PingER Malaysia-Internet Performance Measuring Project: A Case Study

Saqib Ali, R. Les Cottrell, and Anjum Naveed

***Abstract*—PingER measurements indicate that there is a moderate to strong positive correlation between the Internet performance metrics and economic and development indices available from the UN and International Telecommunications Union (ITU). Therefore, it is critically important to measure and understand the Internet performance of a country and the place where it needs improvement. In this paper, Internet Performance is measured using PingER (Ping End-to-end Reporting), the name given to the Internet End-to-end Performance Measurement (IEPM) project to monitor end-to-end performance of Internet links. The project was started by the SLAC National Accelerator Laboratory at Stanford in California, USA, in 1995. It involves hundreds of sites in many countries all over the world. In Malaysia, the project was started in 2012. Currently, it consists of 9 Measuring Agents (MAs) configured at UNIMAS, Universiti Teknologi Malaysia (UTM), Universiti Malaya (UM), Universiti Utara Malaysia (UUM) and MYREN along with 27 monitored remote sites in Malaysia and 94 in South East Asia. The objectives of this paper are to provide an overview of the PingER-Malaysia project, to compare the Internet performance within MAYREN, Malaysia and South-East Asia using the PingER-Malaysia infrastructure and, to provide recommendations to the subject agencies to improve the Internet performance within the country as it has a strong relationship with the economic and development indices of a country.**

***Index Terms*—Internet performance, packet loss, ping, round trip time**

I. Introduction

PingER worldwide [1] measurements indicate that throughputs are typically improving by 20% per year and losses by up to 25% per year [2]. Most countries have converted from using Geostationary Satellite (GEOS) connections to terrestrial fiber optic links [2]. This has improved Internet performance in particular for Round Trip Time (RTT) and throughput. The improved Internet performance has a moderate to strong positive correlation between the Internet performance metrics and economic and development indices available from the UN and International Telecommunications Union (ITU). For example, links between the more developed regions including N. America, E. Asia (in particular Japan, South Korea and Taiwan) and Europe are much better than elsewhere (3-10 times more throughput achievable). Regions such as S.E. Asia, S.E. Europe and Latin America are 5-9 years behind [3]. However, in 2009, Africa was $\sim$15 years behind Europe, which strongly correlated with the economic and development indices of many African countries [4]–[6]. The World Bank reports that for every 10% increase in high-speed Internet connections there is an increase in economic growth of 1.3 percentage points. It is therefore critically important to measure, understand, and be able to see where the Internet's performance needs improving [7]. Thus, the aim of this paper is to study the Internet performance within the MYREN-Malaysian Research & Educational Network[1], within S. E. Asia, and between Malaysia and the rest of the world. The Internet performance is measured with the help of a specific Malaysian PingER project[2]. Finally, the paper provides recommendations to the subject agencies to increase the Internet performance within the country as it has a strong relationship with the economic and development indices of a country.

II. What is PingER?

PingER (Ping End-to-end Reporting) is the name given to the Internet End-to-end Performance Measurement (IEPM) project to monitor end-to-end performance of Internet links. It is led by SLAC[3][7-8] and development includes NUST/SEECS[4] (formerly NIIT), FNAL[5], and ICTP/Trieste[6], together with UM[7], UNIMAS[8] and UTM[9] in Malaysia. Originally in 1995, it was for the High Energy Physics community, however, this century it has been more focused on measuring the Digital Divide from an Internet Performance viewpoint [4]. PingER now has over 80 active monitoring nodes in 20 countries. PingER monitors over 700 remote (monitored) nodes. This corresponds to a total of over 10,000 MA-remote node pairs. The remote hosts are located in over 170 of the world's 227 countries. The only countries with more than 1 Million population that are not currently (Dec 2014) monitored are the Central African Republic, Chad, Guinea-Bissau, and North Korea. The monitored countries contain over 98% of the world's population as shown in Fig. 1 and Table I and over 99.5% of the on-line users of the Internet. Most of the hosts monitored are at educational or research institutes and are usually web sites. The detailed installation requirements, instructions to install a PingER MA, access to the data, location of the sites, measurement methods, and a tutorial on

