In and Out of Cuba

Characterizing Cuba's Connectivity

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ABSTRACT

The goal of our work is to characterize the current state of Cuba's access to the wider Internet. This work is motivated by recent improvements in connectivity to the island and the growing commercial interest following the ease of restrictions on travel and trade with the US. In this paper, we profile Cuba's networks, their connections to the rest of the world, and the routes of international traffic going to and from the island. Despite the addition of the ALBA-1 submarine cable, we find that round trip times to websites hosted off the island remain very high; pings to popular websites frequently took over 300 ms. We also find a high degree of path asymmetry in traffic to/from Cuba. Specifically, in our analysis we find that traffic going out of Cuba typically travels through the ALBA-1 cable, but, surprisingly, traffic on the reverse path often traverses high-latency satellite links, adding over 200 ms to round trip times. Last, we analyze queries to public DNS servers and SSL certificate requests to characterize the availability of network services in Cuba.

Categories and Subject Descriptors

C.2.4 [**Computer Communication Networks**]: [Network Protocols]; C.4 [**Performance of Systems**]: [Measurement techniques]

Keywords

Developing countries; Measurement; Performance; Satellite

1. INTRODUCTION

It may have taken 54 years, but change is coming to Cuba. Last December, the US government announced plans to restore relations with Cuba and ease restrictions on travel and trade. It took little time for American businesses – from the obvious tourist sector to telephony and video streaming services – to start scouting opportunities. In February, IDT Corp reached an agreement with the Empresa de Telecomunicaciones de Cuba, S.A. (ETECSA) to provide direct international long distance telephony between the USA and Cuba [16]. The same month, Netflix announced their plan to offer their video streaming service and two months later Airbnb brought their sharing economy to the island [3].

Despite the promising news, the state of Cuban infrastructure, particularly in the computing and network segment, pose no small challenges to these plans. Today, less than 5% of the population have their own fixed-line Internet connection [18] and only an estimated 25% of the population are able to get online [9]. Those that are actually connected experience very poor performance. Ookla's NetIndex, for instance, ranks Cuba among the *worst ten countries* in terms of average bandwidth – 197th out of 202 – with a measured broadband download speed of 1.67 Mbps. An even bigger barrier to Internet access is cost with services that are prohibitively expensive for much of the population. While the average monthly income in Cuba is around $20 a month, paying by the hour at an Internet cafe can cost about $5 per hour [19]. A broadband subscription is even more expensive with private subscription plans costing about 386% of the gross national income per capita [6].

Recent years have brought some progress in connecting Cubans to the rest of the Internet and the recent commercial interest may help speed up the process. In February of 2011, Cuba completed its first undersea fiber-optic cable, ALBA-1 (640 Gbps), with landings in Jamaica and Venezuela. The US government has also set the promotion of Internet access in the island as one of their top priorities [17] and the US Department of Defense stated plans to build a submarine cable between Florida and the Guantanamo Bay Naval Base in Cuba and to eventually extend it to the rest of Cuba [15].

Our goal is to characterize the current state of Cuba's access to the wider Internet. We collected and analyzed two months of measurements (March and April of 2015) with probes going in and out of Cuba launched from 50 RIPE Atlas [13] nodes and our 6,000 Namehelp [12] clients. Our analysis validates some of the anecdotal evidence on the limited connectivity of the island. Though bandwidth capacity to the country is severely limited, we find that end-to-end latency is a key bottleneck in international network traffic with a large number of paths traversing high-latency satellite links despite the availability of ALBA-1. Interestingly, we find that many of the high RTT measurements are linked to high degrees of path asymmetry in traffic to/from Cuba. Specifically, most traffic going out of Cuba travels through the ALBA-1 submarine cable,

IMC'15, October 28–30, 2015, Tokyo, Japan.

ACM 978-1-4503-3848-6/15/10 ...$15.00.
DOI: http://dx.doi.org/10.1145/2815675.2815718.

