EXPLANATORY MEMORANDUM ISSUED BY THE
THE INFO-COMMUNICATIONS DEVELOPMENT AUTHORITY OF SINGAPORE

IDA'S DECISION ON THE REVIEW OF THE INTERNET PROTOCOL TRANSIT AND PEERING LANDSCAPE IN SINGAPORE

24 AUGUST 2016

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PART I: INTRODUCTION

1. In an increasingly connected society, many people and businesses now rely on the Internet for their day-to-day activities and communication needs. While the Internet is easily accessible through wired and wireless telecommunication platforms in an information society such as Singapore, the underlying infrastructure that enables ubiquitous, 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**"). Each of these players manages parts of the large and complex network of interconnected computer networks globally that form the Internet, and which is organised into units, each known as an Autonomous System ("**AS**"). Each AS is identified by a unique AS Number ("**ASN**")[1]. Currently, the Internet comprises more than 50,000 public ASNs, which would include those held by 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 via Internet Protocol ("**IP**") **Transit** or **Peering** arrangements with other industry players, which are described below:

   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 and the content hosted by the provider. An IP Transit arrangement is usually chosen when the customer does not have a network of similar size to the provider, and the traffic volume to be exchanged between the two operators is unequal.

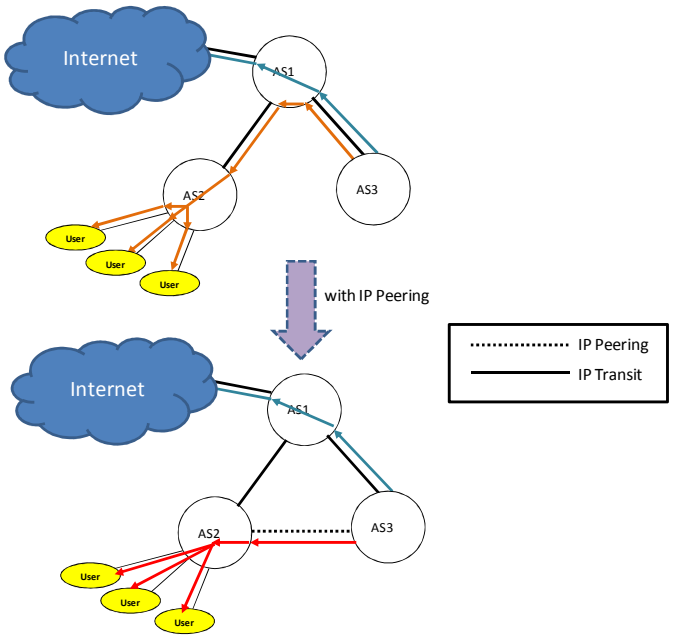
   b) IP Peering arrangement/relationship: A relationship between two operators to facilitate direct, mutual exchange of traffic (e.g., of content they host, and connectivity to their respective end users) between their networks. IP

[1] An AS is a network or a network consisting 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.

Peering arrangements are usually settlement-free (i.e., there is no payment involved between the two operators for the exchange of traffic), and usually do not include transit to networks that are not within the IP Peering arrangement. This, however, does not mean there is no cost involved in establishing connectivity between the two parties (e.g., there will be ancillary costs such as equipment, circuit and management costs of interconnection). IP Peering arrangements usually occur between two operators of similar network size and traffic volume.

3. Operators who are smaller in size will typically rely solely on IP Transit for their connectivity needs as their traffic volume is relatively small. As their traffic volume increases, these smaller operators may consider converting their existing IP Transit relationships into IP Peering relationship(s) when they reach a "breakeven point", whereby the unit cost of an IP Peering arrangement with another operator is less than the unit cost of purchasing IP Transit to reach that operator.

4. Besides ISPs, IP Transit and Peering arrangements can also be made with players such as ICPs or Content Delivery Networks ("**CDNs**"). Given the differences between IP Transit and Peering arrangements (i.e., IP Transit arrangements usually provide access to the entire Internet, while IP Peering arrangements usually facilitate the direct mutual exchange of traffic between directly connected players), IP Transit and Peering can be both complementary and substitutable arrangements depending on the network configuration chosen by an operator. This is illustrated in the following diagram where an operator (AS3) can rely solely on IP Transit or on a combination of IP Transit and IP Peering arrangements to achieve its connectivity needs:



5. 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.

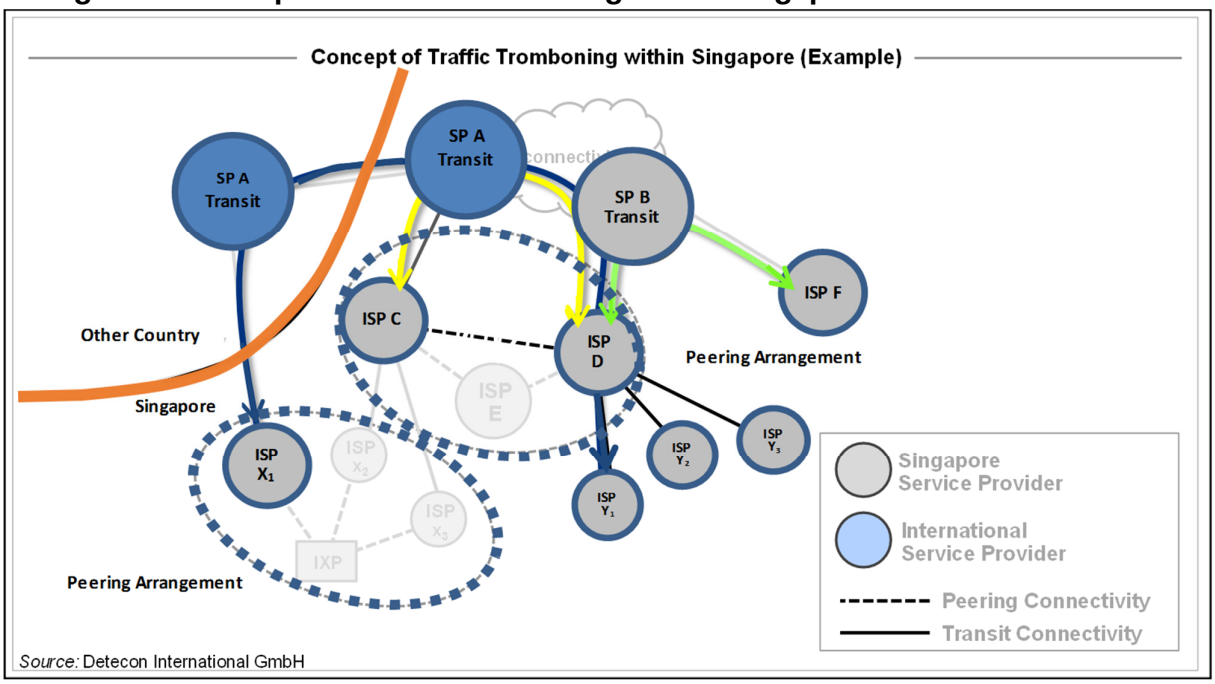
   b) Topological international tromboning: Traffic is sent from one AS to another via one or more upstream providers. If at least one of the AS is registered in another country, this would be referred to as topological international tromboning. This is independent of the location of the nodes (i.e., all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