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[1]http://www.myren.net.my/
[2]http://pinger.unimas.my/pinger/
[3]http://www-iepm.slac.stanford.edu/pinger/
[4]http://maggie.seecs.nust.edu.pk/
[5]http://pinger.fnal.gov/
[6]http://sdu.ictp.it/pinger/
[7]https://www.um.edu.my/
[8]http://www.unimas.my/
[9]http://www.utm.my/

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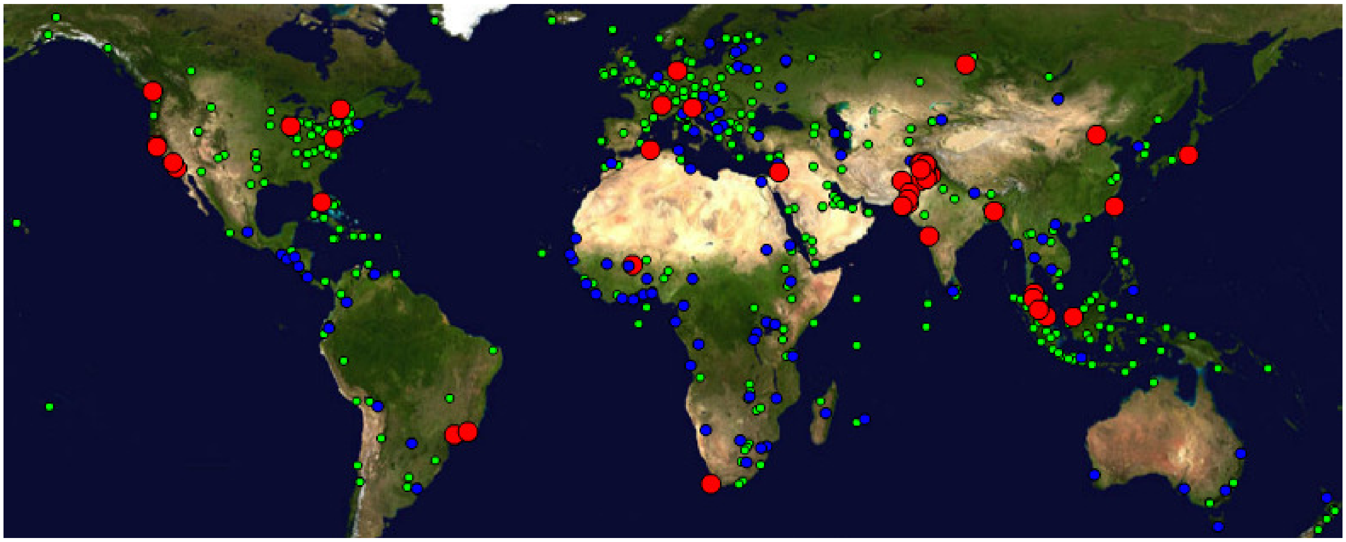

Fig. 1. Locations of PingER MAs and remote sites as of June 2015. Red sites are MAs, blue sites are beacons that are monitored by most MAs, and green sites are remote sites that are monitored by one or more MAs.

TABLE I
PINGER MONITORED COUNTRIES AND POPULATIONS BY REGION [9]

Region	No. of countries	Population of the region (Millions)	% of world population
Africa	50	988	14.57
Balkans	10	69	1.02
Central Asia	9	80	1.18
East Asia	4	1534	22.62
Europe	31	527	7.76
Latin America	21	557	8.21
Middle East	13	226	3.33
North America	3	342	5.05
Oceania	4	33	0.49
Russia	1	142	2.09
S.E. Asia	11	578	8.52
South Asia	8	1585	23.37
Total	165	6660	98.21

