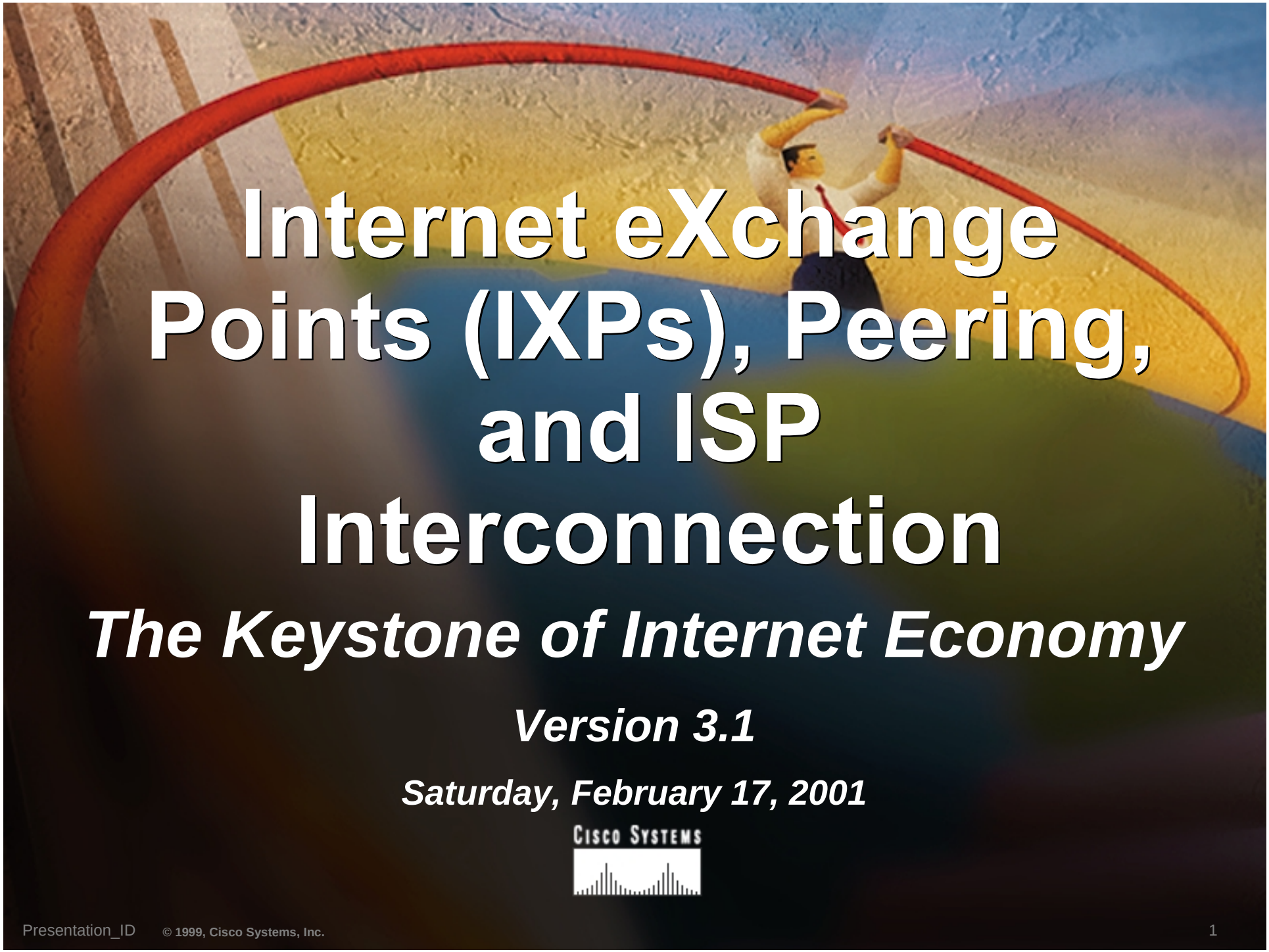


Internet eXchange Points (IXPs), Peering, and ISP Interconnection

The Keystone of Internet Economy

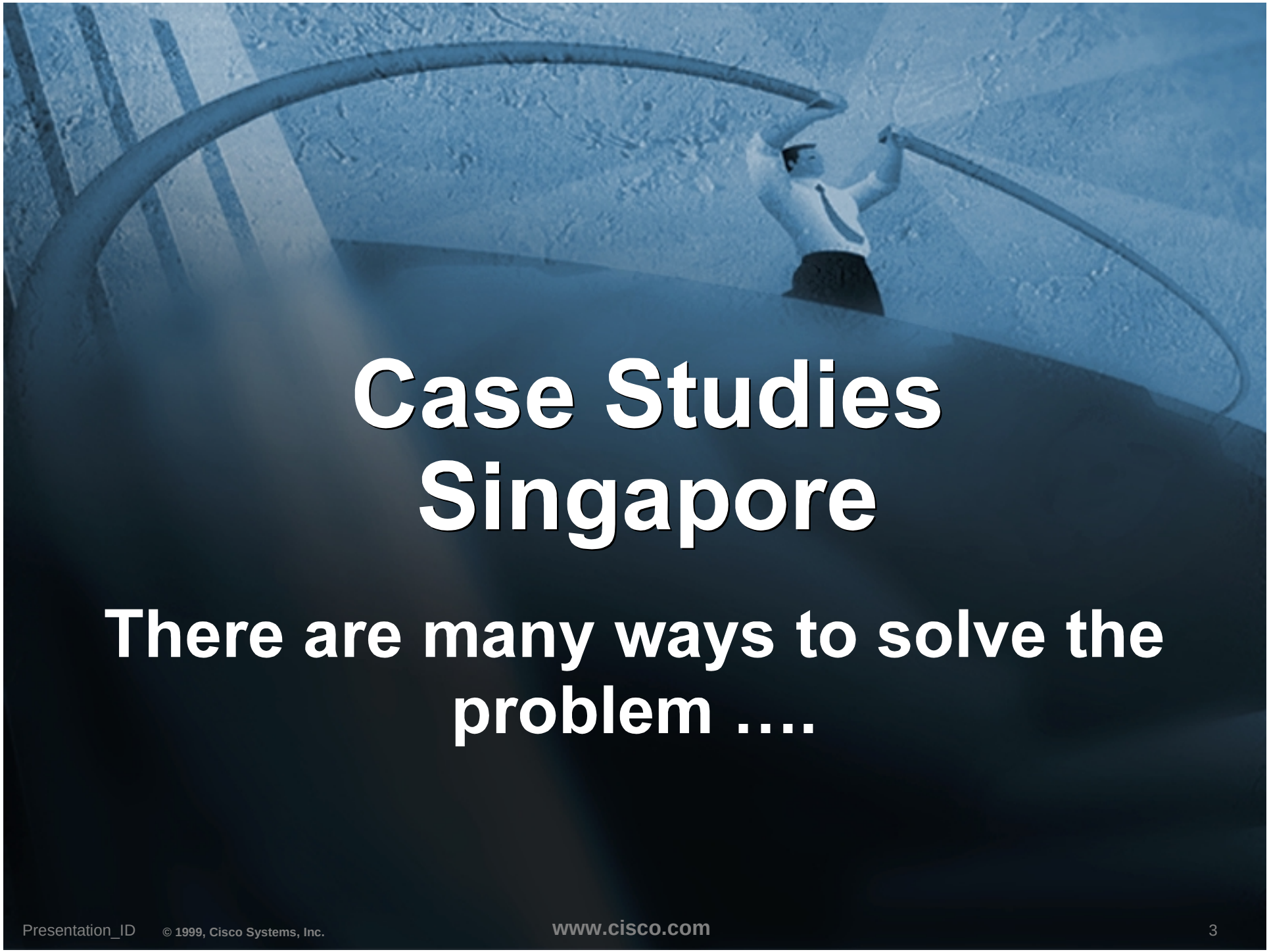
Version 3.1

Saturday, February 17, 2001

CISCO SYSTEMS

Agenda

- ✓ IXPs - The *keystone* to Internet Economy
- ✓ Why should I connect to an IXP?
- ✓ Transit and Peering
- ✓ Interconnections - A Short History
- ✓ Types of IXPs & Examples of IXPs
- ✓ Cisco's Role
- ✓ Case Studies & Global Survey
- ✓ Technical Addendum



Case Studies Singapore

There are many ways to solve the problem ….

Singapore Case Study

- **The evolution of Singapore's local peering is an interesting case study.**
- **Provides examples for other countries on how the different techniques were used at different time.**
- **Core theme was maintained – keep Singapore traffic in Singapore – insure Singapore was a regional Internet Hub.**

Singapore Case Study

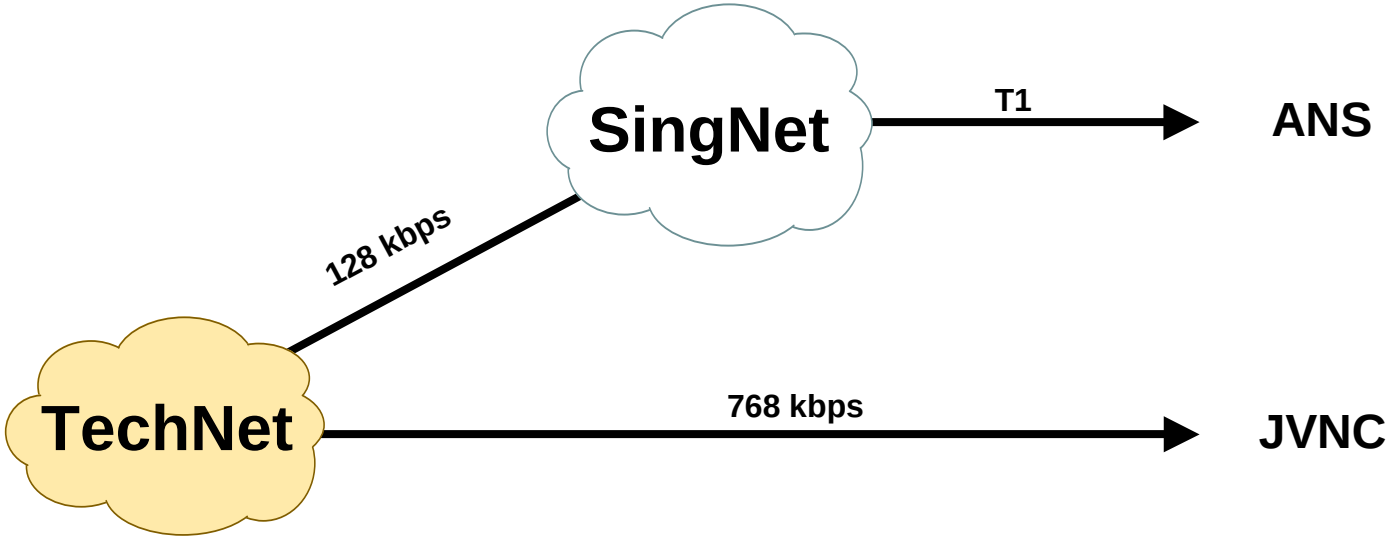
- **Major Factor:**
  - ✓ **Orginal Peering – the theme was established**
  - ✓ **STIX & A-Bone**
  - ✓ **Singapore Internet Backbone (SIB)**
  - ✓ ***AP Mesh* Peering Technique**
  - ✓ **SIB + AP Mesh = Regional Hub**
  - ✓ **IHUB & Singapore ONE**
  - ✓ **SingTel IX**
  - ✓ **SingTel IX + STIX = STIX**
  - ✓ **Peering in the year 2001**

Singapore – In the Beginning

- **TechNet was the first authorized IP provider in Singapore. AUP only allowed R&D use (similar to the NSFNET).**
- **1994 SingNet was created by Singapore Telecom as the first commercial ISP. At that time, only SingTel could have a commercial ISP.**

Singapore – First Peering

- SingNet pays for a 128Kbps to TechNet to get started (before the T1).
- Keeps paying for the 128Kbps circuit to keep local peering.



Singapore - Internet Backbone

SIB: *Internet Regulatory Environment*

- ✓ **Telecommunications Authority of Singapore (TAS) Licenses *Telecommunications Services***
  - **Three Licenses Issued – SingNet, Pacific Internet, and Cyberway**
  - **Internet License is a derivative of Basic Services**
  - **QOS parameter on the three ISPs**
  - **Price Control (insuring the best prices in the region)**
- ✓ **Singapore Broadcasting Authority (SBA) License *Electronic Content***
  - **ISPs, WWW Content Providers, and specific content editors will require registration and license.**
- ✓ **National Computer Board (NCB) is not a regulator – but is charged with promoting computerization, information technology, and the IT2000 plan.**

Singapore Telecom Internet eXchange (STIX)

- **STIX started as a regional transit service.**
- **ISPs who terminated in Singapore, would get transit to the Internet plus routes from all the other regional STIX customers.**
- **The “IX” part of the name was for marketing and PR. L3 IXPs are not really true peering points.**

Pacific Internet and A-Bone

- **Pacific Internet is one if the founding members of Asia Internet Holds (AIH) and the A-Bone service.**
- **Establishes the southern end of the A-Bone.**

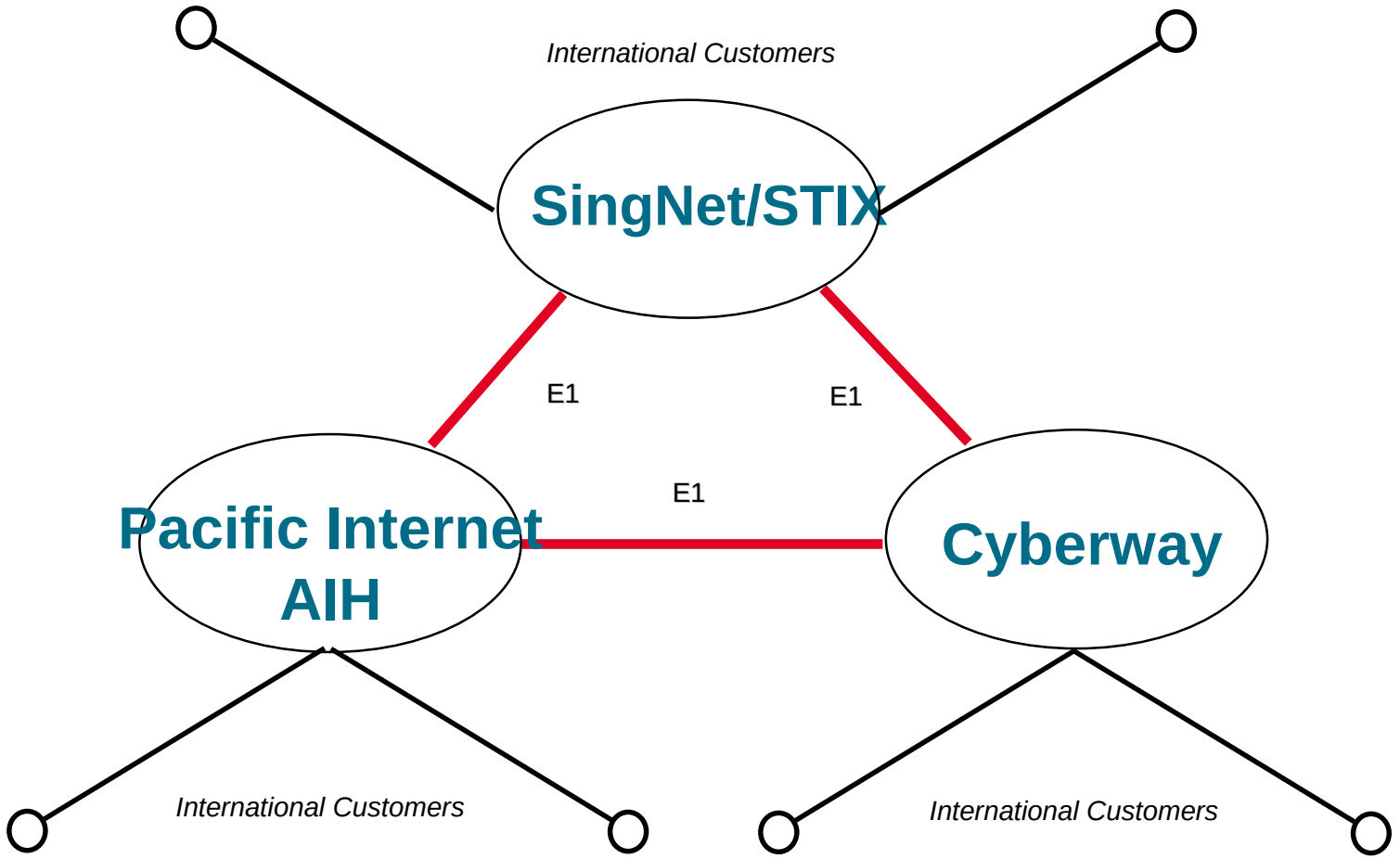
STIX & A-Bone

- **STIX and A-Bone start a new phase in Singapore's Internet infrastructure:**
  - ✓ **Regional connectivity through customers and backbone links.**
  - ✓ **Competition domestically & regionally begins.**
  - ✓ **Efforts begin to make Singapore a regional Internet Hub.**
  - ✓ **First special lease line circuit discount (25%) is provided to the ISPs for their links to the US. SingTel provides the discount via a request from TAS.**

