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THE INTERNET PROTOCOL TRANSIT AND PEERING LANDSCAPE IN SINGAPORE

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PART I: INTRODUCTION

1. In an increasingly connected society, many people now view access to the Internet as being essential. While Internet access through wired and wireless telecommunication platforms is pervasive in an information society such as Singapore, the underlying "nuts and bolts" that actually enable pervasive, fast and resilient Internet connectivity is complex and intricate. The Internet connectivity business is part of the global Internet ecosystem that involves many different players, from global connectivity providers to domestic Internet Service Providers ("**ISPs**") and Internet Content Providers ("**ICPs**"). The Internet is a large and complex network of interconnected computer networks, which are organised into units, each known as an Autonomous System ("**AS**"). Each AS is identified by a unique AS Number ("**ASN**")[1]. Currently, the global Internet comprises more than 45,000 public ASNs which would include players such as ISPs and ICPs.

2. Since the full liberalisation of the Singapore telecommunications sector in April 2000, many ISPs have entered the local Internet services market, serving residential and/or business end users. These ISPs transport Internet traffic across networks via Internet Protocol ("**IP**") **Transit** or **Peering** arrangements with other industry players, which are described as follows:

   a) IP Transit arrangement/relationship: a relationship between two operators that provides full connectivity to the Internet. IP Transit allows exchange of traffic, which is usually chargeable, i.e., a transit fee is payable by the "customer" to the "provider" in order to gain access to the Internet or, the content hosted by the provider. An IP Transit arrangement is usually chosen when the customer is not of a similar size with the "provider", and the traffic volume to be exchanged between the two operators is unequal.

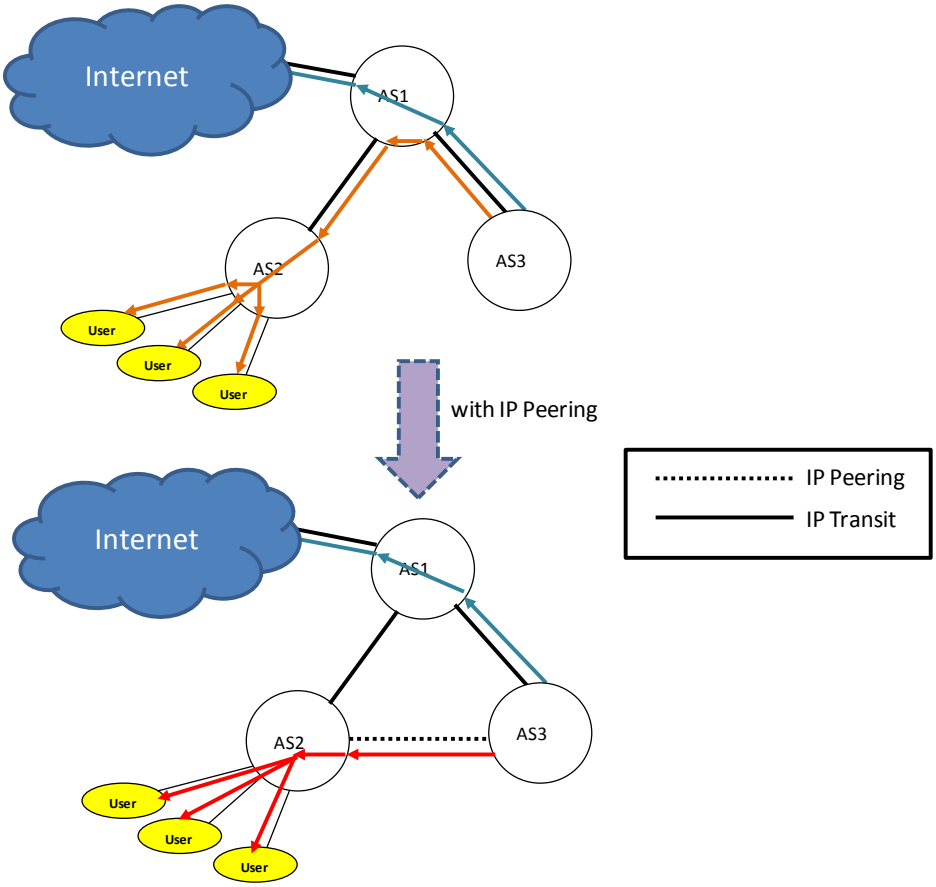
   b) IP Peering arrangement/relationship: a relationship between two operators to

[1] An AS is a network or a network of multiple networks operated by one organisational unit. These units can be dedicated IP Transit providers, integrated Service Providers such as ISPs, ICPs or non-profit organisations, e.g., universities.

facilitate direct, mutual exchange of traffic between their networks. IP Peering arrangements usually do not include transit to networks that are not within the IP Peering arrangement and are usually settlement-free (i.e., there is no fee payment involved between the two operators for the exchanging of traffic). IP Peering arrangements usually occur between two operators of similar size and traffic volume.

Operators with a large traffic threshold will prefer to peer once they reach a certain peering breakeven point while IP Transit agreements are beneficial if the unit cost of IP Transit is less than the unit cost of IP Peering.

Besides ISPs, IP Transit and Peering arrangements can also take place amongst players such as ICPs or Content Delivery Networks ("**CDNs**"). Given the differences between IP Transit and Peering arrangements, i.e., IP Transit arrangements provide access to the entire Internet, while IP Peering arrangements facilitate the direct mutual exchange of traffic between a pair of operators, IP Transit and Peering are both complementary and substitutional arrangements depending on the network configuration chosen by an operator. This is illustrated as the red arrows in the following diagram:-



3. Globally, IP Transit and Peering arrangements are usually commercially negotiated and agreed upon between the different players without regulatory intervention. Depending on the agreements between the players, traffic may be forwarded from one AS to another AS either: (1) directly via an IP Transit arrangement or IP Peering arrangement between the first AS and the second AS; or (2) indirectly via an IP Transit arrangement between the first AS and other third party upstream AS networks, which are in turn connected to the second AS. The latter is often referred to as traffic "tromboning". There are three main types of tromboning:

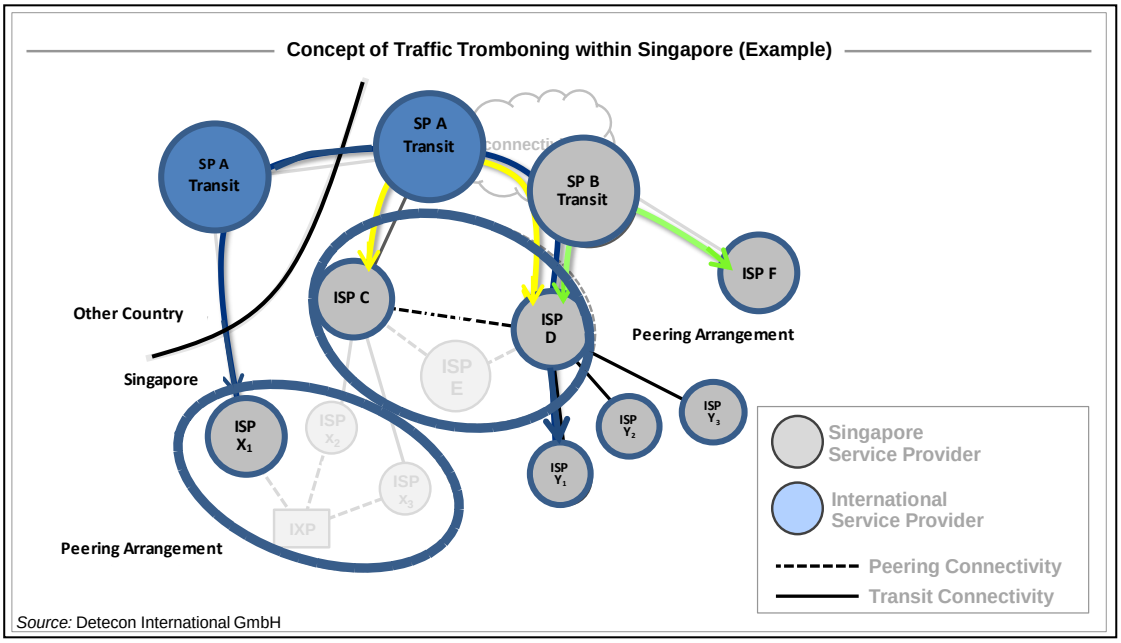
   a) Local tromboning: Traffic is sent from one AS to another via one or several upstream providers registered in the same country. This is illustrated by the green arrow in Figure 1 below.

   b) Topological international tromboning: Traffic is sent from one AS to another via one or several upstream providers. If at least one of the AS is registered in another country, this would be referred to as topological international tromboning. This is independent of the location of the nodes (i.e., all the nodes may be physically located in the same country). This case is illustrated by the yellow arrow in Figure 1 below; and

   c) Geographical international tromboning: Traffic is sent from one AS to another via one or several upstream providers. If at least one node is located in another country, this would be referred to as geographical international tromboning. In this case, the actual location of the node is of relevance. This is represented by the blue arrow in Figure 1 below. The passed node located in the foreign country may either be operated by a company registered in the same country or in a foreign country. Figure 1's example shows the case where the international Point-of-Presence ("**PoP**")[2] is operated by an IP Transit service provider registered in another country.

[2] A PoP refers to a physical location at which an ISP has a presence for network access and is generally in the form of a switch or node. A PoP is also a meeting point for ISPs where traffic and routes are exchanged. ISPs generally operate multiple access points.

Figure 1: Concept of Traffic Tromboning within Singapore



Developments in the Singapore Internet Services market

4. Internet access services have been available to end users in Singapore since the mid 1990s, when Pacific Internet Corporation Pte Ltd, SingNet Pte Ltd and Cyberway Pte Ltd were granted licences to provide retail Internet access services to consumers. More players entered the market when we fully liberalised it in 2000. In 2009, IDA embarked on a Nationwide Broadband Network ("**NBN**") project to deploy ultra-high speed broadband fibre infrastructure into residential and non-residential buildings nationwide, capable of supporting broadband speeds of 1Gbps or more[3]. Today, the NBN has achieved nationwide coverage, with about 29 ISPs offering a wide range of broadband Internet services over the NBN fibre infrastructure. Global Internet connectivity has also proliferated in Singapore, as shown by the strong presence of Global Tier-1[4] and Tier-2 operators[5] (including their corresponding subsidiaries) providing connectivity in and out of Singapore. As at October 2014, there were about 1.4 million wired residential and business broadband subscriptions[6] and 10 million

[3] More information on the NBN can be found here: http://www.ida.gov.sg/Infocomm-Landscape/Infrastructure/Wired
[4] Global Tier-1 Operators include players such as XO Communications, Verizon, TeliaSonera International Carrier, Telefonica, Telecom Italia Sparkle, Tata Communications, Sprint, NTT, Level3 Communications, Deutsche Telekom, CenturyLink, etc.
[5] Global Tier-2 Operators include players such as Vodafone, Telkom Indonesia, Moratel, etc.
[6] Includes all retail residential and retail business wired broadband subscriptions (i.e., for connection speeds equal to, or greater than, 256 kbit/s, in one or both directions) provided over xDSL, cable modems, leased line and optical fibre.

wireless broadband subscriptions in Singapore[7]. The volume of domestic Internet traffic generated in Singapore is likely to grow exponentially with increasing Internet use by consumers and businesses.

5. Internet Exchange Providers[8] ("**IXPs**") in Singapore play an important role to support the growth of Singapore's Internet traffic. In the Internet ecosystem, IXPs serve as a connectivity platform for a variety of Internet players including: ISPs, research and education networks, universities, and content providers, among others. In order to further enhance interconnectivity among Internet players in Singapore, IDA initiated the setting up of the Singapore Internet Exchange ("**SGIX**") in 2009, which commenced operations in June 2010. SGIX is a cost-based, open and neutral Internet Exchange platform designed to facilitate the exchange of Internet traffic amongst operators, thereby improving traffic routing efficiency in Singapore. SGIX increases interconnectivity within Singapore, so as to reduce potential latency issues and improve Quality of Service ("**QoS**") for Internet services. Currently, there are approximately 50 ISPs and ICPs interconnecting at SGIX. Aside from SGIX, there are other notable IXPs operating in Singapore, such as Singapore Open Exchange and Equinix Exchange Singapore.

6. With these developments, consumers and businesses have been able to enjoy more innovative and higher-speed Internet broadband services at more competitive prices. IDA notes that not all ISPs in Singapore have established IP Peering arrangements with each other for the routing of locally-originated and locally-bound Internet traffic ("**Local Traffic**"). Instead, many have purchased IP Transit for inter-operator connectivity.

7. As part of IDA's effort to continually review its regulatory frameworks to ensure that they remain relevant and effective to support Singapore as a competitive business hub in the region, IDA reviewed the issue of whether regulatory intervention in the IP Transit and Peering arrangements was necessary to further improve competition in the local Internet services market, as well as the quality and reliability of broadband Internet services for end users. Specifically, IDA also considered whether it was necessary for IDA to mandate IP Peering arrangements among all ISPs, or require that all Local Traffic should be kept local, so as to minimise incidences of Local Traffic being tromboned via a longer, indirect path overseas, which may affect the quality of Internet services.

[7] Includes all retail residential and retail business broadband Internet access subscriptions (i.e. for connection speeds equal to, or greater than, 256 kbit/s, in one or both directions) provided via wireless platforms such as 3G, 3.5G/HSDPA, 4G/LTE, WiMAX or its equivalent and Wi-Fi hotspots (including Wireless@SG subscriptions).

[8] A stricter definition of IXP refers to a physical network access point through which Operators connect their networks to exchange traffic, its primary focus being to facilitate network interconnection.

8. IDA commissioned a study to better understand Singapore's Internet traffic connectivity landscape and analyse the market conditions surrounding IP Transit, IP Peering and the tromboning of Local Traffic in Singapore. The study also compared the development of the local IP Transit and Peering landscape with overseas markets such as Hong Kong and Taiwan, in areas such as pricing of IP Transit, the number of IP Transit operators, and the overall Internet connectivity infrastructure. The study included a high-level assessment of the competitiveness of the IP Transit and IP Peering landscape in Singapore and the impact on the QoS for end users. The study involved interviews with more than 50 ISPs, local and international IP Transit providers operating in Singapore, local Internet exchanges, ICPs and CDNs (collectively referred to herein as the "**Operators**").