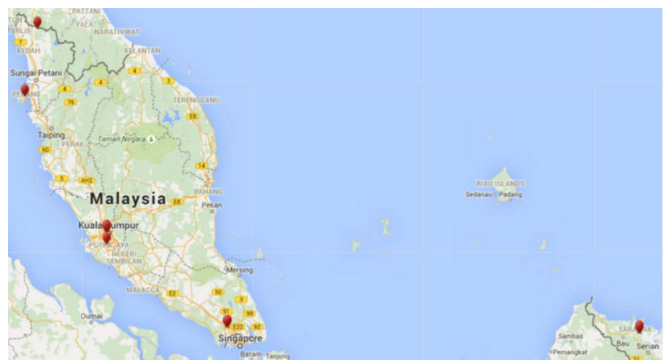

Fig. 2. PingER MAs in Malaysia

the derivation and meaning of the metrics are available online [8]. Table 1 highlights the number of countries monitored in each of these regions, and the distribution of population in these regions.

III. METHODOLOGY: PINGER-MALAYSIA

The PingER installations in MYREN consist of four PingER MAs at UNIMAS, UTM, UM, and UUM. In addition, since February 2015, there are five MYREN administered MAs at UNIMAS, UM, UTM, USM and MYREN itself. Table II lists the MAs in Malaysia and are shown in red in Fig. 2. In addition, there are 27 monitored remote sites in Malaysia and 94 in S. E. Asia that are shown in Fig. 3. Similarly, Table III indicates the number of pairs of Malaysian MA remote hosts, and remote hosts per S. E. Asian country starting from 2012 and onwards.

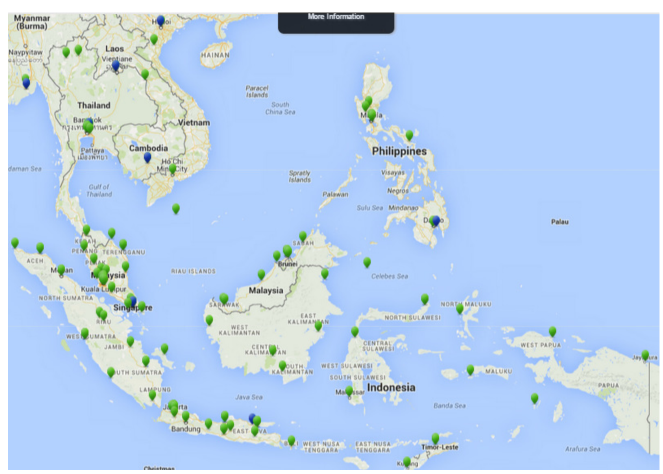

Fig. 3. PingER beacon (blue) and remote nodes (green) in S. E. Asia

TABLE II
MONITORING SITES IN MALAYSIA

Organization	Node Name	IP Address	City	Latitude	Longitude
UNIMAS	pinger.unimas.my	49.50.236.98	Kota Samarahan, Sarawak	1.4696	110.4280
MYREN-UNIMAS	perfsonar-unimas.myren.net.my	203.80.20.254	Kota Samarahan, Sarawak	1.4696	110.4280
UTM	pinger.fsksm.utm.my	161.139.146.158	Skudai, Johor	1.5592	103.6414
MYREN-UTM	pingersonar-utm.myren.net.my	203.80.20.244	Skudai, Johor	1.5592	103.6414
MYREN-Cyberjaya	perfsonar.myren.net.my	203.80.20.66	203.80.20.66	2.923629	101.656189
UM	pinger.fsktm.um.edu.my	202.185.107.238	Wilayah Persekutuan, Kuala Lumpur	3.122521	101.65366
MYREN-UM	pingersonar-um.myren.net.my	203.80.20.221	Wilayah Persekutuan, Kuala Lumpur	3.122521	101.65366
UUM	pinger.uum.edu.my	103.5.183.14	Sintok	6.4612	100.5043
USM[10]	pingersonar-usm.myren.net.my	203.80.20.228	Gelugor, Pulau Pinang	5.3569	100.3014

