



PingER End to End Internet measurements: what we learn

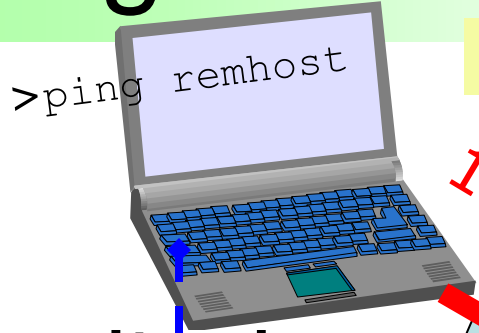
Les Cottrell^{SLAC},

Presented at the OARC/TechDay for the ICANN San Francisco March 7th, 2011

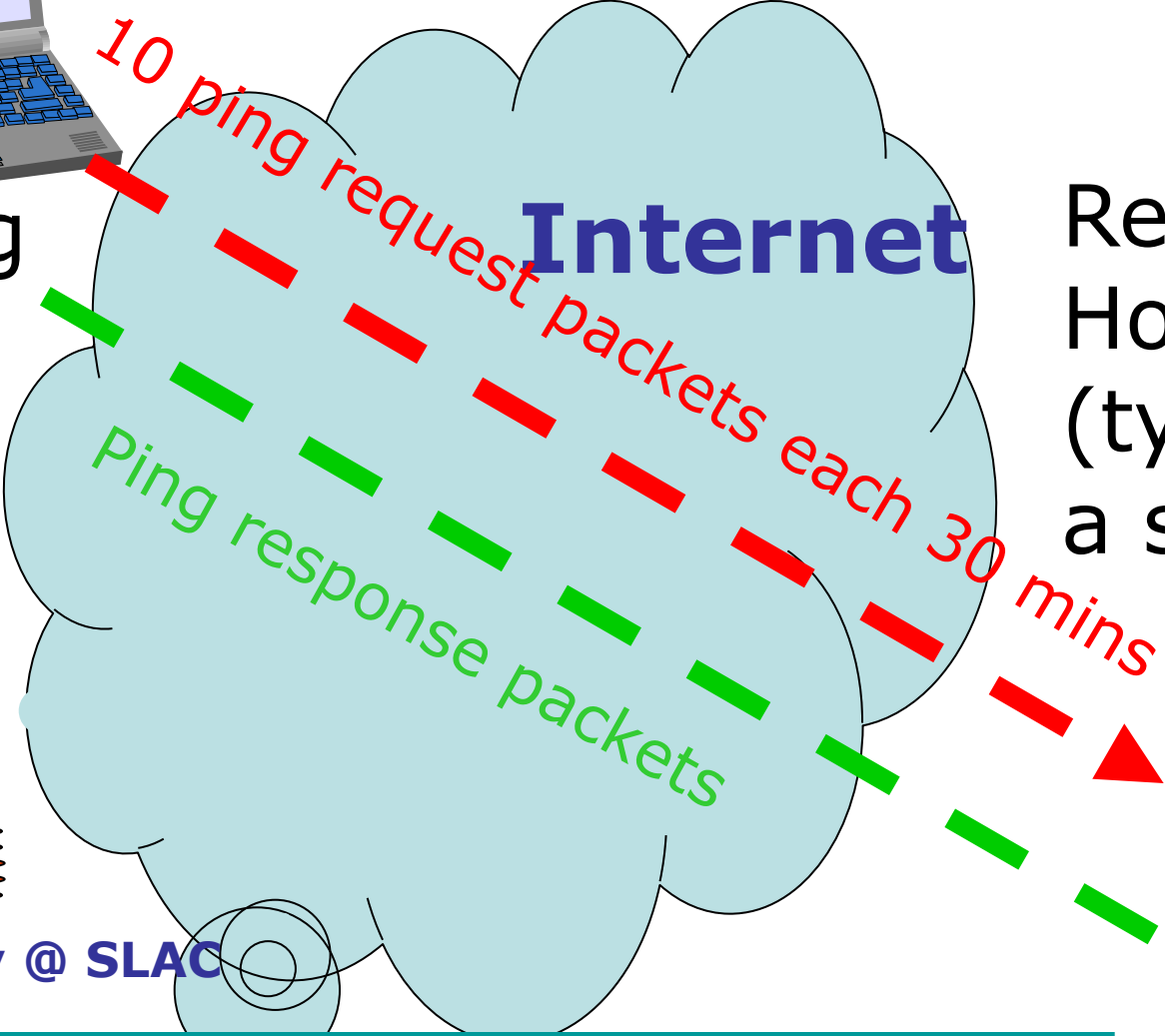
- How do we measure?
- Coverage
- What do we find?
 - Measure: Losses, RTT, Jitter, Unreachability
 - Derivations: Throughput, MOS, Directness of connections
- Relations to Human Development Indices
- Case Studies:
 - Africa and new undersea fibres
 - Fibre cut impacts
 - Egypt, Libya, Japan