9. This consultation document summarises the key findings from the study, and seeks views and comments from the industry on the findings. **Appendix A** provides more details on the study.

PART II: THE CURRENT INTERNET PROTOCOL TRANSIT AND PEERING LANDSCAPE IN SINGAPORE

Current regulatory frameworks

10. IDA has in place several policy and regulatory frameworks to facilitate competition in the provision of broadband Internet services, and to ensure a reasonable quality and reliability of service for end users. These frameworks strike a balance between consumer protection and maximising consumer choice, while giving sufficient flexibility to market players to innovate and compete not only in terms of price but also other value propositions. The relevant frameworks which apply to the broadband Internet services are**:**

a) **Telecom Competition Code ("TCC")**: The TCC promotes and preserves competition in the provisioning of Internet services by ensuring fair competition and facilitating interconnection amongst competing networks:

i) **Competition framework**: The TCC[9] promotes and preserves effective competition in the provisioning of Internet services by prohibiting the abuse of dominant position by service providers with significant market power, and unfair methods of competition. Specific prohibited practices include: no degradation of service availability or quality and no provision of false or misleading information to competitors. Licensees are also

[9] For more information, please refer to the TCC at the following link: http://www.ida.gov.sg/~/media/Files/PCDG/Practice%20Guidelines/TCC/2012TCC.pdf

prohibited from entering into agreements with another licensee or non-licensed entity that has the effect of unreasonably restricting competition in a telecommunication market.

ii) **Interconnection framework**: The TCC imposes a duty on all telecommunication licensees to cooperate and interconnect with other licensees, either directly or indirectly. This helps to ensure the deployment of an integrated "network of networks" that provides seamless any-to-any communication throughout Singapore.

b) **Consumer Protection Frameworks**: IDA has put in place a QoS framework for fixed-line broadband services, to ensure that an acceptable level of QoS is enjoyed by a majority of fixed-line broadband end users. IDA has also introduced a number of information transparency requirements and initiatives to educate and promote awareness amongst end users. The following summarises the measures that IDA has implemented:

i) **QoS framework on retail broadband Internet access services**: ISPs providing fixed line broadband Internet access services are required to submit regular reports to IDA on their QoS performance on indicators[10] such as network availability, network latency and bandwidth utilisation.

ii) **Information Transparency**: IDA requires ISPs providing fixed-line broadband Internet services to residential end users to publish information on their network management practices. IDA also requires all ISPs to publish the typical broadband speeds for each of their service plans, in addition to the theoretical speeds[11]. To further educate and create awareness amongst end users, IDA measures the performance of residential broadband service plans offered by ISPs in Singapore and publishes quarterly performance statistics of these ISPs[12]. In this regard, IDA also publishes "*A Guide to Residential Broadband in Singapore*"[13] which compares Internet broadband service prices and performance.

[10] For more information on the QoS standards for fixed-line broadband Internet services, see http://www.ida.gov.sg/~/media/Files/PCDG/Licensees/StandardsQoS/QualityofService/Qos_webpage_bb.pdf.

[11] For more information on the publication requirements for typical broadband speeds, please refer to: http://www.ida.gov.sg/~/media/Files/PCDG/Licensees/Information%20Papers/PR_ISP.pdf.

[12] Please refer to http://www.ida.gov.sg/applications/rbs/chart.html.

[13] This is available at: http://www.ida.gov.sg/Publications/20061213184450.aspx#performance .

c) **Net Neutrality:** IDA adopts a three-pronged policy approach towards net neutrality[14]. The first prong seeks to facilitate a competitive Internet services market via IDA's TCC which, through fostering competition in Singapore's telecommunication market, reduces the incentives for ISPs and telecommunication network operators to engage in traffic blocking or discriminatory conduct that restricts consumer choice. The second prong focuses on improving information transparency so that consumers can better understand the various broadband Internet services when selecting a broadband Internet package. The last prong aims to protect consumer interests and to ensure that consumers enjoy a reasonable level of quality of Internet access via IDA's QoS requirements as explained above. In line with this policy, ISPs and network operators are prohibited from blocking legitimate Internet content, but have the flexibility to manage their network and offer niche or differentiated Internet service offerings that meet IDA's fair competition rules, information transparency and QoS requirements.

Key findings from the study

11. IDA's study found that the connectivity arrangements amongst Operators tend to depend on the size and business interests of each Operator. As explained earlier, IP Peering arrangements tend to be established between two Operators with similar traffic volumes, provided that the cost of building and maintaining an IP Peering arrangement is lower than the associated costs of sending traffic via an IP Transit arrangement.

12. Another consideration would be the business model of each Operator, which depends on the type of services provided by the Operator. For illustration, an ICP offering online gaming services may place priorities on having low traffic latency, and would likely purchase IP Transit connectivity supported by more stringent Service Level Agreements ("**SLAs**"). In contrast, a small ISP providing basic Internet access services may have different priorities and may opt for an IP Transit package that provides a combination of "best effort" service delivery and bandwidth-burstable options, with limited routing requirements.

13. The study arrived at the following key findings and conclusions:

a) Singapore has a competitive wholesale IP Transit market and is one of the most competitive markets in the region. A large number of national and international Operators have PoPs in Singapore, making Singapore an

[14] For more information on IDA's policy approach towards net neutrality, see http://www.ida.gov.sg/~/media/Files/PCDG/Consultations/20101111_Neteutrality/NetNeutralityExplanatoryMemo.pdf

important hub in Asia for IP Transit providers, ICPs, CDNs and even overseas ISPs. Operators, including smaller ISPs and CDNs, can source Internet connectivity from multiple sources in Singapore and should always be able to optimise their IP Transit with regard to both quality and price.

b) Operators have the incentives to route their traffic locally where they can. ISPs in Singapore should be able to deliver their traffic in Singapore without any unnecessary detours through their network. If there are no direct connections between Global Tier-1 or Tier-2 Operators in Singapore, traffic *may* be forwarded through the region to the next peering point. However, such cases should be rare as such a forwarding scheme unnecessarily burdens the traffic forwarding Operators' internal infrastructure. If there appears to be long-distance traffic detours, these are likely not due to constraints imposed by market conditions, but due to the Operators' commercial decisions. For example, an Operator may choose to purchase a more affordable IP Transit service option to save on IP Transit costs, with the understanding that there may be a compromise in service quality as traffic which is forwarded using this option is unlikely to have guaranteed domestic routing[15]. That being said, even if geographical international tromboning takes place within the region (e.g., traffic is tromboned via Hong Kong), from a technical point of view, the impact on QoS is unlikely to be discernible by most end users, because the increase in latency for geographical international tromboning within the region is unlikely to be significant. Findings from the study also indicate that most traffic should not be tromboned beyond the region because it is not a cost-effective solution, and therefore Operators would tend to offload traffic as soon as possible, with minimal detours from its geographical origin to minimise costs associated with long distance IP Transit.

c) IP Transit prices in Singapore have been declining over the past few years. This decline in price is consistent with broader international trends led by American and European markets. Singapore's average IP Transit prices are comparable[16] to those of its benchmarked cities, e.g., Hong Kong and Taiwan. Hong Kong's IP Transit prices are slightly lower than those in Singapore, but the price ratios for various port capacities[17] are at similar levels. This suggests that there are no significant price level disadvantages

[15] Domestic routing refers to SLAs that specify traffic be routed only in Singapore. Based on IDA's understanding, service guaranteed domestic routing tends to be marketed as a premium product.

