

New E. Coast of Africa Fibre

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Introduction

With the [2010 Soccer World Cup](#) fast approaching the [Seacom](#) undersea fibre optic cable, plugging East Africa ([Network Schematic](#)) into high speed Internet , went live on Thursday July 23, 2009 - as reported by the [BBC](#) and [CNN](#). Such a cable should dramatically reduce the cost of bandwidth measured in \$/Mbps, reduce the Round Trip Times (RTT) from $>\sim 480\text{ ms}$ for a geostationary satellite, down to 200-350ms (seen from N. America) by using shorter distance terrestrial routes. Also by increasing the capacity reduce the congestion and thus the losses and jitter.

In this case study we look at the current state of Internet access for Africa as measured by the [PingER project](#) and also at the effect of the new submarine cable connections on the RTTs to countries of Africa as seen from the [SLAC National Accelerator Center](#) near San Francisco and from the [International Centre for Theoretical Physics](#) (ICTP) near Trieste Italy. The main effects seen so far are on the RTTs for selected sites that have converted to using the terrestrial links. As the new routes stabilize and more and more customers, e.g academia and commercial organizations, subscribe to the service, we can expect to also see lower losses and jitter and higher through-puts together with a wider impact on deployment.

PingER monitors over 165 sites in 50 African countries, that contain about 99% of Africa's population. The African countries that are not currently monitored are Chad, Comoros, Equatorial Guinea, Sao Tome & Principe and Western Sahara. The results from PingER are used heavily in this study. Below is seen a map of the PingER sites in Africa. The red dots indicate PinGER monitoring sites, the blue are beacon sites that are monitored by most of the over 40 PingER monitoring sites around the world, and the green are other sites monitored by at least one monitoring site.

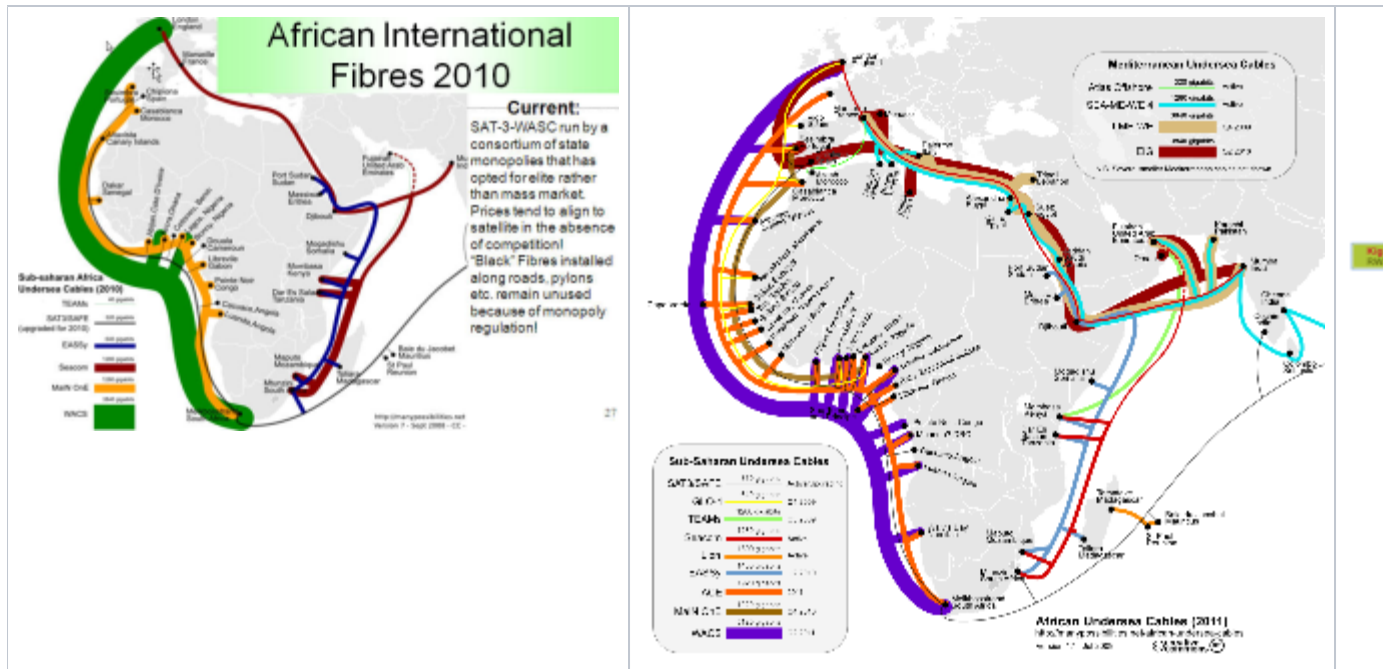


This study first outlines the new submarine fibres coming into place for E. Africa. It goes on to summarize the current state and trends of Internet performance for Africa and the costs particularly for Sub-Saharan and E. Africa. Following this we discuss the role of the emerging National Research and Education Networks (NRENs) and traffic routing. Then we look at the RTTs of hosts in Kenya and Tanzania on the day following the start of operation of the Seacom cable, the identification of further hosts of interest, followed by the changes in RTTs as hosts later moved their routing from satellite to terrestrial routes.

Submarine Fibre Cables for E. Africa

At the moment the [SAT-3/WASC/SAFE](#) fibre has been in place for some time and connects up several countries on the W. Coast of Africa. Up until now however, there have been no fibres on the East Coast of Africa. The Seacom line is not the only fiber-optic cable project on Africa's East coast — others include the [Eastern Africa Submarine Cable Systems \(EASSY\)](#), [The East African Marine System \(TEAMS\)](#) and [Lion](#) — but it will be the longest and have highest capacity (1.28 terabytes per second). The EASSY and TEAMS are designed to build out African telecommunications networking, but Seacom is the only line that directly will connect east coast urban areas in Kenya, Madagascar, Mozambique, South Africa and Tanzania to France and India. TEAMS landed in Mombasa early June 2009 and is currently undergoing testing while EASSY and Lion are expected to be operational by mid-2010. Maps of the various fibres is shown below, more details are available [here](#). Also shown is network schematic of the Seacom link.