Singapore - Internet Backbone

- **Neutral L2 IXP was considered and discarded. Resistance from SingTel and TAS. NCB wanted to be the *IXP.***
- **The ISPs needed something quick, simple, and scalable.**
- **The Answer – a *Tri-Lateral* Peering Agreement.**

Singapore - Internet Backbone



Singapore - Internet Backbone

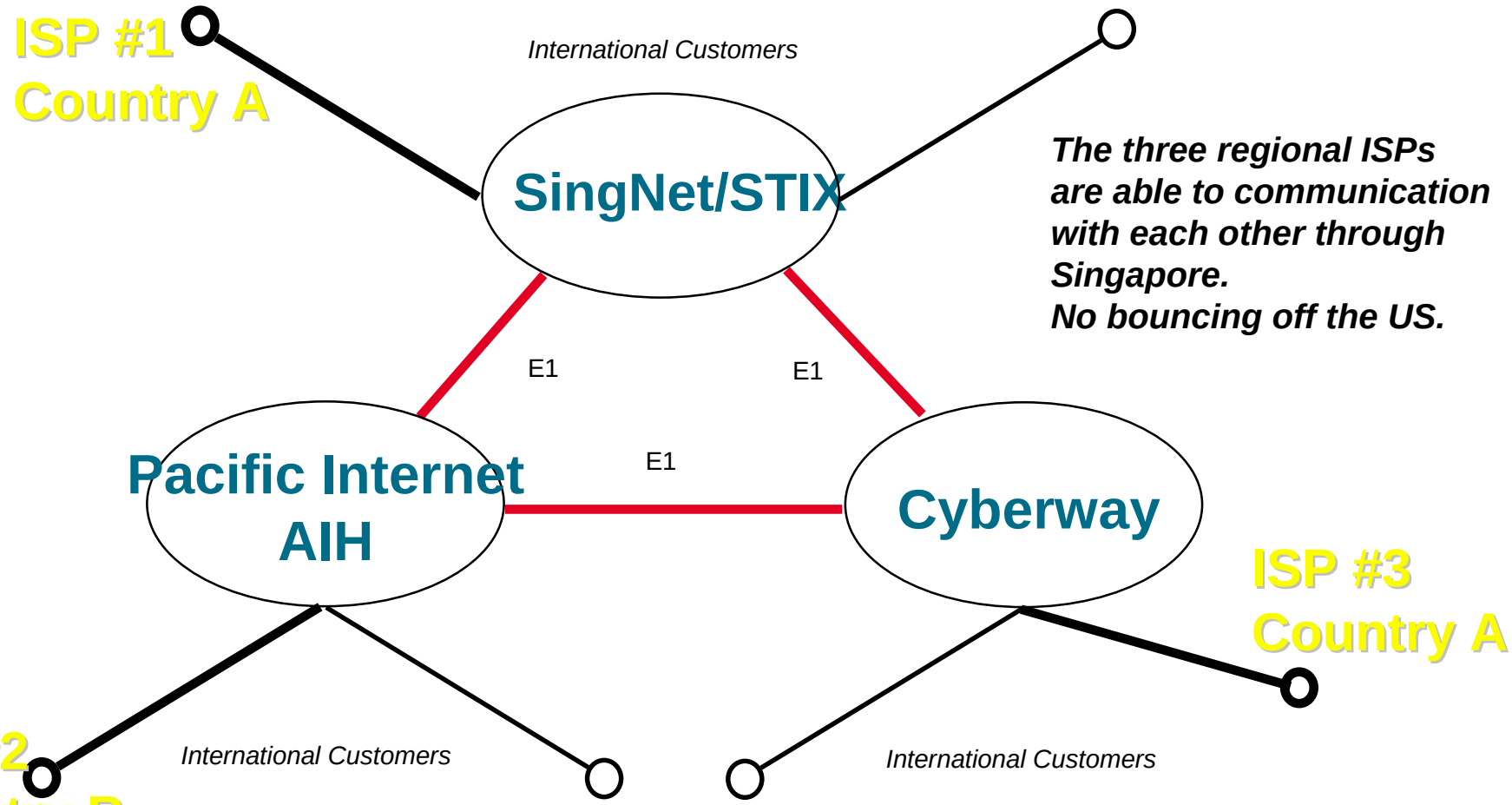
- Tri-Lateral Commercial Agreement between all three ISPs. The Peering Agreement was called the *Singapore Internet Backbone (SIB)*
- High speed links between all three Internet Service providers. Each provider pays for one link. Equal cost for all.
- All domestic Singapore Internet traffic stays in Singapore! No bouncing off the US.
- All customer links into any Singapore ISP will be able to get to any other customer (regional or domestic) of another Singapore ISP.
- The result - All of Singapore turns into a IXP.

Promoting a Regional Hub

- **SIB's agreement went beyond the exchange of domestic traffic.**
- **To promote Singapore as a regional hub, any customer circuit that terminated into Singapore's STIX or A-Bone would allow traffic exchange via SIB.**
- **SingTel provided each ISP with a multi-circuit discount – the discount increases as the ISP gets more International Lease Lines. SingTel's objectives were to get more ISPs to terminate in Singapore (vs US, Hong Kong, or Japan).**

Singapore - Internet Backbone

Exchanging Regional Traffic



The three regional ISPs are able to communication with each other through Singapore.
No bouncing off the US.

I-Hub and Singapore ONE

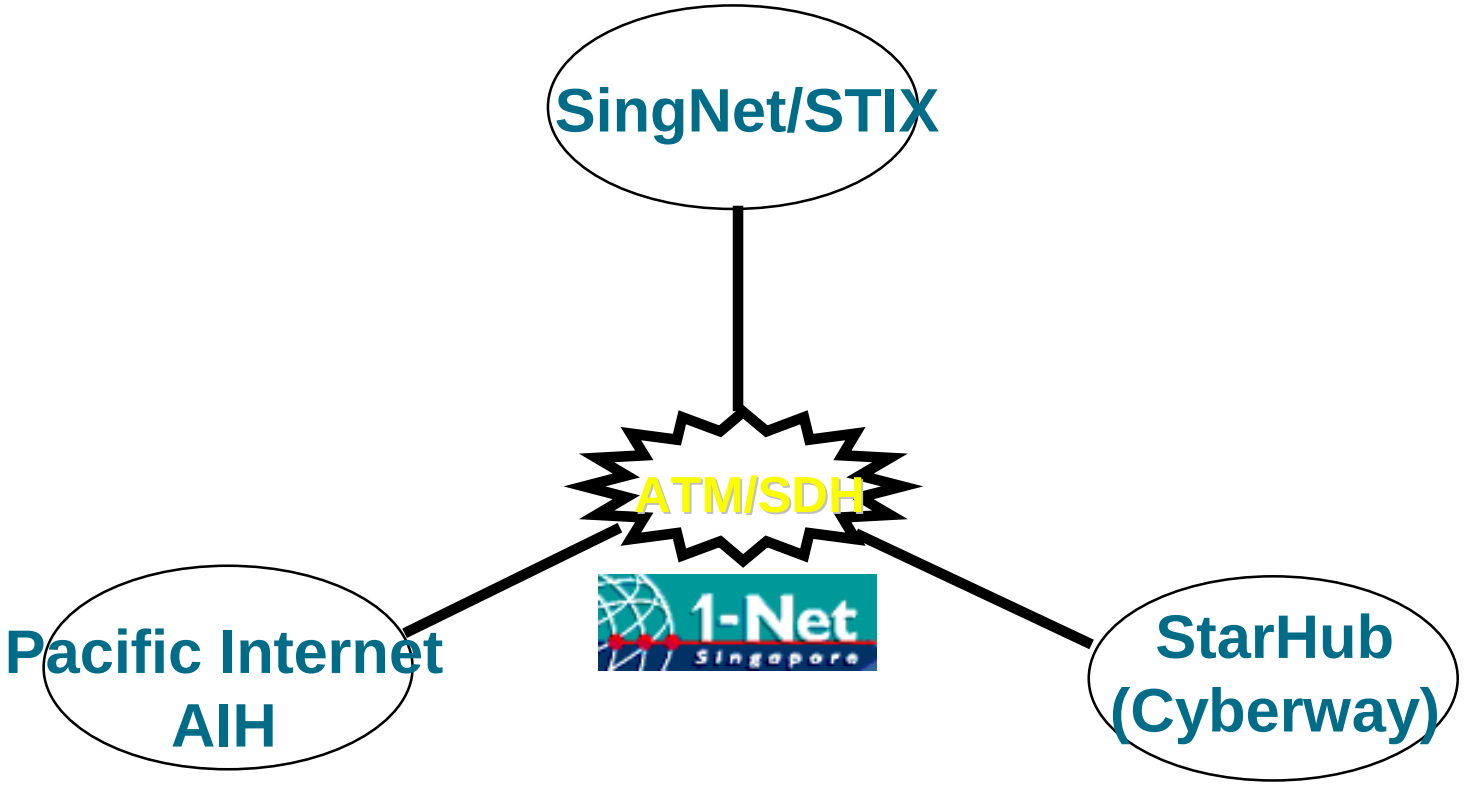
- **National Computer Board (NCB) started a project to build a National Information Infrastructure (NII). The project was called *I-Hub*.**
  - ✓ **The three ISPs offered that the SIB infrastructure would be used vs duplicating existing infrastructure.**
  - ✓ **Three ISPs and NCB sign a MOU to make SIB the "will be the fundamental foundation for the development of a National Information Infrastructure (NII)."**

I-Hub and Singapore ONE

- **TAS created Singapore ONE (S-ONE) to push Singapore into the Broadband world.**
  - ✓ **SingTel and the three ISPs joined TAS to create 1-Net as the ATM based Broundband Service Provider (later bought by MediaCorp).**
  - ✓ **NCB and TAS provided subsidized connections to 1-Net – objective was to encourage the growth of a broadband market.**
  - ✓ **Three ISPs migrated the SIB infrastructure to 1-Net – taking advantage of the subsidies.**

Singapore - Internet Backbone

SIB over 1-Net (1998-2001)



Singapore - Internet Backbone

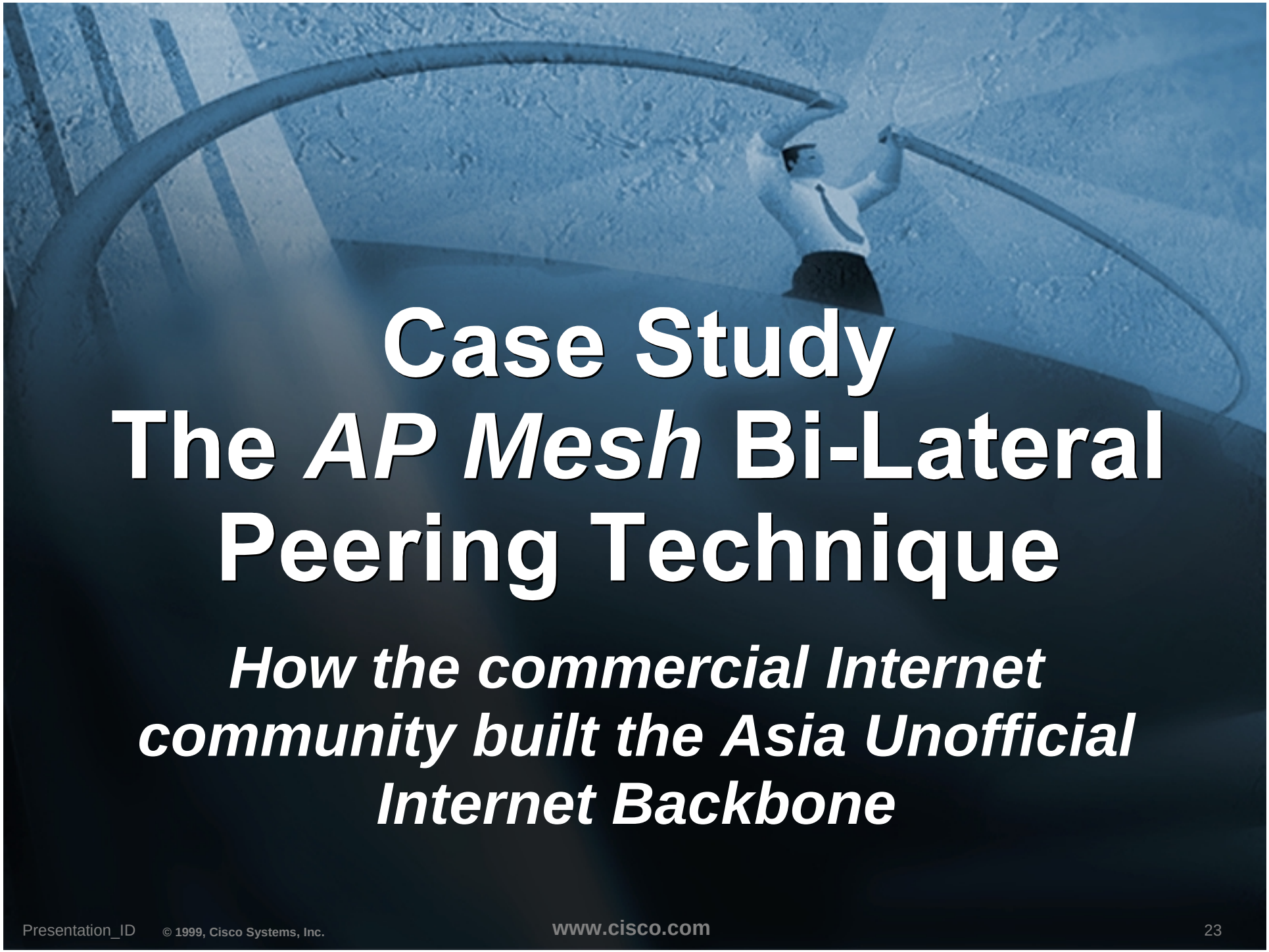
- **Two things to be point out:**
  - ✓ **SIB is the peering agreement that that allows the three ISPs to interconnect and exchange routes.**
  - ✓ **1-Net is the physical infrastructure. PVCs are treated the same as lease lines.**

Issues Today

- **The Telecommunications Market is fully opened.**
  - ✓ **New ISPs and Co-Locations companies are entering the market.**
  - ✓ **SIB is still in place.**
- **No Clear or transparent way to connect for Singapore routes.**
  - ✓ **Each party needs to work with one of the three incumbents.**

Singapore's Success

- **Win-Win Collaboration was the Key!**
  - ✓ **Regulators and the ISPs Collaborating**
  - ✓ **NCB and the ISPs Collaborating**
  - ✓ **Universities and the ISP Collaborating**
  - ✓ **ISPs Collaborating Amongst Each Other**
- **Result – One of the highest Internet/per-population ratios in the world!**
  - ✓ **Always one of the top five – depending on the study.**



Case Study
The *AP Mesh* Bi-Lateral Peering Technique

How the commercial Internet community built the Asia Unofficial Internet Backbone