   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], i.e., "SP A Transit", is operated by an IP Transit service provider registered in another country and traffic is routed through a node which is located in another country.

   If traffic is tromboned over long distances (e.g., through the USA or Europe), the quality of latency-sensitive traffic, such as high-frequency trading or gaming, may face some degradation due to long distance detours (i.e., in terms of distance, number of routers passed ("hops"), etc.). The impact on service quality is more significant when traffic is subject to *geographical* international tromboning, whereas impact on service quality is usually negligible when traffic is subject to *national* and/or *topological* international tromboning.

[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 PoPs.

Figure 1: Concept of Traffic Tromboning within Singapore



6. IDA notes that in Singapore not every ISP establishes IP Peering arrangements with every other ISP for the routing of locally-originated and locally-bound Internet traffic ("**Local Traffic**"). Instead, ISPs typically use a combination of IP Transit and Peering arrangements for the forwarding of Local Traffic.

Review of IP Transit and Peering Arrangements

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 regional business hub, IDA reviewed the issue of whether regulatory intervention for IP Transit and Peering arrangements was necessary to further improve competition in the local Internet services market, and the quality and reliability of broadband Internet services for end users. Specifically, IDA also considered whether it was necessary 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 longer, indirect paths overseas, which may affect the quality of Internet services.

8. IDA had thus commissioned a study to better understand Singapore's Internet traffic connectivity landscape and analyse the market conditions surrounding IP Transit and Peering and the tromboning of Local Traffic in Singapore. The IDA study also compared the development of Singapore's 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 IDA study included a high-level assessment of the competitiveness of the IP Transit and Peering landscape in Singapore and the impact on the Quality of Service ("**QoS**") for end users. The IDA study involved interviews and surveys 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**", and each, an "**Operator**").

Key Findings from the IDA Study

9. The IDA 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 network size and traffic volumes, provided that the costs of building and maintaining these IP Peering arrangements are lower than the associated costs of sending traffic via IP Transit arrangements.

10. 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 priority 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 traffic routing requirements.

11. The IDA study produced several key findings and conclusions, which are elaborated in paragraphs 12 to 17 below.

12. 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 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.

13. Operators have the incentives to route their traffic locally where they can. ISPs in Singapore should be able to deliver and receive Local Traffic in Singapore without any unnecessary detours. If there are no direct connections between

Global Tier-1[3] or Tier-2[4] 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 shortcomings in the market, but may be 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 local routing[5]. That being said, from a technical point of view, even if geographical international tromboning takes place, but is limited to the same region (e.g., traffic is tromboned via Hong Kong), 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.

14. Findings from the IDA 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.

15. 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[6] to those of 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[7] capacities[8] are at similar levels. This suggests that there are no significant price level disadvantages for Singapore in comparison to the average IP Transit price levels in benchmarked cities. The IDA study further suggested that the actual transacted prices of locally purchased IP Transit

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[3] 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.

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

[5] Local routing refers to SLAs that specify that traffic be routed only in Singapore. Based on IDA's understanding, service guaranteed local routing tends to be marketed as a premium product that is sold on a customised basis.

[6] Based on 2012 statistics from the IDA study. IDA has not received feedback from Operators that these price differentials have changed significantly since then.

[7] To gain access to the Internet, Operators would have to purchase an IP Transit *port*. Prices will vary depending on the 'size' of the port (e.g., 1Gbps, 10Gbps, etc.).

[8] This refers to a term used in the IDA 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)).

services may be below the average price levels reported by market researchers, which could indicate that Operators are able to source low-priced IP Transit locally, depending on the commercial negotiations and customised agreements between Operators.

16. Finally, the IDA 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.

17. The IDA 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 IDA 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.

18. As part of its review, IDA also conducted a public consultation from 13 February 2015 to 15 April 2015 (the "**Public Consultation**") to share the above findings with the public and the industry, and to seek their views and validation of the findings.

19. At the close of the Public Consultation, IDA received comments from nine respondents (individually referred to as a "**Respondent**" and collectively, the "**Respondents**"), namely:

    a) Mr Andrew Ngiam;
    b) Facebook Inc;
    c) Google Asia Pacific Pte Ltd ("**Google**");
    d) M1 Limited;
    e) Mr Marco Huggenberger;
    f) Moratel International Pte Ltd;
    g) Netflix Inc;
    h) Singapore Telecommunications Limited; and
    i) StarHub Limited.

