Session 11: IP network interconnections, peering, and transit

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Objective: To discuss the parameters and methodology for planning interconnections, peering, and transit, for IP network infrastructure

Acknowledgements

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  - I'd like to acknowledge the input from many network operators in the ongoing development of these slides, especially Mark Tinka of SEACOM for his contributions
- 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

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ISP Network Design

- Goals
- Peering
- Upstream Connectivity
- Case Study

Goals

What does a network operator need to achieve today?

Network Operator Goals?

- Today, the vast majority of content consumed by end-users is available by peering:
  - The major content providers (Google, Facebook, etc)
  - Private cross connects
  - Internet Exchange Points
- A network operator’s goal is to obtain as much peering as possible
- Transit is for the last resort, for any content not available by peering

Network Operator Goals?

- Peering
  - Locally with direct cross-connect with other providers
  - Locally at an Internet Exchange Point
  - Getting to the nearest IXP or other interconnect

- Transit
  - Relying on another network operator to get the rest of the Internet
  - Considered a last resort now

Peering

Interconnecting networks

Peers

- A peer is another autonomous system with which the local network has agreed to exchange locally sourced routes and traffic
- Private peer
  - Private link between two providers for the purpose of interconnecting
- Public peer
  - Internet Exchange Point, where providers meet and freely decide who they will interconnect with
- Recommendation: peer as much as possible!

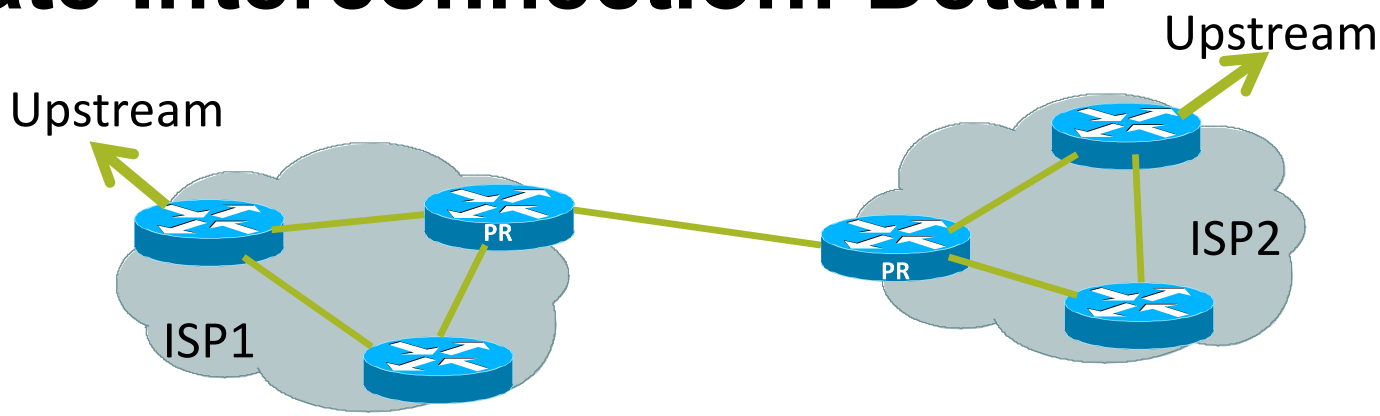
Common Mistakes

- Mistaking a transit provider's for profit "Exchange" business for a no-cost public peering point
- Not working hard to get as much peering as possible
  - Physically near a peering point (IXP) but not present at it
  - (Transit is rarely cheaper than peering!!)
- Ignoring/avoiding competitors because they are competition
  - Even though potentially valuable peering partner to give customers a better experience

Private Interconnection: What it is

- Two service providers agree to interconnect their networks
  - They exchange prefixes they originate into the routing system (usually their aggregated address blocks)
  - They share the cost of the infrastructure to interconnect
    - Typically each paying half the cost of the link (be it circuit, satellite, microwave, fibre,…)
    - Connected to their respective peering routers
  - Peering routers only carry domestic prefixes

Private Interconnection: Detail



- PR = peering router
  - Runs iBGP (internal) and eBGP (with peer)
  - No default route
  - No “full BGP table”
  - Domestic prefixes only
- Peering router used for all private interconnects

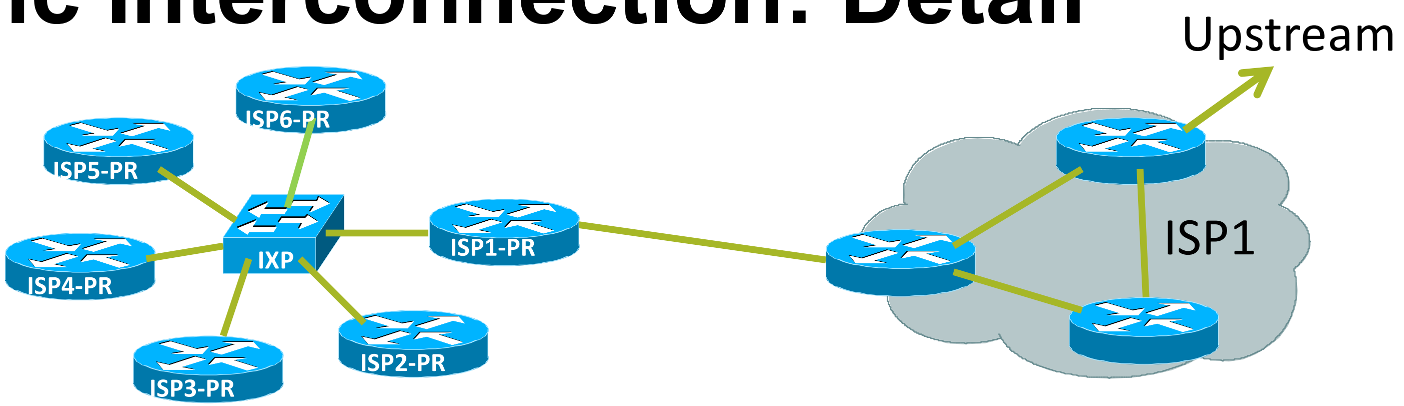
Private Interconnect: Where?