Private Interconnects in Asia

- **Interconnection between ISPs is at the heart of the Internet.**
- **The objective of the Internet is transparent end-to-end connectivity.**
- **Yet, Interconnecting ISPs within Asia and Pacific has been an up hill struggle.**
- **In the mid ’90s. if it was cost effective to build a Asia Pacific Internet Infrastructure (APII), it would have been built.**

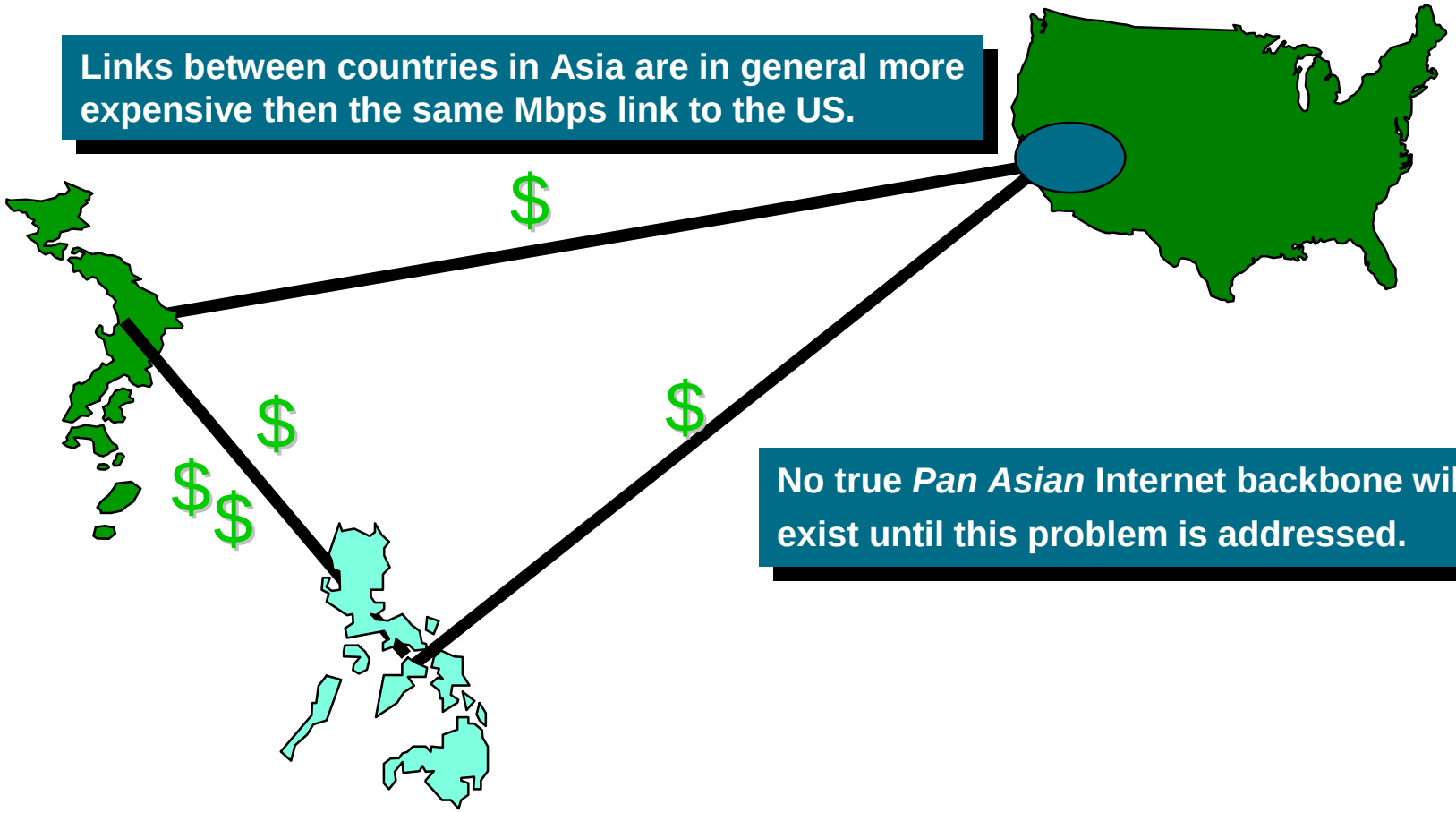
Private Interconnects in Asia

- **Three factors are the primary inhibitors to ISPs interconnecting in Asia and Pacific in the mid 1990s:**
  - ✓ **Price or International Private Lease Circuits between Asian and Pacific Countries**
    - ⇨ **Circuit prices between AP countries have usually been higher than the equivalent circuit to the US.**
  - ✓ **Regional Competition**
    - ⇨ **Everyone want to be *the* regional hub.**
  - ✓ **Multitude of language and cultures**
    - ⇨ **Someone who reads and speaks Chinese will not be browsing Hindi content in India.**

Private Interconnects in Asia

Result: Asian ISPs use the US West Cost as the hub because it is more cost effective - despite the performance impact of crossing the Pacific Ocean twice!

Links between countries in Asia are in general more expensive then the same Mbps link to the US.



No true *Pan Asian* Internet backbone will exist until this problem is addressed.

Private Interconnects in Asia

- **What is needed?**
- **A way to interconnect that is cost effective, adds value, encourages traffic growth, and can scale……**
- **The answer is a peering model that would work with the competitive telecommunication conditions of the mid ’90s ……. *AP Mesh***

AP Mesh

Private Interconnects in Asia

- **What is AP Mesh?**
  - ✓ **It is a term used to describe a bi-lateral peering methodology.**
  - ✓ **It is a a minute subset of existing bi-lateral telephony interconnection technique and applying it to interconnection ISPs in Asia.**
  - ✓ **It mitigates some of the effects of the high inter-country bandwidth cost in Asia.**
  - ✓ **It is a technique that works.**

Private Interconnects

AP Mesh

- **AP Mesh**
  - A informal Internet Backbone effort informally launched by KDD and SingTel in 1996
  - Based off comprehensive analysis of profit margins of existing services that use *backbones* in the region (X.25, TCP/IP, Frame Relay, FAX, and IDD Voice).
  - Took the best of the international telephony network's bi-lateral arrangements to construct a flexible model of building a scaleable backbone based on proven success.
  - Build bi-lateral business cases for interconnection between major Telcos in the region - similar to IDD Voice Interconnect.

Private Interconnects

AP Mesh

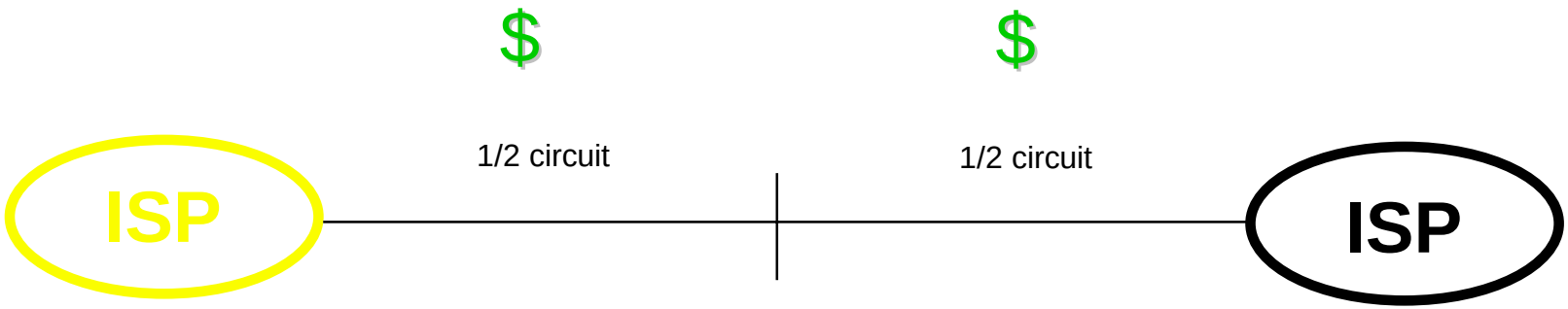
- **AP Mesh (Cont.)**
  - Start small (128K) with link QoS. Upgrade when QoS is exceeded. Hence, backbone link is gradually upgraded when real bandwidth requirements exist.
  - Performance increases from the latency reduction compensate for the gradual increase of bandwidth.
  - Stack services on top of the link basic interconnect agreement. Examples:

iVPN	Roaming	OSS
Web Co-location	Proxy/Cache	USENET News
VoIP	IP Telephony	Stream
Multicast	CDN Networks	

Private Interconnects

AP Mesh

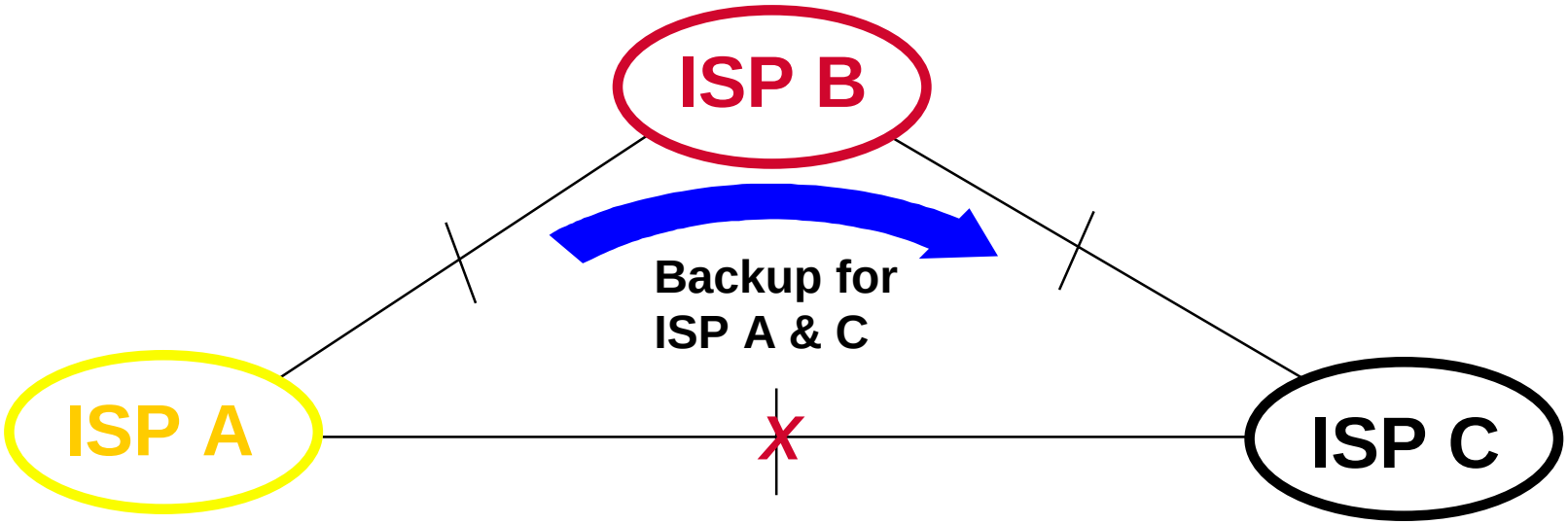
- ✓ Each pays for their 1/2 circuit.
- ✓ Each party open to join other backbones.
- ✓ Each party can compete with each other as a regional *Internet Hub* while enjoying the benefits of mutual collaboration.



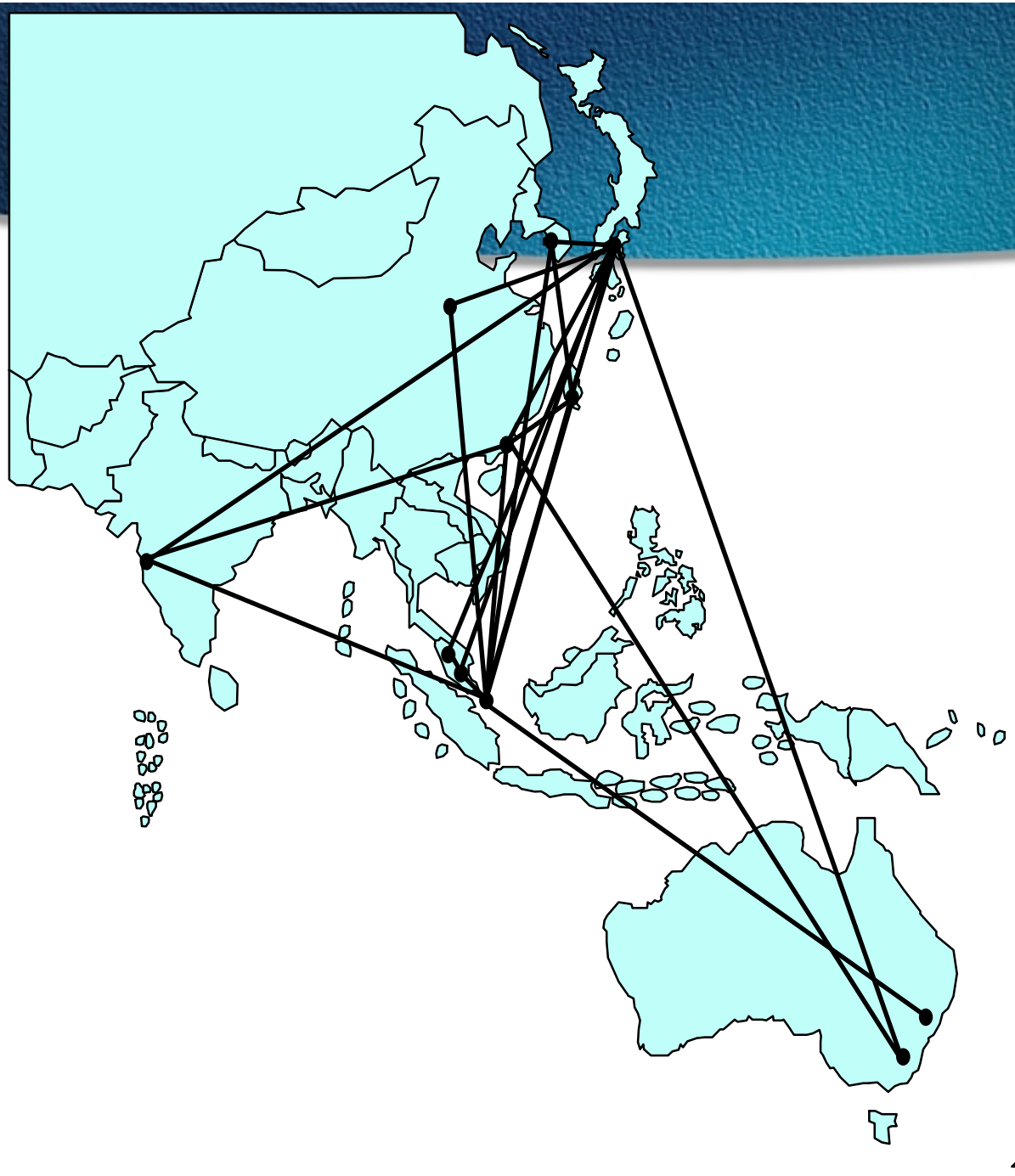
Private Interconnects

AP Mesh

- ✓ Each party open to create tri-lateral and/or settlement based on the number of routes.
- ✓ Allow three links to be configured (via BGP) for mutual backup.