20. IDA would like to thank all Respondents for submitting responses to the Public Consultation.

PART II: SUMMARY OF COMMENTS RECEIVED

21. In the Public Consultation document, IDA sought views 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?

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?

General Comments on the IDA Study

22. Comments on the findings from the IDA study were mixed. On the one hand, some Respondents commented that the findings from the IDA study generally matched their respective experiences in the Singapore Internet services market. Accordingly, these Respondents submitted that IP Transit prices within Singapore and the wider Asia Pacific region had consistently declined over the years and Singapore had ample infrastructure in place for Operators to interconnect with each other. Additionally, some Respondents opined that there was no evidence of market failure in the Internet services market and accordingly, IP Transit and Peering arrangements should be left to commercial decision-making so as to prevent any unintended consequences on innovation, development of new business models and technological advancement.

23. On the other hand, some Respondents disagreed with the findings from the IDA study. These Respondents commented that the IDA study had not considered the differences in costs between small and large ISPs, and that low instances of traffic tromboning did not mean that there was no market failure. In this vein, one Respondent opined that the "incumbents" in the Singapore Internet services market were charging a "premium" for the transmission of Local Traffic, a practice which it deemed "unfair" and "discriminatory".

Comments on whether IP Transit and Peering Conditions have Impacted Competition, or Hindered Operators' Service Offerings

24. Comments were also mixed on the current conditions of IP Transit and Peering and whether they have resulted in any negative impact on competition, or if they have hindered the ability of ISPs, ICPs, or CDNs to offer services.

25. On the one hand, several Respondents commented that they had not observed that the current conditions for IP Transit and Peering resulted in any negative impact on competition, given that Operators had multiple options for traffic delivery that enabled them to innovate and enhance their end users' Internet experience. One Respondent cited the example of a large number of Retail Service Providers ("**RSP**") entering the market since the introduction of the Nationwide Broadband Network as evidence of a well-functioning market under prevailing conditions, and that there was no evidence of anti-competitive conduct within the market.

26. However, one Respondent who believed that current conditions could result in a negative impact on competition submitted that an absence of effective competition in the transmission of Local Traffic through IP Transit arrangements "*may cause harm or exhibit a reasonable probability of harming the Global ISPs*". This Respondent added that these "Global ISPs" would be competitively disadvantaged if they "*do not own the domestic IP backbone; or have not entered into IP Peering Arrangements with owners of the domestic IP backbone*". Another Respondent submitted that the "*premium charged by the incumbents [to ensure that Local Traffic is kept within Singapore's boundaries] stymies local innovation and competition as it raises the costs for new entrants and smaller operators who do not have the volume and bargaining power to compete*".

27. One Respondent submitted that none of the "incumbents" (e.g., the larger ISPs in Singapore) interconnected at Singapore Internet Exchange ("**SGIX**") had an open peering policy and new entrants/smaller Operators would have no choice but to purchase IP Transit from these "incumbents" to reach their end users should they require their network traffic to stay local.

Comments on whether the Quality of ISPs' Service Offerings is Negatively Affected by Today's IP Transit and Peering Landscape

28. Comments on whether the quality of ISPs' service offerings is negatively affected by today's IP Transit and Peering landscape were also mixed.

29. Respondents who opined that there was no negative impact submitted that there were a wide number of interconnection options and well established infrastructures available in the market. One Respondent commented that there was therefore very little reason for an RSP to choose to trombone Local Traffic overseas before returning it to Singapore. This Respondent further noted that RSPs could choose to cache traffic on their own servers to further improve their customers' service experience.

30. Another Respondent opined that IP Peering infrastructures were well established in Singapore and it had observed that the majority of the Internet traffic stays within Singapore without tromboning to neighbouring countries such as Malaysia or Hong Kong. On this note, one Respondent pointed out "*the fact that certain ISPs were able to offer gaming plans with low latencies clearly demonstrates that the current landscape creates the opportunity for ISPs to innovate and provide high performance services*".

31. On the other hand, one Respondent cautioned that the negative effects on performance due to tromboning would be immediately apparent in "*software-as-a-service, high bandwidth (e.g., multimedia streaming) and low-latency (e.g., trading, gaming) applications when it forms a higher percentage of the total latency experienced by the end-user*".

Comments on the Cost of IP Transit vis-a-vis other Operating Costs

32. IDA did not receive feedback that the proportional cost of IP Transit was high compared to Operators' other operating costs nor that the proportion had been increasing.

33. Most Respondents agreed that on the whole, the cost of IP Transit in Singapore had fallen over the past few years, with one Respondent commenting that the cost had *"decreased approximately 30% on an annualised basis over the last 5 years"*.

34. However, one Respondent elaborated that prices were higher "for local transit", which IDA understands to be a service provided by transit providers for the transmission of Local Traffic ("**Local IP Transit**"), as opposed to "global transit", which comprises the transmission of both Local Traffic and international traffic (i.e., Internet traffic that is bound for overseas destinations), due to greater competition in the global IP Transit space.

Comments on other Factors IDA Should Consider in Assessing the Local IP Transit and Peering Landscape

35. One Respondent commented that IDA could consider looking into the constraints for further investments in key components of the Internet in Singapore, for example, availability of data centre facilities, subsea cable landing station access and use, backhaul facilities, etc. This Respondent noted that investments in these areas contributed to the proliferation of existing telecommunication networks by increasing the amount of new capacity, and could help prevent users of various content networks from experiencing higher latency and an overall poorer experience.

36. Another Respondent commented that IDA should not compare the differences between settlement-free IP Peering and paid IP Transit arrangements. Rather, IDA should consider the decisions of Operators (1) *to peer*; and (2) *not to peer*. This Respondent explained that the decision *to peer* would give Operators monetary benefits such as lower costs and greater control over the routing of Internet traffic (as opposed to allowing the IP Transit provider to determine the routing of traffic), and would provide potential for better network performance, due to a smaller number of "hops". On the other hand, the decision *not to peer* would favour an Operator with a large number of end users (or "eyeballs") as it would allow the Operator to charge smaller Operators for access to its network.