- Private Interconnects can be established anywhere
  - Where two providers are in the same facility
    - Usually simple fibre cross-connect between two peering routers
    - Most common scenario – datacentres, at IXP facilities, etc
    - PNI using fibre optics is usually at least 10Gbps
  - Between two providers with PoPs in the same metro area
    - Will involve obtaining and sharing the costs of installing fibre (or other media) between the two locations
    - The more traditional/historical type of interconnect

Public Interconnection: What it is

- Service provider participates in an Internet Exchange Point
  - It exchanges prefixes it originates into the routing system with the participants of the IXP
  - It chooses who to peer with at the IXP
    - Bi-lateral peering (like private interconnect)
    - Multi-lateral peering (via IXP’s route server)
  - It provides the router at the IXP and provides the connectivity from their PoP to the IXP
  - Their IXP router carries only the prefixes they will share with other peers across the IXP

Public Interconnection: Detail



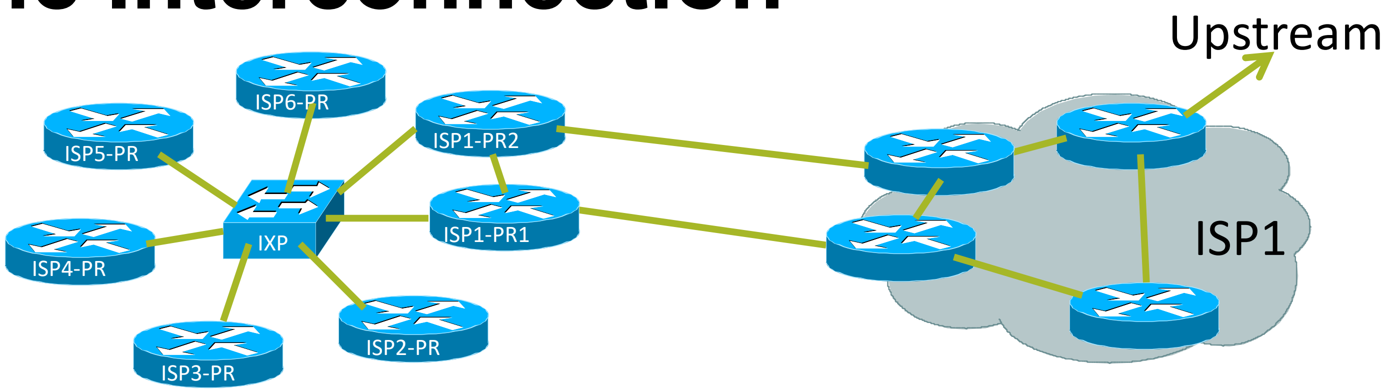
- ISP1-PR = peering router of our ISP
  - Runs iBGP (internal) and eBGP (with IXP peers)
  - No default route
  - No "full BGP table"
  - Domestic prefixes only
- Usually physically located at the IXP

Public Interconnection

- The ISP's router IXP peering router needs careful configuration:
  - It is remote from the domestic backbone
  - Should not originate any domestic prefixes
  - (As well as no default route, no full BGP table)
  - Filtering of BGP announcements from IXP peers (in and out)

- Provision of a second link to the IXP:
  - (for redundancy or extra capacity)
  - Usually means installing a second router
    - Connected to a second switch (if the IXP has two more more switches)
    - Interconnected with the original router (and part of iBGP mesh)

Public Interconnection



- Provision of a second link to the IXP means considering redundancy in the SP's backbone
  - Two routers
  - Two independent links
  - Separate switches (if IXP has two or more switches)

What if there is no local IXP?

- If there is no local IXP, one is usually created by the network operators once there are more than two who wish to interconnect
- Private peering means that the three operators have to buy circuits between each other
  - Works for three operators, but adding a fourth or a fifth means this does not scale
- Solution:
  - Internet Exchange Point

Internet Exchange Point

- Every participant has to deploy just one link
  - From their premises to the IXP
- Rather than N-1 links to connect to the N-1 other ISPs
  - 5 ISPs will have to share the cost of 4 links = 2 whole links → already twice the cost of the IXP connection
- Today metro area connectivity to get to a local IXP is easy using fibre-optics
  - Which means 10Gbps speeds is inexpensive to do
  - Most IXP switch ports now start at 10Gbps (and offer 1Gbps for smaller operators)

Internet Exchange Point

- Solution
  - Every operator participates in the IXP
  - Cost is minimal – one local link covers all domestic traffic
  - International links are used for just international traffic – and backing up domestic links in case the IXP suffers any outage
- Result:
  - Local traffic stays local
  - QoS considerations for local traffic is not an issue
  - RTTs between members are typically sub 1ms
  - Customers enjoy the Internet experience
  - Local Internet economy grows rapidly