TABLE III
NUMBER OF PAIRS OF MALAYSIAN MA REMOTE HOSTS, AND REMOTE HOSTS PER S. E. ASIAN COUNTRY

Pairs (remote hosts)	2012	2013	2014	2015
Malaysia	18(18)	88(24)	162(25)	192(22)
Brunei	2(2)	11(2)	19(5)	33(5)
Cambodia	0(0)	1(1)	8(1)	13(1)
Indonesia	8(8)	73(7)	149(38)	212(37)
Laos	0(0)	0(0)	8(1)	9(1)
Singapore	3(3)	13(3)	32(7)	46(7)
Vietnam	0(0)	2(2)	13(3)	19(3)
Thailand	3(3)	18(3)	40(10)	57(9)
Myanmar	0(0)	0(0)	9(2)	14(2)
Phillippines	2(2)	14(2)	33(8)	40(7)

IV. RESULTS AND DISCUSSION

A. Packet loss observed from SLAC to the Malaysian monitoring hosts

Originally the quality threshold levels for packet loss were set at 0-1% = good, 1-5% = acceptable, 5-12% = poor, and greater than 12% = bad. More recently, the threshold levels are refined to 0-0.1% excellent, 0.1-1% = good, 1-2.5% = acceptable, 2.5-5% = poor, 5%-12% = very poor, and greater than 12% = bad. This change in the thresholds values reflects the changes in emphasis from email and ftp services in the mid 1990s to VoIP, X-window applications, web performance, and packet video conferencing traffic from 2005. As a rule, packet loss in VoIP should never exceed 1 percent, which essentially means one voice skip every three minutes. Digital Signal Processing (DSP) algorithms may compensate for up to 30 ms of missing data; any more than this, and missing audio will be noticeable to listeners. Packet losses are usually independent of the distances between the sites since they typically occur at the edges of the network. Fig. 4 summarizes the losses as seen from SLAC to hosts at the Malaysian MA sites. They are shown on a log scale since there is a wide range of losses. It is seen that in general the two hosts at a given site track one another. UNIMAS and UTM shows acceptable results as losses are typically less than 0.5%. However, in the case of UM the losses for the last two years have been consistently higher (several times) and typically well over 1%.

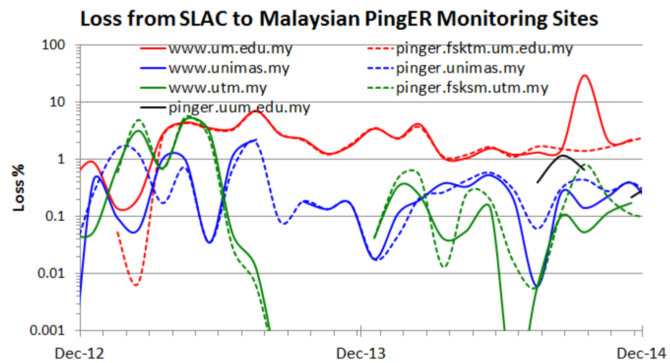

Fig. 4. Packet loss observed from SLAC to the Malaysian monitoring sites

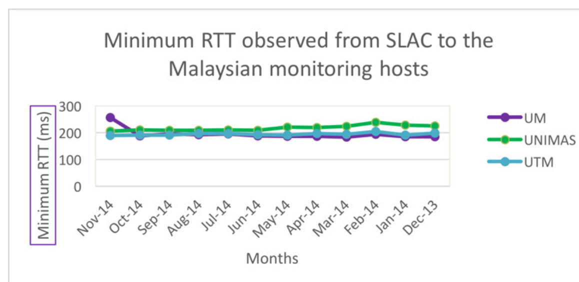

Fig. 5. Minimum RTT observed from SLAC to the Malaysian monitoring hosts

B. Minimum RTT observed from SLAC to the Malaysian monitoring hosts

The minimum RTT observed from SLAC to the Malaysian monitoring hosts is seen to be typically between 200 ms and 250 ms as shown Fig. 5. RTT measurements are influenced by the distances between the sites. The distance between SLAC and Malaysia is about 13,000 km. The minimum RTT delay over a fibre following a great-circle route is 100 km/ms. This yields 130 ms for 13,000 km. The minimum is often exceeded by factors (we refer to this factor as the Directivity, see Section IV-D) of 2 or more due to indirect routing of the cable paths. The median Directivity seen from SLAC to Malaysia is ~0.7 with an Inter Quartile Range of 0.07. This high Directivity is since the path from SLAC to Malaysia crosses fairly directly across the Pacific.

