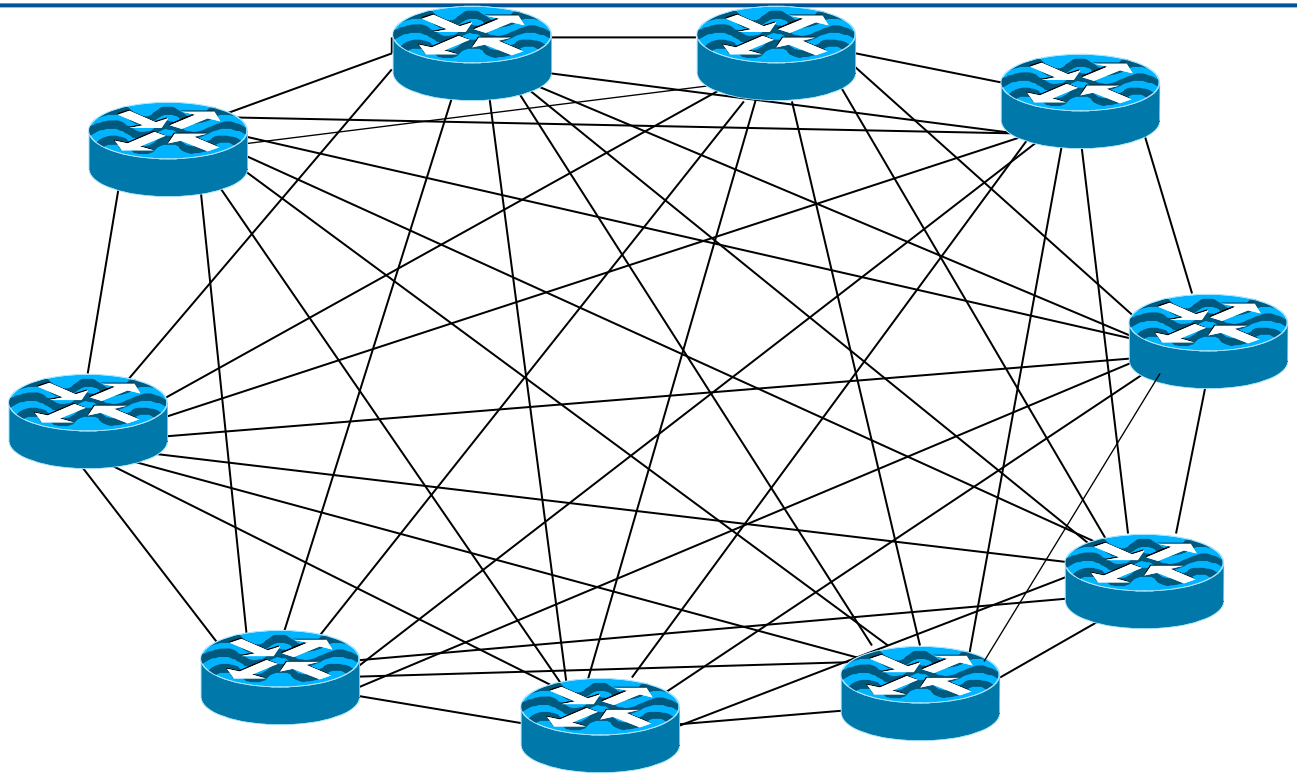
What is a Route Server?

- Has all the features of a Route Collector
- But also:
  - Announces routes to participating IXP members according to their routing policy definitions
- Implemented using the same specification as for a Route Collector