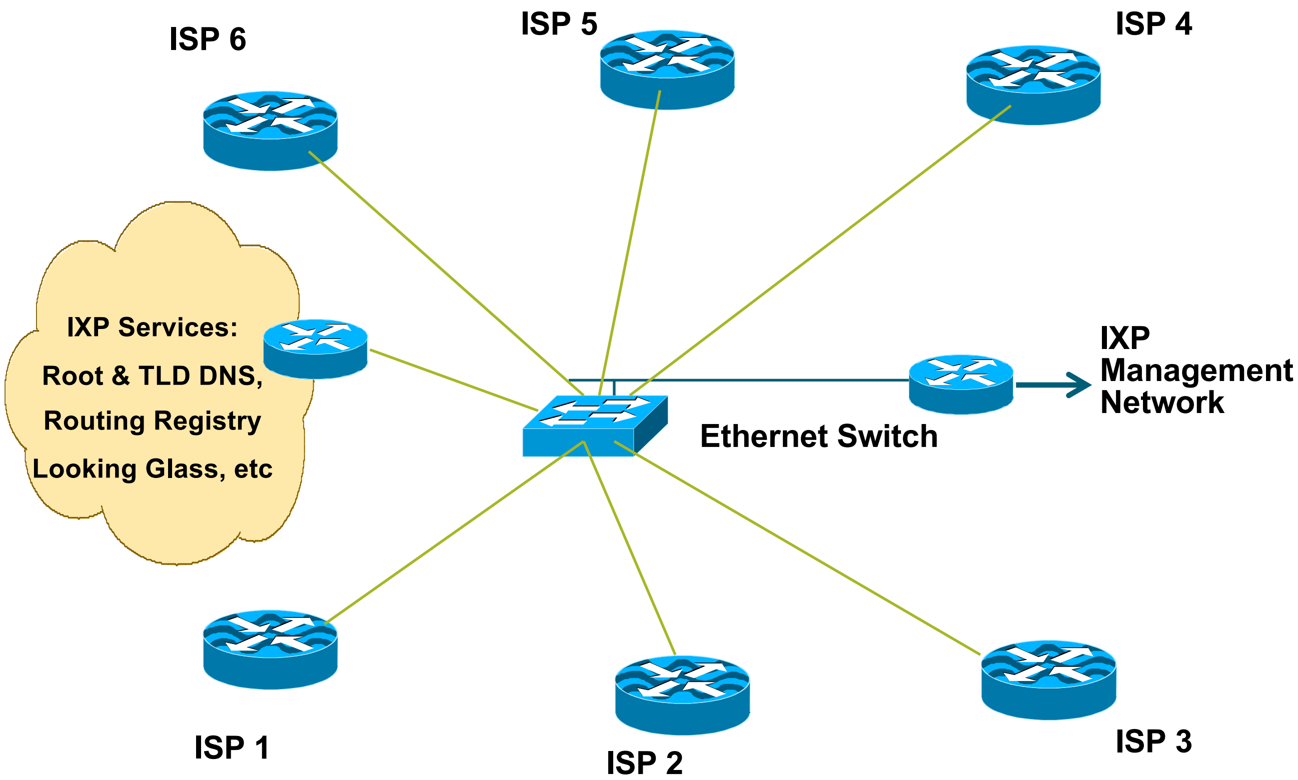
Who can join an IXP?

- Requirements are very simple: any organisation which operates their own autonomous network, and has:
  - Their own IP 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

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
- Known as a Layer-2 Exchange Point

Internet Exchange Point



Single site internet exchange point

IXP Features

- Neutral location
  - Anyone can install fibre or other connectivity media to access the IXP
    - Without extra 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 within the facility

IXP Features

- 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

IXP Standards

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

Services Offered by IXPs

- 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 Offered by IXPs

- 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 Offered by IXPs

- 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)

Notes on IXP Services

- If IXP is offering services to members:
  - Services need transit access
  - Transit needs to be arranged with one or two IXP members (cost shared amongst all members)

- Consider carefully:
  - Should services be located at the IXP itself?
    - How to arrange and pay for the transit to those services?

    -or-
  - Should services be hosted by members and shared with the others?

What if there is no local IXP?

- If there is no local IXP, and there aren't sufficient operators to justify creating one:
  - Private Network Interconnect with other operator
  - Purchase capacity (bandwidth) to get to the topologically closest major interconnect (RTT matters!)
- Many major locations around the world are focal points of operator interconnects
  - These are known as Regional IXPs

Regional Internet Exchange Point

- These are also "local" Internet Exchange Points
- But also attract regional ISPs and ISPs from outside the locality
  - Regional ISPs peer with each other
  - And show up at several of these Regional IXPs
- Local ISPs peer with ISPs from outside the locality
  - They don't compete in each other's markets
  - Local ISPs don't have to pay transit costs
  - ISPs from outside the locality don't have to pay transit costs
  - Quite often ISPs of disparate sizes and influences will happily peer – to defray transit costs

Examples of Regional Interconnects

- Sydney
  - Serves Australia, NZ and much of the Southern Pacific
- Singapore
  - Serves South & South East Asia
- Hong Kong
  - Serves South East Asia
- Tokyo
  - Serves East & South East Asia
- London/Amsterdam/Frankfurt
  - Serve Europe, Africa, Middle East
- Los Angeles, Bay Area, Seattle
  - Serve Asia, Pacific and North America
- New York, Washington, Miami
  - Serve Europe & Latin America

All attract operators from all around the world

All encourage interconnection

What should operators do?