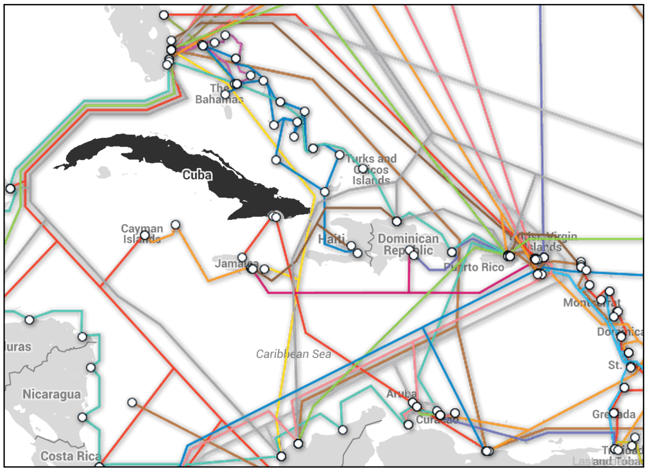


Figure 1: Map of submarine cables in the Caribbean. (Source: `http://www.submarinecablemap.com/`)

but on the reverse path, responses often traverse satellite links, typically adding over 200 ms of additional end-to-end latency. We also survey a number of popular network services, such as public DNS and web services, checking their availability in Cuba, finding that some services appear to be blocking users in the island.

The rest of the paper is organized as follows. In Sec. 2 we discuss the state of Internet connectivity in Cuba. Section 3 describes the datasets that we use for our analysis. We then discuss the domestic and international connectivity of Cuba's networks in Sec. 4 and look at how routing through these connections affects performance in Sec. 5. In Sec. 6, we discuss our preliminary findings on the availability of network services in Cuba before concluding in Sec. 7.

2. BACKGROUND

Although Cubans have been able to legally acquire a computer since 2008 [8], getting access to the Internet has remained a challenge. Network availability has been problematic for such a long time that several makeshift "offline Internets" have appeared, with individuals and companies sharing or selling content downloaded from the Internet (e.g., films, TV shows, magazines, news articles, or applications) via USB flash drives or CDs – a popular service known as "El paquete" [18].

Things have been changing, if slowly. In early 2011, Alcatel-Lucent began work on a submarine fiber-optic cable, named ALBA-1, with landing points in Ocho Rios, Jamaica; Siboney, Cuba; and La Guaira, Venezuela [1]. Estimates suggested that this link would increase capacity to the island by a factor of 3,000.

Prior to this, all traffic was routed to and from the island via satellite links. These satellites are located in geosynchronous orbit, at a distance of about 36,000 km from the equator. Sending a single packet from the Earth's surface to the satellite and back to Earth takes approximately $2 \times 36,000\ km/c = 240\ ms$ where c is the speed of light. Traversing a satellite link on both the forward and reverse path would add approximately 480 ms to RTT measurements.

The ALBA-1 cable was not actually activated until two years later, in January 2013 [11]. Even after the addition of ALBA-1, Cuba's connectivity to the rest of the Internet remains relatively poor, even compared to other Caribbean islands. Figure 1 shows a map of the submarine cables in the region. Despite the large number of cables in the surrounding area, Cuba is one of the least connected countries in the region, with a number of submarine cables detouring around the island in order to reach their destination.

Affordability remains a problem, with a broadband subscription costing close to 4x the gross national income per capita [6], but in March of 2015, the Cuban government approved the first public Wi-Fi hub in Havana [2] potentially improving citizens' (and visitors') access to the Internet.

3. DATASETS

To characterize the current state of Cuba's connections to the rest of the Internet we collected measurements over a two month period (March and April, 2015). Probes going in and out of Cuba were launched from RIPE Atlas [13] nodes and our Namehelp [12] clients. The following paragraphs describe our datasets in more detail.

RIPE Atlas probes. The RIPE Atlas data was collected from approximately 50 probes across North and South America. One probe was located in Cuba (the only available one) and approximately half of rest were located on other islands throughout the Caribbean, including the Dominican Republic, Jamaica, Puerto Rico, Saint Barthélemy, Saint Kitts and Nevis, Guadeloupe, Trinidad and Tobago, Martinique, and Grenada. The rest of the probes were located in the US, Mexico, Venezuela, and Brazil. Most of our analysis in this paper focuses on the measurements collected from the Atlas probe located in Havana, Cuba.