[16] Based on 2012 statistics from the study.

[17] This refers to a term used in the study relating to the prices of IP Transit between Hong Kong (HK) and Singapore (SG), covering the differences between prices for a similar service by using a ratio (e.g., for 10Mbps port, SG:HK is $65.46:$49.24 (ratio 1.33), similarly, for GigE the ratio is 22.20:17.03 (ratio 1.30).

for Singapore in comparison to the average IP Transit price levels in benchmarked cities. The study further suggested that the actual transacted prices of locally purchased IP Transit services may be below the average price levels reported by market researchers, which could indicate that Operators are able to source for low-priced IP Transit domestically, depending on the commercial negotiations and customised agreements between Operators.

d) Finally, the study also found that internationally, regulatory intervention in IP connectivity arrangements is rare, and in those cases where the regulator intervened, it was on the basis that an ISP had abused its dominant position to harm its competitor. Generally, regulators have refrained from intervening as the players such as ISPs, ICPs and CDNs are able to route traffic via various arrangements, whether through IP Transit or Peering.

14. The study did not find any competition concerns or adverse impact on the quality of Internet services arising from the current situation in the IP Transit and Peering landscape in Singapore. The study also suggested that Operators should be given the flexibility to offer differentiated Internet connectivity business models, and the flexibility to adopt the connectivity arrangements that best meet their business and operational needs.

IDA's Assessment

15. While IDA has already implemented a suite of measures to promote the healthy development of the Internet services market in Singapore, IDA recognises that there may be possible areas of concern. IDA notes that there has been feedback by some ISPs that mandating local peering amongst all ISPs in Singapore will improve Internet service quality and remove situations where some ISPs' traffic are routed overseas such as through Hong Kong. Another view is that without IP Peering arrangements amongst all ISPs, Singapore broadband users are enjoying speeds that are half or one third of that in South Korea, Japan and Hong Kong. These feedback further suggest that bigger ISPs in Singapore may be displaying anti-competitive behaviour by refusing to establish IP Peering arrangements with the smaller ISPs.

16. From the study, IDA notes that even though the smaller ISPs may not be able to enter into settlement-free IP Peering arrangements due to smaller traffic volumes when compared to the bigger ISPs, they are not denied connectivity to the Internet as they are able to purchase IP Transit. The market has also demonstrated that differences in traffic routing arrangements have not prevented

smaller ISPs from competing aggressively by offering innovative and differentiated products targeted at specific user segments, such as higher speeds, lower latency, and lower prices to provide more options to consumers. Some ISPs have offered 1Gbps fibre broadband Internet services for as low as S$50 per month, while others entice new customers with differentiated products such as latency-based routing and free static IP addresses.

17. In terms of the impact of tromboning of Local Traffic on service reliability and quality, IDA notes that if the traffic is tromboned within the region (e.g., Hong Kong), the impact on quality (e.g., latency) of the Internet services is likely to be insignificant for most end users. With regard to broadband throughput speeds, IDA's measurements via the National Internet Measurement Infrastructure have shown that the various popular fixed-line broadband plans provided by ISPs in Singapore have performed close to the theoretical broadband speeds promoted. In addition, Singapore has also continued to climb steadily up the global rankings in terms of broadband speeds. On 30 January 2015, the Ookla NetIndex, which provides a snapshot of speed tests performed by individual end users in each country, ranked Singapore in first place (out of 196 countries) with an average broadband connection speed of 104.92Mbps. Akamai, which passively measures the average connection speed to its edge servers, also noted an 18% jump in speed in its Q3 2014 report over the previous quarter[18] and 57% over the last year for the same quarter, putting Singapore in tenth place globally for Akamai's average connection speed charts.

18. IDA also understands anecdotally from industry sources, as well as from Operators in the study, that the amount of Internet traffic that is tromboned overseas is very small, approximately 5% or less, as most of the Operators would have the commercial incentives to route locally-bound traffic locally. IDA notes that the precise amount of traffic that is tromboned overseas may be difficult to establish, as the routing of Internet traffic is often not tracked. As for concerns that submarine cable cuts may affect tromboned traffic and consequently access to local content, IDA is of the preliminary view that this can be addressed by more targeted solutions, such as ensuring sufficient redundancy of critical network components, as well as establishing sufficient diversity with multiple paths and connections with multiple parties.

19. While IDA has considered imposing regulatory measures, for example, by mandating IP Peering arrangements between local ISPs, as a possible option to

[18] Singapore broadband speed now world's 10th fastest, says Akamai: http://www.straitstimes.com/news/singapore/more-singapore-stories/story/singapore-broadband-speed-now-worlds-10th-fastest-says-a

further level the playing field for the smaller ISPs, or to keep locally originated-and-bound traffic within national boundaries (i.e., to minimise traffic "tromboning"), IDA is of the preliminary view that there is no strong basis for such an intervention at this juncture.

20. Firstly, as evident from the findings above, the local Internet services market is vibrant with many ISPs offering innovative products at competitive prices. The study did not identify evidence of market failure, such as abuse of dominance by a dominant player, to warrant regulatory intervention.

21. Secondly, it would be difficult for IDA to exercise regulatory control over the routing of IP Transit traffic due to the complex nature of traffic exchange which, amongst others, involves a large number of Operators spanning various geographical areas. Finally and most importantly, the Internet services market is dynamic and constantly evolving. IDA notes that other than the traditional IP Transit or Peering agreements discussed above, at least three new IP interconnection business models, namely, Deep Caching[19], Assured Delivery[20], and Secure Machine-to-Machine ("**M2M**")[21], have recently surfaced which offer the potential for ISPs more control over their service delivery to end users. These new interconnection business models suggest that innovation in IP interconnection that goes beyond IP Transit and Peering arrangements can support further development of the Internet at large and facilitate the take-up of next-generation applications and services which require exceptional service quality. Given the market dynamics, IDA is mindful of any unintended consequences of regulation in the area of new business models, technological advancement and service innovation.

22. IDA notes that globally, settlement free IP Peering arrangements are usually commercially negotiated amongst Operators. In Hong Kong, the Hong Kong Internet Exchange ("**HKIX**"), as part of its commercial terms, requires ISPs connected to HKIX to establish peering arrangements with all other members of

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[19] **Deep Caching** provides better delivery quality by further reducing the physical distance between content and end users. Managed or transparent caches, installed deep into ISPs' networks are offered as a means of interconnection. They provide reduced latency, and consequently enable further improvement to throughput and reduction in packet loss.