- Many operators participate in their local IXP
  - Keeps local traffic local
  - Gives best experience to the end-user for content

- Many operators also purchase connectivity (bandwidth) to Regional IXPs
  - Bandwidth as IPLC (international private leased circuit)
    - NOT buying transit to the Regional IXP
  - And establish peering across the IX fabric
  - And establish PNI with major content operators for Cache fill

Footnote: ”Layer 3 IXPs”

- Some entities talk about Layer 3 Internet Exchange Points
  - These are not IXPs
- Layer 3 IXP today is marketing concept used by Transit ISPs
  - Some incumbent telecom operators 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 get 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

Upstream Connectivity

Transits

- Transit provider is another autonomous system which is used to provide the local network with access to other networks
- Access for
  - Local traffic only
  - Maybe local and regional traffic
  - Content Cache fill for a locally hosted Cache
  - But more usually the whole Internet

Transits

- Transit providers need to be chosen wisely:
  - Only one
    - No redundancy
  - Too many
    - Very difficult to load balance
    - No economy of scale (costs more per Mbps)
    - Hard to provide good service quality
- Recommendation: at least two, no more than three

Common Mistakes

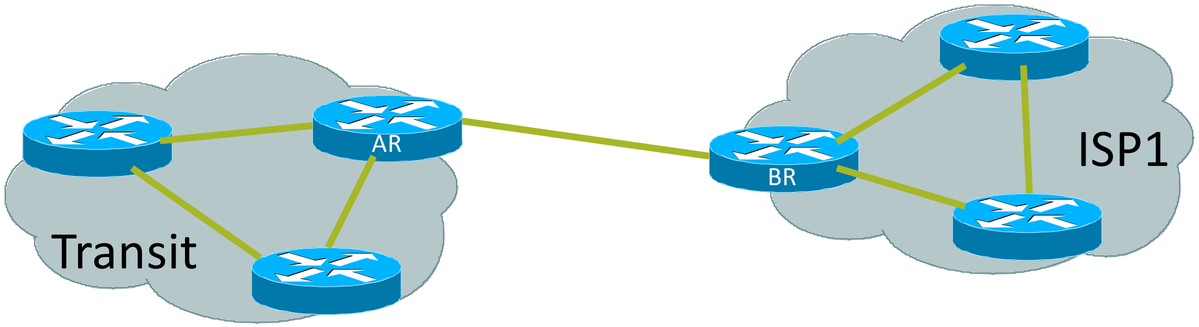
- Operators sign up with too many transit providers
  - Results in lots of small circuits (cost more per Mbps than larger ones)
  - Transit rates per Mbps reduce with increasing transit bandwidth purchased
  - Hard to implement reliable traffic engineering that doesn't need daily fine tuning depending on customer activities

- No diversity
  - Chosen transit providers all reached over same satellite or same submarine cable
  - Chosen transit providers themselves have poor onward transit and peering arrangements

Upstream/Transit Connection

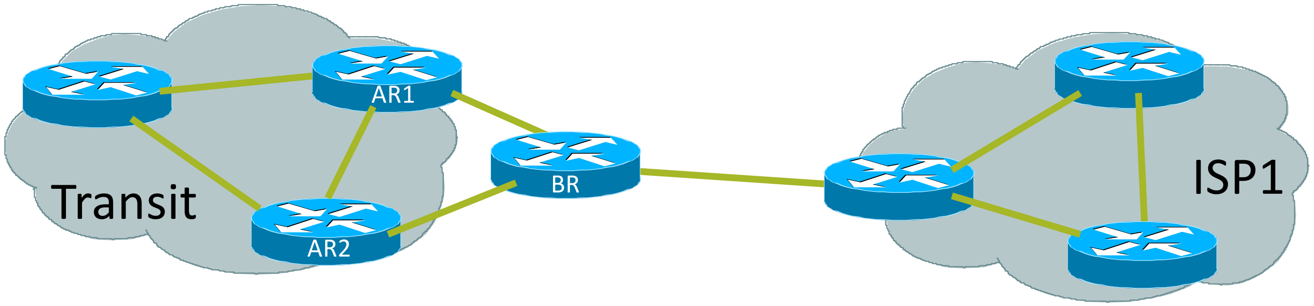
- Two scenarios:
  - Transit provider is in the locality
    - Which means bandwidth is cheap, plentiful, easy to provision, and easily upgraded
  - Transit provider is a long distance away
    - Over undersea cable, satellite, long-haul cross country fibre, etc
- Each scenario has different considerations which need to be accounted for

Local Transit Provider



- BR = ISP's Border Router
  - Runs iBGP (internal) and eBGP (with transit)
  - Either receives default route or the full BGP table from upstream
  - BGP policies are implemented here (depending on connectivity)
  - Packet filtering is implemented here (as required)

Distant Transit Provider



- BR = ISP's Border Router
  - Co-located in a co-lo centre (typical) or in the upstream provider's premises
  - Runs iBGP with rest of ISP1 backbone
  - Runs eBGP with transit provider router(s)
  - Implements BGP policies, packet filtering, etc
  - Does not originate any domestic prefixes

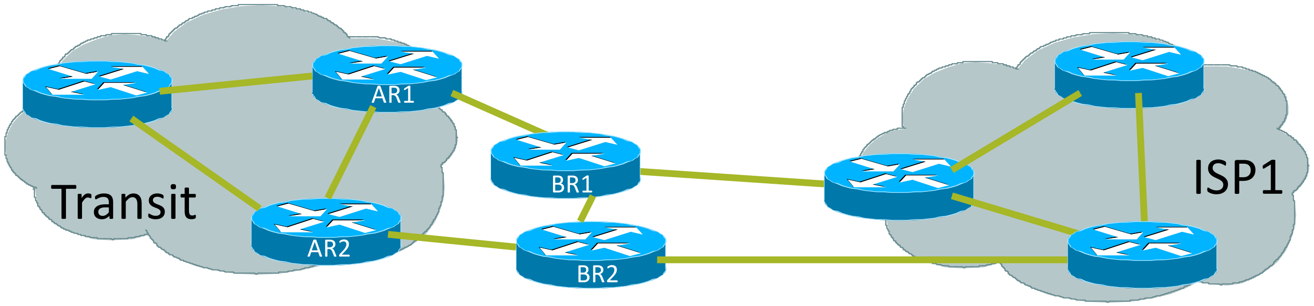
Distant Transit Provider

- Positioning a router close to the Transit Provider's infrastructure is strongly encouraged:
  - Long haul circuits are expensive, so the router allows the ISP to implement appropriate policies first
  - Moves packet buffering away from the Transit provider
    - Their router may not have the packet buffer sizing to support long haul links
  - Using remote co-lo allows the ISP to choose another transit provider and migrate connections with minimum downtime