The RIPE Atlas API allows us to schedule ping and traceroute measurements, issue DNS queries, and fetch SSL certificates on each of these nodes. We measured the routes between each vantage point by running traceroutes between all pairs of our selected RIPE Atlas probes. Additionally, the RIPE Atlas probe in Cuba ran traceroute measurements to every Namehelp endhost. To test the availability of network services in Cuba, we had the Atlas probe in Havana fetch SSL certificates for popular websites that supported HTTPS. We also measured DNS performance to the probes' configured DNS server and to a number of public DNS services. We compared the results of these tests to other requests issued simultaneously from the other 49 Atlas probes. These measurements are discussed in greater detail in Sec. 6.

Namehelp clients. In addition to the RIPE Atlas data, we also leveraged 6,000 endhosts running Namehelp, with presence in over 600 networks across 78 countries. Namehelp is a tool based on the popular DNS benchmark utility, *namebench*, that aims to both provide a comparative evaluation of DNS services and act as a DNS proxy to improve CDN mappings. [1]

Namehelp is also able to conduct controlled network measurements, such as `ping`, `traceroute`, or `wget`. For this dataset, Namehelp clients ran hourly traceroute measurements to prefixes located in Cuba. While running these traceroutes, Namehelp did not run any other network measurements simultaneously. By combining this data with

[1] http://aqualab.cs.northwestern.edu/projects/namehelp

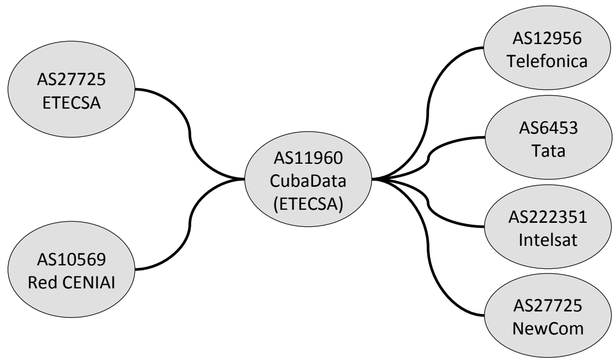


Figure 2: AS map of Cuba's networks and their connections.

Autonomous System	# of IPv4 prefixes	# of IPv6 prefixes
AS11960 CubaData (ETECSA)	2	1
AS27725 ETECSA	20	0
AS10569 Red CENIAI	1	1

Table 1: Number of IPv4 and IPv6 prefixes in each Cuban network.

the traceroute measurements of the Atlas probe in Havana, we were able to construct the forward and reverse path between Namehelp users and this Atlas probe.

4. CONNECTIVITY

In this section, we briefly describe the structure of Cuba's networks and its connectivity to the global Internet. According to Prefix WhoIs, there are a total of three Autonomous Systems (ASes) in Cuba, two of which (AS11960 and AS27725) are operated by ETECSA, a government-owned telecommunications service provider. The third AS (AS10569) is operated by Centro de Intercambio Automatizado de Informacion (CENIAI). All international traffic to and from the island flows through AS11960. Table 1 lists the number of IPv4 and IPv6 prefixes in each of the Cuban ASes.

Using the traceroute measurements launched from Namehelp clients targeting each prefix in Cuba [4, 5], we created the AS map in Figure 2, which describes how these three networks are connected to each other and to the rest of the Internet (via the four ASes listed on the right side of the diagram). Before reaching Cuba, all of our traceroute measurements traversed one of four networks: Tata's, Telefonica's, NewCom's, or the Intelsat's network. Traffic that travels through Tata's (AS6453) or Telefonica's (AS12956) networks appears to travel to Cuba via the ALBA-1 submarine cable as it leaves those networks. Paths that reach Cuba via Intelsat's (AS222351) or Newcom's (AS27725) networks are reaching the island via satellite.

In AS11960, we found that one of the IPv4 prefixes (200.13.144.0/21) hosts a small number of domains, including cubacel.cu, a website for ETECSA. The remaining IPv4 and IPv6 prefixes are part of the Cuban Internet Exchange Point (IXP). All of our measurements into and out of Cuba flow through this IXP.