PingER Methodology extremely Simple

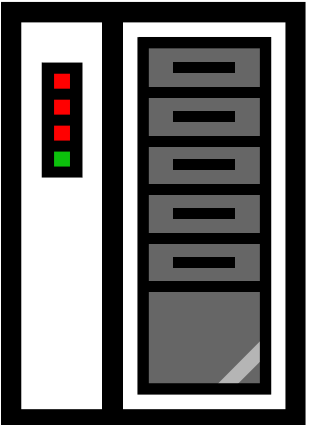
Uses ubiquitous ping



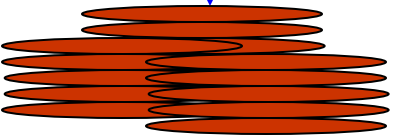
Monitoring host



Remote Host (typically a server)



Once a Day



Data Repository @ SLAC

Measure Round Trip Time & Loss

- Monitors ~70 in 23 countries – 4 in Africa
- Beacons ~ 90
- Remote sites (~740) – 50 African Countries
– ~ 99% of world's population in monitored countries



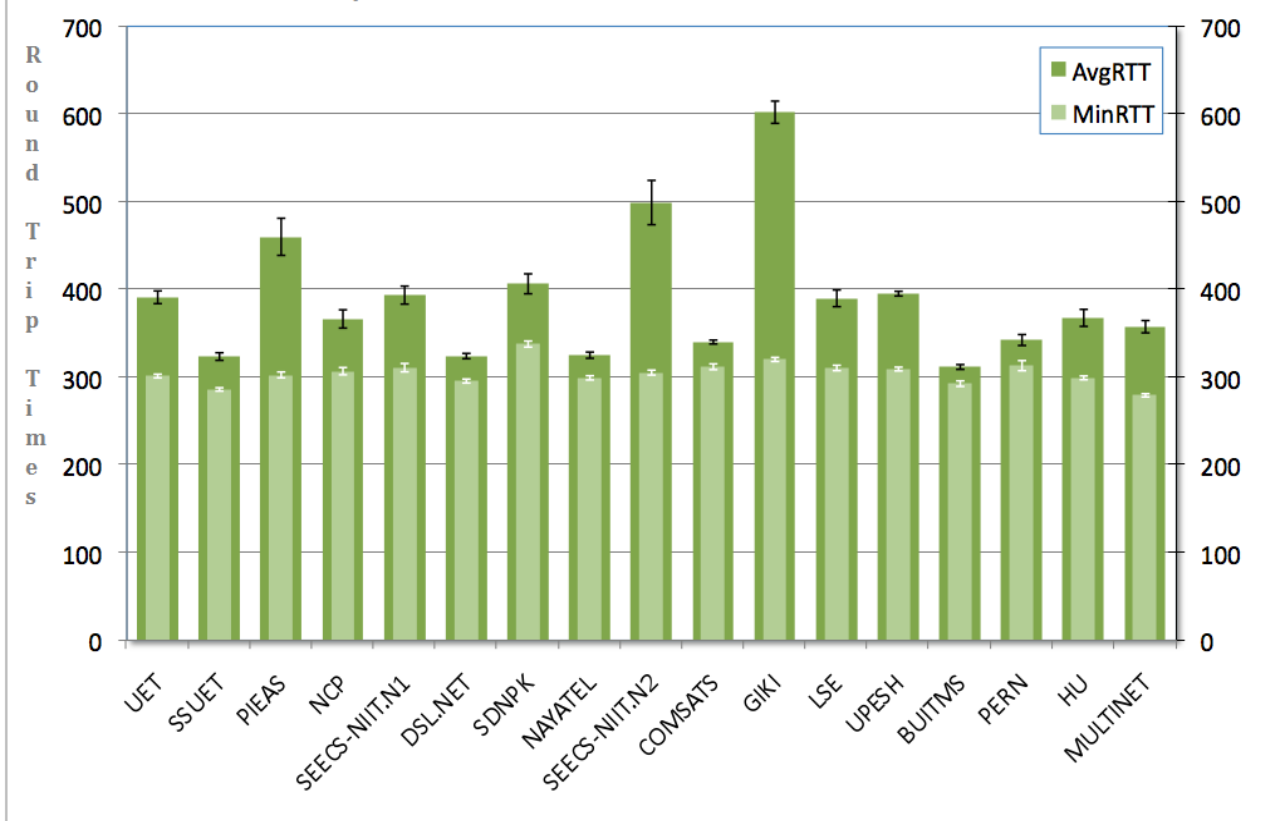
Measure: RTT, jitter, loss, unreachability