[20] **Assured Delivery** is a more advanced networking option that foretells the dynamic establishment of dedicated routing for specific applications by applying the innovative concepts of software-defined networks ("**SDNs**"), network functions virtualisation ("**NFV**") and massive use of Multiprotocol Label Switching ("**MPLS**") technology. Ad hoc network capacity is released dynamically and upon request. The interconnection seeker requests, as a permanent rule or only on demand, the establishment of managed capacity across two points (the interconnection interface and terminating interface, being either an end user or another network), with a defined service-level agreement thereby attached (e.g., capacity vs. latency vs. jitter).

[21] **Secure M2M** is similar to Assured Delivery, but security features are added at network edges, and some parameters (e.g., latency or service availability) are stressed for mission-critical applications.

the IX for local routes. The Japan Internet Exchange also encourages the formation of multilateral peering groups, on a voluntary basis. In Singapore, there are approximately 50 service operators interconnecting in SGIX, with more than half of these adopting an "open" peering policy[22].

23. Hence, based on the findings of IDA's study, IDA's preliminary view is that:

a) There appears to be no strong justification for IDA to take further regulatory measures, such as mandating IP Peering arrangements at this juncture. The Internet services market is vibrant with many ISPs competing and providing end users with multiple choices of high speed broadband plans at competitive prices. Currently, ISPs, ICPs and CDNs can commercially negotiate and enter into IP Peering arrangements or purchase IP Transit from multiple Operators, and have multiple options for Internet connectivity. IDA's existing regulatory frameworks will continue to facilitate competition, and ensure that a reasonable level of quality and reliability of broadband Internet services to safeguard consumer interests.

b) IDA should continue to foster a conducive wholesale environment for a diverse and agile ISP retail marketplace, leaving IP Transit and Peering arrangements to commercial decision-making. In addition, further user experience improvements can be achieved by promoting Singapore's position as an important Information and Communications Technology ("**ICT**") hub in Asia, and in doing so, enhance Singapore's attractiveness to ICPs and CDNs to host content locally. This will allow service providers to deliver more content to end users with greater efficiency and reliability.

PART III: INVITATION TO COMMENT

24. IDA would like to seek the views and comments from the industry and members of the public on this consultation and any other issues pertaining to local IP Transit and Peering arrangements. Specifically, IDA would like to seek views and comments on:-

a) The findings from the IDA study on the current market conditions in the Singapore Internet services market;

b) Whether the current conditions for IP Transit and Peering have resulted in any negative impact on competition, or if it has hindered the ability of ISPs, ICPs or CDNs to offer services?

[22] See http://sgix.sg/en/memberslist/list-of-members/

c) Whether the quality of ISPs' service offerings is negatively affected by today's IP Transit and Peering landscape?

d) Whether the cost of IP Transit as a proportion of other operating costs has fallen, or has increased significantly for Operators?

e) Whether there are other factors that IDA should consider in assessing the local IP Transit and Peering landscape?

f) What are the possible areas in the local IP Transit and Peering landscape that would require regulatory intervention, and why?

25. Parties that submit their views or comments regarding the issues identified in this consultation document should organise their submissions as follows: (a) cover page (including their personal/company particulars and contact information); (b) table of contents; (c) summary of major points; (d) statement of interest; (e) comments; and (f) conclusion. Supporting materials may be placed as an annex to the comments raised.

26. All views and comments should be submitted in soft copies (in Microsoft Word or PDF format), and should reach IDA **by 12 noon 27 March 2015**. All views and comments should be addressed to:

Ms Aileen Chia
Deputy Director General (Telecoms and Post)
Infocomm Development Authority of Singapore
10 Pasir Panjang Road
#10-01 Mapletree Business City
Singapore 117438
Fax: (65) 6211 2116

AND

Please submit your soft copies, with the email header "**Consultation on Singapore's Internet Protocol Transit and Peering Landscape**", via email to **IDA_consultation@IDA.gov.sg.**

27. IDA reserves the right to make public all or parts of any written submission and to disclose the identity of the source. Commenting parties may request confidential treatment for any part of the submission that the commenting party believes to be proprietary, confidential or commercially sensitive. Any such information should be clearly marked and placed in a separate annex. If IDA grants confidential

treatment it will consider, but will not publicly disclose, the information. If IDA rejects the request for confidential treatment, it will return the information to the party that submitted it and will not consider this information as part of its review. As far as possible, parties should limit any request for confidential treatment of information submitted. IDA will not accept any submission that requests confidential treatment of all, or a substantial part, of the submission.

Appendix A

Summary of Internet Protocol Transit and Peering Study

BACKGROUND

1. In 2013, IDA undertook a study of the Internet Protocol ("**IP**") Transit and Peering landscape in Singapore. The study mainly analysed the IP Transit and Peering landscape at the wholesale level, but also took into consideration the impact of the international Internet connectivity business on Singapore Internet Service Providers ("**ISPs**") at the retail level.

2. The analysis of the Singapore IP Transit and Peering landscape included a survey on ISPs, Internet Content Providers and Internet Exchange Providers ("**IXPs"**), as well as Content Delivery Network ("**CDN**") players in Singapore (collectively referred to herein as the "**Operators**"). The survey addressed issues such as Internet bandwidth utilisation, IP Transit and Peering arrangements, wholesale pricing, IP Transit sourcing strategies, as well as present and future ISP requirements for new product and service offerings. Over 50 ISPs, IXPs and CDN players responded to the survey.

SUMMARY OF KEY FINDINGS

3. The following sections summarise the key findings of the study in the following manner:

   a) Technical Context for International Connectivity and IP Transit and Peering Landscape;

   b) Business Models, International Connectivity and IP Transit and Peering Agreements; and

   c) IP Transit Pricing, IP Transit Port Pricing and IXPs in Singapore and within the Region.

TECHNICAL CONTEXT FOR INTERNATIONAL CONNECTIVITY AND IP TRANSIT AND PEERING LANDSCAPE

4. There are a number of product classes which are available for ISPs to gain access to the Internet, namely:

a) **Private Internet Peering**: Provides connectivity to direct and indirect customers of an Autonomous System ("**AS**"). Such arrangements come about as a bilateral agreement, rather than as a purchased product. IP Peering agreements will generally include Service Level Agreements ("**SLAs**") and may have varied peering policy terms[1]. Connectivity between partners in the IP Peering arrangement would be provided by the participants themselves, or leased from a third party.

b) **Leased Line Connectivity**: Where Operators are willing to establish an IP Peering arrangement but do not operate Points-of-Presence ("**PoPs**") in the same location, the connectivity (i.e., geographical distance) can be bridged by either building a new physical connection or by leasing dedicated connectivity from an existing telecommunication network (i.e., Leased Lines or International Private Leased Circuits ("**IPLC**"), if operated in different countries).

c) **Public IP Peering (via IXPs)**: ASs may connect and establish IP Peering arrangements via a Public IP Peering platform (most commonly provided by IXPs). IXP operators are often third parties (i.e., non-ISPs) and provide the infrastructure requirements of peering, such as space, power, and air-conditioning. IXPs may charge fees[2] to the connected ASs. IXPs may also apply specific rules as to how members are to establish IP Peering arrangements amongst themselves. Public IP Peering platforms may be operated as a single location or group of locations connected via a dedicated IXP-internal network.

d) **IP Transit / IPLC IP Transit**: IP Transit is a paid[3] service via a point-to-point connection that provides full connectivity to the Internet, independent of the location of the communication partner. Access to IP Transit services will require connectivity to an upstream provider, either via an ISP's existing connectivity or through Leased Lines. IP Transit services are therefore often sold bundled with a Leased Line service, or an IPLC service, often referred to as IPLC IP Transit service[4].