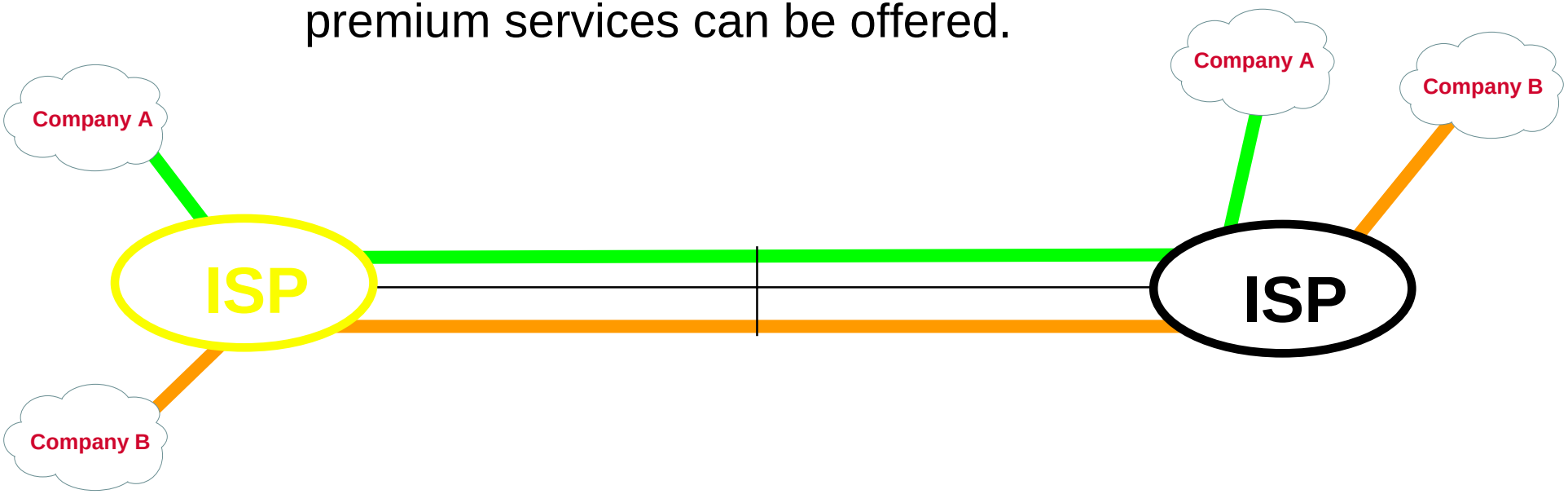
AP Mesh



* *Access One*
* *AAPT (Connect.Com)*
* *ChinaNet*
* *Chunghwa Telecom (HiNet)*
* *Dacom*
* *Hong Kong Telecom*
* *IDC (Japan)*
* *ITJ (Japan)*
* *KDD*
* *Korean Telecom (KorNet)*
* *Jaring (MIMOS)*
* *SingTel/STIX*
* *Telekom Malaysia*
* *Telstra*
* *VSNL*

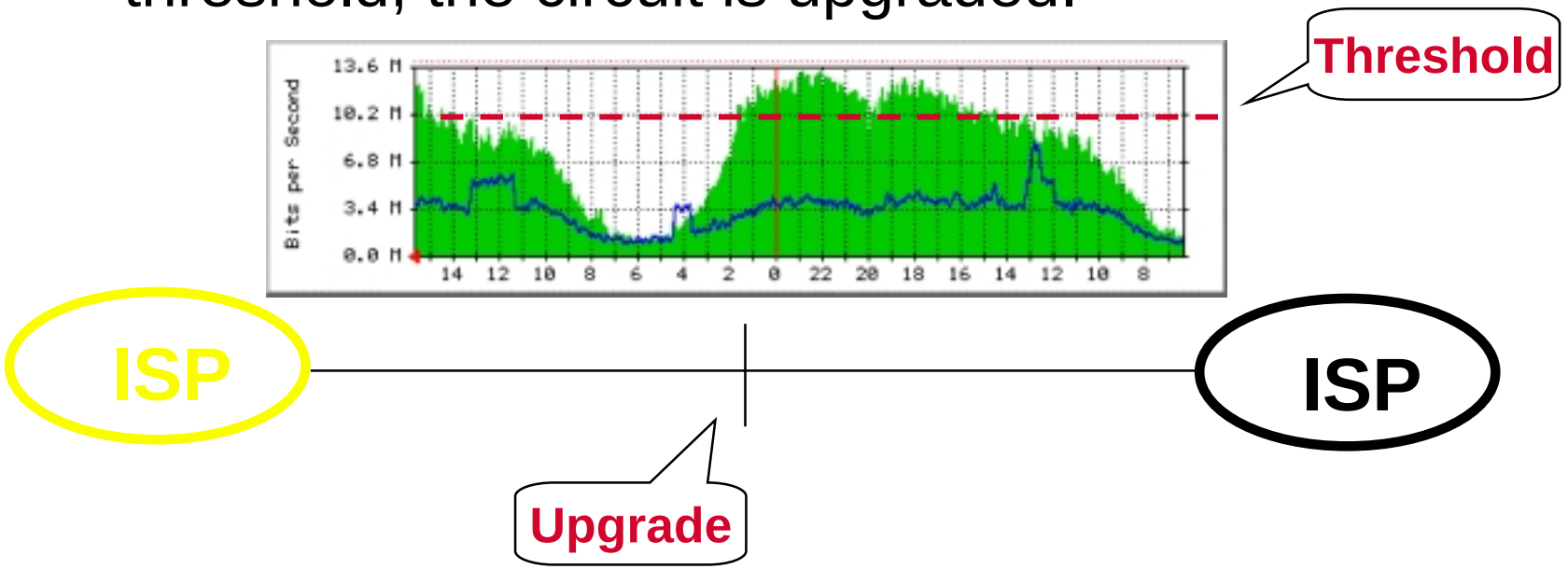
Private Interconnects in Asia

- ✓ Once the bi-lateral connection is installed, services are added that would fill the link with inflows of revenue.
- ✓ Example - VPNs
  - ⇨ Each party can sell VPN services with or without the cooperation of the partner.
  - ⇨ With cooperation, *service level agreements* an premium services can be offered.



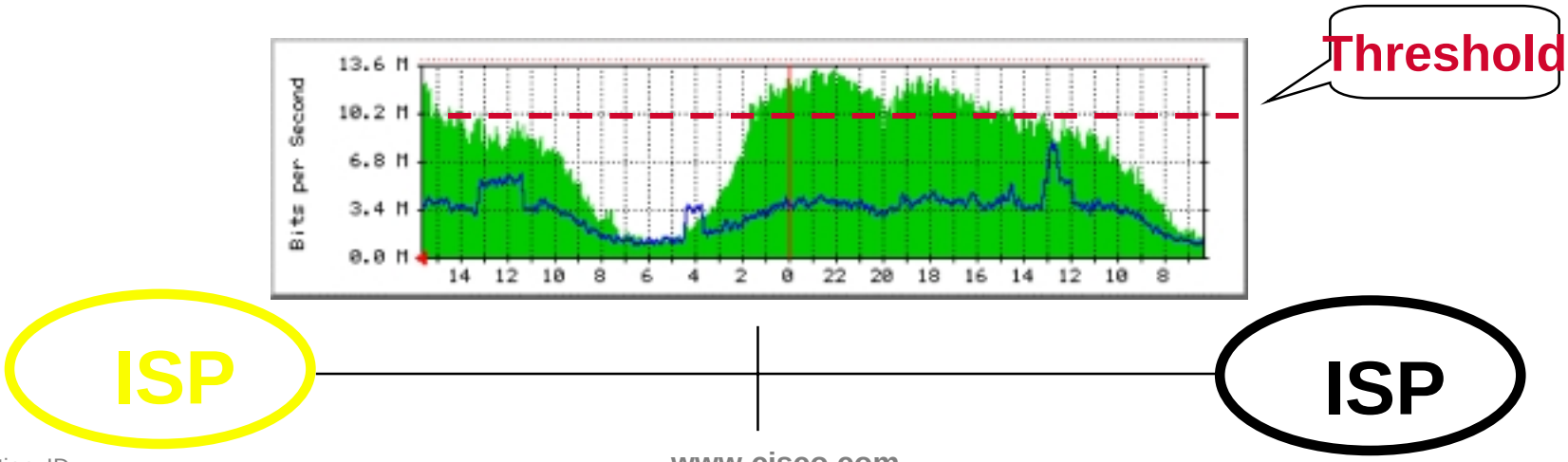
Private Interconnects in Asia

- Quality Levels can be build into the interconnection agreement.
  - ✓ Each party monitors the link with SNMP.
  - ✓ When the average utilization reaches a agreed threshold, the circuit is upgraded.



Private Interconnects in Asia

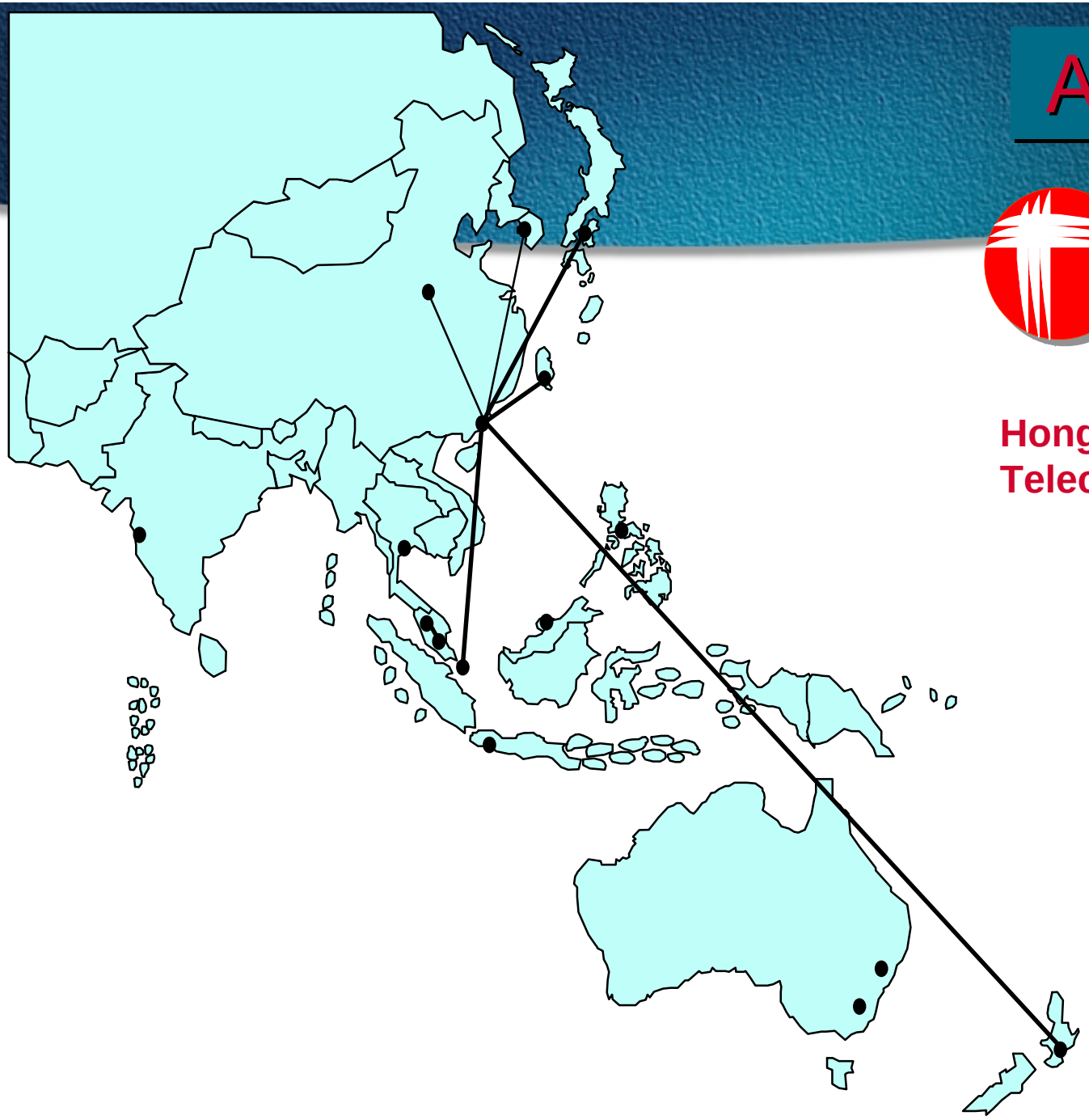
- Upgrades are incremental
  - ✓ Typically, 128 Kbps is used to start the relationship. As the traffic pattern and trends are established, automatic incremental upgrade will take the circuit from 128Kbps to 256 Kbps, to 512 Kbps, to 2 Mbps, etc.



Private Interconnects in Asia

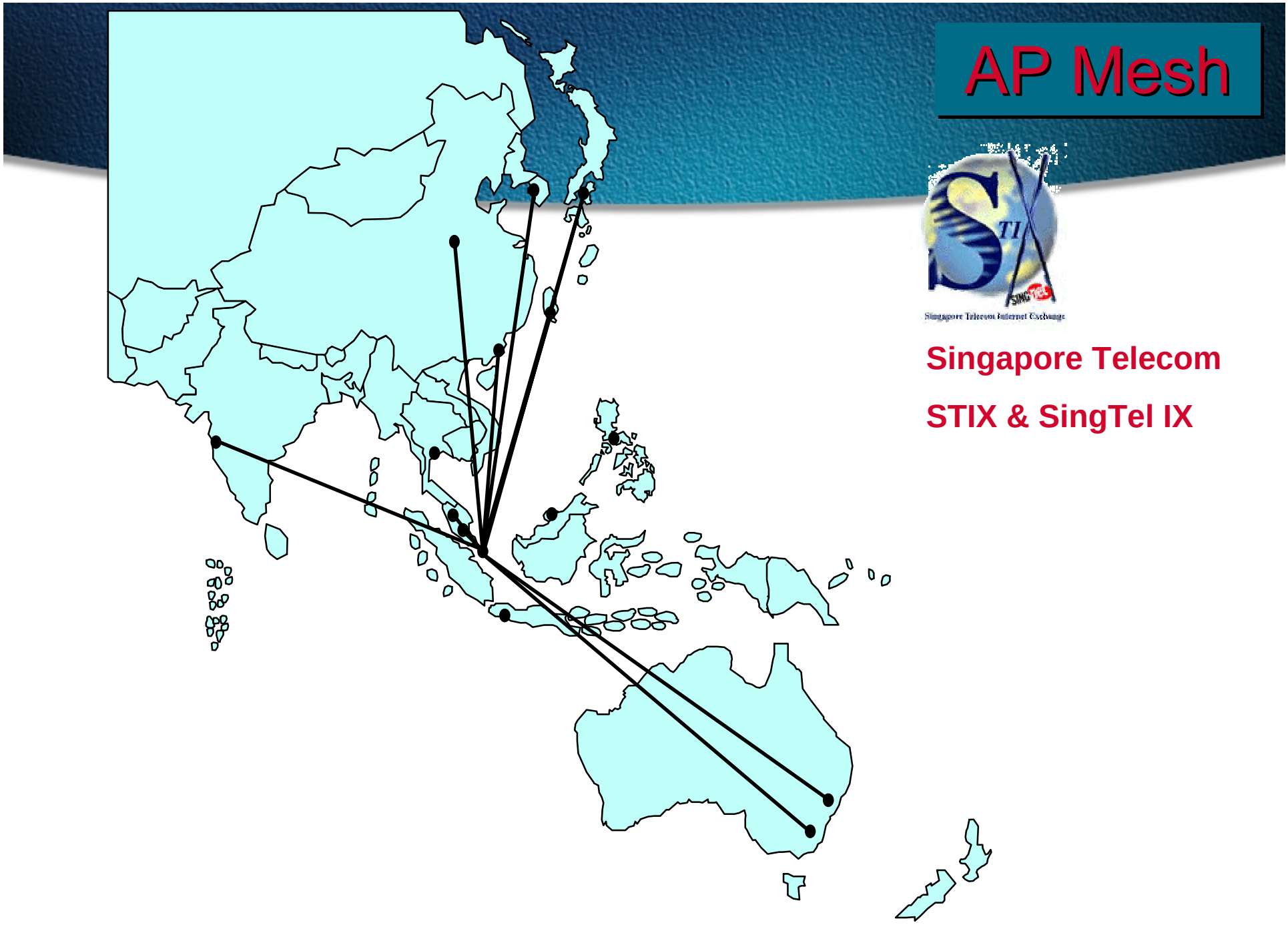
- **AP Mesh solves the #2 problem with a APII …. Everyone wants to be the hub.**
- **With the AP Mesh peering technique, ISPs and Telcos can have a wide range of regional connectivity and be perceived as the regional hub ….** ***from their point of view*** **…..**
  - ✓ **For example, Hong Kong Telecom, KDD, Singapore Telecom, and Telstra all appear the be the regional hub - from their point of view.**