In AS27725, a number of prefixes are assigned to governmental and educational organizations. After analyzing traceroutes from Namehelp users to the island, we found that of the 20 IPv4 prefixes in AS27725, 15 of the prefixes appeared to be consistently routed over the ALBA-1 cable on both the forward and reverse paths. Looking at the forward paths going into Cuba, it is clear that traceroutes to these prefixes did not travel through either Intelsat's or NewCom's networks (satellite link). Considering that the end-to-end RTT was always less than 200 ms, it is also clear that the reverse path did not traverse the satellite link as this would have added over 230 ms.

The five remaining prefixes were frequently routed asymmetrically; traffic traveling out of the country went through the ALBA-1 cable into either Tata's or Telefonica's network, while incoming traffic was, in the majority of cases, routed through one of the satellite networks.

Using a list of popular Cuban websites [7], we also looked at where websites under the .cu TLD were hosted geographically. Of the websites ending with .cu that we were able to successfully resolve, about 80% were located in the island. Cuban websites that were located outside of Cuba were typically in the US, France, Venezuela, or Canada. Of the listed websites that were hosted in Cuba, about 60% were located in a single prefix, 190.91.112.0/20. Domains that were hosted in other Cuban prefixes were typically government websites, in the prefix assigned to the respective government organization.

5. PERFORMANCE

With an understanding of the island connectivity, we now look at how the routing of international traffic to and from Cuba affects end-to-end RTT performance. We start by looking at individual cases where asymmetry is causing a significant increase in RTT, before discussing how frequently this issue occurs across all measurements in our global dataset.

5.1 Case studies

As we mentioned in the previous section, we found a high degree of path asymmetry in Cuban international traffic. Unfortunately, since there is only one available probe in Cuba, we are only able to verify the outgoing path from a single prefix. However, based on RTT measurements, this asymmetry appears to apply to the prefixes that route incoming traffic via the satellite networks.

We compute the AS path for each traceroute in our dataset using the methodology presented in Chen et. al. [5]. We then match traceroutes with opposite source and destination IP address to get the forward and reverse path and calculate the asymmetry of the path [10, 14].

Figure 3 shows one example of path asymmetry to/from Cuba. In this case, traceroutes were run simultaneously by Atlas nodes in Havana, Cuba and Miami, Florida (in NTT's network), with each node targeting the other.

We start with the traceroute launched by the Atlas node in Cuba, shown on the top half of Figure 3. RTT measurements to the edge of the Cuban IXP were very low, typically taking less than 3 ms. The first jump in latency occurs as the traceroute leaves AS12956 and enters Telefonica's transit network. Though we were unable to verify the exact location of this hop, we believe that it likely located in Venezuela; the only other landing of the ALBA-1 submarine is located in Jamaica and is reportedly intended to be a backup. The next hop is still in Telefonica's network, but there is another

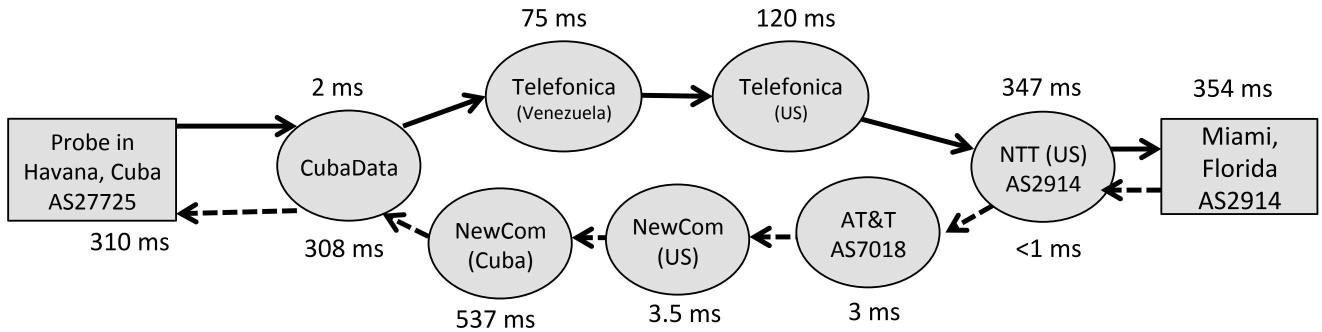


Figure 3: Forward and reverse paths between RIPE Atlas nodes in Havana, Cuba and Miami, Florida. The solid arrows and latency measurements on the top of the figure represent the forward path (Cuba to US) while the dotted arrow and latency measurements on the bottom are from the reverse path (US to Cuba). The numbers above and below each network represent the RTT to each hop. Note that hops with similar RTTs in the same AS have been omitted. As a result, the diagram is not representative of the total number of end-to-end hops.

significant jump in RTT. Based on traceroute measurements to this router's IP address from Atlas probes in the US, this hop appears to be near Washington DC; the Atlas probe with the shortest latency to this probe (less than 1 ms) was located in the DC metropolitan area.