Distant Transit Provider

- Other points to consider:
  - Does require remote hands support
  - (Remote hands would plug or unplug cables, power cycle equipment, replace equipment, etc as instructed)
  - Appropriate support contract from equipment vendor(s)
  - Sensible to consider two routers and two long-haul links for redundancy

Distant Transit Provider



- Upgrade scenario:
  - Provision two routers
  - Two independent circuits (check fibre path)
  - Consider second transit provider and/or turning up at an IXP

Optimising Long Haul Links

- Strategies for choosing Transit Providers
  - Geographical diversity
    - If one is in the East, choose the other one to be in the West
    - For example, a South Pacific Network Operator would connect to Australia and to the US
    - If the US link fails, there is back up via Australia – and vice-versa
    - Traffic for Asia and Pacific goes via Australia; traffic for Europe and US goes via US
  - Cost
    - Two transit providers optimises transit costs
    - More providers means greater cost per Mbps and greater challenges to make traffic engineering work

Optimising Long Haul Links

- Transit providers are too often focused on being a monopoly
  - Unless legislated, this is a failed strategy
  - Monopolies tend to be bypassed, and only harm the country with the monopoly
- The important criteria today are:
  - Round Trip Time (RTT) – latency
  - Bandwidth
  - Reliability
- Every network operator goal needs to be to minimise RTT for all traffic, provide at maximum bandwidth, and with maximum reliability

Examples: Pacific

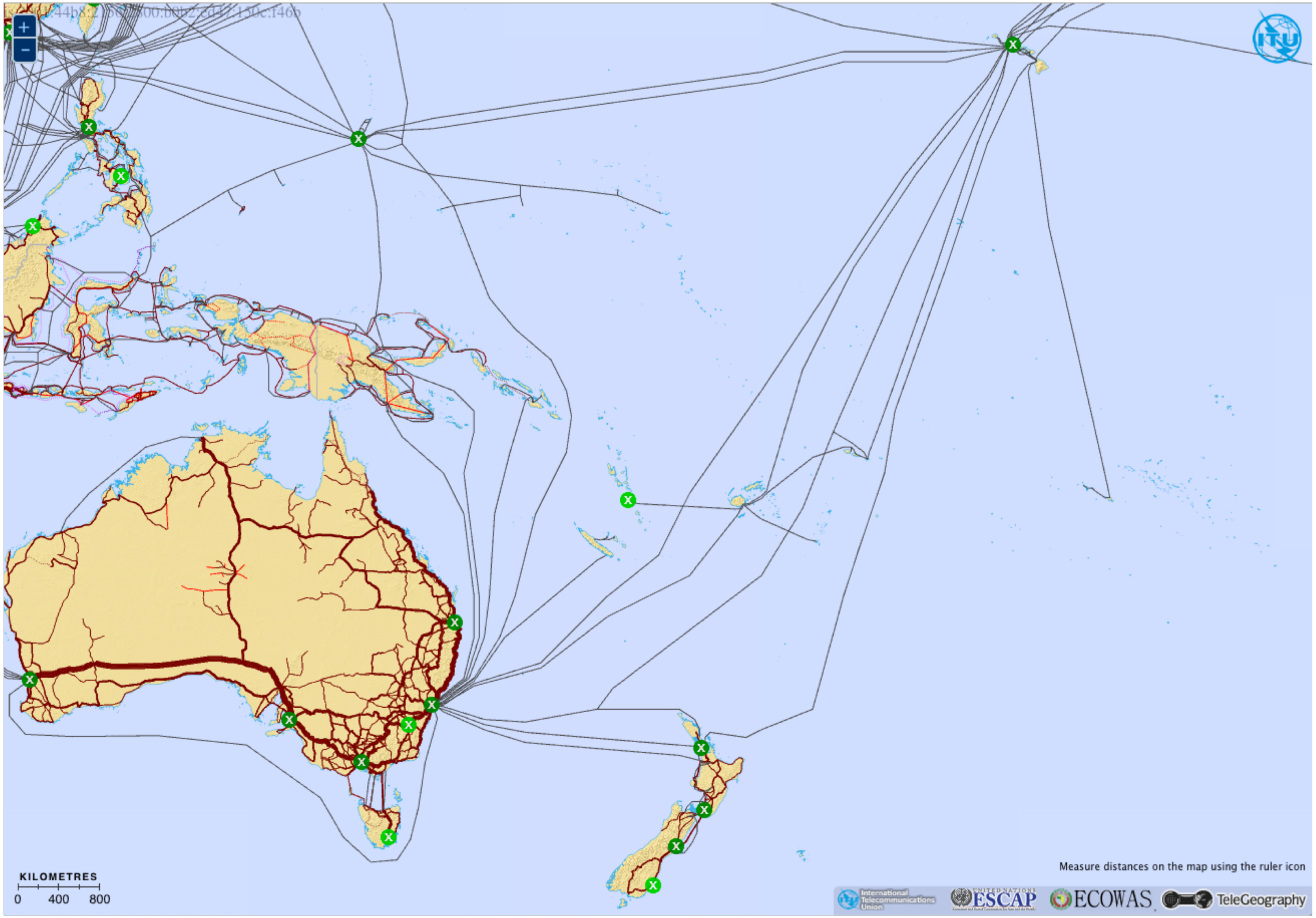
- Sydney and Los Angeles are the interconnect hubs for the Pacific
  - There are more optimum locations which offer much better RTT and performance than hauling traffic to/from/via Sydney and/or Los Angeles

