Inferring a Nation’s Inbound Route Diversity Using Country-Level Transit Influence of Autonomous Systems

Alexander Gamero-Garrido
Ph.D. Candidate in Computer Science
CAIDA, UC San Diego

Research in collaboration with: Esteban Carisimo, Shuai Hao, Bradley Huffaker, Amogh Dhamdhere, Alex C. Snoeren and Alberto Dainotti
Why Study a Nation’s Inbound Route Diversity?

**Transit** Autonomous Systems
Responsible for delivering traffic within their network and to their customers

**Origin** (access) Autonomous Systems
Responsible for delivering traffic within their network
Why Study a Nation’s Inbound Route Diversity?

Transit Autonomous Systems

Origin (access) Autonomous Systems
Why Study a Nation’s Inbound Route Diversity?
Why Study a Nation’s Inbound Route Diversity?

**Peer ASes:**
Exchange traffic with one another and one another's customers
Why Study a Nation’s Inbound Route Diversity?

Healthy Ecosystem: Higher Route Diversity

Unhealthy Ecosystem: Lower Route Diversity

- Identify countries with lower diversity
- Quantify route concentration
Transit Concentration Exposes Country to Disconnections

Rest of the Internet

Indirect Transit ISP

Direct Transit ISP

Transit Autonomous Systems

Origin (access) Autonomous Systems

University

Residential ISP

Mobile ISP
Transit Concentration Exposes Country to Observation

Rest of the Internet

Indirect Transit ISP

Direct Transit ISP

Transit Autonomous Systems

Origin (access) Autonomous Systems

University

Residential ISP

Mobile ISP
In countries with concentrated routes, some networks have the potential capability to *observe, manipulate and disrupt* Internet traffic flowing towards a country.
Most vulnerable countries from anecdotal evidence are least represented in networking literature (e.g., Africa and Central Asia)

DDoS attack boots Kyrgyzstan from net

Russian bears blamed

By Dan Goodin 28 Jan 2009 at 19:57

The two primary Kyrgyzstan ISPs (www.domain.kg, www.ns.kg) have been under a massive, sustained DDoS attack. Few alternatives for Internet access exist in Kyrgyzstan. ... the attacks] essentially knocked most of the small, Central Asian republic offline.

How Ethiopia Controls the Internet

A one-week internet shutdown ends, but the government has more methods to silence online critics, a rights group says.

By Sicilia Radu Staff Writer June 23, 2019, at 11:14 a.m.

Government control is facilitated by how internet connectivity works in Ethiopia. The country is landlocked and connects to the internet via satellite, a fiber-optic cable that passes through Sudan and connects to the international gateway, and another cable that connects through Djibouti to an international undersea cable.
We built tools to identify countries with concentrated inbound routes
First Sign of Concern on Route Diversity: Foreign Peering is Rare

Healthy Ecosystem: Higher Route Diversity

Unhealthy Ecosystem: Lower Route Diversity

Border Gateway Protocol (BGP): the system relied upon by network operators to announce and implement their routing policies.
We built tools to identify countries with concentrated inbound routes.

Identify Countries with Lower Route Diversity: origin ASes generally do not have foreign peers and therefore traffic flows through (often concentrated) transit links.
First Sign of Concern on Route Diversity: Foreign Peering is Rare (Step 1)

Infer share of country’s addresses where lack of foreign peering suggests a fragile infrastructure without visible opportunities for improvement

No existing peers

No potential peers

No potential peers
First Sign of Concern on Route Diversity: Foreign Peering is Rare (Step 1)

Percentage of each country’s address space where we have found no evidence of international peering.
Countries where blue routes are dominant may have fragile inbound connectivity
First Sign of Concern on Route Diversity: Foreign Peering is Rare (Step 2)

Is this country served primarily by transit ASes?
We confirmed these assertions with operators in seven countries:

1. Cameroon
2. D.R. Congo
3. Sudan
4. Zimbabwe
5. Lesotho
6. Ethiopia
7. Venezuela

First Sign of Concern on Route Diversity: Foreign Peering is Rare (Step 2)

Is this country served primarily by transit ASes?
Country-Level Transit Influence Defined (1/3)
Transit influence of AS_t on country C:
Fraction of addresses originated by any AS_o in country C where AS_t is present as a transit provider filtered to account for incomplete observations

CTI ~ [0,1]
Using CTI to Quantify Inbound Route Diversity

Lower route diversity
Most vulnerable to adverse events affecting a single AS

Higher route diversity
Least vulnerable to adverse events affecting a single AS
Using CTI to Quantify Inbound Route Diversity

Lower route diversity
Most vulnerable to adverse events affecting a single AS

Higher route diversity
Least vulnerable to adverse events affecting a single AS

CTI declines quickly: in many countries route are concentrated

n = 75
Using CTI to Quantify Inbound Route Diversity

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Most vulnerable to adverse events affecting a single AS

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Least vulnerable to adverse events affecting a single AS
Using CTI to Quantify Inbound Route Diversity

Lower route diversity
Most vulnerable to adverse events affecting a single AS

Higher route diversity
Least vulnerable to adverse events affecting a single AS

In 49 of 51 non-landlocked countries, a submarine cable operator is ranked in top 5 by CTI
Using CTI to Quantify Inbound Route Diversity