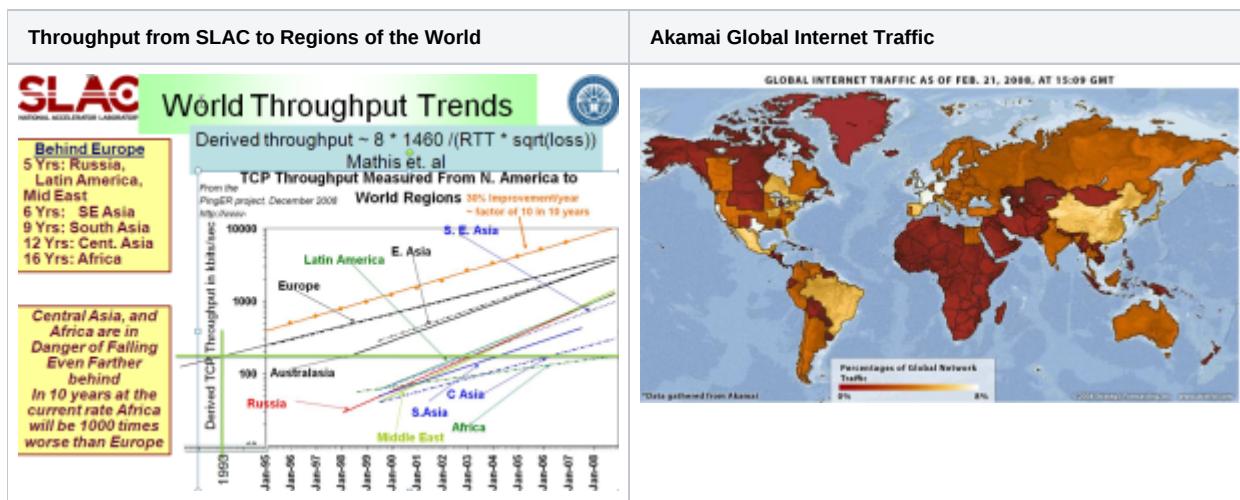
	From African Undersea Cables	Sea
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For the interior backbones (or backhauls) associated with these landing points, see [here](#).

Current State of the African Internet

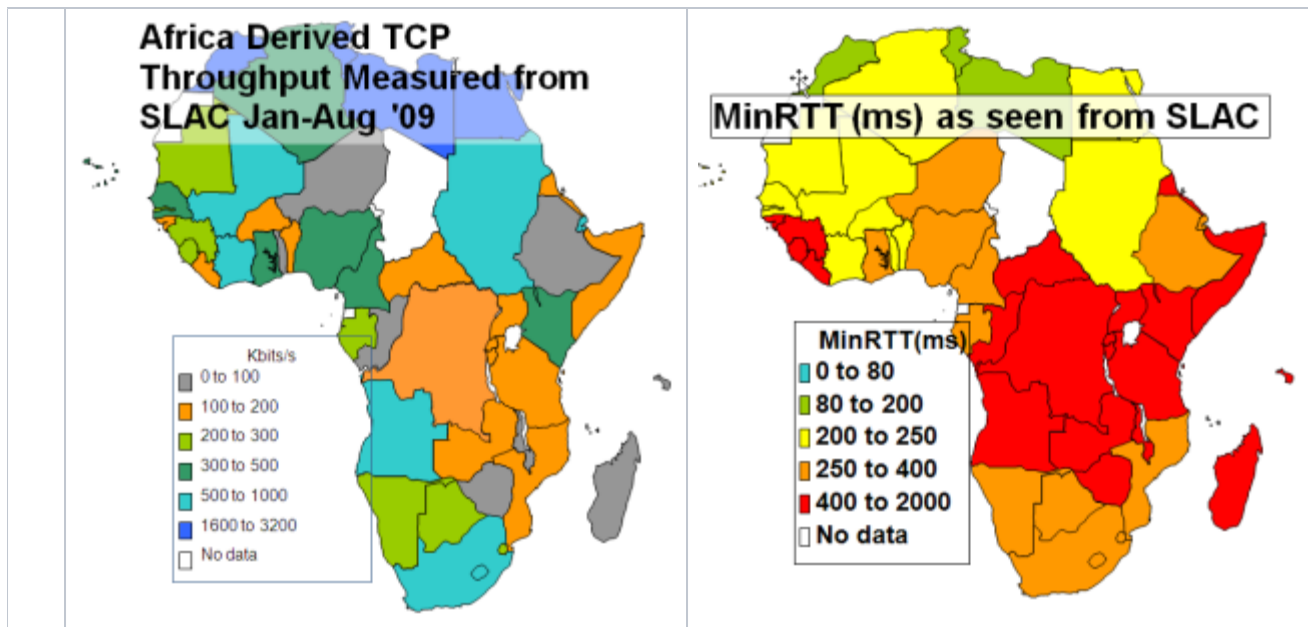
The [derived throughputs](#) measured to Africa from N. America for the last decade are shown below in the left hand figure. It is seen that not only do African sites lag the rest of the world in throughput, being roughly in the state that European sites were over a decade and a half ago, but also they are falling further behind with time.



Further, bear in mind that for Africa, Mediterranean countries and South Africa have the better performance and E. Africa is the worst off (see the middle map below). Thus the arrival of a terrestrial submarine fibre cable link to the rest of the world for E. Africa is a very significant development.

