Unintended Consequences: Effects of Submarine Cable Deployment on Internet Routing

By

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Mesh of Submarine Cables, the Backbone of the Internet

Source: Telegeography Submarine Cable Map, [https://www.submarinecablemap.com](https://www.submarinecablemap.com), 2020

- As of early 2020, over 406 cables carry >99% of international traffic [1, 2, 3]
- Little research to isolate end-to-end performance changes induced by their launch

[2] Bischof et al, Submarine Cables and Internet Resiliency, 2018
Launch of SACS on Sept 18, 2018, the First South-Atlantic Cable System

6,165 km
4 fibers
40 Tbits/s


• Angola Cables (AC, AS37468) activated the SACS cable mid-Sept 2018 [4]
• SACS links Fortaleza (Brazil - South America) to Sangano (Angola - Africa) [5]

[5] Madory, D., First Subsea Cable Across South Atlantic Activated, Sep 2018
In the Press

**First Africa–South Americas Fibre Optic Cable Opens for Commercial Traffic**

Staff Writer  26 September 2018

**South Atlantic Cable System goes live – offering lower latencies to the US**

**First Subsea Cable Across South Atlantic Activated**

By Doug Madory, Dyn
September 19, 2018

Angola Cables lights up world’s first submarine cable linking Africa to the Americas

The South Atlantic Cable System (SACS) is ready for operation

September 28, 2018  By: Tanwen Dawn-Hiscox

**7 Reasons Why SACS is a Game Changer**

Winston Qu  SACS  31 October 2018

**Teraco data centres will benefit from SACS cable**

Bradley Prior  14 November 2018
Press Reports Expected Performance Improvements

- Angola Cables (AC) & Oracle Dyn, 2018 [4,5]:

  - Latencies between servers in Brazil and Angola decreased from over 300ms to as low as 100ms

  - Latencies to Angola from other locations outside Brazil (e.g. Ashburn, Tokyo, Singapore) also experienced improvements

[5] Madory, D., First Subsea Cable Across South Atlantic Activated, 2018
[6] Prior, B., Teraco Data Centres Will Benefit from SACS Cable, 2018
Press Reports Expected Performance Improvements

- Prior, 2018 [6]:

  Teraco data centres will benefit from SACS cable

  Bradley Prior  14 November 2018

  - SACS reduces latency to the Americas substantially including a reduction from 338ms to 163ms between Cape Town and Miami

[5] Madory, D., First Subsea Cable Across South Atlantic Activated, Sep 2018
[6] Prior, B., Teraco Data Centres Will Benefit from SACS Cable, 2018
Research Questions

• Can we scientifically study the macroscopic effects of a cable launch on AS topology and end-to-end performance?

• Does end-to-end performance improve for all regions using the new cable?

• Do AS paths connecting those regions shorten?
Challenges

Translating research questions into a set of goals/tasks

- Identify IP addresses that represent this cable using IP-layer traceroute measurements
- Figure out which (IP/AS) paths cross the cable
- Find out which effects crossing the cable had on:
  - paths and latencies between linked countries
  - paths and latencies from/destined to different continents
Methodology

1. Collect candidate IP paths that could have crossed the cable
2. Identify router IP interfaces on both sides of the cable
3. Search for comparable traceroutes
4. Annotate collected paths
Datasets

• Active traceroute (monitors and topology data)
  - CAIDA’s Ark (100+ monitors)
  - RIPE NCC’s Atlas (10,000+ monitors)


Source: RIPE NCC’s Atlas measurement platform, https://www.atlas.ripe.net, 2020
Datasets

• Active traceroute (monitors and topology data)
  - CAIDA’s Ark (100+ monitors)
  - RIPE NCC’s Atlas (10,000+ monitors)

• Geolocation
  - Netacuity
  - Hostnames-based geolocation

• CAIDA’s MIDAR, Vela Alias, Macroscopic Internet Topology Dataset Kit (ITDK)

• CAIDA’s IXP dataset
Step 1: Collect Candidate IP Paths crossing SACS

- Collect detailed information about SACS launch
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- Collect detailed information about SACS launch
- Select all Ark VPs in Brazil and the Angola Cable (AC) Looking Glass in Angola
Step 1: Collect Candidate IP Paths crossing SACS

- Collect detailed information about SACS launch
- Select all Ark VPs in Brazil and the Angola Cable (AC) Looking Glass in Angola
- Run traceroutes in both directions to obtain candidate IP paths
Step2 (1): Identify Link IPs