AP Mesh



Hong Kong Telecom

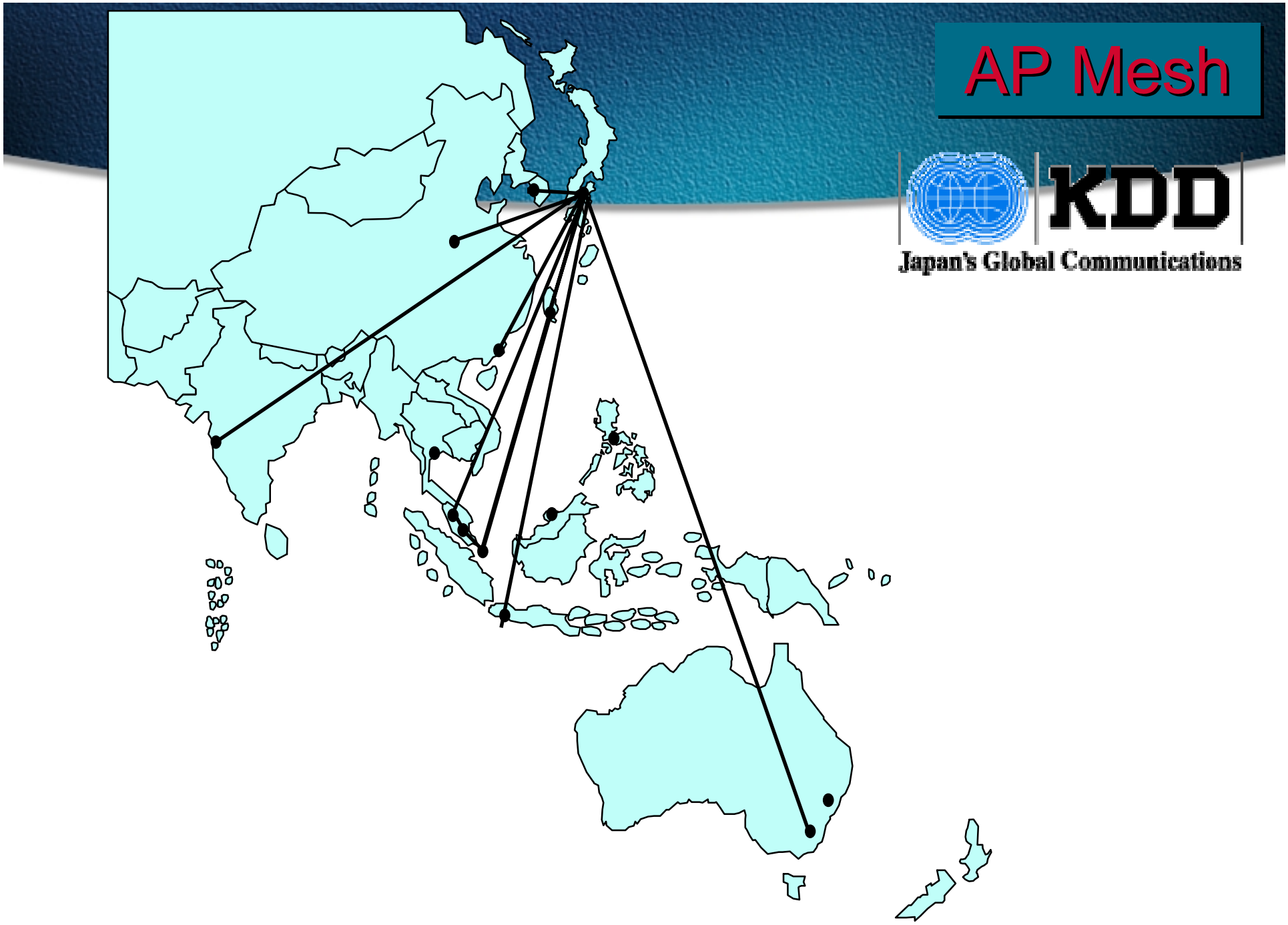
AP Mesh



Singapore Telecom

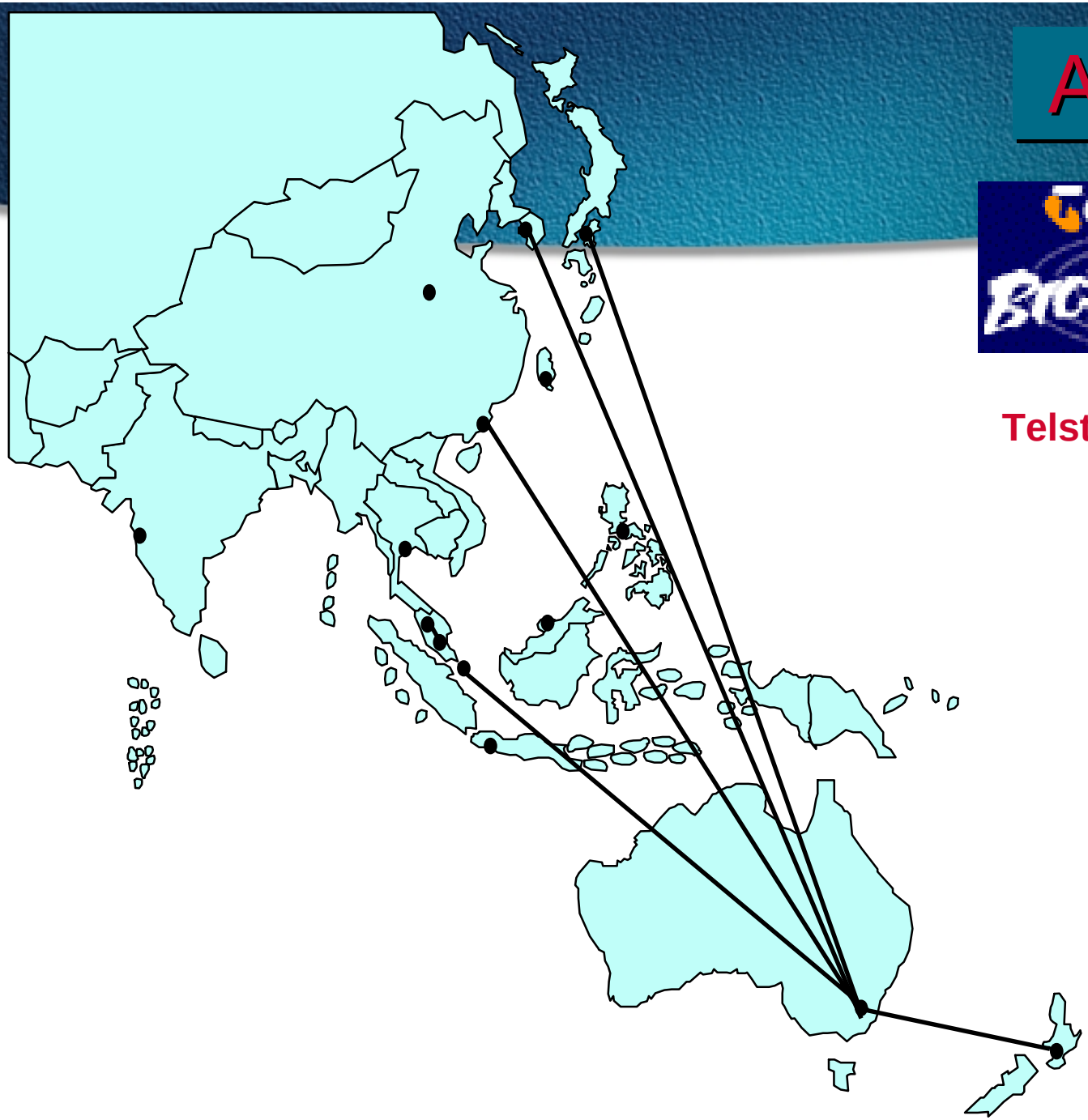
STIX & SingTel IX

AP Mesh



KDD
Japan's Global Communications

AP Mesh



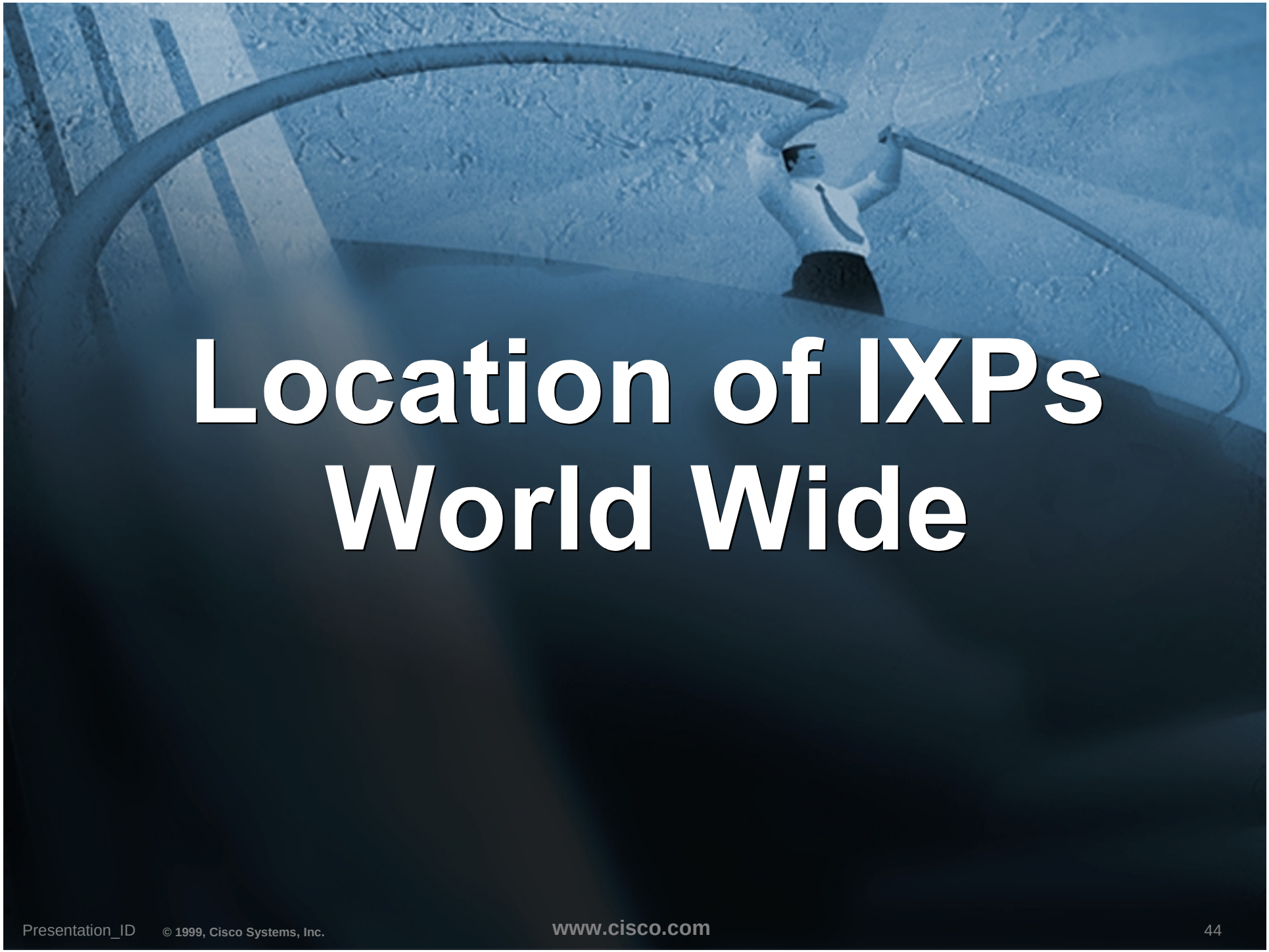
Telstra Big Pond

AP Mesh Technique Today

- **From the first peering agreement in 1996 to today, practically all the major ISP in Asia have used the technique in one shape or another.**
- **Circuits that started at 128 Kbps in 1996 are 45 Mbps in 2001. All upgrades were driven by bi-lateral peering traffic!**
- **In 2001, things are changing that would evolve the technique.**

AP Mesh Technique Today

- **Times are changing:**
  - ✓ **Telecommunication De-Regulation and Re-Regulations has opened the doors to a wide range of new telecommunications players.**
  - ✓ **Companies are not isolated by country. For example, SingTel is moving to Hong Kong and HKT is moving to Singapore.**
- **The combination of AP Mesh Bi-laterals, local peering (IXPs), Regional Backbones, and US Peering make Asia the most complicated peering on the planet.**