[1] IP Peering policies vary from open policies to restricted policies usually containing a Non-Disclosure Agreement ("**NDA**"). There are three general categories of peering policies: *Open Peering* – peering is open to all parties; *Selective Peering* – open peering with certain restrictive conditions or prerequisites; and *Restrictive Peering* – selective with which parties to peer, subject to non-disclosure agreements.

[2] Often these fees may vary based on the number of peering policies, number of ports, and duration of connectivity.

[3] IP Transit is typically charged on a monthly basis for a selected port capacity or actual usage (per Mbps).

[4] IPLC IP Transit refers to the case where an international peering point is accessed via a line leased from the same operator.

BUSINESS MODELS, INTERNATIONAL CONNECTIVITY AND IP TRANSIT AND PEERING AGREEMENTS

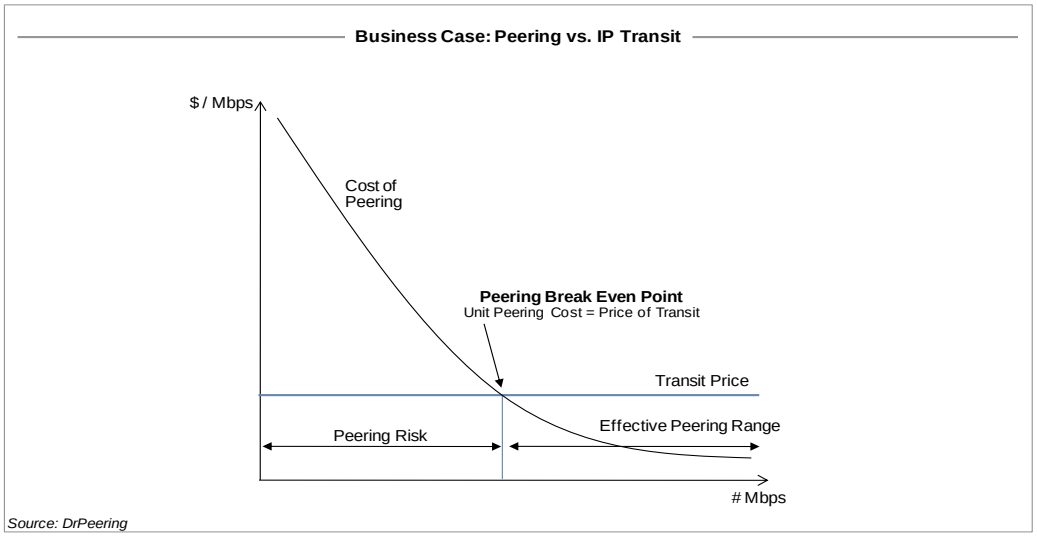
Business Models for Sourcing Internet Services

5. The business models and associated costs of IP Peering and IP Transit can be summarised broadly as follows:

   a) **IP Peering**: In this model, two ISPs exchange traffic between their respective networks without paying fees to each other for the transfer of traffic. Hence, the total peering cost would include: connectivity costs (usually a fixed monthly recurring charge), equipment costs, and other miscellaneous costs (likely marginal). Thus, the greater the amount of traffic peered, the cheaper the cost of peering per unit of traffic. Operators with a large traffic threshold will prefer to peer once they reach the peering breakeven point (as highlighted in Figure A1 below).

   b) **IP Transit**: In this model, ISPs would have to incur costs for IP Transit (usually charged per Mbps, depending on port capacity and committed data rate). As costing is based on metered traffic volumes, IP Transit agreements can be beneficial if the unit cost of IP Transit is less than the unit cost of IP Peering. Please refer to the following Figure A1 for an illustration of the business case for IP Transit.

Figure A1: Business Case of IP Peering vs. IP Transit



Global Internet Connectivity in Singapore and the Implications for IP Transit Relations

6. Global Internet connectivity in Singapore is provided by most Global Tier-1[5] and important Tier-2 Operators[6]. Global Tier-1 Operators are assumed to exchange Internet traffic on a settlement-free (i.e., IP Peering) basis only, as these Operators carry most of the world's traffic.

7. As an important hub in Asia, the study found that most Global Tier-1 and Tier-2 Operators offer connectivity directly in (and out of) Singapore. The strong presence of Global Tier-1 and Tier-2 Operators in Singapore provides various options for local and international traffic routing and offloading. Even if smaller Operators in Singapore do not establish local IP Peering relationships, they will always be able to source for alternative traffic routing through IP Transit relationships with Global Tier-1 or Tier-2 Operators within Singapore. That being said, ISPs in Singapore should be able to deliver their traffic in Singapore without any unnecessary detours through their network. If there are no direct connections between Global Tier-1 or Tier-2 Operators (including their corresponding subsidiaries), traffic *may* be forwarded through the region to the next peering point. However, such cases should be rare as such a forwarding scheme unnecessarily burdens the traffic forwarding Operators' internal infrastructure. Thus, from a technical point of view, geographical international tromboning and the associated impact on latency should not be a significant issue in Singapore.

8. Singapore is also well-connected via submarine cables – with more than 15 submarine cable systems landed with a total potential capacity of more than 180Tbps.

Implications of the Presence of Global CDNs in Singapore

9. In terms of traffic volume, CDNs also play an important role in the global Internet business. The business model of CDNs is the provision of fast and reliable traffic delivery on behalf of their customers. They host websites, web applications and large data such as videos from their customers, and make this content available globally. The closer the content is located to the end user, the more efficient and reliable will be the delivery. For that purpose, CDNs mirror the content on several data centres all over the world to ensure that their customers get the

[5] Global Tier-1 Operators include players such as XO Communications, Verizon, TeliaSonera International Carrier, Telefonica, Telecom Italia Sparkle, Tata Communications, Sprint, NTT, Level3 Communications, Deutsche Telekom, CenturyLink, etc.

[6] Global Tier-2 Operators include players such as Vodafone, Telkom Indonesia, Moratel, etc.

content from the closest available source. CDNs usually speed up service delivery and make applications more robust against server failures, network failures and attacks.

10. CDNs are generally well connected with global and local Operators alike. The provision of fast and reliable traffic delivery is a key business driver for CDNs, and is a key determinant in their overall costing and pricing models. An ISP could potentially have CDNs as customers (i.e., paid IP Transit) and avoid sending traffic via their upstream providers (i.e., bought IP Transit) so long as it is commercially viable for both parties.