Derive: throughput, MOS, Directness of links

Variation in RTT & Congestion

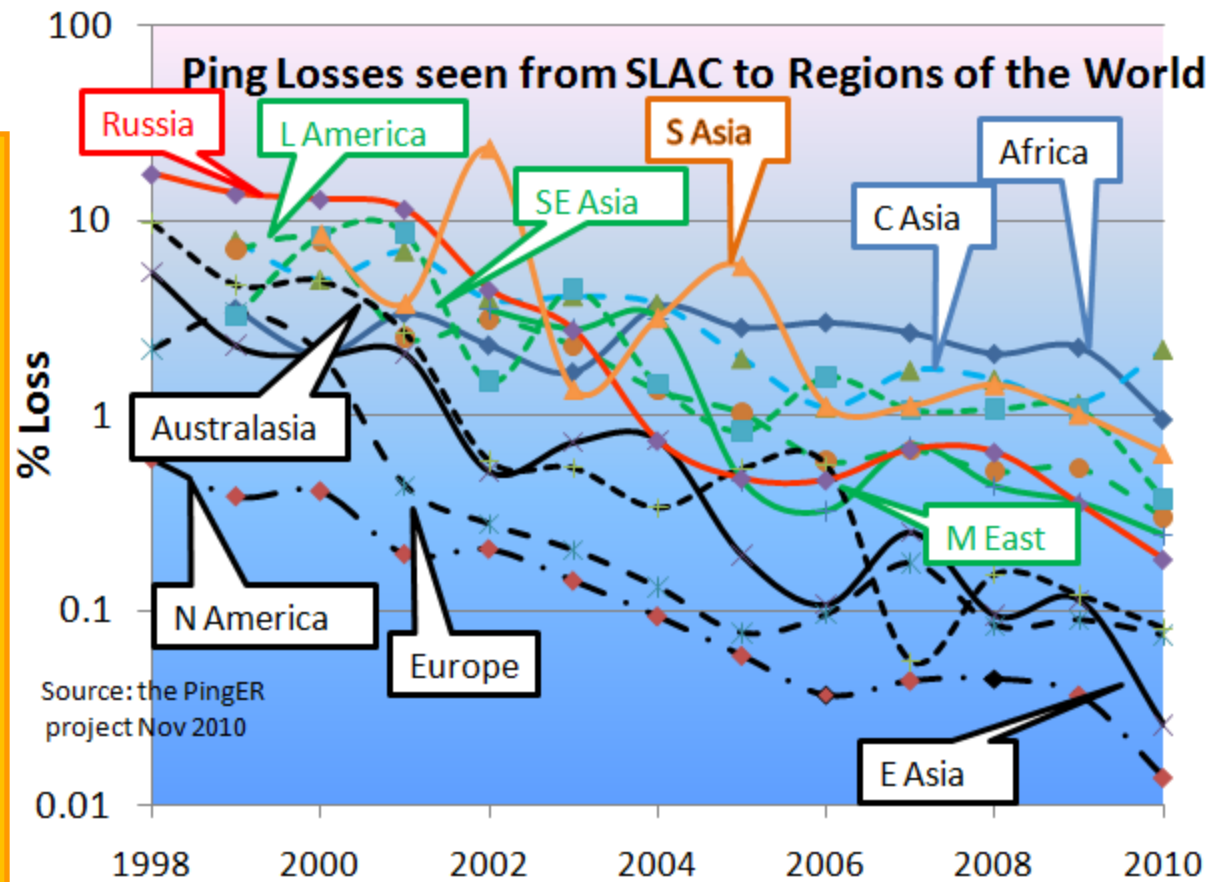
- Can use difference in min_RTT and Avg_RTT
- Or measure Inter packet variation to get jitter