It should be noted that in Fig. 5, the minimum RTT of UNIMAS is larger compared to UM and UTM when observed from SLAC. This is because UNIMAS is located in Kuching n

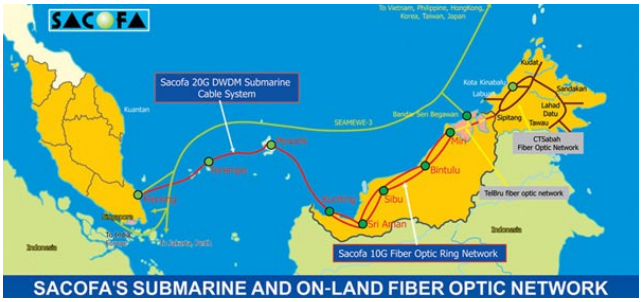

Fig. 6. Submarine cable from Mersing (West Malaysia) to Kuching (East Malaysia)

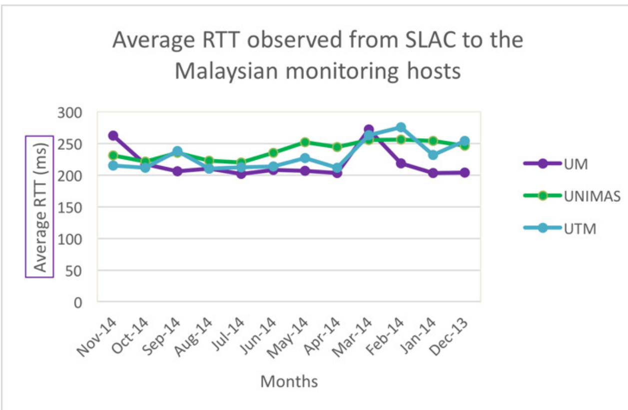

Fig. 7. Average RTT observed from SLAC to the Malaysian monitoring hosts

(East Malaysia) about 1100 km from Kuala Lumpur. The connection from SLAC goes via Singapore and Cyberjaya (near Kuala Lumpur) and then doubles back through a submarine cable from Mersing (300 km from Kuala Lumpur) to Kuching (888 km route length) as shown in Fig. 6. Thus, it causes a delay of 11 ms (1 ms in 100 km) as compared to UM which is in accordance with the results shown in Fig. 5.

C. Average RTT observed from SLAC to the Malaysian monitoring hosts

The average RTT of UNIMAS is also higher as compared to UM and UTM as shown in Fig. 7. This is due to the indirect longer route present between SLAC and UNIMAS described above. It is also seen that the variability of the average RTT(Fig. 7) is greater than that of the minimum RTTs (Fig. 5) due to the effect of queueing.

D. Directivity observed from SLAC to Malaysian monitoring hosts

This is a metric to identify the directness of the connection between 2 nodes at known locations. Directivity values close to one mean the path between the hosts follows close to a great circle route. Values much smaller than 1 mean the path is very indirect. Values greater than one are impossible and indicate an error (typically the location of one or both of the end-points, or a proxy more closely located hosts is responding to the ping). The Directivity observed from SLAC to Malaysian MAs as shown in Fig. 8.