Connectivity amongst Singapore ISPs

11. Internet connectivity amongst the major ISPs in Singapore can be evaluated using each ISP's customer cone size ("**CCS**"). The CCS specifies the number of direct and indirect customer system an ISP has. It indicates the number of wholesale and large business customers, traffic of which is aggregated towards the Internet. This value usually gives an approximate indication on the amount of traffic that is aggregated based on the IP Transit services sold. The study found that the established ISPs in Singapore were able to aggregate the most customer traffic, due to their strong presence in the wholesale, retail and business markets. This characteristic of established ISPs justifies the establishment of IP Peering arrangements with each other. However, in the case of the smaller and newer ISPs, the aggregated traffic volume is significantly smaller. This gap in traffic volumes between the established ISPs and the smaller ISPs would suggest that there may be comparatively less commercial advantage for the established ISPs to establish IP Peering arrangements with the smaller ISPs. In this regard, the gap in traffic volumes also indicates that among the ISPs, they are likely to adopt a combination of IP Transit and Peering relationships.

IP TRANSIT PRICING, IP TRANSIT PORT PRICING AND IXPS IN SINGAPORE AND WITHIN THE REGION

Overview of Internet Pricing Analysis

12. As part of the analysis of the Singapore market, the study considered how wholesale pricing of Internet access products in Singapore compares to the international market, as well as how the cost of such products have changed over time. The following categories of product pricing were studied:

a) IP Transit prices;

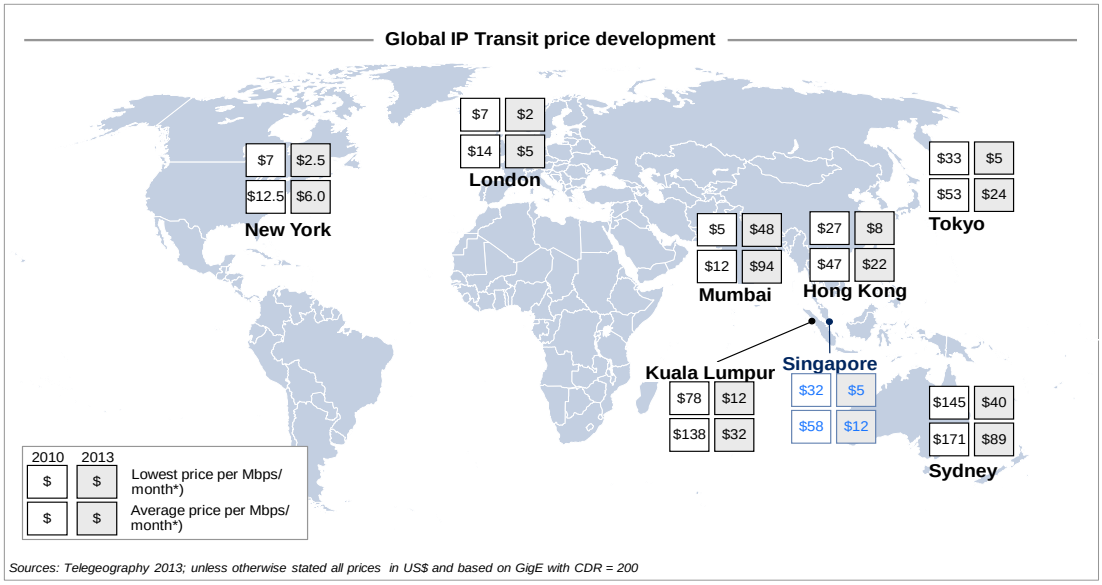
b) IP Transit port prices; and

c) IXPs in Singapore and within the region.

IP Transit Prices

13. The development of IP Transit prices globally has to be understood in the context of the historical implications[7] of Internet access originating in the United States, and the resultant spare capacity between North America and (Western) Europe. Hence, IP Transit prices have traditionally been the lowest in the respective major hubs in Western Europe (London and Frankfurt) and North America (Los Angeles and New York). Furthermore, in general, the further a city is away from these aforementioned hubs, the more expensive the sourcing of Internet traffic, especially if majority of the Internet traffic to/from the city is bound for or sourced from these hubs[8]. Please refer to Figure A2 for further details on IP Transit prices in a number of benchmark cities internationally.

Figure A2: Global IP Transit Prices (as at Q1 2013)

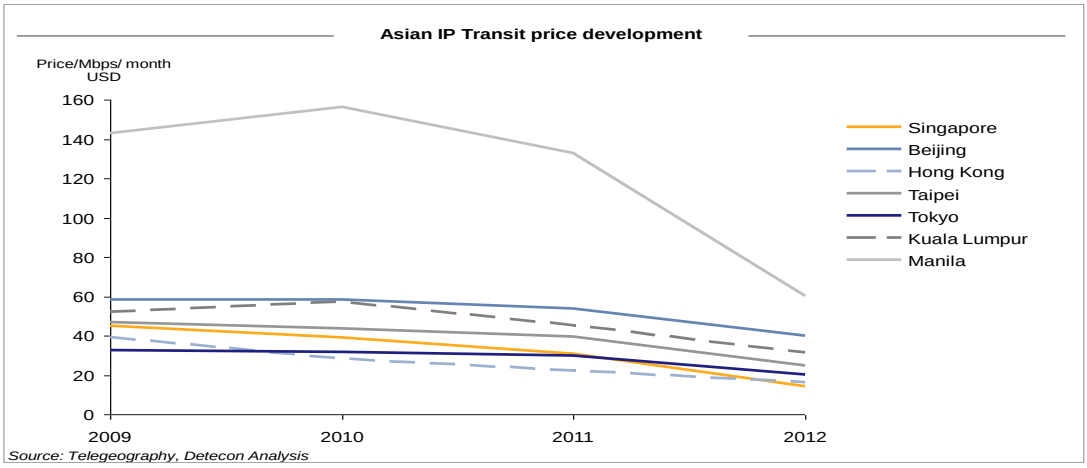


7 Capacity was initially built up between United States and Europe, resulting in spare capacity of bandwidth.

8 This, of course, follows dynamic market patterns. The more capacity and bandwidth deployed in and in-between regions, the more overall pricing levels will likely converge towards the United States / European levels. This observation is however not a static principle and depends on future infrastructure deployments, traffic developments and bandwidth utilisation.

14. Comparatively, in Asia, the study observed that price levels are less homogeneous and are dependent of the different stages of development of each country. Prices in developed cities including Singapore, Hong Kong and Tokyo have converged to lower levels, implying lower dependency on large capacities to/from the United States and Europe. Please refer to Figure A3 indicating IP Transit price trends in a number of Asian cities between 2009 and 2012.

Figure A3: Asian IP Transit Price Development (GigE with Committed Data Rate 1,000 Mbps)



15. The study also compared the prices of IP Transit price levels between Singapore, Hong Kong and Taiwan. Corresponding IP Transit price levels are overall slightly higher in Singapore as compared to the Hong Kong market as shown in Figure A4 below.