Once the traceroute from Cuba to Miami had a high enough TTL to reach a router in NTT's network, RTT suddenly increases by over 200 ms. Based on the router's hostname, the router is located near Ashburn, Virginia, and is likely within 60 km of the previous hop. In fact, once the TTL was high enough to leave Telefonica's network, RTT was never below 345 ms.

The reason for this sudden jump in latency becomes clear when examining the reverse path. The dashed arrows and RTTs on the bottom of Figure 3 summarize the output of the traceroute initiated by the probe in NTT's network. Instead of routing through Telefonica's network, probes from the Atlas node in Miami are being routed to Cuba via AT&T's transit network to NewCom's network, traversing the satellite link to the island. Interestingly, the RTT actually reaches its highest point once the path arrives at the NewCom's base station in Cuba. At this point, packets must travel over the satellite link in both directions (which must take at least 477 ms). Once the TTL is high enough to reach the Cuban network, RTT drops by over 200 ms, as the traceroute responses are now returning via the submarine cable.

Although this example only covers a single forward and reverse path between Atlas probes in Cuba and Florida, the sudden jumps in latency and path asymmetry were both common when measuring between Cuba and the US. In our analysis of paths between the Atlas node in Cuba and Namehelp users in the US, we found that all paths going out of Cuba traversed the submarine cable and 92% of paths going into Cuba traversed a satellite link.

This issue also appeared frequently on paths to popular websites. Figure 4 summarizes the path of a traceroute from the Atlas probe in Cuba to google.com. Despite the fact that we were unable to run traceroutes along the reverse path (from Google's network to Cuba), the forward path is very similar to the example in Figure 3; after leaving Telefonica's network, latency suddenly jumps by 220 ms.

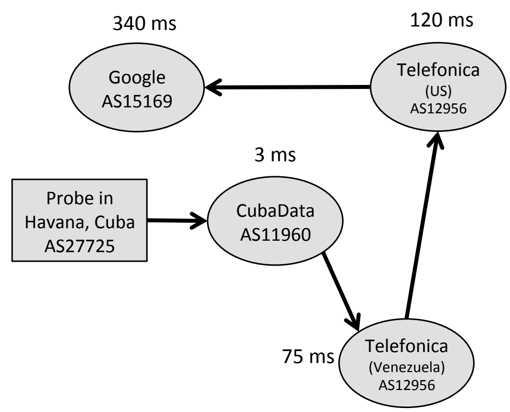
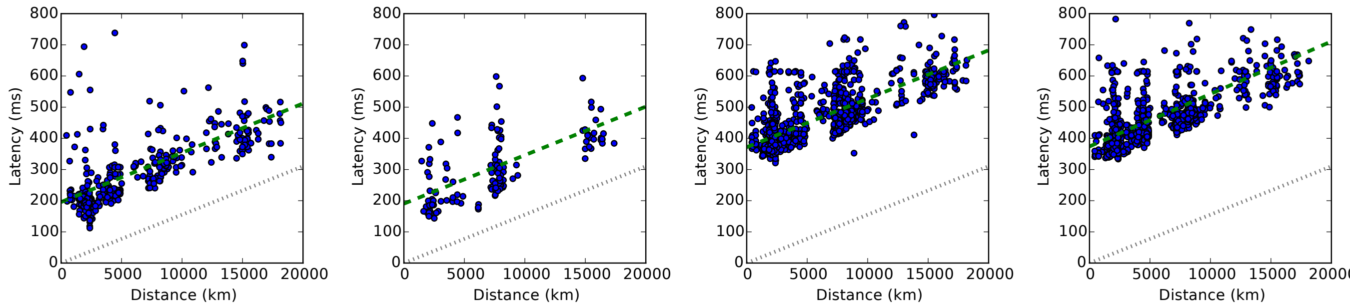


Figure 4: Traceroute from Atlas probe in Cuba to google.com. The latencies represent the RTT at each hop. Hops with similar RTT in the same AS have been omitted.