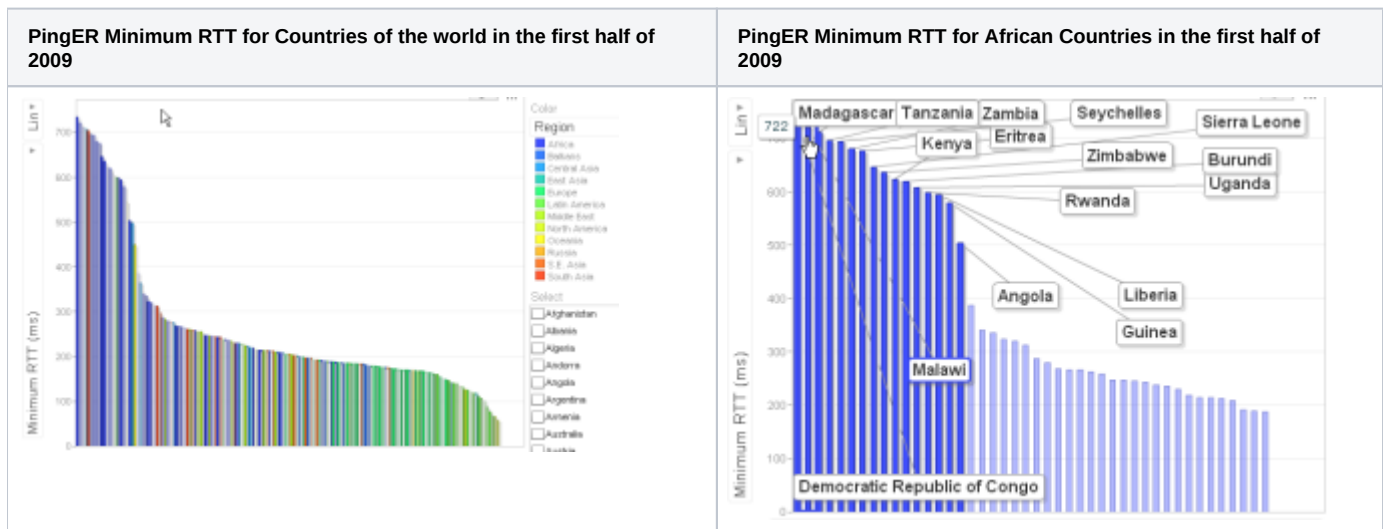
The minimum RTTs measured from SLAC to African countries in August 2009 are seen in the map on the right

Derived Throughput from SLAC to Africa Jan-Aug '09 [xlsx]	MinRTT from SLAC - Aug. 2009 [xls]
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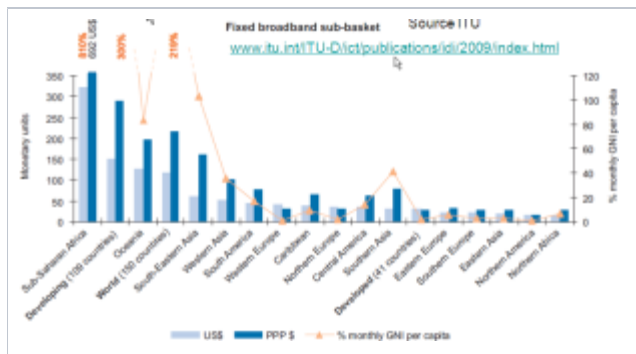
The striking number of countries in Eastern and Central Africa with minimum RTTs of >400ms is indicative that they were using GEO-Stationary (GEOS) satellite links.

Another way of illustrating which countries are using satellites is to look at a bar chart of the PingER measured minimum RTT in the first half of 2009 for each country sorted by the minimum RTT. Such a chart is shown below on the left. It is seen that there is a steep rise around 400ms as one moves to GEOS satellite connections. The predominance of African countries (blue) with large minimum RTT is also apparent. If one creates the same type of bar chart but only using African countries then the result is seen on the right below where the countries with a minimum RTT > 450ms are labelled.



East Africa contains 300M people, yet less than 3% are Internet users (see [Internet usage for Africa](#)). Bandwidth in Africa is very expensive. See for example the left hand figure below where it is seen that bandwidth costs for broadband in Sub-Saharan Africa are 30-40 times that in the US. Taken together with the earnings differences, what takes say 15% of a US Gross National Income (GNI) per capita will take over 800% of a Sub-Saharan GNI per capita.

Costs of Broadband Internet Access in Countries of the world.



Emergence of National Research and Education Networks (NRENs) & Routing

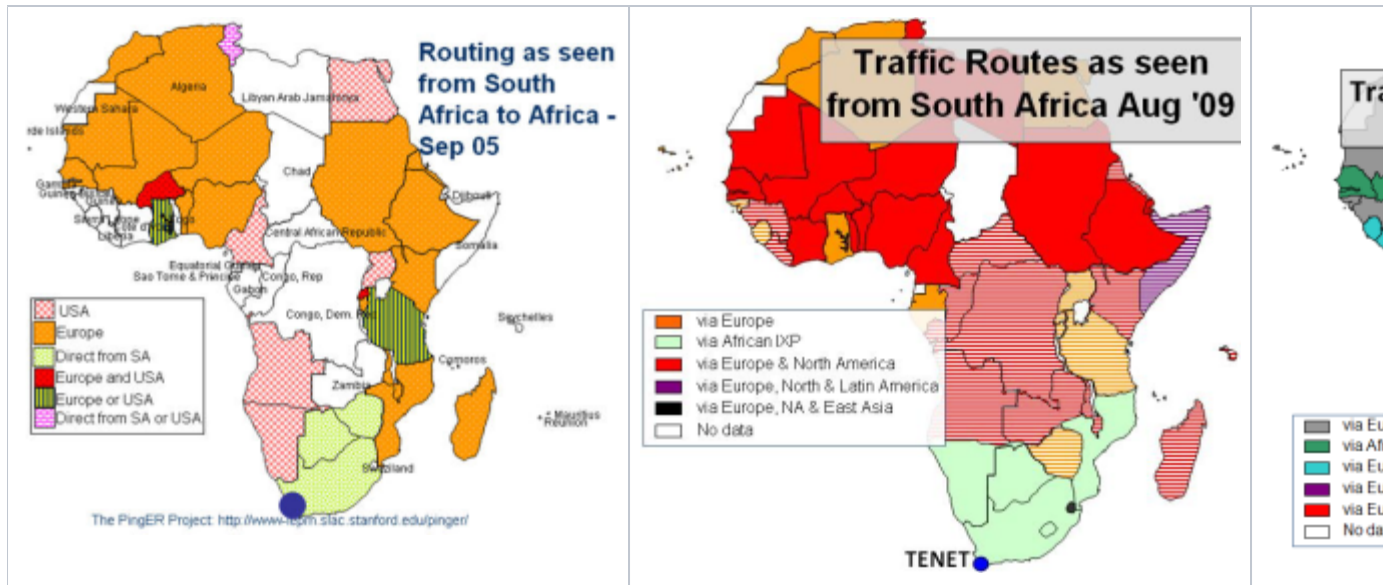
In the past the area has had poor Internet connectivity with heavy use of expensive (in terms of \$/Mbps) geostationary satellite connections to the outside world. (see above) In addition most of the traffic between countries made use of expensive international links via Europe and the U.S. rather than more direct connections. There are active movements to create National Research and Education Networks (NRENs) in the area, see for example "[Sub-Saharan Africa: An update](#)" by Boubaker Barry. This, together with direct connections between countries will enable more direct peering. These NRENs in turn are peering with the [GEANT network](#) in Europe through the [UbuntuNet Alliance](#). The map on the left below shows the state of African NRENs in 2008, the map in the middle shows the Founding UbuntuNet Alliance members and those who have joined since the founding, the figure on the right shows the prediction (in October 2008) for the state of UbuntuNet connections at the end of 2009..