AS topology post-SACS launch

Legend

- IXP
- Router
- AS
- RIPE Atlas probe
- CAIDA Ark probe

Compute $t = \frac{2L}{2c} = \frac{3L}{c}$, with $\frac{2c}{3}$ the speed of light traveling fibre optics
Step 2 (2): Identify Link IPs

Candidate IP path 1: Traceroute from AC Looking glass in Angola to Ark probe poa-br located in Brazil on 03/25/2019 (post-SACS)

\[ \Delta_{RTT} \approx 61ms \approx t = \frac{3 \times 6,165,000}{300,000} = 61.6ms \]
Step2 (2): Identify Link IPs

Candidate IP path 1: Traceroute from AC Looking glass in Angola to Ark probe poa-br located in Brazil on 03/25/2019 (post-SACS)
Step2 (2): Identify Link IPs

**Candidate IP path 1:** Traceroute from AC Looking glass in Angola to Ark probe poa-br located in Brazil on 03/25/2019 (post-SACS)

<table>
<thead>
<tr>
<th>Step 2 (2): Identify Link IPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Router: AO-Luanda</td>
</tr>
<tr>
<td>Command: traceroute inet 189.6.232.127</td>
</tr>
</tbody>
</table>

```
1  pe2-nc026.ang.sgn.as37468.angolacables.ao  (191.140.149.162)  1.432 ms  0.994 ms  1.292 ms
2  170.238.232.145  (170.238.232.145)  61.699 ms  51.582 ms  61.808 ms
3  pel-nc014.br.fitz.as37468.angolacables.ao  (170.238.232.97)  61.883 ms  pel-nc013.br.fitz.as37468.angolacables.ao  (170.238.232.81)
4  lag-9.arl.rio1.gig.gblx.net  (64.210.72.221)  62.455 ms  62.319 ms  62.496 ms
5  * * *
6  ebt-b56-uacc04.rjo.embratel.net.br  (200.211.219.137)  111.980 ms  114.964 ms  111.907 ms
7  ebt-h0-11-0-0-tcore01.rjoen.embratel.net.br  (200.244.211.203)  129.229 ms  ebt-h0-3-0-2-tcore01.rjo.embratel.net.br  (200.244.211.203)
   MPLS Label=24633 CoS=0  TTL=1 S=1
8  ebt-b1211-tcore01.ctmc.embratel.net.br  (200.230.231.57)  129.993 ms  132.195 ms  ebt-b10-tcore01.rjo.embratel.net.br  (200.230.25)
   MPLS Label=25621 CoS=0  TTL=1 S=0
   MPLS Label=24082 CoS=0  TTL=1 S=1
9  ebt-b1451-tcore01.pae.embratel.net.br  (200.230.251.217)  127.899 ms  ebt-b1211-tcore01.ctmc.embratel.net.br  (200.230.231.57)  13
   MPLS Label=24082 CoS=0  TTL=1 S=1
10 ebt-h0-1-0-0-uacc01.pae.embratel.net.br  (200.244.213.26)  125.608 ms  ebt-b1451-tcore01.pae.embratel.net.br  (200.230.251.217)  13
    MPLS Label=24000 CoS=0  TTL=1 S=1
11 ebt-h0-1-0-0-uacc01.pae.embratel.net.br  (200.244.213.26)  161.470 ms  bd06e87f.virtua.com.br  (189.6.232.127)  131.173 ms  ebt-h0-1
```
Step2 (3): Identify Link IPs

Candidate IP path 2: Traceroute output from poa-br to AC

Looking glass on 03/25/2019 (post-SACS) using CAIDA Vela
Candidate IP path 2: Traceroute output from poa-br to AC
Looking glass on 03/25/2019 (post-SACS) using CAIDA Vela
Step 2 (3): Identify Link IPs

Candidate IP path 2: Traceroute output from poa-br to AC

Looking glass on 03/25/2019 (post-SACS) using CAIDA Vela
Step2 (3): Identify Link IPs

• Validate IP geolocation
  - Combine Netacuity and hostname-based geolocation to locate IPs on both sides of the RTT bump
  - Run RTT measurements to check if min RTT to each IP<10ms from VPs in inferred country

• Find Link IPs: Resolve selected IPs’ router aliases using CAIDA’s MIDAR, Vela alias, and ITDK: obtain 2 lists of IPs $R_{Angola}$ and $R_{Brazil}$ called link IPs
Step 3: Fetch Matching Traceroutes