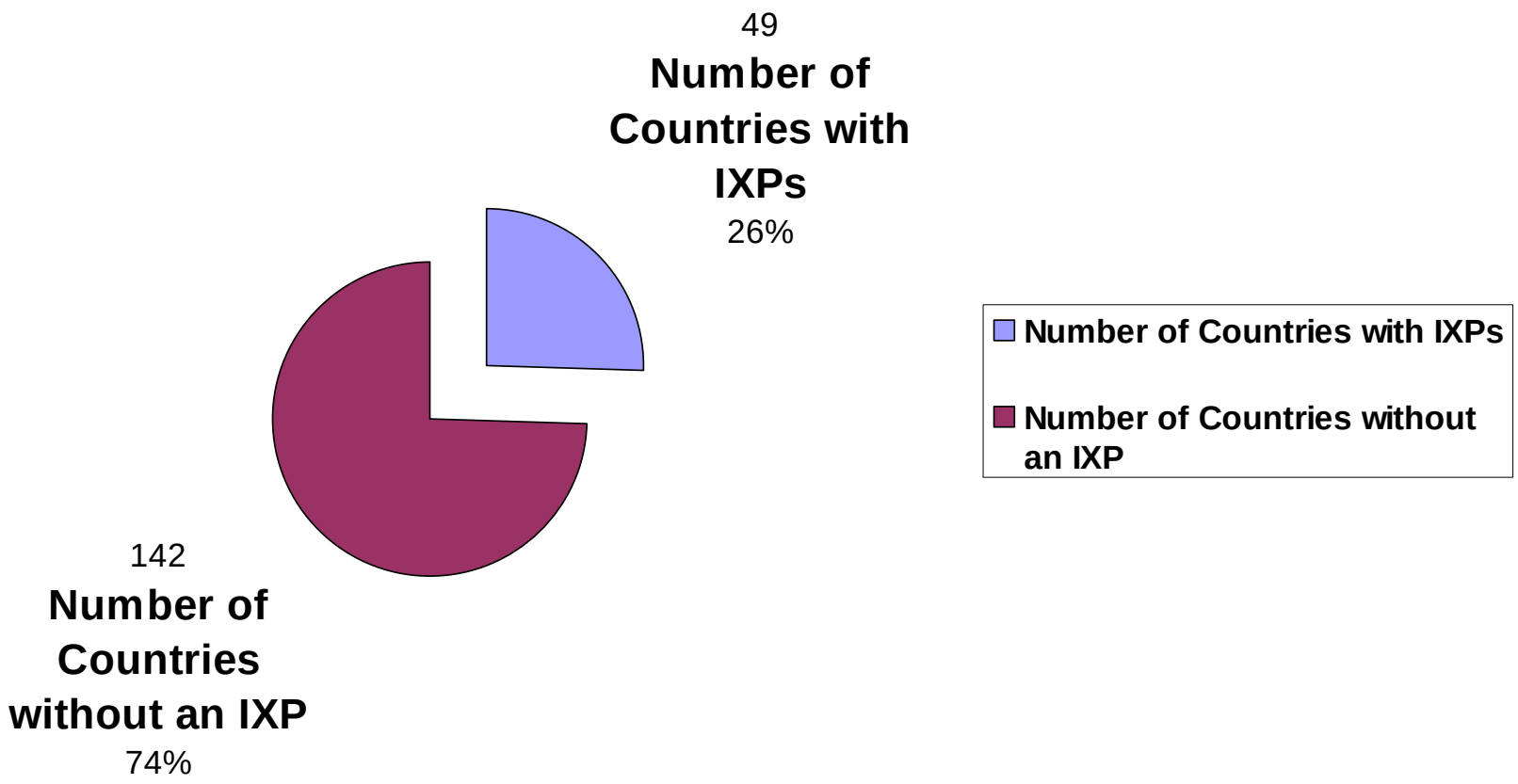


Location of IXPs World Wide

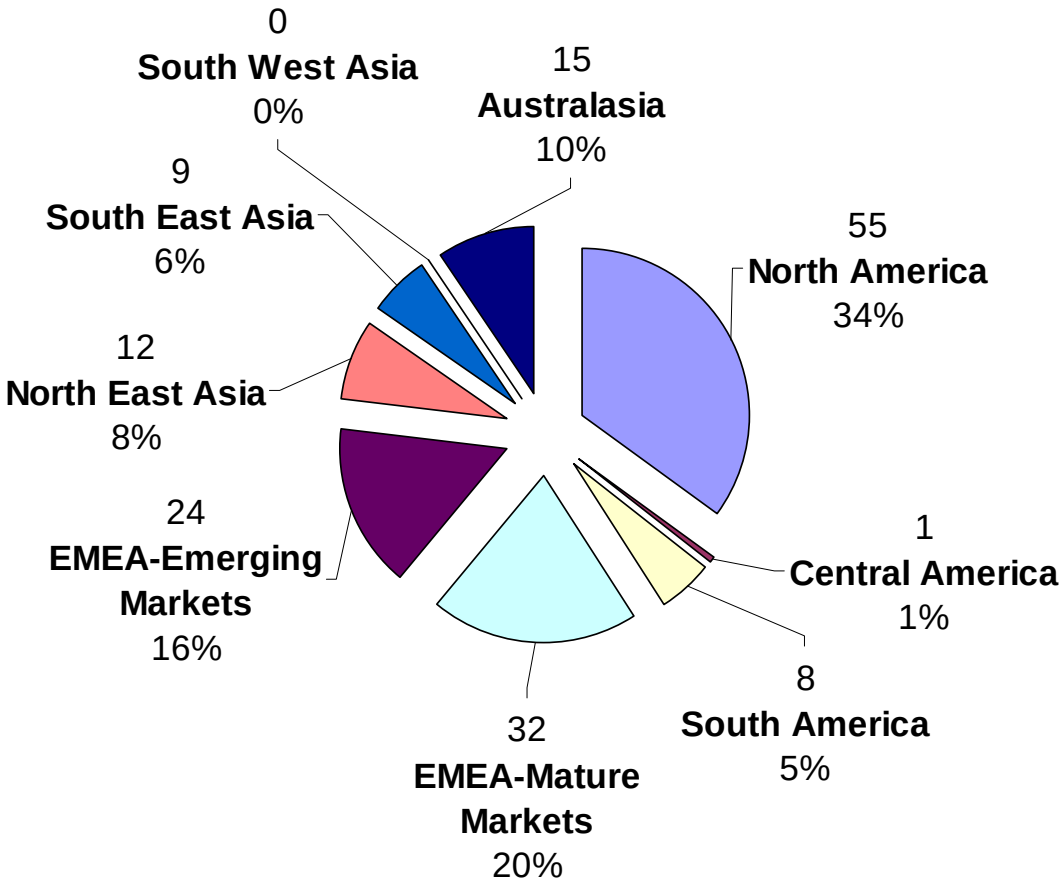
Location of IXPs World Wide

- **Central Collection point for information on IXP World Wide:**
  - ✓ **http://www.ep.net**

Global IXP Distribution: An Overview

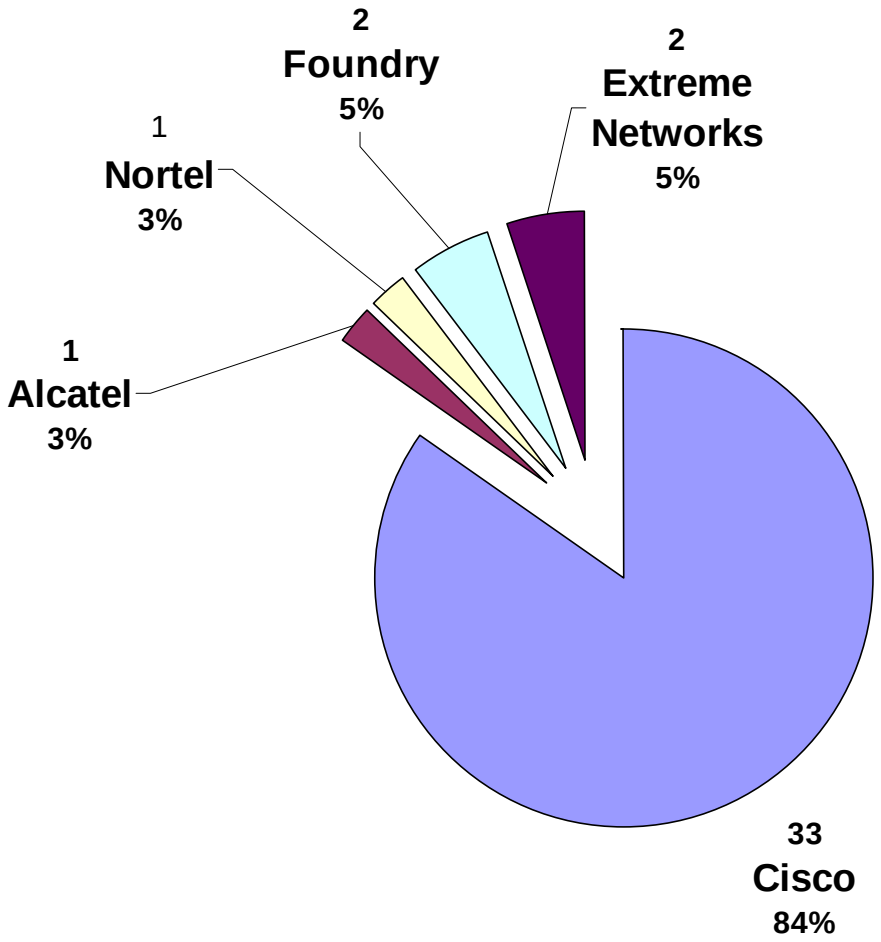


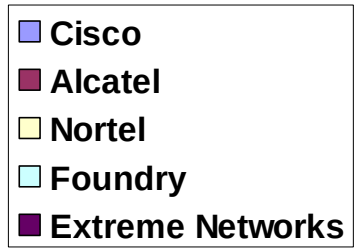
Global IXP Distribution: 157 IXPs among 49 countries



Estimated 191 countries worldwide

Cisco Equipment in the IXP Core





No vendor information for core equipment of 118 of 157 IXPs

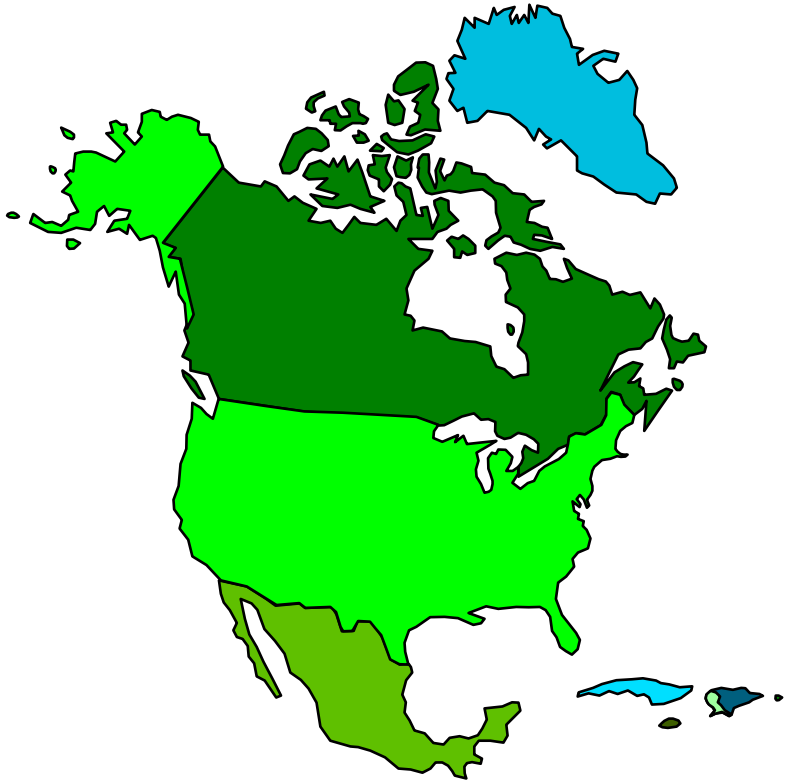
Geographic Areas: EMEA

- **Europe**
  - ✓ North
  - ✓ UK
  - ✓ South
  - ✓ Germany
  - ✓ Eastern Europe
  - ✓ Central Europe
  - ✓ South East
- **Africa**
  - ✓ North Africa
  - ✓ Sub-Saharan
- **Middle East**
- **Near East**

Geographic Areas: Americas and Asia

- **Americas**
  - ✓North America (US and Canada)
- **Americas International**
  - ✓Central America (Mexico to Panama)
  - ✓South America (south of Panama)
- **Asia**
  - ✓North East Asia (Japan, Korea, China and Taiwan)
  - ✓South East Asia (Thailand, Singapore, etc.)
  - ✓South West Asia (India, Pakistan, etc.)

North America



North America has more than 55 Internet Exchange Points/Network Access Points

U.S. East Coast IXPs-13

- ATL-NAP Atlanta
- BMPX - Boston Metropolitan Exchange Point
- BNAP - Baltimore NAP
- ipx - A New Jersey Activity
- MAGPI - a Mid Atlantic Gigapop for Internet2
- NNAP - Neutral NAP

East Coast Continued

- NYIIX - New York International Internet Exchange (Telehouse)
- Philadelphia Internet Exchange
- Pittsburg Internet Exchange
- Research Triangle Park
- Sprint NAP (Pennsauken NJ)
- Vermont ISP Exchange Private(Password Required)
- PAIX-VA/Palo Alto Internet Exchange, Virginia

U.S. West Coast IXPs-12

- AMAP - Anchorage Metropolitan Access Point
- AIX-Ames Internet Exchange
- CIX-Commercial Internet Exchange
- COX-Central Oregon Internet Exchange
- HIX-Hawaii Internet Exchange
- LAP-a Los Angeles Exchange, Includes MAE-LA
- OIX-Oregon Internet Exchange
- Pacific Bell NAP Information
- PAIX-Palo Alto Internet Exchange
- SD-NAP-San Diego (Caida)
- SIX-Seattle Internet Exchange
- SNNAP-Puget Sound Regional Interconnect

U.S. Inner Western States & Texas IXPs-11

- DIX-Denver Internet Exchange
- Mountain Area eXchange (Denver)
- Utah REP
- New Mexico Network Access Point
- TTI-The Tucson Interconnect
- Austin-AMAP
- Compaq's Houston NAP
- Dallas-Ft. Worth DWFMAP
- Mae Houston
- Magie-a Houston Exchange
- San Antonio SAMAP

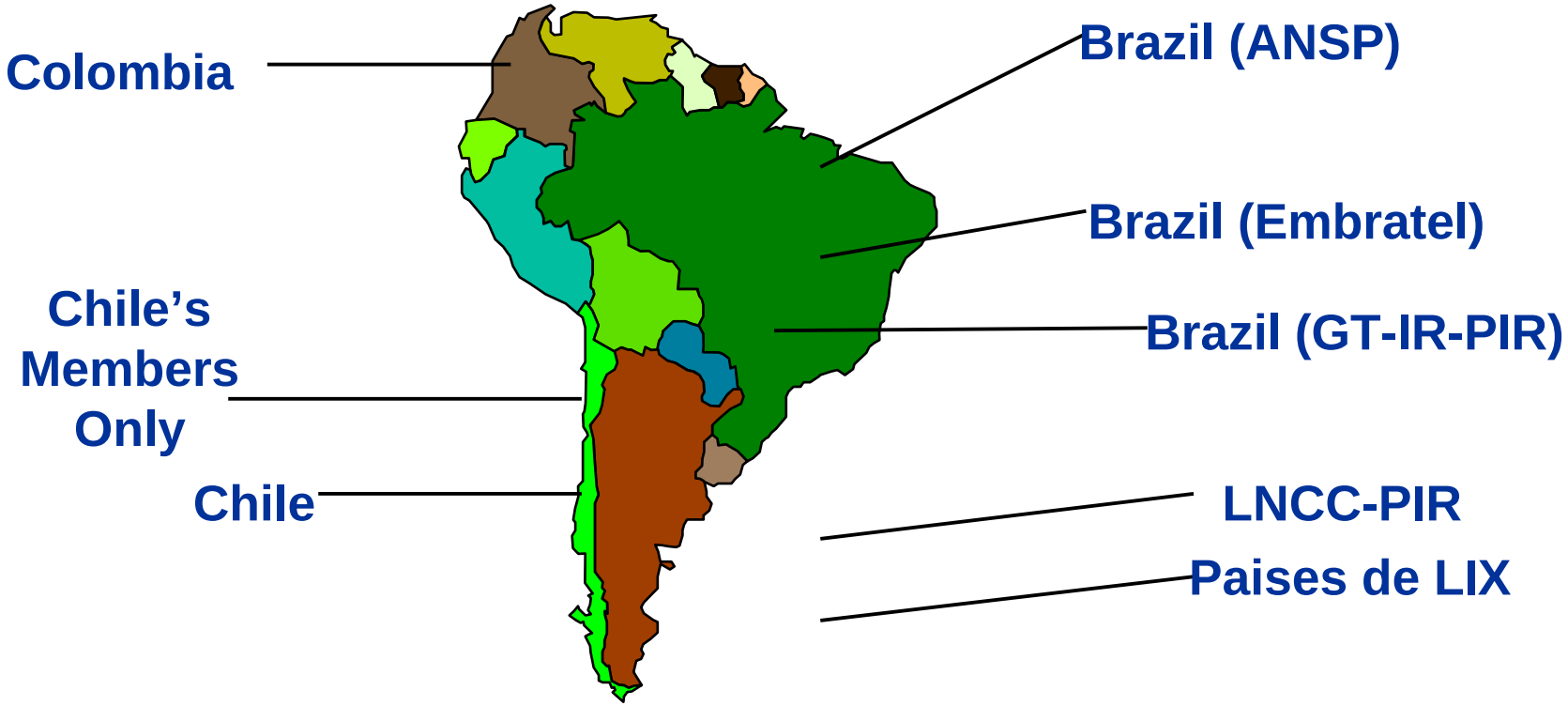
U.S. Midwest IXPs-7

- Ameritech NAP info (Chicago NAP)
- CMH-IX--Columbus Internet Exchange
- Indy-X-Indianapolis Data Exchange
- Nashville City Net
- Ohio Exchange
- STAR TAP (12 GIGPOP)
- The Arch-St. Louis, MO.