Round Trip Times for Pakistan as seen from SLAC Jan 08 - Jan 09



- Low losses are good.
- Losses are mainly at the edge, so distance independent
- Losses are improving exponentially, ~factor 100 in 12 years

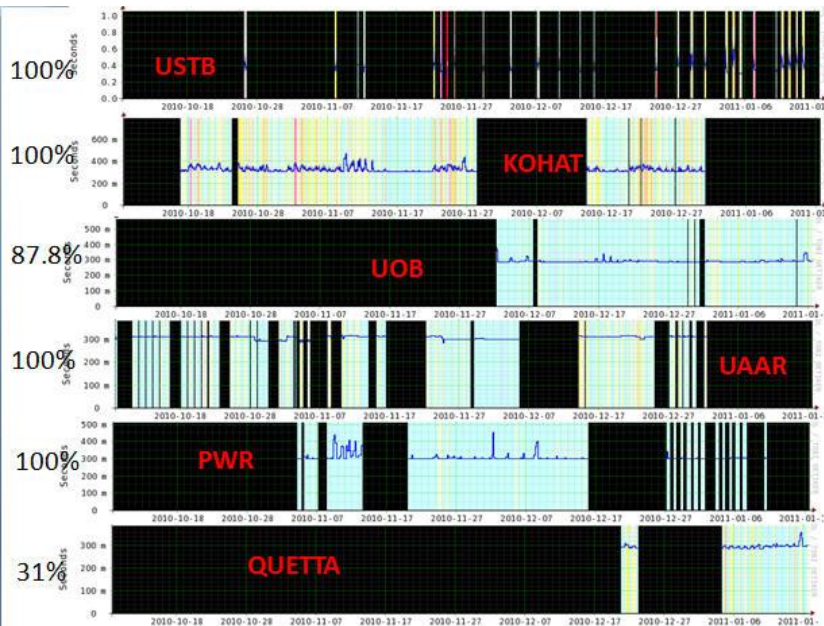
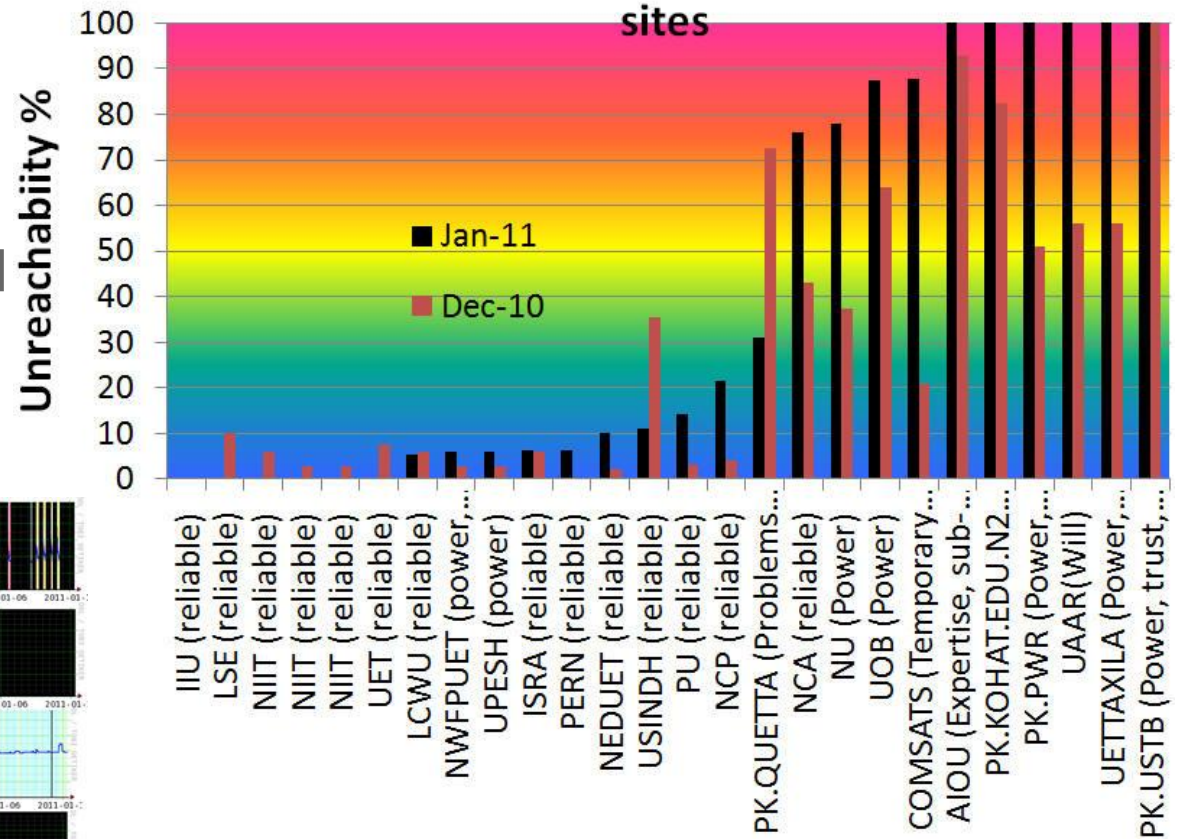
- Best <0.1%: N. America, E. Asia, Europe, Australasia
- Worst > 1%: Africa & C. Asia