Based on the hostname of the Google server targeted by the Atlas node in Cuba, the server appeared to be located near Dallas-Fort Worth, Texas. Ping measurements from Atlas probes in the DC area (near the last hop in Telefonica's network) to the same Google server took less than 35 ms. However, between Telefonica's network and the destination, RTT increases by 220 ms. Given the similarity to the previous example, we believe that this sudden increase is also a result of the reverse path being routed to Cuba via a high latency satellite link. We observed this same trend for all of the other top sites included in our tests (i.e., Yahoo, Wikipedia, Facebook, Twitter, and Reddit).

5.2 Wider impact

We now summarize the paths between our population of Namehelp users and the Atlas probe in Cuba. Using the Atlas node in Havana, we launched traceroutes targeting



(a) Tata (AS6453)
$y = 0.0158x + 196$

(b) Telefonica (AS12956)
$y = 0.0156x + 190$

(c) Intelsat (AS22351)
$y = 0.0155x + 372$

(d) NewCom (AS32034)
$y = 0.0168x + 374$

Figure 5: RTT from Namehelp users to prefixes in Cuba by distance. Paths are split across figures based on the network immediately prior to CubaData (AS11960). Traffic through Tata's and Telefonica's network reach Cuba via the ALBA-1 submarine cable while IntelSat and NewCom use satellite connections. The equation below each figure represents the linear regression between distance and RTT.

each Namehelp user in our dataset. We found that all traceroutes launched by this probe and targeting the IPs of Namehelp users would leave the country via either Tata's and Telefonica's network, avoiding the high-latency satellite connections.

However, the reverse path (going into Cuba) was not as consistent. For each traceroute measurement from Namehelp, we identified the last AS hop that appeared before entering the Cuban IXP network (AS11960). We then calculated the approximate distance between the Namehelp user and the Atlas node using MaxMind's GeoIP database to map users' IP addresses to geographic locations. Finally, we grouped measurements according to the last AS seen before entering Cuba.

Figure 5 shows the relationship between RTT and distance, grouped by the last AS before entering Cuba. The gray dotted line represents the RTT of light moving through a cable of length x (assuming that light is moving through the medium at $c/2$). The green dashed line represents the linear regression between distance and latency for each group of vantage points. Below each figure, we also include the equation of the linear regression. We find that the slope of the linear regression of measurements that travel through satellite networks is similar to that of the measurements traversing the submarine cable, but is approximately 180 ms higher.

Despite the fact that approximately 40% of the Earth's surface should be able to communicate directly with satellites in geostationary orbit, we were unable to find any satellite base stations outside of North America in either of the satellite networks. As a result, packets headed to Cuba had to first be routed to North America and *then* to Cuba over a satellite connection.

For example, packets originating in Europe had to first traverse an intercontinental submarine cable before traversing a satellite link, even though some countries should be within the satellite's serviceable area. The slopes of the linear regression lines are thus roughly consistent across each group of users, and similar to the slope of the estimated speed of light through a fiber cable. The difference in the y-intercept of the regression lines in Figs. 5a and 5b when compared to Figs. 5c and 5d is a result of traversing a satellite link.

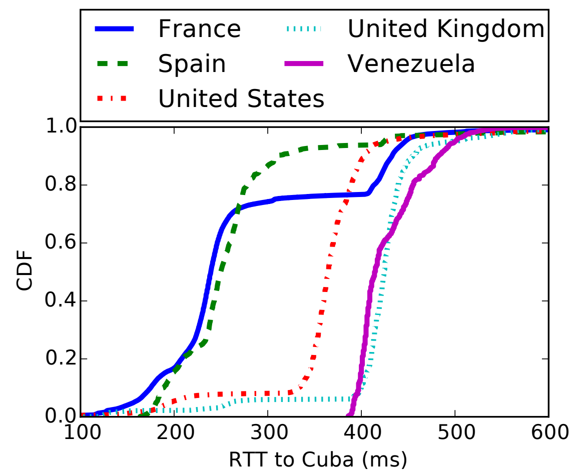


Figure 6: CDFs of the RTT to Cuba, as measured by users in each country.