- The PacPeer Project explores optimum interconnections for network operators across the Pacific
  - https://pacpeer.org/
  - https://pacpeer.org/presentations/brewerj_peering_strategy_pacific_pacnog18.pdf

Examples: Pacific

- Fiji could be the regional hub for the South Pacific
- Guam could be the regional hub for the North Pacific
- Both Fiji & Guam have:
  - Large amounts of submarine fibre passing through
  - No open neutral interconnect facility
- Hawaii should be the regional hub for the whole Pacific
  - (following the fibre paths)
  - But capacity is cheaper direct to Los Angeles (even though latency more than doubles)
    - (Pacific to Hawaii + Hawaii to Los Angeles is more expensive than Pacific to Los Angeles)

Pacific Fibre Map

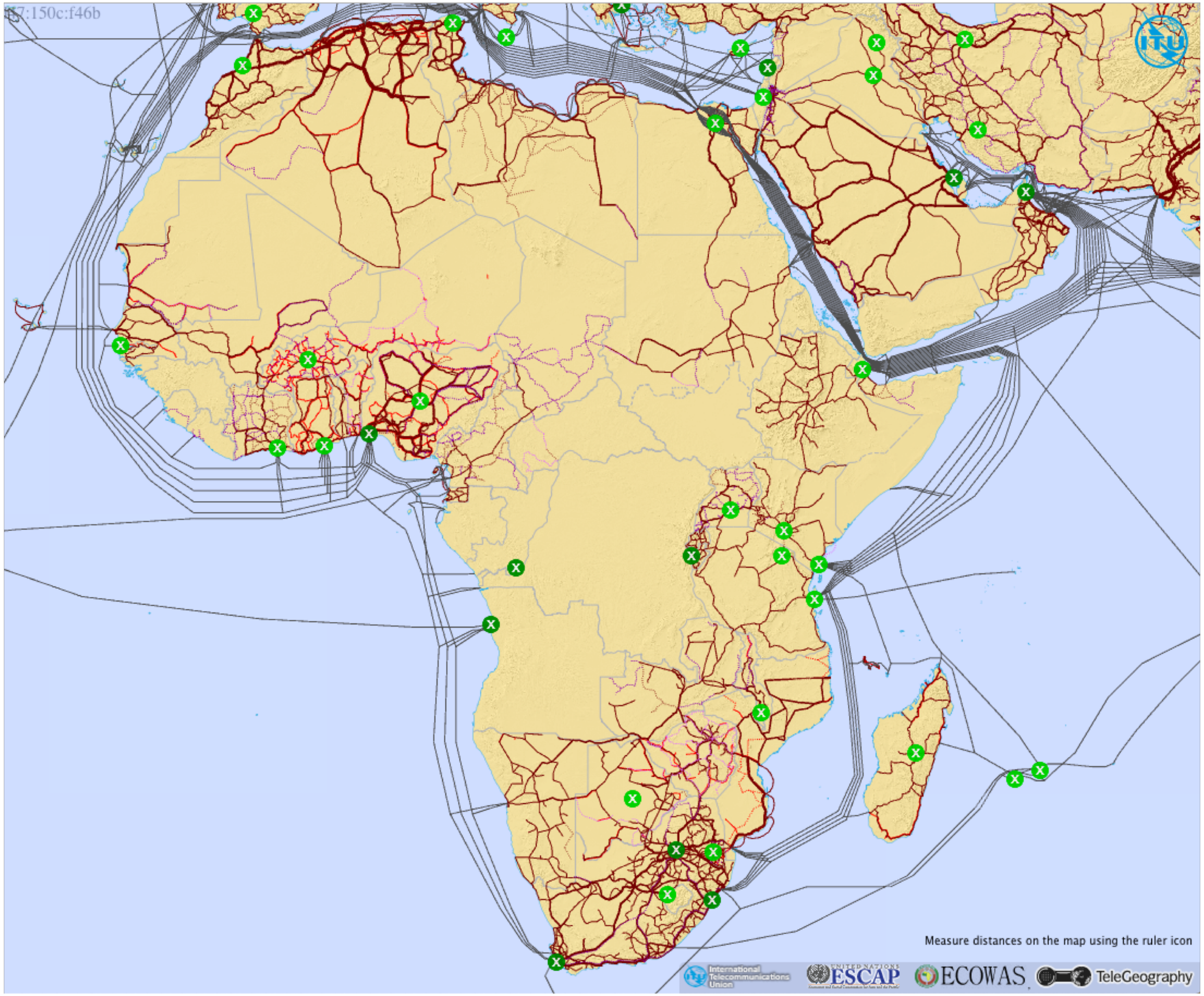


Source: https://www.itu.int/itu-d/tnd-map-public/

Examples: Africa

- There is still no obvious regional Interconnect on the whole of the African continent
- Historically fibre went to Europe – and providers would connect based on their parent European operator
  - Inter-country traffic usually went via Europe
- Cairo, Alexandria and Djibouti could be a major hubs
  - Large amounts of fibre transit Djibouti & Egypt
  - No open neutral interconnect facility
- Mombasa (Kenya) could well become one in the near future for Eastern Africa
  - Major landing point for submarine fibre and for terrestrial fibre infrastructure
- What about Western Africa?
  - Lagos? Accra?