Canada IXPs-12

- BCIX-British Columbia Internet Exchange
- BC Gigapop-British Columbia Gigapop
- CA/NAP Canada/Toronto Exchange
- CANIX: Originally CA* net sponsored
- Edmonton Internet Exchange
- MIX-Montreal Internet Exchange
- The Nova Scotia Gigapop
- Quebec Internet Exchange
- Toronto Internet Exchange
- Equinix
- LA NAP
- Napnet A GTE Company

South America



South America has an estimated 8 exchange points

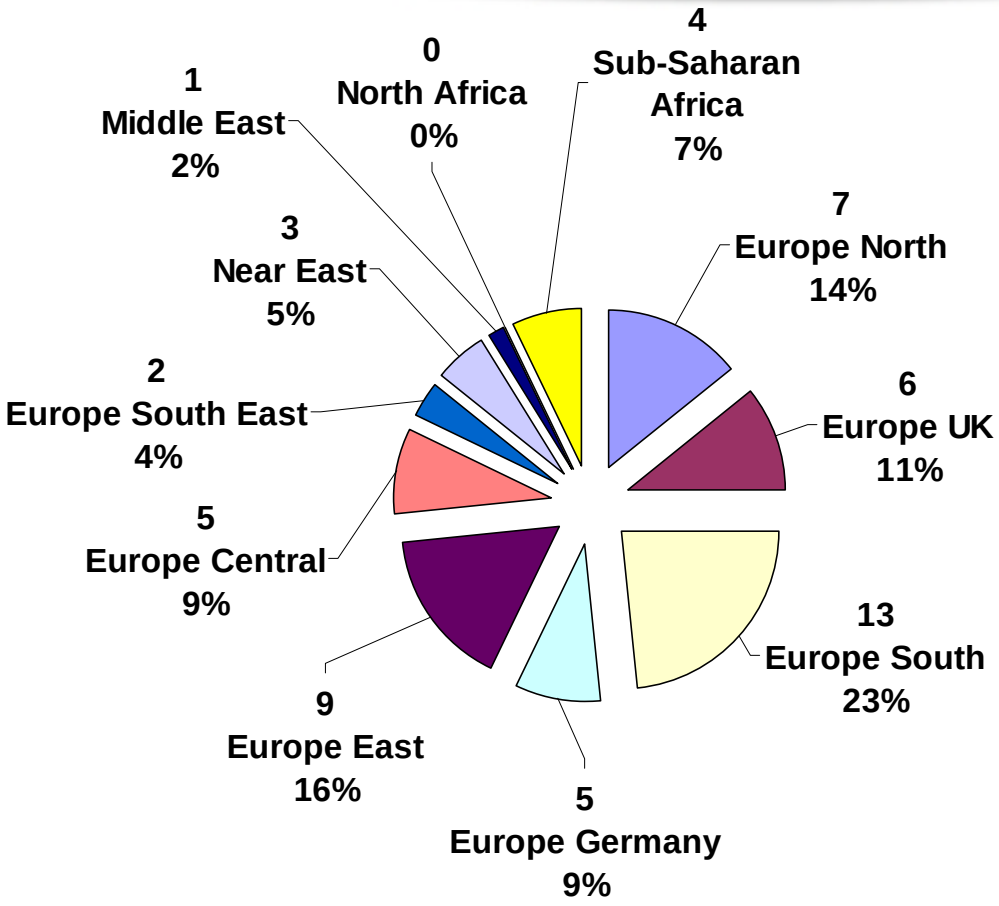
South America IXPs-8

- A members only exchange in Chile
- ANSP-Brazil
- Chile's Internet Exchange Point Embratel in Brazil
- GT-ER-PIR in Brazil
- InterRed-Colombia
- LNCC-PIR
- Paises de LIX

Central America IXPs-1

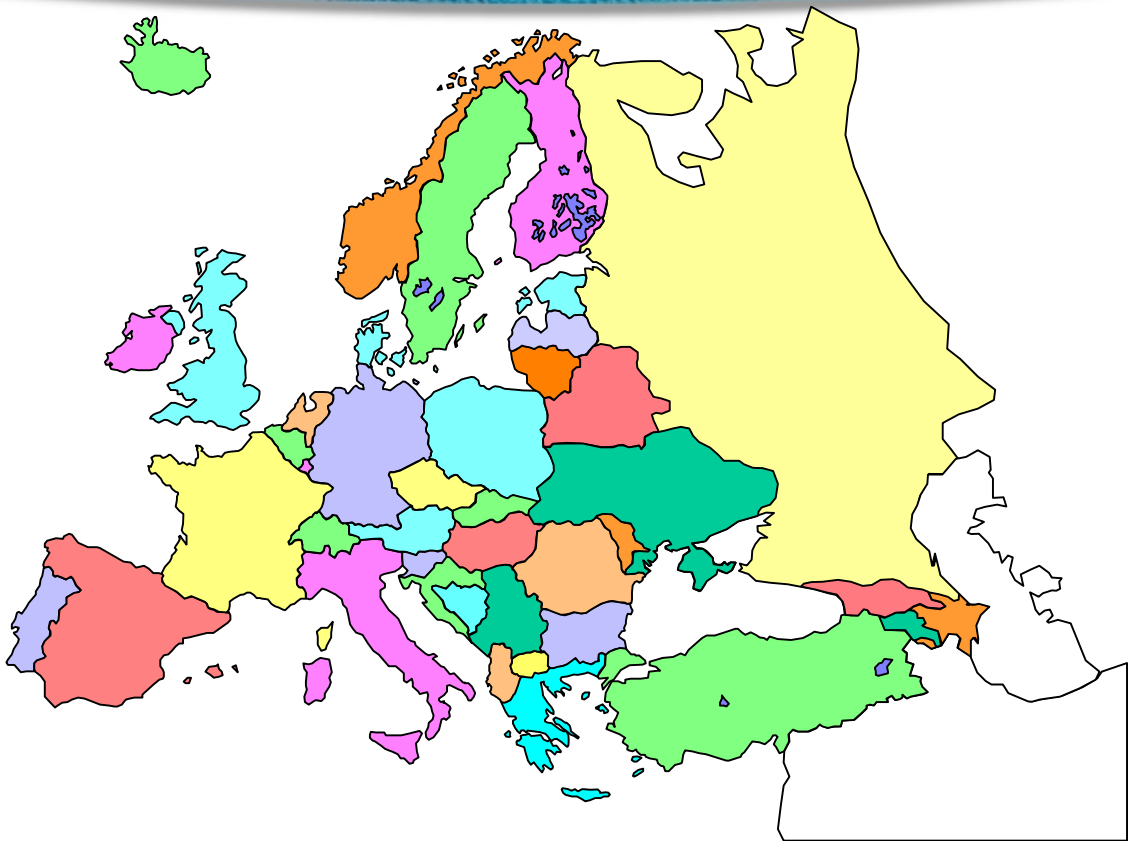
- **InteRED-Panama**

EMEA
IXP Distribution



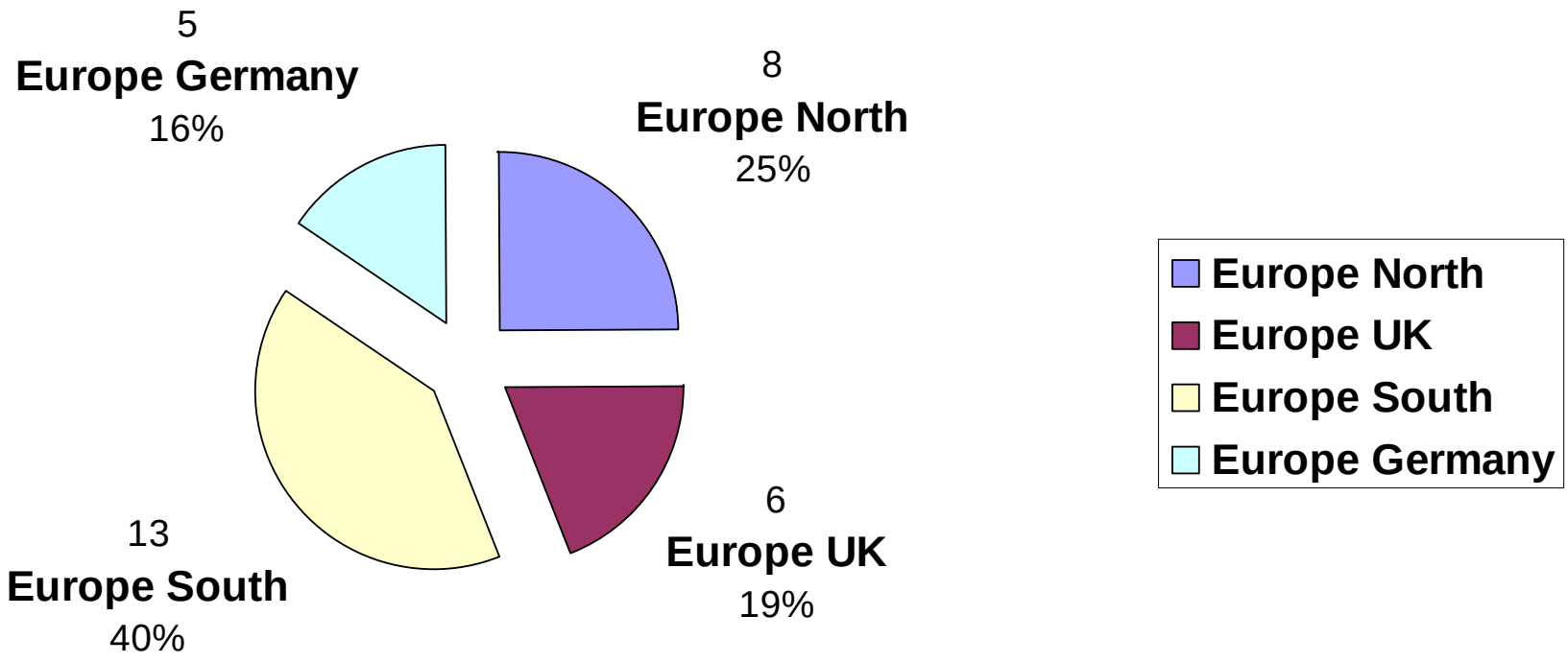
Estimated total of 101 countries throughout this theatre

EMEA Mature Markets IXP Distribution



European countries with mature markets have a total of 32 Internet Exchange Points

EMEA Mature Markets IXP Distribution



Europe North IXPs-8

- AMS-IX-Amsterdam Internet Exchange
- BNIX-Belgium Neutral Internet Exchange
- LIX-Luxembourg Internet Exchange
- DIX-Danish Internet eXchange
- fiCIX-Finnish CIX
- KTHNOC (formally the dGIX)-Sweden
- NIX-Norwegian Internet Exchange
- Latvian GIX

Europe UK IXPs-6

- SCOTIX-Scottish Internet Exchange
- World.IX-European Commercial IX (Edinburgh)
- INEX-Ireland Neutral Exchange
- LINX-London Internet eXchange
- LoNAP
- MaNAP-Manchester Network Access Point

Europe South IXPs-13

- CIXP-CERN Exchange for Central Europe
- SIX-A Swiss Exchange
- TIX-A Zurich Exchange
- VIX-Vienna Internet eXchange
- GNI-Grenoble, France
- The Paris ATM Network Access Point
- SFINX-A Paris Activity

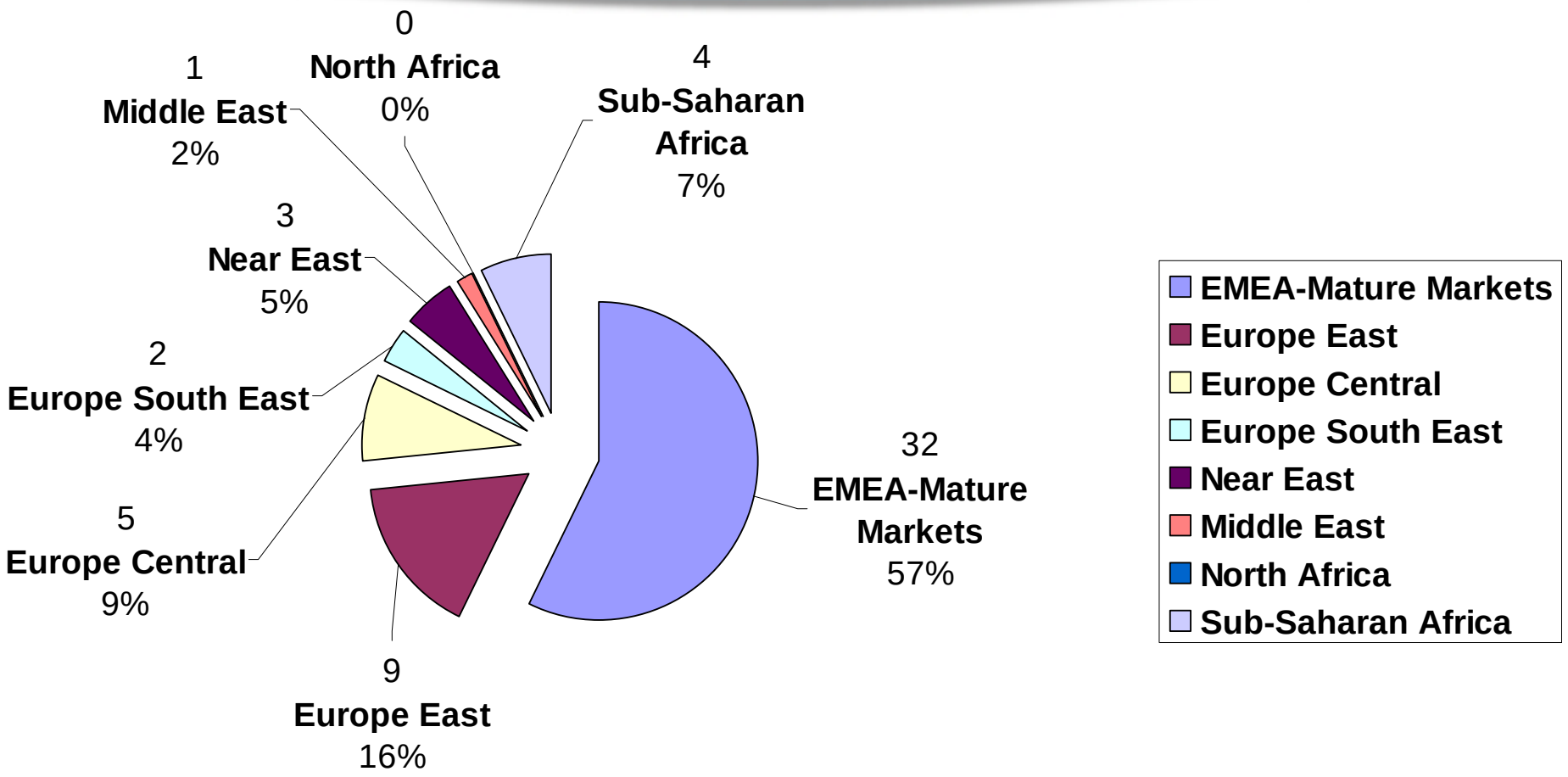
Europe-South IXPs Continued

- MAE Paris
- CATNIX-Barcelona, Spain
- ESPANIX-Madrid Interconnect Exchange
- MIXITA-Milan Internet Exchange
- NAP Nautilus-A Rome Exchange Point
- PIX-Portuguese Internet Exchange

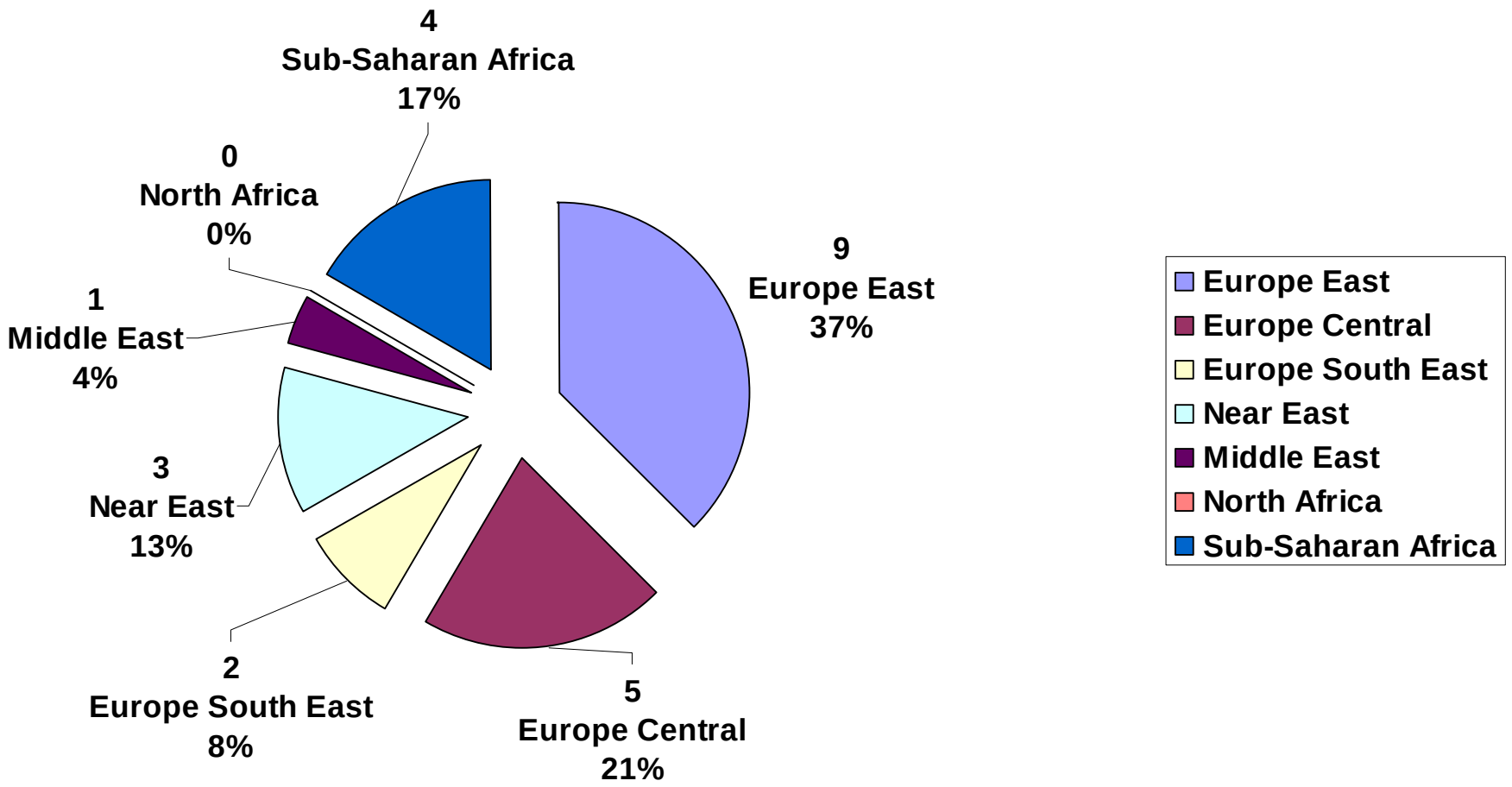
Europe-Germany IXPs-5

- deCIX-Deutsch CIX/Link
- M-CIX-Munich Commercial Internet Exchange
- INXS-A Munich Exchange
- MAE Frankfurt
- MANDA-Metropolitan Area Network Darmstadt