We also looked for trends between the origin of the traceroute measurement and which network was used to reach Cuba. We found that RTT could vary widely between countries, even those in the same region, due to differences in routing. In some cases, vantage points that were in countries much further away from Cuba (e.g., in Europe) would have significantly lower RTTs than those in North and South America.

Figure 6 shows the CDF of RTTs for users in France, Spain, the US, the UK, and Venezuela. Latency measurements from Namehelp users in France and Spain had the lowest median latencies of all subpopulations in our dataset, nearly half that of the median latency of users in the UK. Despite the fact that users in the US and Venezuela are much closer to Cuba, their RTTs were much higher. This difference is due to the fact that most users in France and Spain are routed to Cuba through Telefonica's transit network, and were sent via the ALBA-1 submarine cable instead of satellite networks. In total, 77% of routes to Cuba from France and 94% of routes from Spain were routed over the ALBA-1 submarine cable in both directions.

In contrast to previously reported networking performance issues in developing countries, such as Ghana [20] and Zambia [21], Cuba presents an interesting case in that at least part of the performance issues can be attributed to asymmetric routing and could be addressed via changes to routing policy.

6. NETWORK SERVICE AVAILABILITY

We also survey a number of popular network services and websites, checking their availability in Cuba. To test website availability, we issued SSL certificate requests from our set of 50 Atlas probes in North and South America to 4,434 domains supporting HTTPS from the top 10,000 most popular websites.[2] While we would have liked to test the availability of any website, the RIPE Atlas API does not support general HTTP tests. For every site, if the request succeeded (replied with a valid certificate), we removed it from our list. If the request failed, we tried four more times before labeling the site as "unavailable". The experiment ran between August 31st and September 4th, 2015.

We found that, while most of the sites replied with a valid certificate, requests from the Atlas probe in Cuba timed out consistently across all five tests for 111 (2.5%) of sites. Nearly every other Atlas probe was able to successfully retrieve a valid SSL certificate from these domains. Most of the "unavailable" websites in Cuba fall into a few categories, such as finance-related (e.g., paypal.com, bankofamerica.com, capitalone.com, and usbank.com), ad network (e.g., adcash.com, adnetworkperformance.com, and tradeadexchange.com), computer hardware (e.g., dell.com and seagate.com), and adult content. A few of these sites were registered by the same entity but provided different services or different TLDs (e.g., capitalone.com and capitaloneinvesting.com, blizzard.com and battle.net, and the multiple TLDs of cam4.com), hinting at a parent company policy. Table 2 list the percentage of websites per category, along with a few examples.

We also found that many of the same sites we labeled as unavailable in Cuba also timed out when requested from Atlas probes in other US-sanctioned countries. Specifically, 51 of the 111 (46%) domains timed out when requests originated from a probe in Sudan.

Beyond websites, we surveyed the availability of public DNS services in Cuba and found all of those tested to be reachable. A first analysis showed as if some services were unavailable; however, the result was due to the Recursion Desired (RD) flag of the request being unset by default in the Atlas probe while many of the DNS servers are configured to ignore requests with RD unset or respond with an empty answer. We diagnosed the issue by comparing our results with those of dig, which sets RD by default.

7. CONCLUSION

We have started to characterize the state of Cuba's access to the wider Internet. Our work is motivated by recent improvements in connectivity to the island and the growing commercial interest following the ease of restrictions on travel and trade with the US. This paper reports on some of our early findings, including high RTTs to websites hosted off the island, even after the addition of ALBA-1, a high degree of path asymmetry in traffic to/from the island that partially traverse high-latency satellite links, and several web services that return invalid responses to requests originating from the island. We plan to make a periodic status report on the state of the Internet in Cuba and the associated data available to the research community.

[2]As ranked by Alexa `alexa.com`

Acknowledgements

This work was supported in part by the National Science Foundation through Awards CNS 1211375 and CNS 1218287.

8. REFERENCES

[1] Venezuela-Cuba undersea cable link work starts. http://www.bbc.com/news/world-latin-america-12260410, January 2011.