NRENs in Africa	UbuntuNet Alliance	UbuntuNet End 2009, from Duncan Martin

It can be seen that NRENs are being created.

To understand the importance of NRENs and IXPs to reduce the use of intercontinental providers to get between African countries, we can look at the state of direct connections between African countries by measuring the traceroutes within Africa. Below on the left and in the middle are the routes taken from South Africa to other African countries in September 2005 and August 2009 and on the right the routes from Burkina Faso to other African countries in August 2009. In the middle map countries which were only accessible by satellite have horizontal shading lines.

Routing from South Africa to African Countries (Sep '05)	Routing from South Africa to African Countries (Aug '09) [xls]	Routing from [xls]
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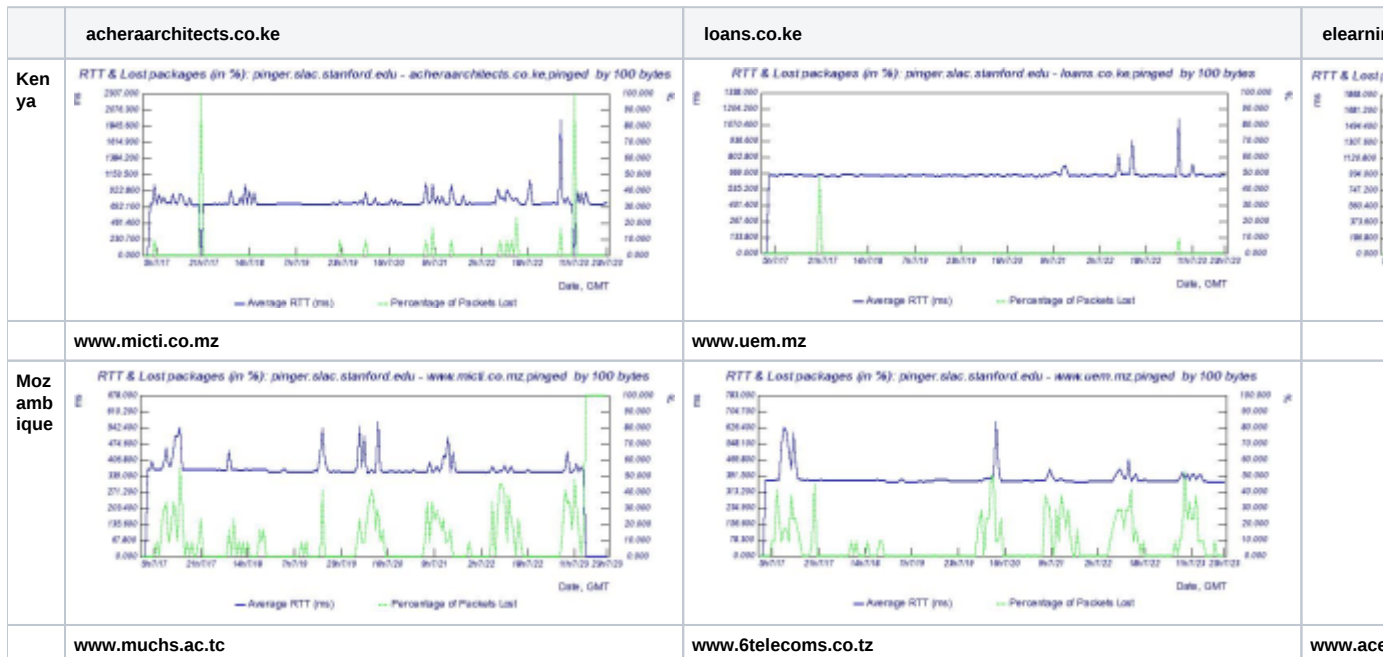