- Use CAIDA’s Ark and RIPE Atlas topology data
- Fetch traces with an IP address in $R_{Angola} \rightarrow R_{Brazil}$ or $R_{Brazil} \rightarrow R_{Angola}$ post-SACS (separated by $\Delta RTT \geq t$)
- Collect traces between the same $<s,d>$ pairs pre-SACS, splitting these historical data into 2 sets:
  - **Before SACS:** ARK-BEFORE/RIPE-BEFORE
  - **After SACS:** ARK-AFTER/RIPE-AFTER
Step 4: Add Supplementary Datasets

• **Traceroutes annotation:** For every IP hop, add
  - ASN
  - router hostname
  - geolocation information
  - whether or not it belong to an IXP & IXP name

• Group $T_{s,d}$ & $T'_{s,d}$ and their annotation per week using their timestamp of execution
Comparing RTT before & after SACS

- **Challenge:** Finding common IP hops in traces before and after SACS

- **Method:**
  
  - Among all $T_{<s,d>}$ for a given $<s,d>$, we locate the common IP hop $h_c$, closest to the destination IP
  
  - We extract RTT from $s$ to $h_c$ in $T_{<s,d>}$ and $T'_{<s,d>}$, while ignoring all cases in which $h_c = \emptyset$
Surprising Results

Boxplots of minimum RTTs from Ark & Atlas VPs to the common IP hops closest to the destination IPs.
Surprising Results

Overall, SACS had little impact on latencies from all VPs to all destinations prefixes
Surprising Results

Latencies from VPs in South America significantly dropped,
Surprising Results

...while latencies from VPs in Europe and Asia significantly increased.
RTT changes at the Country level

\[ \Delta \text{RTT AFTER} - \text{BEFORE} \] of the medians of minimum RTTs per week pre & post SACS for observed \(<s,d>\) pairs.

The number of observed \(<s,d>\) pairs can be seen in the chart, with countries such as China, Brazil, Nigeria, Angola, Canada, United States, South Korea, Congo, South Africa, Mozambique, and Australia listed. The chart also indicates the locations of the Ark and RIPE Atlas probes.
Asymmetrical RTT reduction: the decrease of the median RTT from Africa to Brazil is a third of that from South America to Angola (226ms)
RTT changes at the Country level

Packets routed through SACS for pairs from Africa to Angola or Europe to Angola, leading to latency increase.

Unpredicted and unreported performance degradation
Comparing Transit Structure

• A higher centrality of an AS post-event indicates increased transit importance.

• Method:
  - Use bdrmapIT [7] to infer AS paths from IP paths
  - AS’s centrality [8]: percentage of observed <s,d> pairs for which the AS path with the minimum observed RTT contains the considered AS.

[7] Marder et al., Pushing the Boundaries with bdrmapIT: Mapping Router Ownership at Internet Scale. In ACM IMC, 2018
Partial AS paths from South America to Angola (Observed RTT improvement)

AS-centrality of AS37468 increased from 46% to 100%
Effects on Transit Structure (1)

Partial AS paths from South America to Angola (Observed RTT improvement)

Median RTT on IP paths crossing AS37468 decreased from 346ms to 159ms
Effects on Transit Structure (2)

Partial AS paths from Europe to Angola (Observed RTT degradation)

AS-centrality of AS37468 increased from 74% to 100%
Effects on Transit Structure (2)

Partial AS paths from Europe to Angola (Observed RTT degradation)

Median RTT on IP paths crossing AS37468 increased from 156ms to 259ms
Examples of Paths Changes

(A) Africa to Angola (at least 55% <s,d>)

(B) North America to Brazil (25% <s,d>)

(C) Europe to Angola (99.3% <s,d>)

(D) South America to Angola (100%)

Most IP paths from Africa to Angola crossing SACS went through South Africa, Europe, North America, Fortaleza before reaching their destination
Examples of Paths Changes

(A) Africa to Angola (at least 55% <s,d>)

(B) North America to Brazil (25% <s,d>)

(C) Europe to Angola (99.3% <s,d>)

(D) South America to Angola (100%)

Most IP paths from North America to Brazil crossing SACS went through Europe/Asia, South Africa, Angola before reaching Fortaleza.
Examples of Paths Changes

(A) Africa to Angola (at least 55% \(<s,d>\))

(B) North America to Brazil (25% \(<s,d>\))

(C) Europe to Angola (99.3% \(<s,d>\))

(D) South America to Angola (100%)

Most observed IP paths from Europe to Angola crossing SACS went through North America before reaching their destination.
Examples of Paths Changes