Comments on the Other Possible Areas in the Local IP Transit and Peering Landscape that would Require Regulatory Intervention

37. One Respondent opined that more could be done to provide for direct traffic exchange which would help to further reduce costs and improve efficiency of operations. For example, IDA could lend its support towards fostering a conducive wholesale environment through continued funding for SGIX to build on its growth and enhance its market position in offering an affordable and efficient central point for traffic exchange.

Other Comments

38. One Respondent submitted that "*without regulatory intervention, 'incumbents' have the incentive to charge for traffic prioritisation and to throttle speeds – neither of which is too sophisticated nor too expensive to implement*". This Respondent added that tromboning, in this instance, could be viewed as a "*manifestation (albeit low-tech) of paid prioritisation and throttling*". Accordingly, this Respondent submitted that this went against the "*spirit of Net Neutrality. In addition, end-users suffer reduced performance*".

PART III: IDA'S DECISION

IDA's Policy Objective

39. As mentioned in paragraph 7 of this Explanatory Memorandum, IDA's objective in reviewing the IP Transit and Peering landscape in Singapore was to determine whether regulatory intervention in this space was necessary to further improve competition in the local Internet services market, and improve the quality and reliability of broadband Internet services for end users. This section sets out IDA's findings in these aspects, taking into consideration the comments from the Public Consultation.

IP Transit and Peering Landscape and Competition

Singapore has Ample Infrastructure to Support IP Transit and Peering Arrangements

40. Connectivity platforms such as Internet Exchanges ("**IX**") are important pieces of infrastructure in facilitating interconnection between Operators, i.e., through IP Transit or Peering arrangements. IDA notes that there are a number of IXes operating in Singapore today[9], such as Singapore Open Exchange and Equinix Exchange Singapore. IDA also facilitated the setting up of SGIX in 2009, which commenced operations in June 2010. SGIX is a not-for-profit, open and neutral IX 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 QoS for Internet services. Currently, there are approximately 70 Operators interconnecting at SGIX.

41. The availability of IXes has facilitated an increase in the establishment of IP Peering arrangements, and correspondingly, boosted the amount of traffic delivered over IP Peering arrangements. For example, at SGIX, the amount of peak peered traffic has increased steadily over the last four years. This suggests that Operators have become more receptive to IP Peering arrangements and are exchanging more traffic via their respective IP Peering arrangements. For example, from December 2011 to December 2015, the peak peering traffic exchanged at SGIX increased by nearly 160 times. This trend is also observed amongst CDNs and ICPs working with ISPs in Singapore to optimise the delivery of file transfers, streaming audio and video, web pages, and other applications[10] to end users in Singapore. Presently, major ICPs such

[9] IDA has licensed more than 37 operators to provide Internet exchange services in Singapore, including neutral IXes such as SGIX and Singapore Open Exchange.

[10] Source: *Telegeography: Global Internet Geography*

as Amazon, Facebook, Google, Microsoft and Yahoo have established IP Peering arrangements with Operators at various IXes in Singapore[11] as they continue to expand their network reach. In this respect, one Respondent noted that *"peering infrastructures are well established in Singapore"*. Refer to **Appendix A** for an international comparison of the developments in IP Peering locations for major content providers from the years 2009 to 2015.

42. Besides IXes which facilitate the direct exchange of Internet traffic among Operators, the availability of other interconnection infrastructures such as submarine cable networks[12] and data centre facilities[13] have also attracted many Global Tier-1 and Tier-2 Operators (including their corresponding subsidiaries) to provide connectivity and Internet traffic delivery services within and out of Singapore. As such, Operators have multiple options (which differ in areas such as cost, service quality, etc.) available to them when sourcing IP Transit. This also allows Operators to optimise the routing of their Internet traffic depending on their business interests and end users' needs. Therefore, Operators in Singapore should be able to deliver their traffic in Singapore without any unnecessary detours. If Operators have purchased IP Transit from Global Tier-1 or Tier-2 Operators with PoPs in Singapore and these Global Tier-1 or Tier-2 Operators are not directly interconnected with each other in Singapore, nor interconnected with Operators in Singapore with a domestic backbone, traffic may be forwarded through the region to the next peering point. However, such cases should be infrequent as such a forwarding scheme unnecessarily burdens the traffic forwarding Operators' internal infrastructure. As noted in the IDA study, if there appears to be long-distance traffic detours, these are unlikely to be due to constraints imposed by market conditions, but may be due to the Operators' commercial decisions.

Falling IP Transit Costs and Alternatives to IP Transit and Peering

43. Apart from having multiple IP Transit options, IDA notes that Operators in Singapore have experienced falling IP Transit costs, in line with international trends. For example, between 2013 and 2016, median 10 GigE[14] IP Transit prices in Singapore declined approximately 23%[15] on an annual basis, from

[11] Source: Peeringdb.com

[12] Singapore is also well-connected via submarine cables – today, there are 17 submarine cable systems landed with a total potential capacity of more than 381Tbps.

[13] Operators in Singapore are investing in more data centre facilities to meet growing demand for data storage and interconnection facilities by businesses. For example, see: http://www.channelnewsasia.com/news/business/singtel-to-build-s-400/2177770.html and http://www.channelnewsasia.com/news/singapore/google-to-build-2nd-data/1888102.html.

[14] 10 Gigabit Ethernet = 10,000 Mbps

[15] In comparison, median 10 GigE IP Transit prices in Hong Kong declined 23% on an annual basis in the same period, while prices in Seoul declined 30% and prices in Tokyo declined 36%. In New York and London, prices declined 16% and 13% respectively.