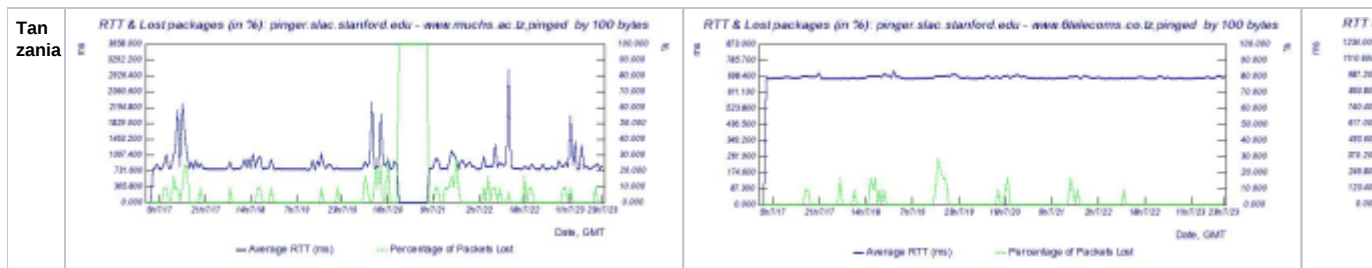
In September 2005 most traffic from South Africa to the rest of Africa took costly international links, only Botswana and Zimbabwe had direct routes. The situation has improved recently as direct routes from South Africa to Namibia and Botswana were added. More details on the routes to African countries from several measurement points around the world measured in Spring 2009 can be seen in a spreadsheet of [African routing and inferences](#).

Connections from Burkina Faso in August 2009 were direct to only Senegal, Mali, and Benin (in green). Most other countries in grey were reached by intercontinental connections via Europe, followed by many in teal that go via Europe and N. America. Somalia was reached via Europe, N. and S. America. Burundi was reached via Europe, N. America and E. Asia.

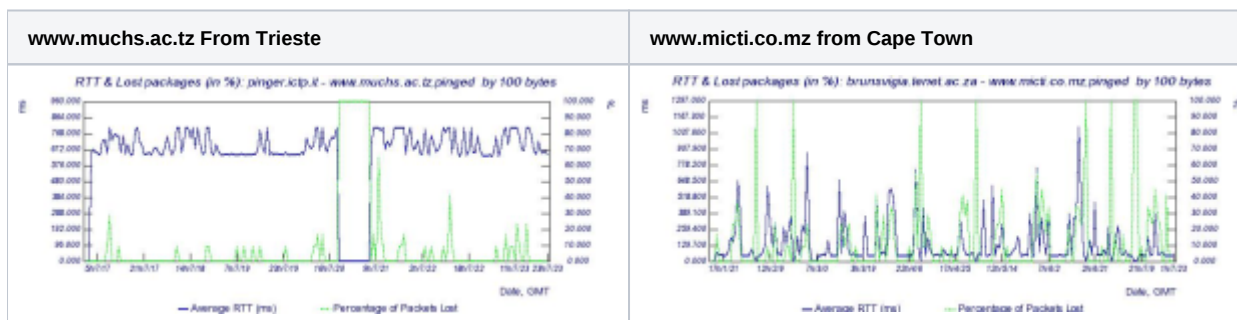
Initial Results on First Day

One would expect with the use of a terrestrial fibre rather than a geo-stationary satellite that the minimum RTT would be reduced from ≥ 400 ms to 200-300ms as seen from the US. Also the reduced congestion enabled by the higher speed links should make the average RTT more stable and reduce the packet loss. Below are shown the average RTTs and losses from SLAC on the West Coast of the US to various hosts on the East Coast of Africa. These are all measured using the [PingER](#) project's data.





It is apparent we do not observe any dramatic reduction in RTT on July 23rd. We also looked at the PingER recorded RTT from ICTP Trieste, Italy to a host in Tanzania in case the routes from SLAC were still using satellite while those from Italy were not. We also looked at the RTT seen from a TENET host in cape Town South Africa to a host in Mozambique. In this case (see below) the RTTs have long been << 400ms so they already were not using geostationary satellite to connect the sites.



Again there is no dramatic reduction. looking at the TENET to www.micti.co.mz RTTs it is apparent that there is a direct (non geo-stationary) satellite connection between the two sites since the RTT << 400ms.

According to the BBC report five institutions are already benefiting from the faster speeds - national electricity company Tanesco, communications company, TTCL, Tanzania Railways and the Universities of Dar es Salaam and Dodoma. we also heard from Alem who was visiting Kenyatta University from Ethiopia for a one day conference that "You can get connected and download data like what you can do in Europe."

From SLAC, we pinged hosts at each of these organizations, the Round Trip Time (RTT) results in msec. are shown below: For the # pings with an asterisk the host did not respond to pings so we used [synack](#) to probe the web server:

Country	Organization	Host	# pings	Min RTT	Avg RTT	Max RTT	Std dev	Loss
Tanzania	Tanzania railways	www.trctz.com	100	764	790	893	19.5	0%
Tanzania	Tanzania Telecommunications Company	www.tlcl.co.tz	100*	714	721	730	4.3	1%
Tanzania	University of Dar Es Salaam	www.udsm.ac.tz	151	696	711	1130	45	0%
Tanzania	University of Dodoma	www.udom.ac.tz	100*	753	783	845	18	0%
Tanzania	Tanesco National Electric Company	www.tanesco.com	49	12.6	12.997	13.53	0.251	0%
Kenya	Kenyatta University	www.ku.ac.ke	138	650.138	652.36	668.44	1.97	2%

The host www.tanesco.com is probably a proxy located somewhere in the Western US. The other hosts all have minimum RTTs of well over 400ms which indicates they are probably still using a geo-stationary satellite.

When looking at the lack of effects seen initially following the fibre install it is important to understand the [caveats](#).

To enable easier selection and looking for changes for these East African Coastal countries, we added a PingER affinity group (E.AFRICA_COAST) for hosts monitored in Kenya, Mozambique and Kenya. The minimum RTT should be very sensitive to a change in the route from a geo-stationary satellite to a terrestrial fibre link. An example of selecting data sensitive to the E. African fibre connection can be seen in the [table of PingER daily minimum RTT data for the group E.AFRICA_COAST](#). This data is updated daily.