Unreachability Example Pakistan

- An unreachable host doesn't reply to any pings.
- We chose a reliable host at SLAC (pinger.slac.stanford.edu) and analyzed the unreachability of Pakistani hosts.

Unreachability from SLAC to Pakistani monitoring sites



Big problems with power, lack of oil, budgets etc.

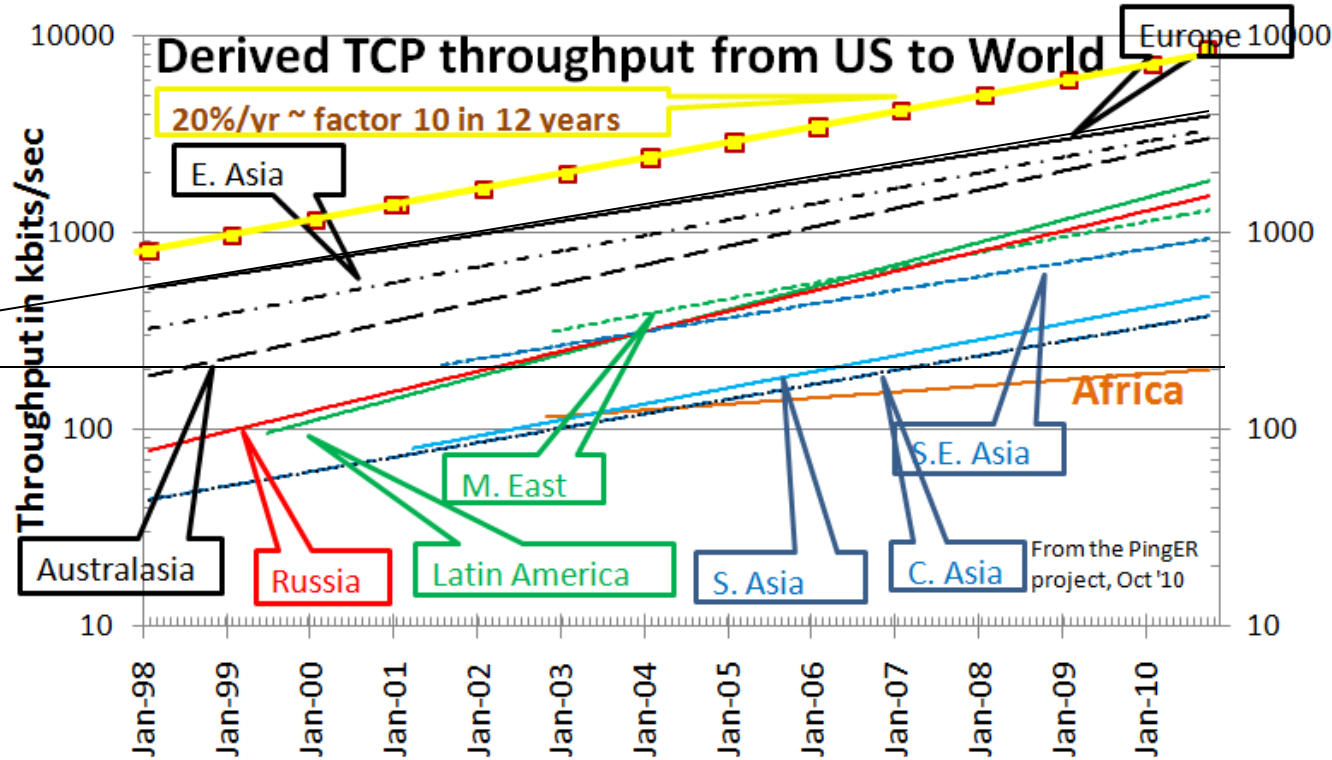
World Throughput Trends

Derived throughput $\sim 8 * 1460 / (RTT * \text{sqrt}(\text{loss}))$
Mathis et. al