[2] Cuba approves first public wi-fi hub in Havana. http://www.bbc.com/news/technology-31905794, March 2015.

[3] The thrill of the law. *The Economist*, April 11 2015.

[4] Z. S. Bischof, J. S. Otto, and F. E. Bustamante. Distributed Systems and Natural Disasters: BitTorrent As a Global Witness. In *Proc. of CoNEXT SWID*, 2011.

[5] K. Chen, D. R. Choffnes, R. Potharaju, Y. Chen, F. E. Bustamante, D. Pei, and Y. Zhao. Where the sidewalk ends: Extending the Internet AS graph using traceroutes from P2P users. In *Proc. ACM CoNEXT*, 2009.

[6] C. Dewey. In Cuba, connecting to the Internet costs four times the average annual salary. http://www.washingtonpost.com/blogs/worldviews/wp/2013/10/08/in-cuba-connecting-to-the-internet-costs-four-times-the-average-annual-salary/.

[7] DomainTyper. Top websites with .cu. https://domaintyper.com/top-websites/most-popular-websites-with-cu-domain.

[8] M. Frank. Cuba lifts ban on computer and DVD player sales. http://www.reuters.com/article/2008/03/13/us-cuba-reforms-idUSN1329909720080313, March 2008.

[9] ITU. Statistics. http://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx, 2014.

[10] E. Katz-Bassett, H. V. Madhyastha, V. K. Adhikari, C. Scott, J. Sherry, P. Van Wesep, T. Anderson, and A. Krishnamurthy. Reverse traceroute. In *Proc. of USENIX NSDI*, 2010.

[11] D. Madory. Mystery cable activated in Cuba. http://research.dyn.com/2013/01/cuban-mystery-cable-activated/, January 2013.

[12] J. S. Otto, M. A. Sánchez, J. P. Rula, and F. E. Bustamante. Content delivery and the natural evolution of DNS: Remote DNS trends, performance issues and alternative solutions. In *Proc. of IMC*, 2012.

[13] RIPE NCC. RIPE Atlas. http://atlas.ripe.net.

[14] M. A. Sánchez, J. S. Otto, Z. S. Bischof, D. R. Choffnes, F. E. Bustamante, B. Krishnamurthy, and W. Willinger. Dasu: Pushing experiments to the Internet's edge. In *Proc. of USENIX NSDI*, 2013.

Category	Examples	% of sites
Advertising and marketing	adcash.com	11.7
Adult content	xhamster.com	28.9
Communication and social	lovoo.com	2.7
Computers	adobe.com, dell.com, tinyurl.com	15.3
Employment	shine.com	1.8
Financial	paypal.com, citi.com	17.1
Gaming	blizzard.com, secondlife.com	5.4
Online commerce and services	eventbrite.com	8.1
News	moneycontrol.com	5.4
Travel	priceline.com	3.6

Table 2: Percent of websites by category for which SSL certificate requests from Cuba consistently failed.

[15] J. Sutton. U.S. to establish cable link to Guantanamo base in two years. http://in.reuters.com/article/2013/09/20/usa-guantanamo-cable-idINDEE98J0FO20130920, September 2013.

[16] S. Varadhan. IDT Corp to provide long distance telephony between U.S. and Cuba. http://reut.rs/1EZDxFT, February 2015.

[17] K. Vyas. U.S. sets a goal in Cuba: Open Internet. http://www.wsj.com/articles/u-s-sets-a-priority-in-cuba-open-internet-1421792275.

[18] J. Watts. Cuba's 'offline internet': no access, no power, no problem. http://www.theguardian.com/world/2014/dec/23/cuba-offline-internet-weekly-packet-external-hard-drives, December 2014.

[19] S. Wills. Cuba's Internet: It's Bad, But It Might Get Better. http://abcnews.go.com/ABC_Univision/internet-cuba-facts-myths-web-access/story?id=19895951.

[20] Y. Zaki, J. Chen, T. Pötsch, T. Ahmad, and L. Subramanian. Dissecting web latency in ghana. In *Proc. of IMC*, 2014.

[21] M. Zheleva, P. Schmitt, M. Vigil, and E. Belding. The increased bandwidth fallacy: performance and usage in rural Zambia. In *Proc. of ACM DEV*, 2013.