Adding Extra Hosts

We received suggestions from Don Riley of UMD:

I would be watching kdn.co.ke, kenet.or.ke in Kenya. maybe also Univ. of Nairobi. KDN should change soon, since they're connecting directly to SEACOM and lighting fiber to Uganda and Rwanda. KENET should be first on the university side, I think. and Univ. of Nairobi - typical for lead univ. in capitol to come up first. Similar in TZ and MZ, but looks like you've got the right lead univ's there. Would probably track MORENET and TERNET there.

We have been monitoring kdn.co.ke so we will have a nice history and see the change.

Kenet.or.ke does not respond to pings, using synack the response time to its web server (kenet.or.ke:80) on 7/25/09 was about 667ms.

For the University of Nairobi I Googled it and got www.uonbi.ac.ke however it has an RTT of 78ms from SLAC and appears to be in Virginia USA. Instead I added library.uonbi.ac.ke that is a University of Nairobi host that appears to be in Nairobi. On 7/25/09 it had an RTT of ~ 658ms.

I googled MORENET Mozambique and came up with morenet.mct.gov.mz. However it does not respond to pings. It does respond to synack on port 80 (www) and the response time to a trivial request is ~368ms so it may have already moved over. However GeoIPTool (see <http://www.geoiptool.com/en/?IP=morenet.mct.gov.mz>) says it's in Buenos Aires which I do not believe. Visualroute's (at <http://visualroute.visualware.com/>) tests fail. Looking at the [traceroute from SLAC](#) and using GeoIPTool to locate the nodes, it appears that on leaving the US the route goes directly from the West Coast of the US (Sunnyvale) through Buenos Aires (node telkomsa.ge9-16.br02.ldn01.pccwbtn.net 152ms) then to Pretoria (rrba-ip-lir-1-pos-1-0-4.telkom-ipnet.co.za 352 ms) and then to Mozambique. This it is not currently using the new fibre optic cable running South down the E. African coast. Looking at a map of the world's undersea fibre cables in the region may help explain this.



I have added www.tenet.or.tz on 7/25/09 it had a ping RTT of 705ms.

We also [added some hosts in Somalia](#).

Steve Song pointed out that a good PingER point would be the Durban University of Technology. They are the only university in South Africa to be currently connected to Seacom. This was confirmed by Duncan Martin of TENET in an [email](#). All the rest are waiting for the development of the national [SA NREN backbone](#), later this year. I added www.dut.ac.za to the list of hosts monitored by PingER on 8/6/09. We will look to see whether we can see differences between it and other hosts monitored in South Africa.

Later Results Illustrating Impact of Changes

To assist in the selection of hosts in this region from the [pingtable results](#), we created an affinity group that contains all hosts in Kenya, Mozambique and Tanzania. This makes it much simpler to look at the [minimum RTT for just such hosts for the last few days](#)

Uganda should be connected soon. KDN was building the fiber to Uganda and Rwanda. We therefore also set up a group for countries in the UN definition of Eastern Africa to simplify reviewing [minimum RTT for all East Africa](#).

Kenya

On Aug 2, 2009 following an email from Don Riley who had detected that kdn.co.ke had dropped to 370ms. We were Unfortunately not monitoring kdn.co.ke. However on further investigation we found the RTT from SLAC to acheraarchitects.co.ke (see below) had changed between 14:00 and 17:00 hours 6/1 /09 GMT from a steady 716 ms to a steady 325ms. This is exactly what one would expect as the route moves from a GEOS to a terrestrial line. The [traceroute from SLAC to Kenya](#) went via ESnet to Sunnyvale, then via Level3 to New York and London and thence to Kenya. The RTT between London and Kenya was about 200ms.

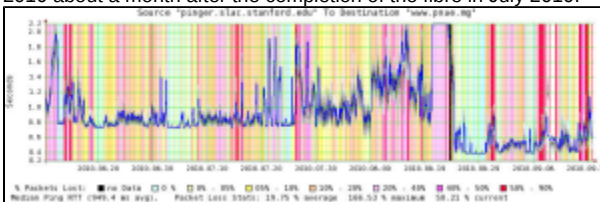
On August 3, 15:00 hours www.ku.ac.ke dropped to about 370ms (see below), the earlier step change from 650ms to 550ms may have been since only one direction of the route was using the terrestrial line. The large difference by time of day indicate that there is probably still congestion somewhere in the route. A [traceroute](#) after the changeover shows the route going via ESnet to New York and via Level3 onto London, there it is transferred to InterRoute and is carried to Kenya by Seacom and thence to [Nairobinet](http://nairobinet.net). According to http://www.interoute.com/news_and_events/news/1278 Seacom partners with Interoute.

On August 3, around 19:00 hours elearning.braeburn.ac.ke dropped from about 750ms to about 400ms (see below). The [traceroute from SLAC to Braeburn](#) is different from that to www.ku.ac.ke. It goes from SLAC via Esnet to Sunnyvale, crosses to Teleglobe and then to AS6453 to get to London. AS6453 is GLOBEINTERNET TATA Communications. In Kenya one of the nodes is Access Kenya which according to <http://www.accesskenya.com/> "Access Kenya: ACCESSKENYA SETS AMBITIOUS TARGET OF 1MB GUARANTEED SPEED FOR THE AVERAGE CUSTOMER. ACCESSKENYA UPGRADES CORE NETWORK IN PREPARATION OF SEACOM AND TEAMS CAPACITY" (their capitalization).

More details on the Kenyatta University (www.ku.ac.ke) and Braeburn (elearning.braeburn.ac.ke) links can be found in an [email from Kevin Chege of KENET](#).

Mozambique

Mozambique is connected through the EASSY submarine cable. It appears one of the hosts we measure activated the terrestrial link on ~ 25th August 2010 about a month after the completion of the fibre in July 2010.



Rwanda

Between the 22nd and 25th of September the RTT from SLAC to The Kigali Institute of Education host www.kie.ac.rw in Kigala, Rwanda dropped by a factor of 2 from 720msec to 320msec (see below). The [connection](#) was through Kampala Uganda to Kenya. The [traceroute](#) appears to go via Austria.