Africa Fibre Map

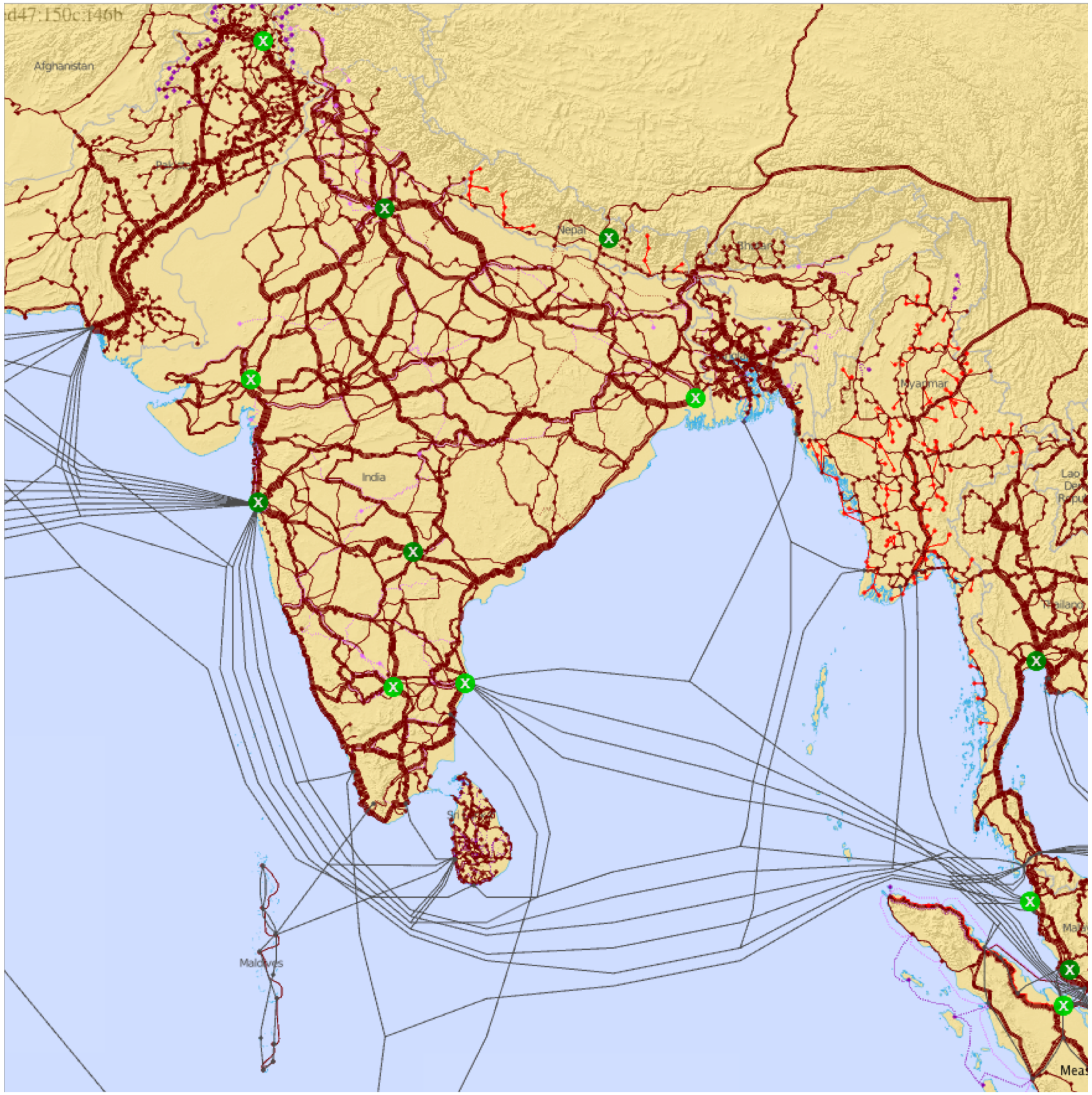


Source:
https://www.itu.int/itu-d/tnd-map-public/

Examples: South Asia

- There is still no obvious regional Interconnect in South Asia
- Mumbai and Chennai in India are obvious locations
  - Large concentrations of fibre landing in both cities
- But only Indian licenced operators are permitted to provide transit
  - No open neutral interconnect facility
  - All traffic subject to Indian laws, even if it doesn't go to Indian consumers
  - So South Asia loses interconnect business to Singapore, which has become the interconnect for the whole region