$7.00 per Mbps to $3.15 per Mbps (in USD). In this respect, several Respondents agreed with the findings in the IDA study that the cost of IP Transit in Singapore has consistently declined in the past few years, following international market trends. This decline in price of IP Transit can be attributed to healthy competition amongst Operators, and supports the view that the prices of IP Transit services are to a certain degree, affected and constrained by international price trends for IP Transit services. An international comparison of declining IP Transit prices can be found at **Appendix A**.

44. IDA also did not receive feedback that IP Transit (a wholesale input required for the provision of Internet access services) costs comprised a significant proportion of Operators' costs, nor that this proportion had been increasing. If these costs comprised a significant proportion of Operators' costs or had been kept at uncompetitive levels, a knock on effect on prices at the retail level would have been observed, affecting the competitiveness of prices for end user retail services. The market has instead witnessed the falling of retail prices for broadband service plans by more than 90%[16] in the last five years.

45. In addition to the increase in Internet traffic exchanged via IP Peering arrangements and falling IP Transit costs, IDA observes that there are multiple solutions (described in paragraphs 56 to 57 below) which Operators can adopt to optimise the delivery of Internet traffic to their end users which will improve the service quality experienced by their end users.

Dynamics of the IP Transit and Peering Landscape

46. IDA understands that Operators typically do not make a binary decision between IP Transit and IP Peering. Given the differences in IP Transit and Peering arrangements, most Operators employ a combination of both IP Transit and Peering arrangements, depending on the network configuration chosen by an Operator. In other words, Operators generally do not rely on one form of interconnection arrangement (i.e., IP Transit or Peering) to fulfil their connectivity needs. IDA understands that a significant majority of Operators purchase transit from other Operators, even in the case of Operators who have global networks. For example, a global ISP that has networks in USA and Europe may purchase IP Transit from an Asian Operator who has a more expansive Asian network than the former's own network.

47. The proportion of Operators' traffic transmitted through IP Transit vs IP Peering links may vary greatly depending on size of the Operator. Generally, the larger the Operator, the larger the proportion of traffic exchanged through IP Peering

[16] For example, a smaller ISP's 1Gbps residential retail broadband plan was offered at $399/month in October 2010. As at August 2016, a similar configuration by the same ISP was offered at $39/month.

arrangements as opposed to IP Transit. This is mainly due to the fact that a larger Operator's network will carry more traffic and will physically reach more locations, and as such, the larger Operators will have the propensity to establish IP Peering arrangements in more locations and with a greater number of similarly-sized Operators, compared to the smaller Operators.

48. One Respondent submitted that "*none of the incumbents*" interconnected at SGIX "*have an open peering policy*" and "*new entrants/smaller operators have no choice but to purchase transit from the incumbents to reach their end-users when they need their network traffic to stay local*". In this regard, IDA notes that IP Peering arrangements, while generally settlement-free, involve ancillary costs such as equipment, circuit and management costs of interconnection, etc. Besides these costs, Operators also have to determine whether a particular pair of IP Peering arrangements would achieve the necessary scale (e.g., in traffic volume) to justify the necessary investment, and whether the IP Peering arrangement would be beneficial for both parties. In other words, larger Operators may not find it beneficial to establish IP Peering relationships with smaller Operators given the asymmetries in traffic volumes. For example, even in a situation where there is a perception by a smaller Operator of mutual benefit for an IP Peering arrangement to be established with another Operator, this benefit might not be sufficient to justify the cost of establishing the two-way connection.

49. Furthermore, with reference to one Respondent's comment that "Global ISPs" may be harmed if they were unable to enter into IP Peering arrangements with the larger ISPs in Singapore, IDA notes that there has been no feedback by Global ISPs that they have been harmed by the current conditions in Singapore's IP Transit and Peering landscape. Moreover, IDA notes that Global ISPs are likely to have significant negotiating power when entering markets (i.e., markets other than these Global ISPs' home markets) given their network sizes.

50. While some Respondents recognised that larger Operators may not enter into IP Peering arrangements for the above reasons (i.e., asymmetric network size and traffic volume), some Respondents commented that the prices of the alternatives to IP Peering, e.g., local or domestic IP Transit products sold by some of the larger ISPs, were high compared to the prices of global and international IP Transit. IDA understands that Local IP Transit is a product that gives Operators specific access to content hosted on the local networks of the larger ISPs and to their end users. In comparison, global and international IP Transit products offer access to the entire Internet, i.e., both local and international networks.

51. To better understand the differences between these products, IDA sought further clarifications from some ISPs and these ISPs explained that Local IP Transit services are usually offered on a customised basis. Given that Local IP Transit would require specific configuration to support more stringent QoS and to ensure that traffic over these links is kept strictly within Singapore, the prices of Local IP Transit may be higher than global or international IP Transit offered by the same ISP. IDA also notes that IP Transit prices reflect various business considerations. For example, the IDA study revealed that Operators who purchase larger volumes of IP Transit are able to negotiate for better prices with IP Transit providers, depending on the commercial negotiations and customised agreements between Operators. In other words, the actual transacted prices of IP Transit services, including Local IP Transit sold in Singapore, are generally lower than their corresponding list prices.

No Evidence of Anti-Competitive Behaviour

52. IDA has not found evidence (either through the IDA study or through submissions provided by Respondents) of anti-competitive behaviour by the larger ISPs in the IP Peering and Transit market. While IDA acknowledges that some smaller ISPs in Singapore are not able to enter into settlement-free IP Peering arrangements with the bigger ISPs due to differences in traffic volumes, and may not be willing to pay for a link in the form of Local IP Transit that provides a similar service, these smaller ISPs are not prevented from accessing content on the Internet or content hosted by the larger ISPs as they have multiple IP Transit options to choose from.