Tanzania

On the 26th September 2009 the RTT from SLAC to www.acet.or.tz in Dar Es Salam Tanzania dropped from about 720msec to about 310msec (see below).

Uganda

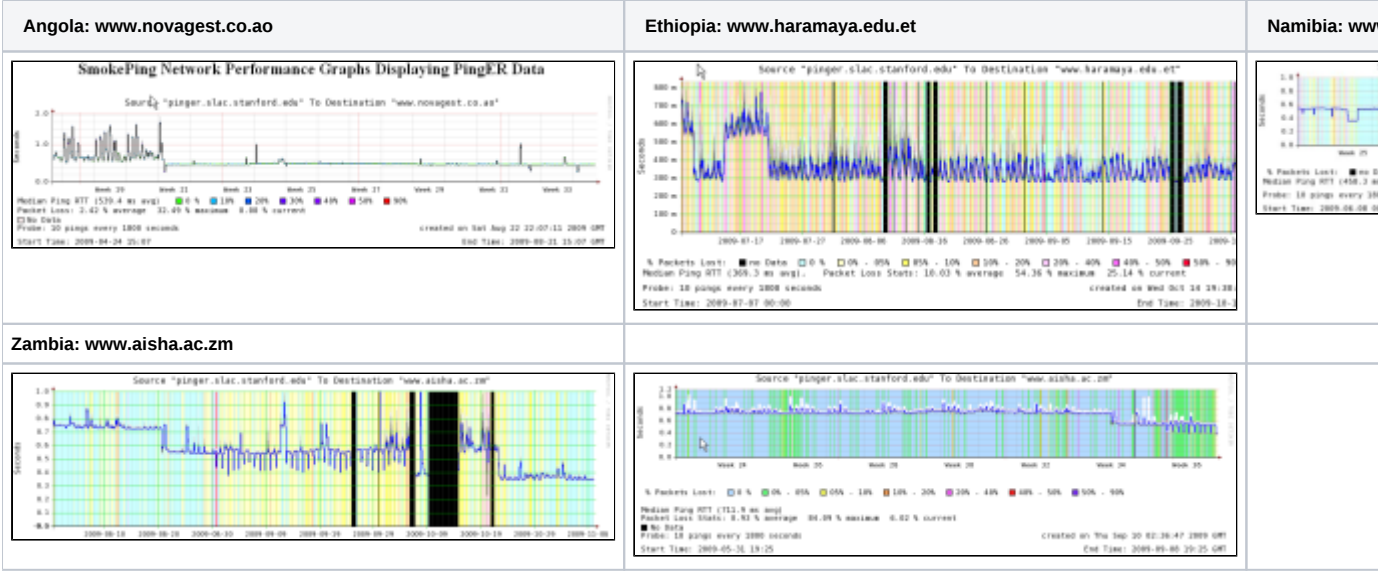
By August 3rd, the average RTT from SLAC to mail2.starcom.co.ug in Kampala **Uganda** reduced from about 780ms to about 540ms. On August the average RTT dropped further to about 380ms. Possibly in the intermediate state (540ms) only one direction was using the fibre. The [traceroute measured on 8/15/09](#) shows the route going via ESnet to Sunnysvale then onto San Jose and Level3 that carries it to New York and London, the next hop is in Nairobi an [InterSat Africanode](#). Hop 18 is also in Nairobi and hop 19 in Kampala. Looking at the time series of the average RTT below it is not clear the route has fully stabilized yet.

In some cases such as Uganda Telecom (81.199.21.194) the losses and fluctuations in RTT went up dramatically after the changeover. In others such a libRARY.uonbi.ac.ke and acherarchitects.co.ke the losses and stability appeared to improve.



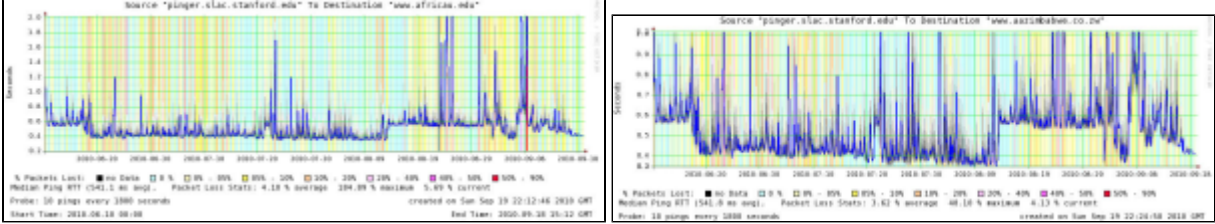
Zambia

One host (www.aisha.ac.zm) of the 6 monitored in **Zambia** improved its RTT from about 720ms to 550ms on August 20, 2009 (see below). They then spent many days moving the link over to the terrestrial lines. During this time the performance was very unstable (high losses) and there were big changes in RTT. It is probable the link in one direction was using a GEOS while the other was an all terrestrial link and the large dips to 400ms were when both legs were using terrestrial links. We believe the terrestrial path goes via Botswana and Namibia. The [traceroute](#) from SLAC on 9/9/09 appeared to use a satellite link in at least one direction. The final cutover to terrestrial links in both directions appears to have been made on October 23rd when the RTT dropped to ~350ms and the link appeared more stable. On October 2, 2009 Mike Jensen reported that the [traceroute from Rome to www.aisha.ac.zm on Oct 2, 2009 from Rome](#) was well below 450ms and thus appears to be a terrestrial link. However the traceoute from SLAC was still taking over 550ms. Also the [traceroute from TENET/Cape Town South Africa to www.aisha.ac.zm](#) took over 650ms. The [traceroute from NUST, Islamabad, Pakistan to mail.unza.zm](#) takes less than 450ms and appears to be a terrestrial path going via Namibia. On October 7th 2009 the [traceroute from SLAC to mail.unza.zm](#) appeared to be terrestrial and went via Namibia.