South Asia Fibre Map



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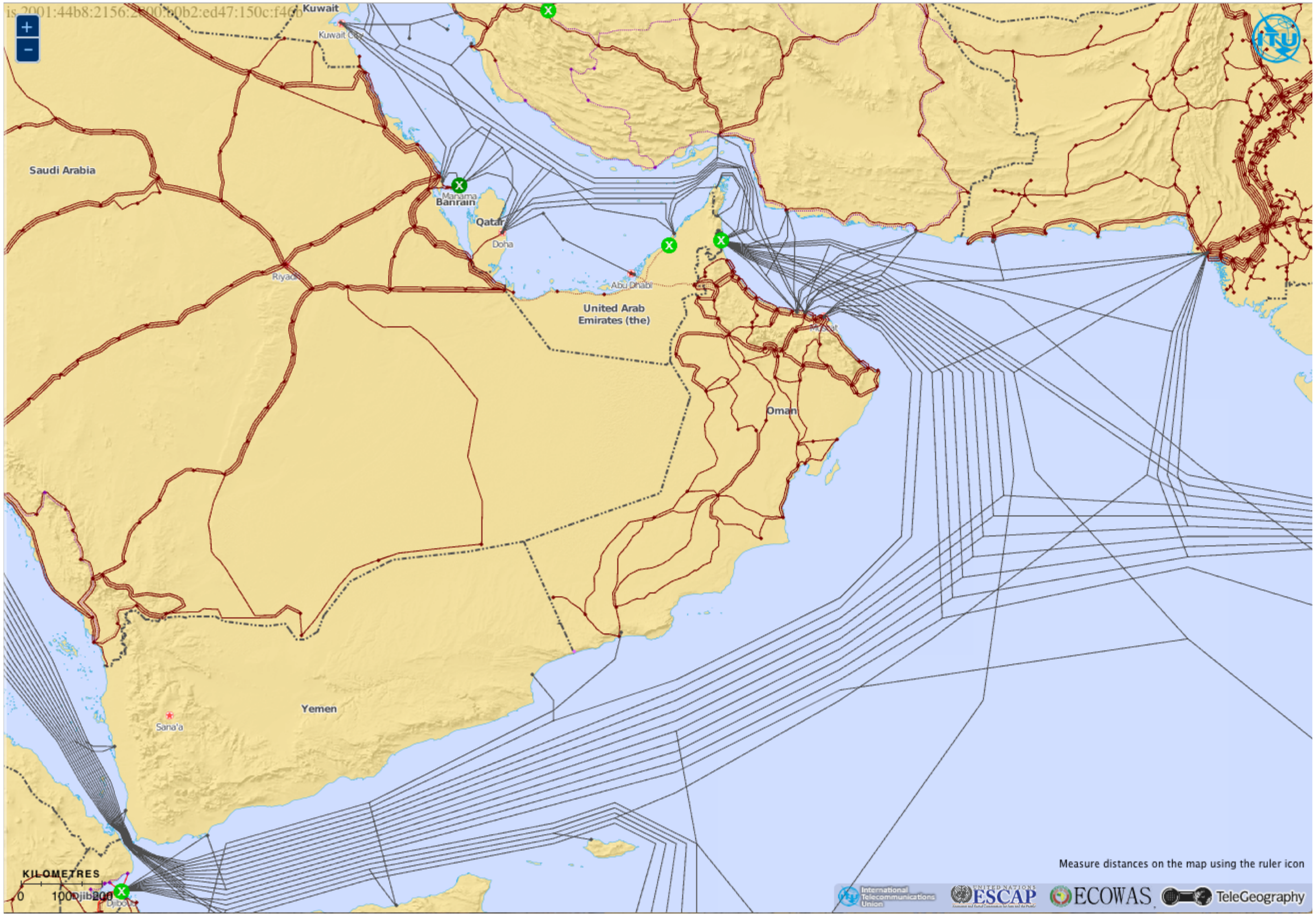
Examples: Middle East

- There is still no obvious regional Interconnect in the Middle East
- Reasons:
  - Regional rivalries, similar to those common in Asia in the 1990s
  - Everyone wants to be the hub!
- A lot of fibre lands around Fujairah (UAE)
  - Would be an obvious regional hub
- Only UAE licenced operators can provide transit & interconnects
  - No open neutral interconnect facility

Middle East Fibre Map



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Optimising Long Haul Links

- Network operators will participate in open neutral regional interconnects, where they:
  - May choose who they peer with
  - May choose who they buy transit from
  - Are not subjected to irrelevant domestic content laws
    - They are not selling services in the country in question
    - Some countries enforce domestic laws on all international transit content
- Areas without Regional Interconnects for IP traffic have no mechanisms in place to encourage these Interconnects

Optimising Long Haul Links

- Summary of what's important:
  - Maximising fast and high bandwidth content delivery to end-users
  - Minimising round trip times from content to end-users
  - Enabling ”next-generation” internet services
  - 5G and ”Internet of Things” cannot deliver their promise using last century approach to Internet Service provision

Upstream Connectivity and Peering Case Study

How Seacom chose their international peering locations and transit providers

Objective

- Obtain high grade Internet connectivity for the wholesale market in Africa to the rest of the world
- Emphasis on:
  - Reliability
  - Interconnectivity density
  - Scalability

Metrics Needed in Determining Solution (1)

- Focusing on operators that cover the destinations mostly required by Africa
  - i.e., English-speaking (Europe, North America)
- Include providers with good connectivity into South America and the Asia Pacific.
- Little need for providers who are strong in the Middle East, as demand from Africa for those regions is very, very low.

Metrics Needed in Determining Solution (2)

- Split the operators between Marseille (where the SEACOM cable lands) and London (where there is good Internet density)
  - To avoid outages due to backhaul failure across Europe
  - And still maintain good access to the Internet
- Look at providers who are of similar size so as not to fidget too much (or at all) with BGP tuning.
- The providers needed to support:
  - 10Gbps ports
  - Bursting bandwidth/billing
  - Future support for 100Gbps or N x 10Gbps

Metrics Needed in Determining Solution (3)

- Implement peering at major exchange points in Europe
  - To off-set long term operating costs re: upstream providers.

Implementing Solution

- Connected to Level(3) and GT-T (formerly Inteliquent, formerly Tinet) in Marseille
- Connected to NTT and TeliaSonera in London
- Peered in London (LINX)
- Peered in Amsterdam (AMS-IX)
- BGP setup to prefer traffic being exchanged at LINX and AMS-IX
- BGP setup to prefer traffic over the upstreams that we could not peer away
- No additional tuning done on either peered or transit traffic, i.e., no prepending, no de- aggregation, etc. All traffic setup to flow naturally

End Result

- 50% of traffic peered away in less than 2x months of peering at LINX and AMS-IX
- 50% of traffic handled by upstream providers
- Equal traffic being handled by Level(3) and GT-T in Marseille
- Equal traffic being handled by TeliaSonera and NTT in London
- Traffic distribution ratios across all the transit providers is some 1:1:0.9:0.9
- This has been steady state for the last 12x months
  - No BGP tuning has been done at all

Design Considerations Summary

Summary

- Design considerations for:
  - Private interconnects
    - Simple private peering
  - Public interconnects
    - Router co-lo at an IXP
  - Local transit provider
    - Simple upstream interconnect
  - Long distance transit provider
    - Router remote co-lo at datacentre or Transit premises

Thank You