(A) Africa to Angola (at least 55% <s,d>)
(B) North America to Brazil (25% <s,d>)
(C) Europe to Angola (99.3% <s,d>)
(D) South America to Angola (100%)

All observed IP paths from South America to Angola directly crossed SACS to reach their destination
Comparing AS path lengths

- Analyze length of AS paths between source AS/destination prefix pairs crossing cable operator’s network in BGP pre & post-event

- **Method:**
  - Consider AS paths collected during the first 5 days of the month pre & post-event
  - Filter out all $ASpaths_{<s,d>}$ crossing AS37468 operating the cable post-event
  - Extract all $ASpaths'_{<s,d>}$ between the same $<s,d>$ pairs pre-event
Increased AS paths lengths

Distribution of the length of AS paths between same source AS/destination prefix pairs served via AC (AS37468) pre&post SACS, showing the increase of paths of length 2-7
Validation with the ISP

- AC identified cases where the suboptimality happened outside of their network
- AC highlighted that internal link failures could account for the performance degradations
- AC did not validate suboptimal cases within their network, but most observed IP paths switched to optimal ones after our conversation
Potential Causes of Suboptimal Routing

- IGP/EGP misconfigurations (typos, errors, etc.)
- slow IGP or EGP convergence
- lack of traffic engineering after event in neighbouring AS
- persistent lack of peering among local ASes in Africa
- frequent use of default routes via international transit providers in developing regions
Caveat

• AC noted most traffic crossing SACS through its network goes from South-America to Angola or South Africa to Brazil, the regions pairs that experienced substantial performance improvements

• No complaints from customers, hinting low amount of traffic carried, but suboptimal routes lasted 3.5 months
Contributions

• **Reproducible method** to investigate impact of a cable deployment on macroscopic topology and performance

• **Application of our methodology to the case of SACS**, the first South-Atlantic cable from South America to Africa:
  
  - Discovered RTT decrease from **Africa to Brazil** was roughly **a third** of that from **South America to Angola**
  
  - Discovered surprising performance degradations to/from some regions
Further Contributions

• **Suggestions** to avoid suboptimal routing post-activation of cables in the future:
  - Inform BGP neighbours to allow time for changes
  - Ensure optimal iBGP configs post-activation
  - Use measurements platforms to verify path optimality

• **Access to Code & Data:**
Help build the Ark measurement network by hosting a VP!

We are always looking for volunteers to host VPs!

Contact us:
ark-info@caida.org
or
roderick@caida.org

Thank you. Questions?
Backup Slides
Related Work

• [4,5] investigated effects of disruptions to existing cables
  - In 2010, [4] observed significant congestion on paths from Hong Kong to EU websites caused by submarine cable fault
  - In 2011, [5] studied the impact of SEA-ME-WE 4 submarine cable fault on end-to-end path quality in terms of the delay and packet loss rates

• [6] underlined the need to undertake research to characterize the global submarine cable network

• No scientific study of the macroscopic effects of a cable launch on AS topology and end-to-end performance

[6] Bischof et al, Submarine Cables and Internet Resiliency, 2018
Example of AS Topology

Pre-cable Launch

- AS8 is yet to activate a cable between countries A and B
- AS8 is present at an IXP in both countries (not necessary)
- Red line: AS3 => AS4
- Blue line: AS4 => AS3
Step 1. Collect candidate IP paths that could have crossed the cable

- Collect detailed information about the cable launch
- Select VPs in connected countries and near the 2 cables endpoints (eg: VPs in AS3, AS8, AS2 & AS4)
- Conduct traceroutes in both directions to obtain candidate IP paths
Step 2. Identify Routers Interfaces on both Sides of the Cable (1)

• In our example, AS8 is the AS operating the new cable long of \( L \) km between countries A & B.

• Combine 2 approaches to identify traces crossing the link of interest and interfaces on both sides (1):

  A. RTT-threshold based on speed-of-light constraints

    - Use bdrmapIT to map IP in candidate IP paths to ASes

    - Look for an RTT difference gap between consecutive hops within AS8 of \( t = \frac{2L}{2c} = \frac{3L}{c} \), with \( \frac{2c}{3} \) the speed of light traveling fibre optics

    - Those IP hops likely match the cable landing sites.
Step 2. Identify Routers Interfaces on both Sides of the Cable (2)

- **Combine 2 approaches** to identify traces crossing the link of interest and interfaces on both sides (2):

  B. IP geolocation:

  - Use IP geolocation databases and hostname-based geolocation to locate IPs on both sides of the threshold RTTs.