Zimbabwe

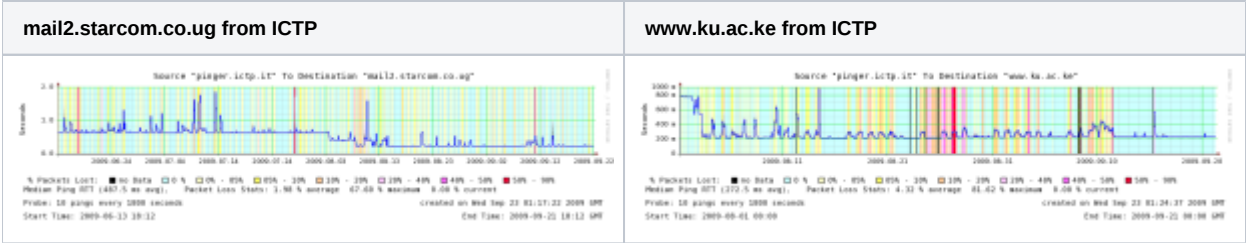
There is some evidence that at least one host in Zimbabwe (www.africau.edu) may have activated a terrestrial route around June 18th 2010, see the graph below. Around that date the RTT dropped from 550 ms to about 400ms, however it went up again around August 12th 2010. Similar results are seen for a second Zimbabwean host www.aazimbabwe.co.zw, suggesting a common access route between them and SLAC.



Seen from ICTP Trieste Italy

If one compares the RTTs seen from SLAC to East Africa with those seen from ICTP in Trieste Italy which is much closer, then:

- for www.ku.ac.ke from ICTP the change is from 800ms to ~200ms (a factor of ~4 improvement) while from SLAC it is 650ms to ~350ms (or less than a factor of 2 improvement)
- for mail2.starcom.co.ug from ICTP the change is from ~600ms to 200ms (or a factor of 3 times) while from SLAC it is 800ms to 350ms (or just over a factor of 2 improvement)



Though we show several time series of median RTT for hosts in various countries which have converted from GEOS to landlines, in all the countries above there are still hosts that are connected via GEOS.

Other Nearby Countries

Similar effects (dramatic reduction in RTTs) have also been observed for other sites in south and eastern African countries.

Angola

For example on May 19th 2009, www.novagest.co.ao one of 4 sites PinGER monitors in **Angola** reduced the average RTT from about 750ms to 450ms and became much more stable (less jitter) in the process (see the time series in the figure below). The [traceroute](#) goes via Globenet TATA Communications and then to the Angola Telecom IP backbone.

Ethiopia

The RTT from SLAC to www.haramaya.edu.et at the University of Addis Ababa in Dire Dawa, **Ethiopia's** second largest city (about 300km as the crow flies from the coast) on the railway line between Djibouti and Addis Ababa, dropped from about 580ms to 300ms on June 9th 2009 (see below).

Malawi

Malawi currently (10/13/09) has only GEOS access. The most likely terrestrial path will be via Mozambique to Maputo (the landing point for both Seacom and TEAMS) see the [email from Bjorn Pehrson](#) and the [article by Telegeography](#). From the PingER measurements from SLAC to www.kcn.unima.mw it appears to have converted to a terrestrial path in Jan-Feb 2010.

Mozambique

Similarly the average RTTs of both hosts that PingER monitors in **Mozambique** (www.uem.mz and www.micti.co.mz) dropped from 780ms to about 360 ms in May 2007.

Namibia

On the other hand hosts in **Namibia** (such as www.adsl.com.na seen below) seem to be switching between using a long RTT path from SLAC and a shorter one.

Fractional Conversion

The table below shows the number of hosts monitored from SLAC in the country and the number of those that used a terrestrial path as of a particular date.

			Monitored	Terrestrial			
	Oldest Measured Data	1st observed conversion	10/17/09	10/17/09			
Angola	Oct 2006	May 19, 2009	3	1			
Botswana	Apr 2009	None	3	2			
Ethiopia	Nov 2008	June 9, 2009	7	1			
Kenya	Feb 2005	Aug 2, 2009	6	5			
Lesotha	Feb 2005	None	2	2			
Madagascar	Dec 2003	None	2	0			
Malawi	Mar 2005	None	3	0			
Mozambique	Dec 2003	May 2007	2	0			
Namibia	Feb 2007	?	2	1			
Rwanda	Mar 2005	Oct 17, 2009	3	1			
South Africa	Feb 2005	None	14	12			
Swaziland	Oct 2007	Feb 2009	3	1			
Tanzania	Dec 2003	Sep 26, 2009	5	1			
Uganda	Nov 2003	Aug 3, 2009	3	2			
Zambia	Feb 2009	Aug 20, 2009	6	1			
Zimbabwe	Feb 2007	None	5	0			

Other Regions in Sub-Saharan Africa

On September 6th, 2009 it was reported that the [Glo-1 Submarine cable landed in Lagos, Nigeria](#). The 9800km cable is coming from Bude in the UK and connects Nigeria to the rest of West Africa and the UK. It has landing points in Nigeria, London and Lisbon in Portugal. It is deploying 16 branching units to connect countries in West Africa. It is a project jointly executed by Globacom and its partners, Alcatel Lucent. this brings competition to the SAT3/WASC/ cable consortium. In May 2010 the [Main One cable](#) will be landing on the West Coast of Africa.

Further Reading

Africa Undersea Cables

[The Cable Guy: How to Network a Continent](#) is a great Wired UK article that tells a compelling story illustrating the physical dimension and the challenges of deploying broadband in Africa.

[How to Cross the Digital Divide, Rwanda-Style](#) provides an interesting case study of how Rwanda has been able to somewhat bridge the digital divide in a methodological manner.

[Celebrating ten years of the Ubuntunet Alliance, Oct 2015](#)

[Internet prices to fall with surge in clients](#)

[Linking Tunisia with Italy](#)

[MANGO-NET \(Made in Africa NGO NETwork\)](#)