Other Comments

53. IDA does not agree with one Respondent's comment that tromboning contravenes the spirit of Net Neutrality. As described above, tromboning is a term primarily used to refer to the routing of Internet traffic (e.g., where Internet traffic takes a longer, indirect route before arriving at its intended destination). In turn, Net Neutrality is a term generally used to refer to Internet access service or network access providers (i.e., access or connectivity platform) treating all sources of Internet content equally, and the right of a consumer to access content and services on the Internet on a non-discriminatory basis. In this regard, there is nothing to substantiate how the practice of tromboning per se would be inconsistent with Net Neutrality. In any event, under IDA's Net Neutrality framework, amongst other things, network management practices that are inconsistent with fair competition and information transparency requirements are prohibited. ISPs must also continue to meet IDA's minimum QoS requirements.

54. As regards the comment by one Respondent that IDA should not analyse the difference between settlement-free IP Peering and paid IP Transit, rather, IDA should instead consider the decisions of Operators (1) to peer; and (2) not to peer, IDA holds the view that such a simplistic comparison may not provide a complete understanding of the market dynamics. As noted above, most Operators employ a combination of both IP Transit and Peering arrangements, depending on the network configuration chosen by Operators, as well as their business considerations, to achieve their Internet connectivity needs. A simple comparison of the decisions "to peer" or "not to peer" omits the assessment of the overarching market conditions in Singapore which include IP Transit and Peering infrastructures, the dynamics of the Internet services market and the provision of connectivity to ICPs and CDNs.

The Current IP Transit and Peering Landscape has not had a Material Impact on Service Quality

55. Several Global Tier-1 and Tier-2 Operators (and their subsidiaries) offer connectivity directly within (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 options through IP Transit relationships with Global Tier-1 or Tier-2 Operators within Singapore.

56. The market-driven approach for the current IP Transit and Peering arrangements has also allowed various players, including smaller Operators, in the Internet services ecosystem to develop optimal solutions for traffic delivery that has benefitted both end users and the overall Internet ecosystem.

57. For example, an ICP such as Google works with ISPs in Singapore *"to store popular content on servers close to users (i.e., "caching"[17])"* so that such traffic is transmitted over a shorter distance (i.e., lower latency and faster access speeds). Similar efforts to "localise" content have been employed by CDNs as well as other ICPs to reduce their reliance on long-distance transmission of traffic, thereby improving service quality for end users. IDA understands that some ISPs in Singapore also cache data on their own servers to improve their end users' service experience. Such data caching further reduces the scope for ISPs in Singapore to trombone Local Traffic overseas.

58. Hence, IDA has not found evidence that the quality of ISPs' services offerings has been negatively affected by today's IP Transit and Peering landscape.

[17] For more information, see: https://peering.google.com/about/ggc.html

Notably, IDA observes that smaller ISPs in Singapore were the first to offer differentiated service offerings such as low-latency (e.g., for gaming) and high-bandwidth plans (e.g., 1Gbps and above) in the current market environment.

Very Little Internet Traffic is Tromboned Outside of Singapore

59. In terms of the impact of tromboning of Local Traffic on service reliability and quality, IDA notes that even if traffic is tromboned within the region (e.g., Hong Kong), the impact on quality (e.g., latency) of Internet services is likely to be insignificant for most end users. Findings from the IDA 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. 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 may be an individual business decision made by Operators.

60. Moreover, IDA notes that none of the Respondents presented evidence that IDA's estimate (that approximately 5% or less of Singapore's Internet traffic is tromboned overseas) was inaccurate. In fact, one Respondent submitted that the Local Traffic in Singapore consists of only 5% of the *total* traffic forwarded by Operators in Singapore. If majority of the Local Traffic is kept within Singapore, then it would be safe to assume that the actual amount of traffic tromboned is significantly less than the 5% IDA had estimated. This is also corroborated by another Respondent who observed that "*majority of the Internet traffic stays within Singapore without tromboning to neighbouring countries such as Malaysia or Hong Kong*".

61. Accordingly, as most traffic should not be tromboned beyond the region and most Operators should be able to interconnect their traffic locally, IDA has not found evidence that the relative prices of Local IP Transit products vis-à-vis those of global or international IP Transit have negatively impacted service quality or competition in the Internet services market.

No Case for Regulatory Intervention to Mandate IP Peering

62. Notwithstanding IDA's assessment of the IP Transit and Peering landscape in the Public Consultation, some Respondents opined that regulatory intervention was still necessary to further enhance competition and service quality in the Internet services market. Broadly, these Respondents argued that mandating

settlement-free IP Peering arrangements among all Singapore Operators would minimise the "disadvantages" of size and scale for smaller Operators and lessen limitations caused by each Operator's own infrastructure, and would induce greater competition in the market, thereby lowering prices for consumers while compelling the larger ISPs to innovate in the process.

63. IDA notes that internationally, IP Peering arrangements are usually commercially negotiated and agreed upon between Operators without regulatory intervention. In those cases where there was regulatory intervention, it was on the basis that an ISP had abused its dominant position to harm competition. As noted above, so far, IDA has not found evidence of anti-competitive conduct in the provision of IP Transit services or IP Peering arrangements. Rather, the IP Transit and Peering landscape in Singapore is dynamic, with the amount of Internet traffic forwarded through IP Peering arrangements increasing in recent years, and with multiple IP Transit providers for Operators to choose from. Furthermore, IDA has not found there to be a significant adverse impact on service offerings or quality due to providers not being able to enter into IP Peering relationships and/or due to tromboning.

64. IDA further notes that one Respondent who opposed regulatory intervention raised several issues regarding the unintended consequences of intervening in IP Peering arrangements. For example, this Respondent held the view that mandating IP Peering arrangements between all Operators would "*slow down the peering activations between networks*". As a result, existing peering links would become congested, leading traffic to trombone internationally. IDA agrees that any regulatory intervention should be well scoped to deliver clear policy outcomes and should minimise risks of unintended consequences, such as disruptions to business innovations.