Features of a Route Server

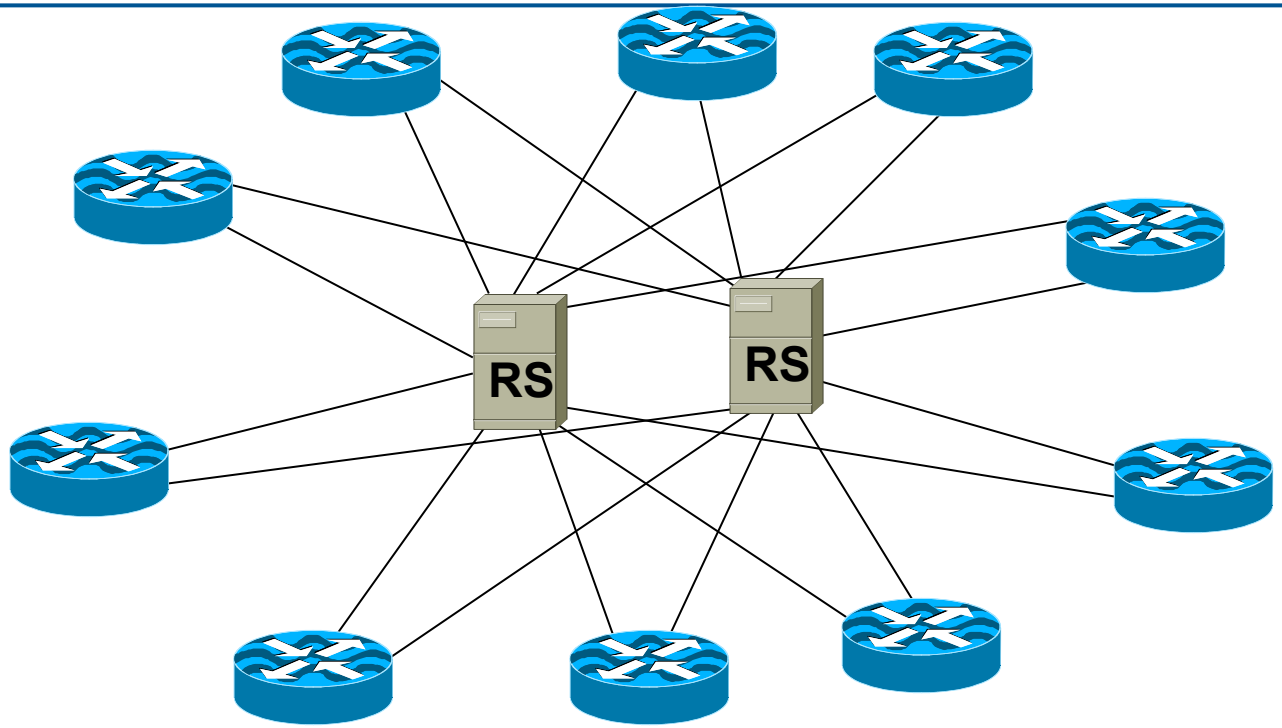
- Helps scale route distribution for IXPs
  - Forwarding of packets is unaffected
  - Makes use of BGP functionality known as “third party next-hop”
- Simplifies Routing Processes on ISP Routers
- Optional participation
  - Provided as service, is NOT mandatory
- If traditional router used, will result in insertion of RS Autonomous System Number in the AS Path
  - To be avoided
- Optionally uses Policy registered in the Internet Routing Registry

Diagram of N-squared Peering Mesh



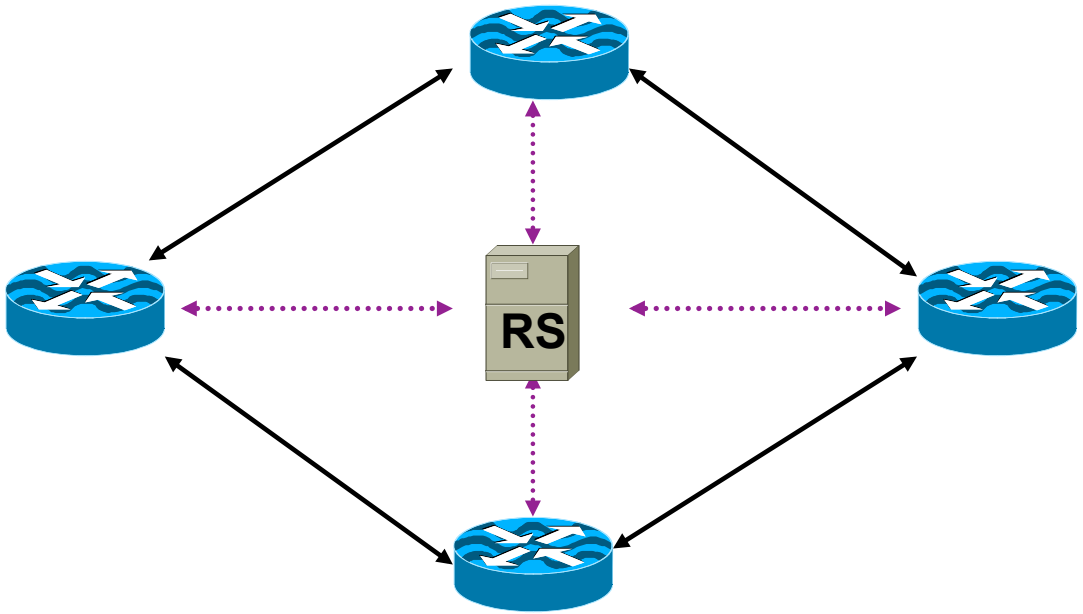
- For large IXPs (dozens for participants) maintaining a larger peering mesh becomes cumbersome and often too hard

Peering Mesh with Route Servers



- ISP routers peer with the Route Servers
  - Only need to have two eBGP sessions rather than N