We discussed the set of top ASes by CTI with operators in 5 countries:

1. Ethiopia
2. Zimbabwe
3. Sudan
4. D.R. Congo
5. Cameroon

n = 75
Telefónica (AS12956) Dominates Transit in Spanish-Speaking Latin America

**Solicitamos apoyo validando esta lista de países en LACNIC**

<table>
<thead>
<tr>
<th>Country</th>
<th>Rank by CTI</th>
<th>CTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolivia</td>
<td>1</td>
<td>0.55</td>
</tr>
<tr>
<td>Peru</td>
<td>1</td>
<td>0.44</td>
</tr>
<tr>
<td>Chile</td>
<td>2</td>
<td>0.24</td>
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<td>Colombia</td>
<td>2</td>
<td>0.19</td>
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<td>Ecuador</td>
<td>4</td>
<td>0.12</td>
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<td>Nicaragua</td>
<td>4</td>
<td>0.08</td>
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<tr>
<td>Guatemala</td>
<td>6</td>
<td>0.04</td>
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<tr>
<td>Belice</td>
<td>8</td>
<td>0.03</td>
</tr>
<tr>
<td>Honduras</td>
<td>8</td>
<td>0.04</td>
</tr>
<tr>
<td>El Salvador</td>
<td>8</td>
<td>0.02</td>
</tr>
</tbody>
</table>
C&W (AS23520) Dominates Transit in the Caribbean

Solicitamos apoyo validando esta lista de países en LACNIC

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<thead>
<tr>
<th>Country</th>
<th>Rank by CTI</th>
<th>CTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trinidad y Tobago</td>
<td>1</td>
<td>0.58</td>
</tr>
<tr>
<td>Belice</td>
<td>1</td>
<td>0.47</td>
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<tr>
<td>Haiti</td>
<td>1</td>
<td>0.40</td>
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<tr>
<td>Guyana</td>
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<td>0.34</td>
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<tr>
<td>Venezuela</td>
<td>1</td>
<td>0.33</td>
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<tr>
<td>Honduras</td>
<td>3</td>
<td>0.14</td>
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<tr>
<td>Cuba</td>
<td>3</td>
<td>0.11</td>
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<tr>
<td>Ecuador</td>
<td>6</td>
<td>0.06</td>
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<tr>
<td>Nicaragua</td>
<td>8</td>
<td>0.04</td>
</tr>
<tr>
<td>Guatemala</td>
<td>8</td>
<td>0.03</td>
</tr>
<tr>
<td>El Salvador</td>
<td>10</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Summary

• We built a tool to identify countries served primarily by transit links

• CTI captures concentration of inbound routes towards each of those countries

• Route diversity varies greatly across countries, some are very centralized
### Countries of Concern (Lower Route Diversity)

<table>
<thead>
<tr>
<th>Region</th>
<th>Countries of Concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central America and the Caribbean</td>
<td>Venezuela, Panama, Haiti, El Salvador, Cuba, Guyana, Bahamas, Nicaragua, Guatemala,</td>
</tr>
<tr>
<td></td>
<td>Jamaica, Trinidad and Tobago, Honduras, Belize, St. Lucia, Barbados, St. Vincent &amp;</td>
</tr>
<tr>
<td></td>
<td>the Grenadines, St. Kitts &amp; Nevis</td>
</tr>
<tr>
<td>South and Central Asia</td>
<td>India, Mongolia, Thailand, Bangladesh, Sri Lanka, Myanmar, Turkmenistan, Georgia,</td>
</tr>
<tr>
<td></td>
<td>Uzbekistan, East Timor, Armenia</td>
</tr>
<tr>
<td>West and Central Africa</td>
<td>Cameroon, Sierra Leone, Cape Verde, Congo D.R.C., Equatorial Guinea, Guinea, Burkina</td>
</tr>
<tr>
<td></td>
<td>Faso, Chad, Mali</td>
</tr>
<tr>
<td>Middle East and North Africa</td>
<td>Libya, Yemen, Qatar, Oman, Turkey, Egypt, Kuwait, Palestine, Jordan, Afghanistan,</td>
</tr>
<tr>
<td></td>
<td>Iraq</td>
</tr>
<tr>
<td>East Africa</td>
<td>Ethiopia, Zambia, Somalia, Sudan</td>
</tr>
<tr>
<td>South Pacific</td>
<td>Tonga, Solomon Islands, Tuvalu, Samoa, Nauru</td>
</tr>
<tr>
<td>Andes Mountains (excl. Caribbean)</td>
<td>Bolivia, Peru, Colombia, Ecuador, Chile</td>
</tr>
<tr>
<td>Balkans</td>
<td>Albania, Montenegro, Macedonia</td>
</tr>
<tr>
<td>Southern Africa</td>
<td>Lesotho, Zimbabwe, Eswatini (Swaziland)</td>
</tr>
<tr>
<td>Western and Central Mediterranean</td>
<td>Portugal, Morocco, Malta</td>
</tr>
<tr>
<td>Landlocked Countries (excl. above regions)</td>
<td>Luxembourg, San Marino, Belarus</td>
</tr>
<tr>
<td>South Korea</td>
<td>South Korea</td>
</tr>
</tbody>
</table>