65. Over and above the reasons cited for non-intervention by some of the Respondents, IDA notes that the Internet services market is one that is constantly evolving and the market-driven approach to regulation has worked well for Singapore. Given the pace of change in the Internet services market, an IP Peering arrangement that is disadvantageous to Operators today (e.g., due to traffic asymmetry) may become advantageous in the longer term (e.g., as traffic volumes grow, or as interconnection business considerations evolve). Unless there is evidence that the current market is not working well or is not competitive, or that there are clear benefits in mandating IP Peering amongst all Operators in Singapore, such regulatory measures should not be introduced.

66. In summary, on the basis of the above, and having reviewed the comments from the Public Consultation, IDA has determined that there is neither strong evidence of market failure nor compelling justification for regulatory intervention

in the form of direct remedies imposed on Operators, such as mandatory IP Peering amongst Operators, to further improve competition or service quality in the local Internet services market.

Facilitating a More Vibrant IP Transit and Peering Landscape in Singapore

67. While there is no substantial evidence to justify specific regulatory intervention by IDA in the IP Transit and Peering landscape in Singapore, IDA will continue to encourage industry developments that would further foster an environment that is conducive to maintaining a vibrant and competitive Internet services market.

68. IP Peering arrangements, although best left to commercial negotiations amongst Operators, could be facilitated if Operators were more transparent with their IP Peering policies. In general, when there is increased transparency in a process (e.g., negotiation for an IP Peering arrangement), other players in the market will be able to learn from best practices of other Operators and improve their IP Peering arrangements. In addition, enhancements to transparency can reduce *perceptions* of lack of fairness or anti-competitive intent in the IP Peering process. Therefore, IDA encourages Operators in Singapore who have existing IP Peering arrangements in Singapore to publish their IP Peering policies, providing information on the basis or criteria on which they are prepared to enter into IP Peering arrangements in Singapore ("**IP Peering Policies**").

69. The practice of publishing IP Peering Policies is not new, as several of the largest ISPs in USA, such as AT&T[18], Verizon[19], etc., have voluntarily published the basis on which they decide with whom they will enter into discussions about peering on a settlement-free basis. IDA also notes that industry players such as Google[20], Yahoo![21] and Microsoft[22] have published their IP Peering Policies, which apply to their global operations. Some of these policies include information on technical requirements such as disclosure of routes, traffic ratios and network capacity requirements. Further, IDA understands that the Federal Communications Commission in USA had assessed that such voluntary publications were a positive development that had significantly enhanced the transparency of the IP Peering process in the industry[23]. IDA thus encourages more Operators in Singapore to adopt greater information transparency in this area.

[18] http://www.corp.att.com/peering/
[19] https://business.verizon.com/MyBusinessAccount/one.portal?_nfpb=true&_pageLabel=gb_policy&page_id=peering_policy
[20] https://peering.google.com/#/
[21] https://www.peeringdb.com/asn/10310
[22] https://www.microsoft.com/peering
[23] https://transition.fcc.gov/nric/nric-5/fg4-appendix-b.doc

70. While IDA does not intend to prescribe regulations on IP Peering Policies and IP Transit arrangements of Operators in Singapore at present, if IDA finds any Operator has adopted IP Peering or Transit arrangements in a manner that unreasonably restricts competition in the telecommunication market, IDA will carry out regulatory actions and/or interventions as appropriate, pursuant to considerations and procedures set out in Section 11 of the Telecom Competition Code 2012. Accordingly, IDA expects all licensees to negotiate in good faith and in a commercially reasonable manner with other licensee(s) for the purpose of entering into an IP Peering and/or Transit arrangements.

71. IDA will continue to monitor technology and market developments in the IP Peering and IP Transit scene to ensure that Singapore remains an attractive destination for Operators to obtain competitive IP connectivity services.

PART IV: CONCLUSION

72. The IDA study and Public Consultation did not discover any evidence that the IP Transit and Peering landscape had not been functioning well, nor had competition in this area been ineffective or impeded. Therefore, having assessed the relevant facts and responses to the Public Consultation, IDA does not find any strong reasons for IDA to directly intervene in IP Transit and Peering arrangements by mandating IP Peering arrangements amongst Operators.

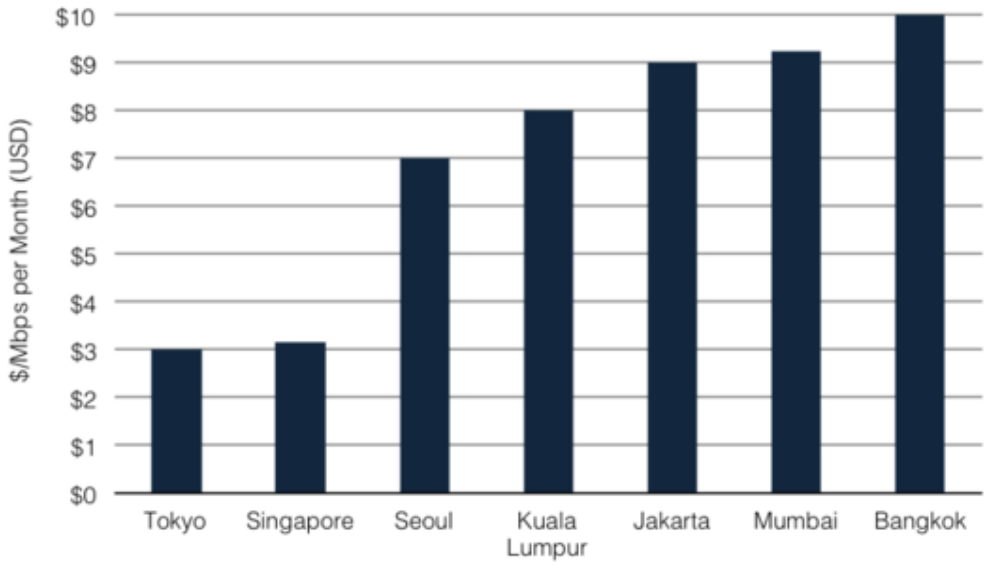
73. Nonetheless, IDA notes that improving the transparency of IP Peering Policies of Operators in Singapore will help to facilitate IP Peering arrangements between interested parties, and remove perceptions of a lack of fairness. To this end, IDA encourages Operators in Singapore who have existing IP Peering arrangements in Singapore to publish their IP Peering Policies on their respective websites. IDA also expects all licensees to negotiate in good faith and in a commercially reasonable manner with other licensee(s) for the purpose of entering into an IP Peering arrangement.