  - Validate with RTT measurements from VPs in inferred countries to those IPs and their adjacent IPs.

  - If inferred geolocations are countries A and B, resolve the router aliases of the selected IPs using CAIDA’s MIDAR, Vela alias, and ITDK (the obtained lists $Ra$ and $Rb$ are called link IPs).
Step 3. Search for Comparable Historical Traceroutes

- Collect traceroutes post-cable launch traversing link IPs:
  - **Ark** and **Atlas** randomly probe within BGP prefixes: We denote $s$ each source IP address and $d$ the longest prefix match for each traceroute destination IP in BGP.
  - We fetch all traceroutes $T_{<s,d>}$ post-cable containing $Ra \rightarrow Rb$ or $Rb \rightarrow Ra$ (separated by RTT difference $t$).

- Search for pre-event traceroutes $T'_{<s,d>}$ for the same source IPs/destination prefix $<s,d>$ pairs for comparison.
Step 3: Fetch Matching Traceroutes

- Use CAIDA’s Ark and RIPE Atlas topology data
- Fetch traces with $Ra \rightarrow Rb$ or $Rb \rightarrow Ra$ post-SACS
- Collect traces between the same $<s,d>$ pairs pre-SACS, splitting these historical data into 2 sets:
  - mid-Sept 2018 - late Jan 2019: ARK-AFTER/RIPE-AFTER
  - Jan 2018-mid - Sept 2018: ARK-BEFORE/RIPE-BEFORE
- Cleaned up dataset: Atlas traceroutes (823 $<s,d>$ pairs) & Ark traceroutes (6,778 $<s,d>$ pairs)
Step 4: Annotate Collected Paths

- For every hop in $T_{s,d}$ & $T'_{s,d}$:
  - We resolve hostname (zdns & qr) & ASN (bdrmapIT[7])
  - We compute difference in RTT with the previous hop
  - We check if it belongs to an IXP prefix

- We group $T_{s,d}$ & $T'_{s,d}$ and their annotation per week using their timestamp of execution

[7] Marder et al., Pushing the Boundaries with bdrmapIT: Mapping Router Ownership at Internet Scale. In ACM IMC, 2018
AS-centrality Computation

- Examples:

  - Suppose 4 \((s,d)\) pairs were measured from region A to country B and that the IP paths with the min RTTs were crossing the ASes above

  - after mapping IPs to ASes, we obtain the AS paths between: \(AS_0 \rightarrow AS_6, AS_4 \rightarrow AS_5, AS_2 \rightarrow AS_7, AS_0 \rightarrow AS_3\)

  \[
  AS-c(AS_1) = \frac{3}{4}, \quad AS-c(AS_2) = \frac{1}{4}, \quad AS-c(AS_3) = \frac{1}{4}, \quad AS-c(AS_6) = 0
  \]
Effects on Transit Structure

Top 3 transit ASes serving \( <s, d> \) pairs from continents to destination countries. The categories in which we noticed Suboptimal routing are highlighted in italic.