Route Server based Exchange Point Routing Flow



TRAFFIC FLOW

ROUTING INFORMATION FLOW

Using a Route Server: Advantages

- Advantageous for large IXPs
  - Helps scale eBGP mesh
  - Helps scale prefix distribution
- Separation of Routing and Forwarding
- Simplifies BGP Configuration Management on ISP routers
  - Don’t need to maintain a large number of eBGP peers
  - eBGP peering only with the Route Server

Using a Route Server: Disadvantages

- ISPs can lose direct policy control
  - If RS is the only peer, ISPs have no control over who their prefixes are distributed to
    - (Okay if ISP has Open Peering Policy though)
- Completely dependent on 3rd party
  - Configuration, troubleshooting, reliability, etc…
- Possible insertion of RS ASN into routing path
  - (If using a router rather than a dedicated route-server BGP implementation)
  - Traffic engineering/multihoming needs more care

Typical usage of a Route Server

- Route Servers may be provided as an **OPTIONAL** service
  - Most IXPs now offer a Router Server as a service to members
- ISPs peer:
  - Directly with significant peers

    -and-
  - With Route Server for the rest
- ISPs with an Open Peering Policy usually prefer to peer with a Route Server

Route Server implementations

- Linux/FreeBSD server:
  - BIRD – the standard & works best
    - http://bird.network.cz
  - Quagga
    - http://www.nongnu.org/quagga/
- Router:
  - Any router (but has RS AS in the AS-path)
  - Cisco IOS 15.2 and IOS XE 3.7 onwards has route-server-client configuration:

```
neighbor 172.16.1.1 route-server-client
```

Things to think about...

- Would using a route server benefit you?
  - Helpful when BGP knowledge is limited (but is NOT an excuse not to learn BGP)
  - Avoids having to maintain a large number of eBGP peers
  - But can you afford to lose policy control?

What can go wrong…

The different ways IXP operators harm their IXP…

What can go wrong? Concept

- Some Service Providers attempt to cash in on the reputation of IXPs
- Market their Internet transit services as “Internet Exchange Point”
  - “We are exchanging packets with other ISPs, so we are an Internet Exchange Point!”
  - So-called Layer-3 Exchanges — they really are Internet Transit Providers
  - Router(s) used rather than a Switch
  - Most famous example: SingTelIX

What can go wrong? Financial

- Some IXPs price the IX out of the means of most providers
  - IXP is intended to encourage local peering
  - Acceptable charging model is minimally cost-recovery only
- Some IXPs charge for port traffic
  - IXPs are not a transit service, charging for traffic puts the IX in competition with members
  - (There is nothing wrong with charging different flat fees for 100Mbps, 1Gbps, 10Gbps etc ports as they all have different hardware costs on the switch.)

What can go wrong? Competition

- Too many exchange points in one locale
  - Competing exchanges defeats the purpose
- Becomes expensive for ISPs to connect to all of them
  - So they don't, or won't, and local traffic suffers, defeating the viability of the IXPs
- An IXP:
  - is **NOT** a competition
  - is **NOT** a profit making business

What can go wrong? Rules and Restrictions

- IXP tries to compete with their membership
  - Offering services that ISPs would/do offer their customers
  - **In reality, IXPs are operated by the members for the members**
- IXP is run as a closed privileged club e.g.:
  - Restrictive membership criteria
  - **In reality, a participant needs to have an ASN and their own independent address space**
- IXP located in a data centre with restricted physical/transmission access
  - **IXP must be a neutral interconnect in a neutral location**

What can go wrong? Rules and Restrictions

- IXP charges for traffic
  - So do transit providers – **charging for traffic is a sure way of ending the viability of the IXP**
- IXPs providing access to end users rather than just Network Operators & Service Providers
  - **A participant at an IXP needs to have their own address space, their own ASN, and their own transit arrangements**
- IXPs interfering with member business decisions
  - **The most common error: Mandatory Multi-Lateral Peering**

What can go wrong? Technical Design Errors

- Interconnected IXPs
  - IXP in one location believes it should connect directly to the IXP in another location
  - Who pays for the interconnect?
  - How is traffic metered?
  - Competes with the ISPs who already provide transit between the two locations (who then refuse to join IX, harming the viability of the IX)
  - Metro interconnections work ok

What can go wrong? Technical Design Errors

- ISPs bridge the IXP LAN back to their offices
  - “We are poor, we can’t afford a router”
  - Financial benefits of connecting to an IXP far outweigh the cost of a router
  - In reality it allows the ISP to connect any devices to the IXP LAN — with disastrous consequences for the security, integrity and reliability of the IXP

What can go wrong? Routing Design Errors

- Route Server mandated from Day One
  - Mandatory peering has no history of success
  - ISPs have no incentive to learn BGP
  - Therefore have no incentive to understand peering relationships, peering policies, &c
  - Entirely dependent on operator of RS for troubleshooting, configuration, reliability
    - RS can't be run by committee!
- Route Server is designed to assist with scaling peering at LARGE IXPs