Appendix A

IP Transit Pricing Trends

1. As a regional hub city, Singapore is a known traffic exchange and content hosting nerve centre. Due to the presence of multiple IP Transit providers in Singapore (including notable Global Tier-1 and Tier-2 Operators), IP Transit prices in Singapore are relatively low and have also been declining. The median prices for 10 GigE IP Transit in Asian markets are set out in **Figure 1**.

Figure 1: Median 10 GigE IP Transit Prices in Asia, Q2 2016



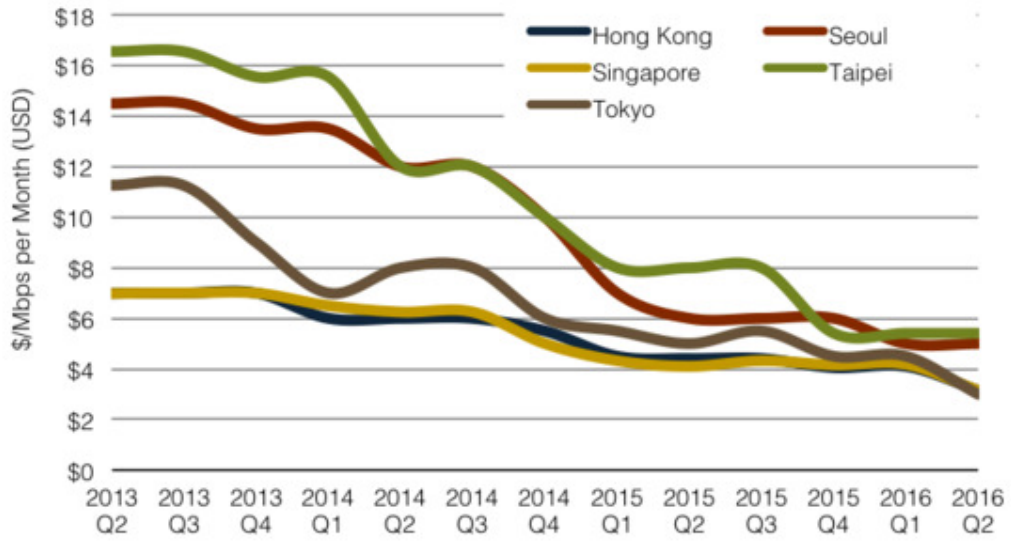
Source: Telegeography

Notes: Each column represents the median monthly price per Mbps in the listed city. Prices are in USD and exclude local access and installation fees. 10 Gigabit Ethernet (10 GigE) = 10,000 Mbps.

2. According to **Figure 1** above, Singapore's median price of US$3.15/Mbps for 10 GigE IP Transit is one of the lowest among major Asian Markets, matching that of Hong Kong and preceded only by Tokyo at US$3.00/Mbps.

3. The decline in median prices for 10 GigE IP Transit in major Asian markets is illustrated in **Figure 2** below. An overview of median 10 GigE IP Transit prices in major Asian cities from 2013 to 2016 can be found in **Figure 3** below.

Figure 2: Median 10 GigE IP Transit Prices in Major Asian Markets, Q2 2013–Q2 2016



Source: Telegeography

Figure 3: Asian IP Transit Prices (per Mbps) in major Asian cities, 10 GigE, Q2 2013 to Q2 2016

City	Q2 2013	Q2 2014	Q2 2015	Q2 2016	CAGR 13-16
Hong Kong	$7.00	$6.00	$4.41	$3.15	-23%
Seoul	$14.50	$12.00	$6.00	$5.00	-30%
Singapore	$7.00	$6.25	$4.10	$3.15	-23%
Taipei	$16.55	$12.00	$8.00	$5.41	-31%
Tokyo	$11.25	$8.00	$5.00	$3.00	-36%

Source: Telegeography

Notes: Prices in Figure 2 and Figure 3 represent the median monthly price per Mbps for a full-port commit in the listed city. Data derived from Q2 of each year. Prices are in USD and exclude local access and installation fees. 10 Gigabit Ethernet (10 GigE) = 10,000 Mbps. CAGR = Compound Average Growth Rate.

Increase in Availability of IP Peering with Content Providers in Singapore

4. IDA notes that global content providers have been aggressively increasing their presence at notable hub cities such as Singapore as they endeavour to expand the reach of their global networks. A comparison of IP Peering locations for major content providers from 2009 compared to 2015 is shown in **Figure 4** below.

Figure 4: Peering Locations for Major Content Providers, 2009 vs 2015

	Amazon	Facebook	Google	Microsoft	Netflix	Yahoo
Asia						
Japan	•	•	•	•	•	•
Korea, Rep.	•			•		•
Singapore	•	•	•	•	•	•
Taiwan	•	•	•	•		
Europe						
Netherlands	•	•	•	•	•	•
United Kingdom	•	•	•	•	•	•
North America						
United States	•	•	•	•	•	•
Oceania						
Australia	•	•	•	•	•	•

Source: Telegeography/ PeeringDB
Notes: Dots reflect peering locations in mid-2015. Shaded areas represent new peering locations added since mid-2009.