Figure A4: IP Transit Price Levels (Hong Kong & Singapore) (as at Q1 2013)

IP Transit Price Levels (in USD)			
	Singapore	Hong Kong	
Port Capacity	IP Transit Price/ Mbps/ Month	IP Transit Price/ Mbps/ Month	Ratio (SG/HK)
10Mbps	65.46	49.24	1.33
E – 3	86.50	39.52	2.19
DS – 3	36.90	36.06	1.02
STM1 – OC3	36.60	23.87	1.53
STM4 – OC12	24.60	18.96	1.30
FastE	38.20	30.56	1.25
GigE	22.20	17.03	1.30

Hong Kong's IP Transit prices may be slightly lower than Singapore, but the ratios for various port capacities are similar: Singapore's price levels for IP

Transit are between 1.02 to 2.19 times higher than the corresponding Hong Kong IP Transit price levels.

16. The same analysis can be applied for IP Transit price levels in Taiwan vis-à-vis Singapore: Singapore's price levels per Mbps are comparable with those of Taiwan (see Figure A5).

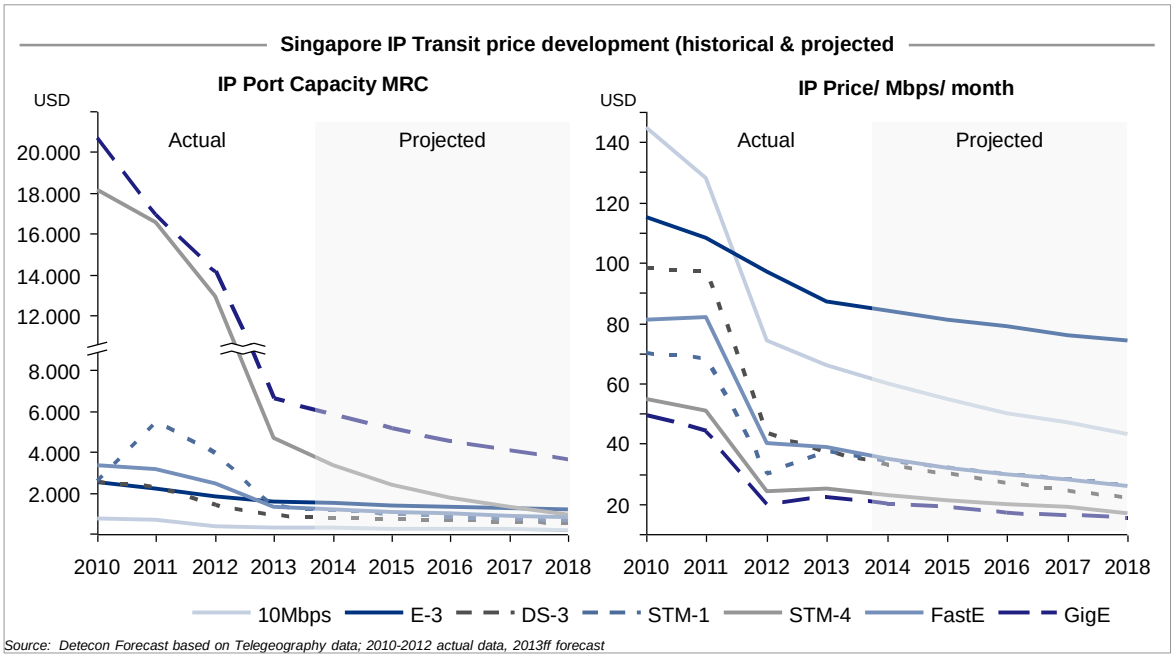
Figure A5: IP Transit Price Levels (Taiwan & Singapore) (as at Q1 2013)

IP Transit Price Levels (in USD)			
	Singapore	Taiwan	
Port Capacity	IP Transit Price/ Mbps/ Month	IP Transit Price/ Mbps/ Month	Ratio (SG/TW)
10Mbps	65.46	61.25	1.07
E – 3	86.50	55.00	1.57
DS – 3	36.90	43.75	0.84
STM1 – OC3	36.60	29.25	1.25
STM4 – OC12	24.60	24.25	1.01
FastE	38.20	39.67	0.96
GigE	22.20	24.22	0.92

IP Transit port prices

17. The study also looked at the changes in IP Transit port prices. Over the past three years, monthly recurring charges ("**MRCs**") for IP Transit port capacity prices have been constantly declining, following international trends. The most substantial price erosion was for the large port capacity connections such as STM-4 and GigE (see Figure A6 below). The study estimates that over the next five years, the price decline will continue. Apart from the corresponding lower port capacities, i.e., 10Mbps and E-3, all unit prices have dropped below the average US$30 level in Q1 2013 (see Figure A6 below):-

Figure A6: IP Transit MRCs



IXPs in Singapore and within the region

18. IXPs[9] are an important element in the Internet infrastructure that enables networks to exchange traffic with one another. There are several IXPs in Singapore, such as Singapore Open Exchange ("**SOX**") Equinix Exchange Singapore ("**EQIX-SIN**") and Singapore Internet Exchange ("**SGIX**"). IXPs in Singapore cater to a variety of Internet players including: ISPs, research and education networks, universities, and content providers, among others. IXPs can choose to impose charges on members in a variety of ways. Some examples of typical charges include: connection charges, initial charges, recurring charges, and backhaul charges.

19. The study compared Singapore's IXPs with other IXPs internationally. Some differences were identified, for example, the Hong Kong Internet Exchange ("**HKIX**") requires all ISPs connected to HKIX to establish peering arrangements with all other members of the IX for local routes. The National Internet Exchange of India requires peering arrangements for selected routes while the Japan Internet Exchange encourages the formation of multilateral peering groups, but on a voluntary basis. In Singapore, SGIX is a not-for-profit, open and neutral

[9] A stricter definition of IXP refers to *a physical network access point through which ISPs connect their networks to exchange traffic, its primary focus being to facilitate network interconnection.*

Internet Exchange which provides local peering options for newer market entrants, and also facilitates voluntary/commercial IP Peering arrangements with established Operators. Today, there are approximately 50 Operators interconnecting in SGIX, with more than half of these adopting an "open" IP Peering policy[10], which suggests an inclination to establish IP Peering arrangements with any other Operator within SGIX.

KEY CONCLUSIONS

20. The study concluded that Singapore has one of the most vibrant wholesale markets in the region, with a large number of national and international players that operate PoPs in Singapore, hence making it one of the most important Asian IP Transit hubs. Two key findings were highlighted as a result of the level of competition present:

    a) ISPs can source IP Transit from multiple sources and thus should always be able to optimise their IP Transit with regard to both quality and price.

    b) Due to the strong presence of IP Transit operators, tromboning should not pose a major concern in Singapore. Most Operators should be able to interconnect their traffic locally, thus large traffic detours (geographical international tromboning) are unlikely to be a constraint imposed by the market, but an individual business decision made by ISPs.

    Thus, no substantial reason for regulatory intervention with regard to IP Transit and IP Peering was identified in the study.

21. That being said, the findings of the study recommended that IDA should continue to closely monitor market developments, and to promote and facilitate the development of Singapore as a global ICT hub to attract more international players and content providers to host here. The study also highlighted that future business requirements are likely to come from high bandwidth-demanding cloud, content or real-time interaction applications. It is therefore important for IDA to continue to understand these developing business models and to consider regulatory intervention if market power is abused or consumer interests are not met in these markets.

[10] See http://sgix.sg/en/memberslist/list-of-members/