What can go wrong? Routing Design Errors (cont)

- iBGP Route Reflector used to distribute prefixes between IXP participants
- Claimed advantages:
  - Participants don't need to know about or run BGP
  - Allows an IXP to be started very quickly
  - IXP operator has full control over ISP activities
  - ISP participants routers sit inside IXP's ASN
- All are disadvantages!
  - Participants never learn BGP
  - Participants have no policy control, IXP policies could impact the participants networks
  - IXP is an ethernet switch, not an Internet operator
  - IXP operator is single point of failure
  - Migration to true IXP with RS is very difficult

What can go wrong: Summary

- Not a transit business, just an L2 switch
- If charging, fair cost recovery only
- Not a competitive service
- No oppressive rules & restrictions
- No Mandatory Peering
- No bureaucratic management
- No interconnection with other IXPs
- No bridging of IX LAN back to members
- No Route Reflector, use a Route Server to scale

More Information

Exchange Point Policies & Politics

- AUPs
  - Acceptable Use Policy
  - Minimal rules for connection
- Fees?
  - Some IXPs charge no fee
  - Other IXPs charge cost recovery
  - A few IXPs are commercial
- Nobody is obliged to peer
  - Agreements left to ISPs, not mandated by IXP

Exchange Point etiquette

- Don’t point default route at another IXP participant
- Be aware of third-party next-hop
- Only announce your aggregate routes
  - Read RIPE-399 and RIPE-532 first

    www.ripe.net/ripe/docs/ripe-399

    www.ripe.net/ripe/docs/ripe-532
- Filter! Filter! Filter!

Exchange Point Examples

- LINX in London, UK
- TorIX in Toronto, Canada
- AMS-IX in Amsterdam, Netherlands
- SIX in Seattle, Washington, US
- PA-IX in Palo Alto, California, US
- JPNAP in Tokyo, Japan
- DE-CIX in Frankfurt, Germany
- HK-IX in Hong Kong

…

- All use Ethernet Switches

Features of IXPs (1)

- Redundancy & Reliability
  - Multiple switches, UPS/Generator
- Support
  - NOC to provide 24x7 support for problems at the exchange
- DNS, Route Collector/Server, Content Caches & NTP servers
  - ccTLD & root servers
  - Content caches
  - Content redistribution systems
  - Route Collector – Routing Table view

Features of IXPs (2)

- Location
  - Neutral, secure & accessible co-location facilities
- Address space
  - Public address for Peering LAN
  - Public address for IXP Services LAN
- AS Number
  - Private ASN needed for Route Collector/Server
  - Public ASN needed for IXP Services
- Route servers (for larger IXPs)
- Statistics
  - Traffic data – for membership

IXP Creation

- No economy or circumstance is unique or different
  - The first excuse for not creating an IXP is "we don't need one"
  - The second excuse for not creating an IXP is "oh, it is different here"
- Every locality has its differences
  - But every locality wants to
    - Keep local traffic local
    - Improve network performance and QoS
    - Improve local Internet economy
  - The available technology is the same for every network operator everywhere
  - There is no excuse for not improving the local Internet

Eco System Development

- Create IXP association
  - Formed by members who have a port on the IXP
- IXP members meet regularly
  - IXP Board meetings
  - IXP Operational strategy and direction
- IXP Technical community could also meet too
  - Network operators meeting, involving network and systems operations engineers
  - Aligned with IXP Association/member meetings
  - Could lead to creation of a Network Operators Group
- IXP could facilitate the creation of a NOG
  - The same engineers are involved in both!

Industry Associations

- Euro-IX
  - European Internet Exchange association
  - Members from Europe, associate members from around the world
  - Website has all the information needed to start an IXP
  - https://www.euro-ix.net/starting-an-ixp
  - IXP Best Practice documentation:
  - https://www.euro-ix.net/euro-ix-bcp
- APIX
  - Asia Pacific Internet Exchange association
  - Members from Asia Pacific region
  - Meets twice a year, during APRICOT and APNIC meeting
  - http://apix.asia

More info about interconnects

- Telegeography
  - http://www.telegeography.com/telecom-resources/internet-exchange-map/
  - A collection of ISP interconnect points
    - Watch out: Not all Telegeography listings are IXPs!
- Internet Society
  - http://www.internetsociety.org/what-we-do/issues/internet-exchange-points-ixps
  - http://www.ixptoolkit.org/

Summary

- IXP is a Layer 2 infrastructure
- At least three players required (two is okay too)
  - Meeting in an open and neutral location
- Minimal rules
- Minimal bureaucracy
- Cost recovery
- Encourage participation by all autonomous networks
- Develop the local Internet eco-system

Internet Exchange Point Design

ISP/IXP Workshops