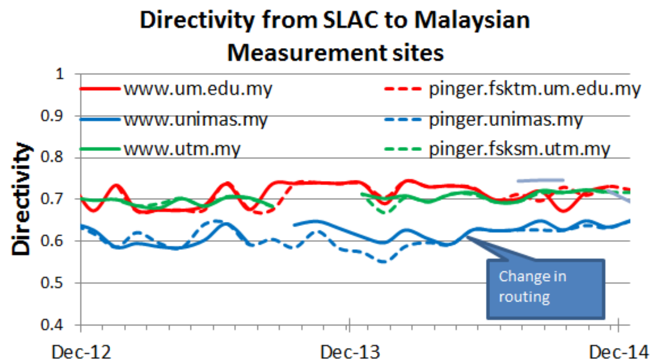

Fig. 8. Directivity observed from SLAC to the Malaysian monitoring hosts

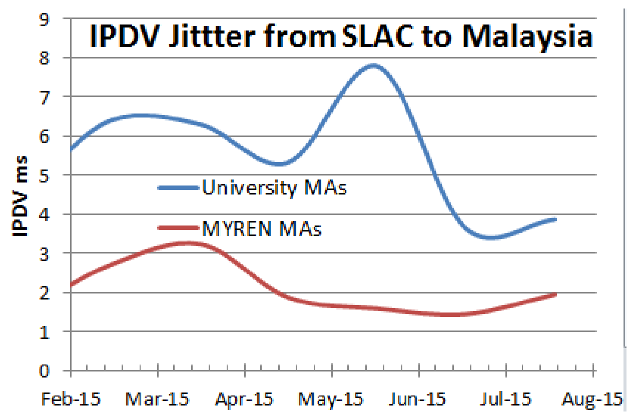

Fig. 9. IPDV jitter for Malaysian University administered MAs versus MYREN administered MAs

Directivity values of UM are higher as compared to UTM and UNIMAS. This is because UM is connected directly to the MYREN KL Point of Presence (PoP) located in UM. On the other hand, UNIMAS is connected to the same KL PoP located in UM, through a submarine cable network between East and West Malaysia of MYREN with a link speed of only 10 Mbps. Therefore, UNIMAS directivity values are lower as compared to UM.

E. Jitter

The short-term variability or jitter of the response time is very important for real-time applications such as telephony. Web browsing and mail are fairly resistant to jitter, but any kind of streaming media (voice, video, music) is quite susceptible to jitter. Jitter is a symptom that there is congestion, or not enough bandwidth to handle the traffic. PingER estimates the jitter by calculating the Inter Packet Delay Variability (IPDV)[11]. When we compare the jitter seen by the University managed PingER MAs with those of the MYREN managed MAs, there is a significant difference (Fig. 9). The averages of the two time series differ by $\sim$2 standard deviations. Since today, jitter is mainly incurred at the network edges, part of the difference is probably due to the extra hop(s) that each University's MA traverses at its edge site.

[11] http://www.slac.stanford.edu/comp/net/wan-mon/tutorial.html#variable

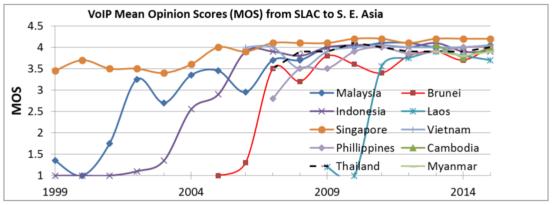

Fig. 10. Mean Opinion Score observed from SLAC to S. E. Asia

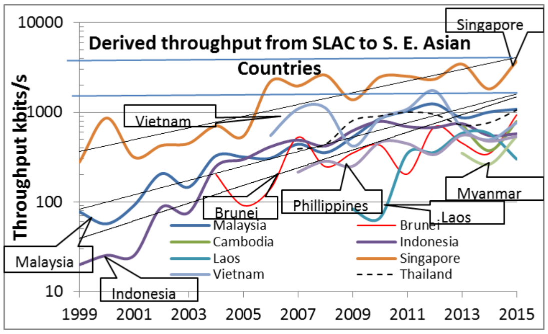

Fig. 11. PingER derived throughput from SLAC to S. E. Asian countries since 1999

F. Mean Opinion Score observed from SLAC to the Malaysian monitoring hosts

The Mean Opinion Score (MOS) is a voice quality metric. The values of the MOS are: 1= bad; 2=poor; 3=fair; 4=good; 5=excellent. A typical range of MOS for Voice over IP is 3.5 to 4.2. In reality, even a perfect connection is impacted by the compression algorithms of the codec, so the highest score most codecs can achieve is in the 4.2 to 4.4 range. The MOS is derived from the RTT, Loss and Jitter. The MOS seen from SLAC to S. E. Asian countries is shown in Fig. 10. It is seen that by 2011 all the countries consistently achieved MOS of $\geq$ the threshold of 3.5, that Singapore consistently has the best performance, and that Malaysia achieved $>$ the threshold in 2007.