EMEA IXP Distribution
Mature vs. Emerging Markets



EMEA Emerging Markets IXP Distribution



Europe East IXPs-9

- CUIX-Central Ukranian Internet Exchange
- UA-IX-Ukranian Internet Exchange
- NSK-IX
- SPB-IX-St. Petersburg
- Ural-IX
- M9-IX-Moscow
- MPIX-A Russian Exchange
- RIPN-Novosibirsk and Ekaterinburg
- Samara-IX

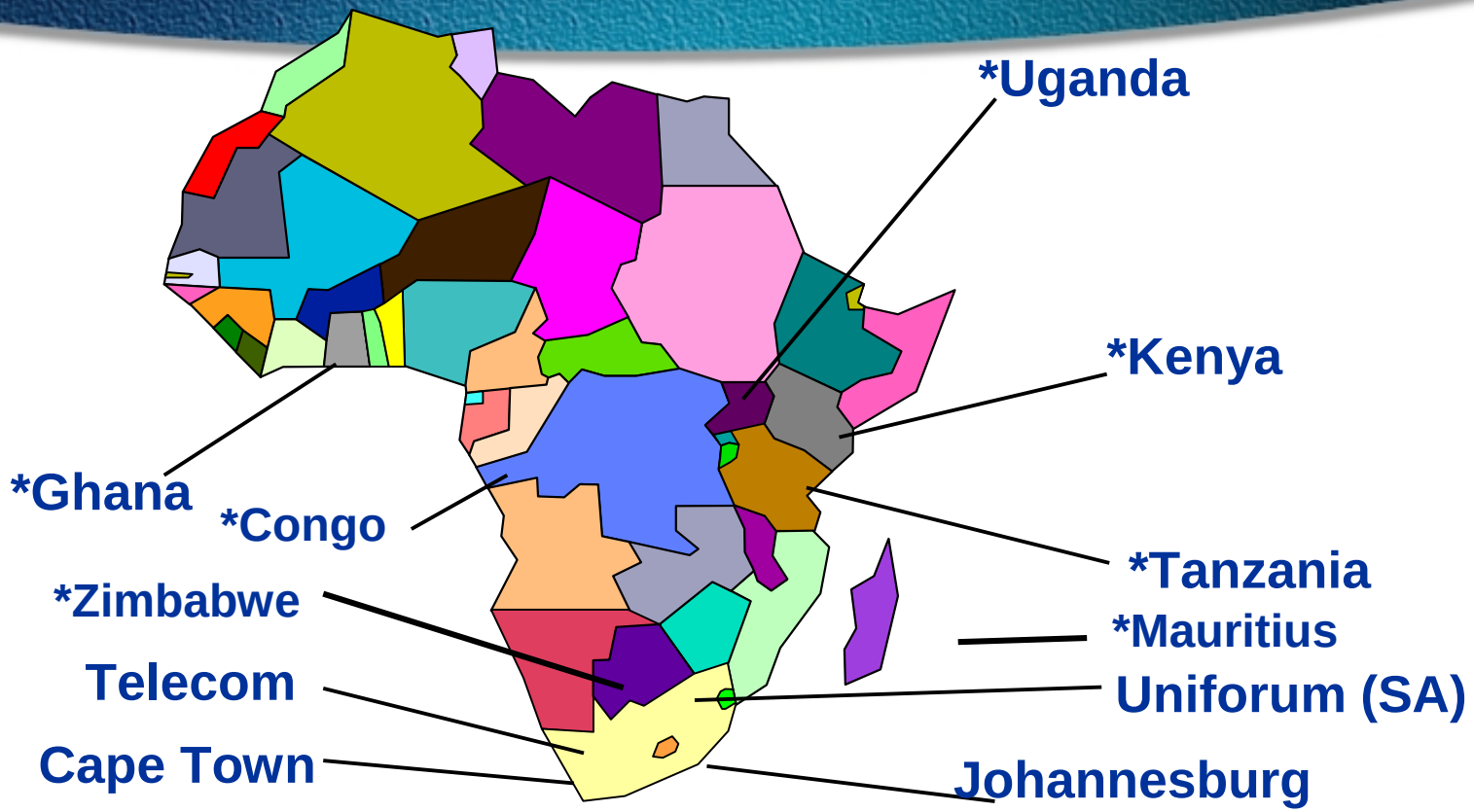
Europe Central IXPs-5

- **BIX-Budapest Internet eXchange**
- **SIX-Slovak Internet eXchange**
- **CIX-Croatia Internet Exchange**
- **Neutral Internet Exchange-Czech Republic**
- **BIX-Bulgarian Internet Exchange**

Europe South East IXPs-2

- **AIX-Athens Internet Exchange**
- **TURNET-The Turkish Internet Exchange**

Africa

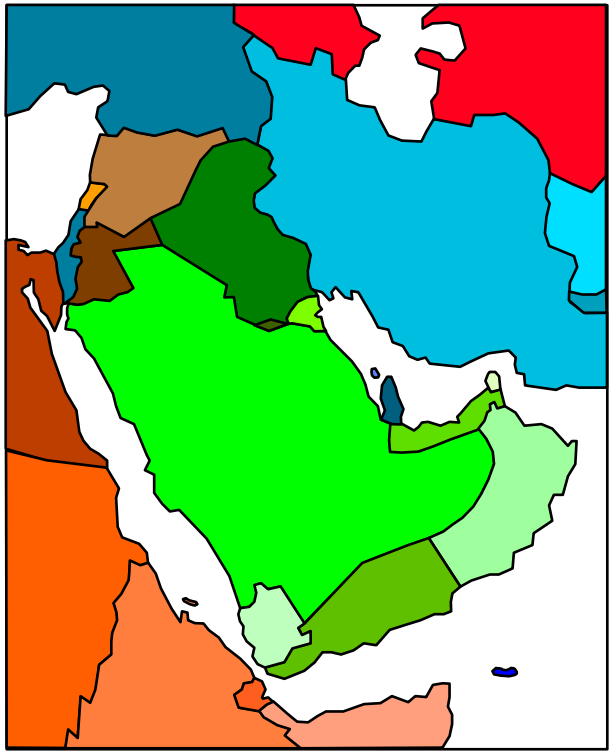


Africa has 4 active IXPs in South Africa, with pending IXPs projects in 6 countries*

Africa Sub-Saharan-5

- **CINX-Cape Town IIX**
- **JINX-Johannesburg IIX**
- **South African Internet Exchange (Telecom)**
- **Uniforum's version of the SA Internet Exchange**

Near and Middle East



Four IXPs are known to be operating in these areas

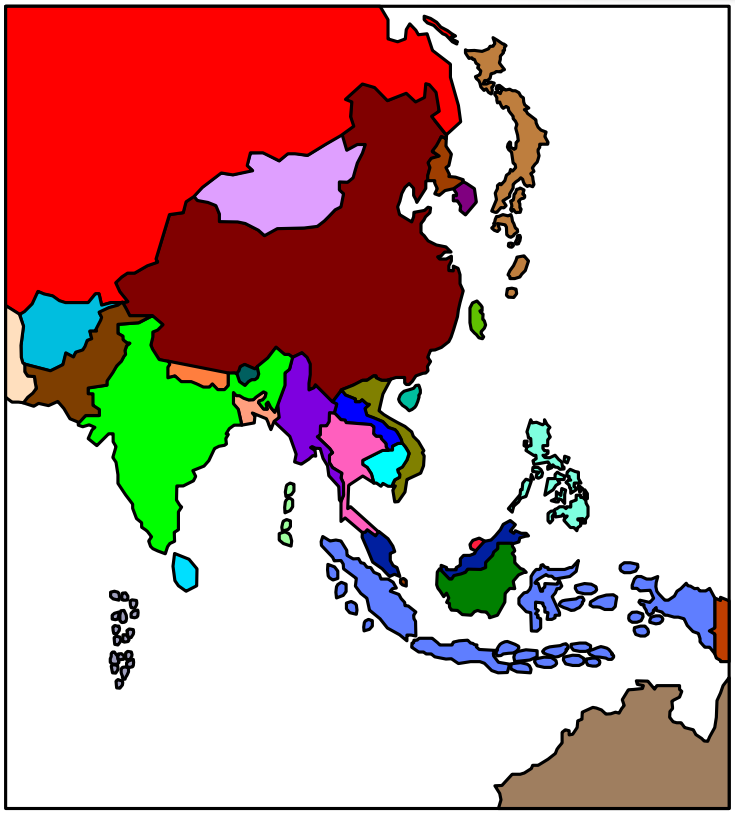
Near East IXPs-3

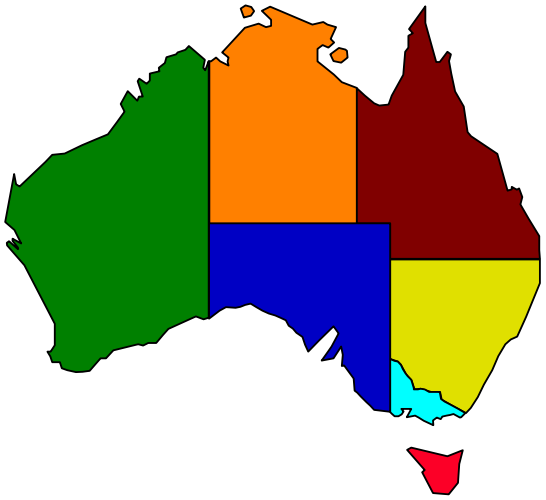
- **CyIX-Cyprus**
- **Israeli IIX**
- **MIX-Malta Internet Exchange**

Middle East

- **EMIX-Emirates Internet Exchange**

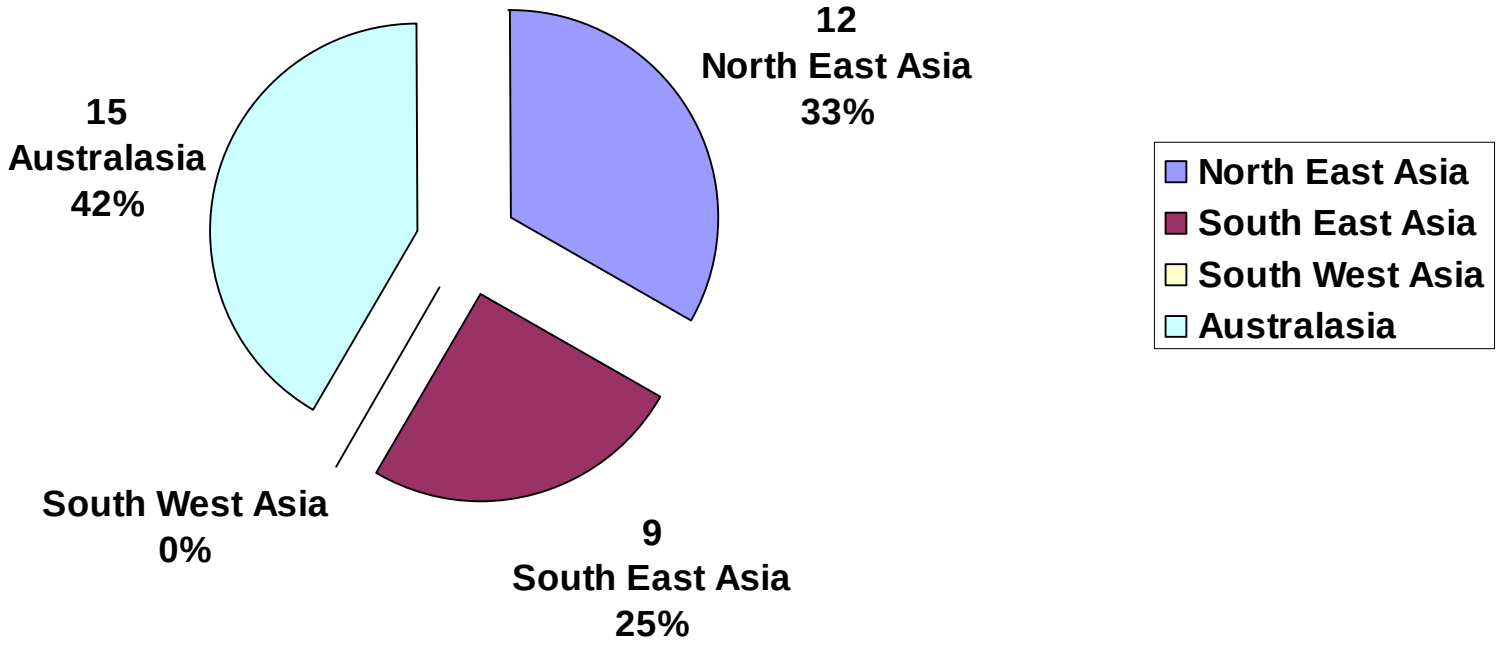
Asia-Pacific





The Asia-Pacific Area has approximately 36 Exchange Points

Asia-Pacific IXP Distribution



North East Asia IXPs-12

- DACOM IX-A Korean Internet Exchange
- IX-Seoul
- KINX-A Private Korean Exchange
- KIX-Korean Internet Exchange
- Imnet-From NTT & KDD
- MEX-Media Exchange Co., Inc.
- NSPIXP-2-in Japanese
- NSPIPX-6-A Japanese IPv6 Exchange
- JPIX-A Commercial Exchange
- TWIX-A Taiwan Exchange
- TNAP-Taiwan Network Access Point
- Shanghai City Exchange

South East Asia IXPs-9

- THIX-Thailand Internet Exchange Service
- PIE-ThaiSarn Public Internet Exchange
- Singtel-Singapore Telecom
- HKIX-Hong Kong Internet Exchange
- IIX-Indonesia Internet Exchange
- KLIX-Kuala Lumpar Internet Exchange (Malaysia)
- PHIX-Philippines Internet Exchange
- PHNET CORE-Philippine Common Routing Exchange
- Manila IX

Australasia IXPs-15

- APE-Auckland Peering Exchange
- NZIX-Neutral New Zealand Exchange
- WIX-Wellington Internet Exchange
- TAIX-Tasmanian Internet Exchange
- AUIX Exchanges around Australia
- AUSBONE-An Australia Exchange
- BIX-Brisbane Internet Exchange (part of AUSBONE network)
- CANIX-Canberra

Australasia Continued

- Melbourne NAPette
- Paradox IX (part of AUSBONE network)
- SAIX-South Australian Internet Association Incorporated
- SIX-Sydney Internet Exchange (part of AUSBONE network)
- SWSPN-South Western Sydney Peering Network
- VIX-Victorian Internet Exchange
- WAIX-Western Australia Internet Exchange