<table>
<thead>
<tr>
<th>Category (#(&lt;s, d&gt;))</th>
<th>CC</th>
<th>AS-centrality</th>
<th>Before</th>
<th>Transit AS</th>
<th>After</th>
<th>AS-centrality</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>From Africa to Angola (201)</td>
<td>AO</td>
<td>66.7%</td>
<td>Angola Cables (AS37468)</td>
<td>WIOCC-AS (AS37662)</td>
<td>90.1%</td>
<td>AO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ZA</td>
<td>32.3%</td>
<td>Internet Solutions (AS3741)</td>
<td>IPPLANET (AS12491)</td>
<td>22.4%</td>
<td>ZA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BG</td>
<td>20.9%</td>
<td>Sofia Connect (AS47872)</td>
<td></td>
<td>16.4%</td>
<td>MU</td>
<td></td>
</tr>
<tr>
<td>From North America to Brazil (122)</td>
<td>US</td>
<td>44.4%</td>
<td>ATT-Internet4 (AS7018)</td>
<td>Angola Cables (AS37468)</td>
<td>100%</td>
<td>AO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BR</td>
<td>30.1%</td>
<td>NipBr (AS27693)</td>
<td>Chinanet-B. (AS4134)</td>
<td>60.2%</td>
<td>CN</td>
<td></td>
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<tr>
<td></td>
<td>US</td>
<td>23%</td>
<td>Nitel (AS53828)</td>
<td>Abilene (AS11537)</td>
<td>58.3%</td>
<td>US</td>
<td></td>
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<tr>
<td>From Europe to Angola (705)</td>
<td>AO</td>
<td>62.9%</td>
<td>Angola Cables (AS37468)</td>
<td>Telianet (AS1299)</td>
<td>78.1%</td>
<td>AO</td>
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<td></td>
<td>BG</td>
<td>18.6%</td>
<td>Sofia-Connect (AS47872)</td>
<td>TWTC (AS4323)</td>
<td>17.6%</td>
<td>EU</td>
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<tr>
<td></td>
<td>EU</td>
<td>14.2%</td>
<td>Telianet (AS1299)</td>
<td></td>
<td>9.9%</td>
<td>US</td>
<td></td>
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<tr>
<td>From Asia to Brazil (141)</td>
<td>AO</td>
<td>50.3%</td>
<td>Angola Cables (AS37468)</td>
<td>TWTC (AS4323)</td>
<td>90.1%</td>
<td>AO</td>
<td></td>
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<tr>
<td></td>
<td>US</td>
<td>28.4%</td>
<td>TATA (AS6453)</td>
<td></td>
<td>31.9%</td>
<td>US</td>
<td></td>
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<tr>
<td></td>
<td>JP</td>
<td>24.1%</td>
<td>KDDI (AS2516)</td>
<td></td>
<td>26.2%</td>
<td>JP</td>
<td></td>
</tr>
<tr>
<td>From South America to Angola (212)</td>
<td>AO</td>
<td>45.7%</td>
<td>Angola Cables (AS37468)</td>
<td></td>
<td>96.2%</td>
<td>AO</td>
<td></td>
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<tr>
<td></td>
<td>BR</td>
<td>36.8%</td>
<td>Terremark do Brasil (AS28625)</td>
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<td>18.4%</td>
<td>BR</td>
<td></td>
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<tr>
<td></td>
<td>US</td>
<td>36.3%</td>
<td>Cogent (AS174 )</td>
<td></td>
<td>11.8%</td>
<td>PY</td>
<td></td>
</tr>
</tbody>
</table>

After SACS activation, AC became the top transit AS for observed paths found to suffer or not from suboptimal routing.
Comparison of Round Trip Time (RTTs) or Delays (RTDs) of IP paths crossing SACS

<table>
<thead>
<tr>
<th>Origin</th>
<th>Destination</th>
<th>RTT (ms) Before SACS</th>
<th>RTT (ms) After SACS</th>
<th>Gain RTT (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miami</td>
<td>Luanda</td>
<td>278</td>
<td>128</td>
<td>-150</td>
</tr>
<tr>
<td>Fortaleza</td>
<td>London (UK)</td>
<td>172</td>
<td>150</td>
<td>-22</td>
</tr>
<tr>
<td>Fortaleza</td>
<td>Lisbon (PT)</td>
<td>193</td>
<td>162</td>
<td>-31</td>
</tr>
<tr>
<td>Fortaleza</td>
<td>Madrid (ES)</td>
<td>208</td>
<td>173</td>
<td>-35</td>
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<td>Fortaleza</td>
<td>Cape Town (ZA)</td>
<td>337</td>
<td>112</td>
<td>-225</td>
</tr>
<tr>
<td>Fortaleza</td>
<td>Luanda</td>
<td>350</td>
<td>63</td>
<td>-287</td>
</tr>
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<td>São Paulo</td>
<td>London (UK)</td>
<td>212</td>
<td>190</td>
<td>-22</td>
</tr>
<tr>
<td>São Paulo</td>
<td>Frankfurt (DE)</td>
<td>222</td>
<td>200</td>
<td>-22</td>
</tr>
<tr>
<td>São Paulo</td>
<td>Johannesburgo (ZA)</td>
<td>384</td>
<td>130</td>
<td>-254</td>
</tr>
<tr>
<td>São Paulo</td>
<td>Cape Town (ZA)</td>
<td>377</td>
<td>152</td>
<td>-225</td>
</tr>
<tr>
<td>São Paulo</td>
<td>Luanda</td>
<td>380</td>
<td>109</td>
<td>-271</td>
</tr>
</tbody>
</table>

Variations of RTT Gains on IP paths crossing SACS hint (internal) routing changes

Source: Angola Cables, https://www.angolacables.co.ao, March 2020

LOW LATENCY IN INTERNATIONAL ROUTES (RTD)

March 2020