G. Derived throughput observed from SLAC to the S. E. Asian countries

PingER derives the TCP throughput using the Mathis formula [10] relating TCP throughput to loss and RTT. Fig. 11 indicates the derived throughput from SLAC to S. E. Asian countries since 1999. Note that y axis is logarithmic, hence a straight line is equivalent to an exponential increase. For Malaysia, the improvement is about a factor of 10 in 14 years. After Singapore, Malaysia was the leading country in S.E. Asia in TCP performance in August of 2015.

Fig. 12 shows the derived throughput from Malaysian MAs to hosts in S. E. Asia for the last 4 years. It is seen that throughputs from Malaysia: to Singapore and Malaysia are now almost a factor of 5 times greater than the other countries; Singapore, Malaysia, Cambodia and Vietnam have improved by roughly a factor of 5; and to Brunei, Indonesia, Myanmar, Laos and the Philippines they have stayed fairly stable.

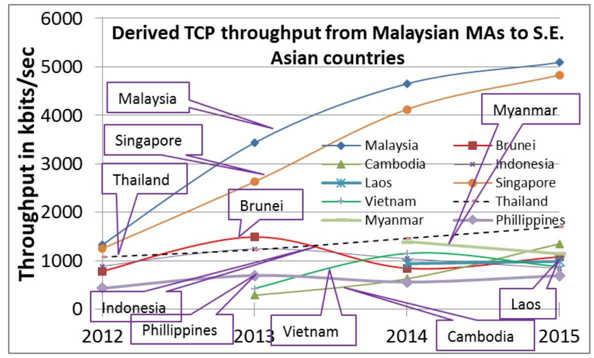

Fig. 12. Derived TCP throughputs from Malaysian MAs to S.E. Asian Countries since 2012

V. Conclusion

Our PingER-Malaysia measurements conclude the following:

1) UM has larger packet losses than the other Malaysian MAs. For 2015, this has resulted in UM having the lowest (2/3 of the next host) TCP throughput of any Malaysian host as seen from SLAC. Similarly, UM is followed by Universiti Pertahanan Nasional Malaysia (UPNM)[12] in Kuala Lumpur, Universiti Putra Malaysia (UPM)[13] in Serdang, Selangor and PingER-UNIMAS[14] in Kuching, Sarawak. Thus, UM and UPM are candidates for investigating the cause and making improvements.
2) The route between SLAC in the US and Malaysia is very direct (high Directivity $>$ 0.5) going directly across the Pacific to Tokyo, then to Singapore and Kuala Lumpur. Even though UNIMAS is closer to the US, as measured by a great circle route, it has a longer minimum RTT since the route goes via Kuala Lumpur.
3) The MYREN administered MAs have significantly lower jitter than the University administered MAs at the same sites, due to their closer proximity (one or two hops) to the Internet backbone.
4) For the last 3 years, Internet connectivity has been good enough to support VoIP for S. E. Asian countries. Internet performance in terms of TCP through put has improved by roughly a factor of 10 in 12 years for most S. E. Asian countries. Among the S. E. Asian countries, Singapore stands out as having the best TCP throughput and VoIP performance. It is followed by Malaysia and Thailand with about three times less throughput.

Thus, the above findings conclude that the PingER-Malaysia provides a real time picture of the Internet performance within the region based on the historical reports which can be used for upgrading the capacity of the network.

[12]www.upnm.edu.my
[13]www.upm.edu.my
[14]http://pinger.unimas.my

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