Europe, E. Asia & Australasia merging Behind Europe
5-6 yrs: Russia, L America, M East
9 yrs: SE Asia
12-14 yrs: India, C. Asia
18 yrs: Africa

Feb 1992

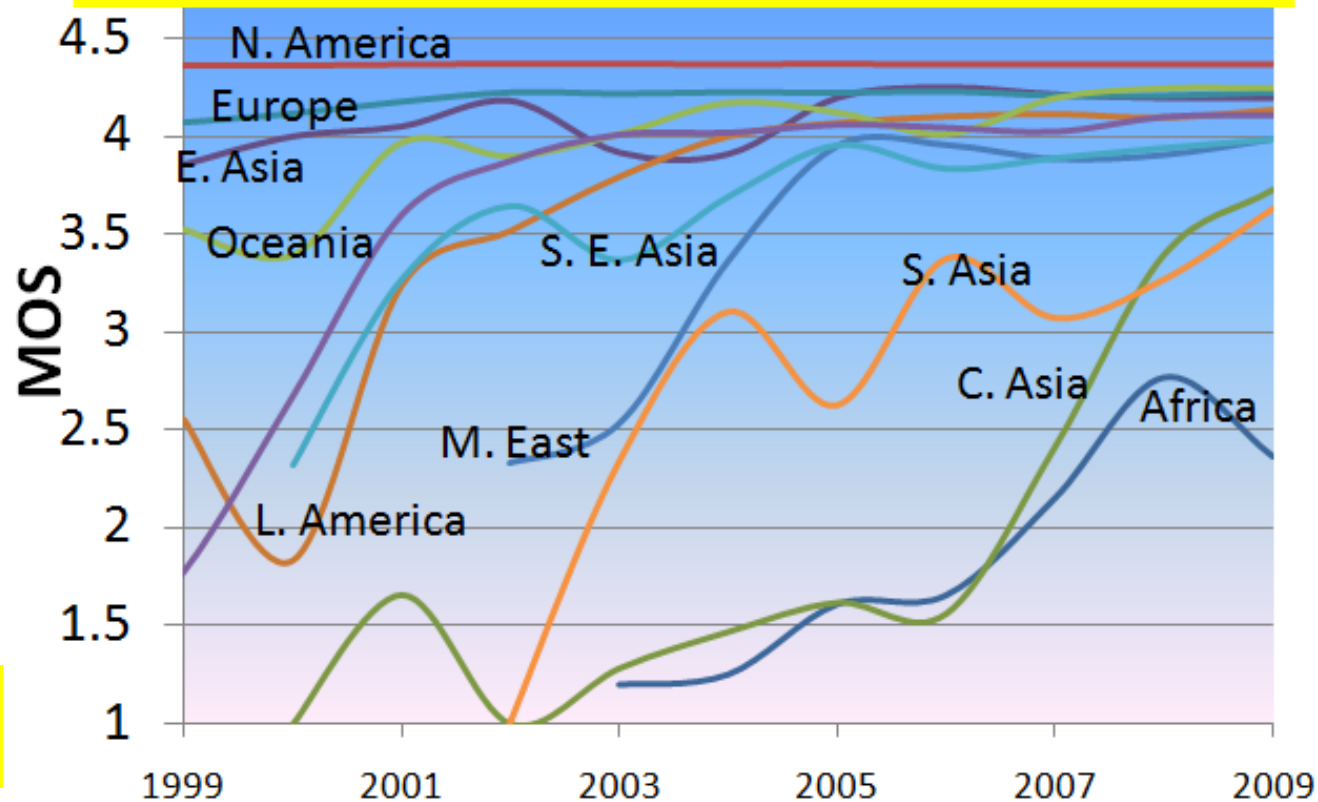
Africa in danger of falling even further behind. In 10 years at current rate Africa will be 150 times worse than Europe



Mean Opinion Score

- Used in phone industry to decide quality of call
- $MOS = function(loss, RTT, jitter)$
- 5=perfect, 1= lowest perceived audible quality
- ≥ 4 is good,
↑
Usable
↓
- 3-4 is fair,
- 2-3 is poor etc.

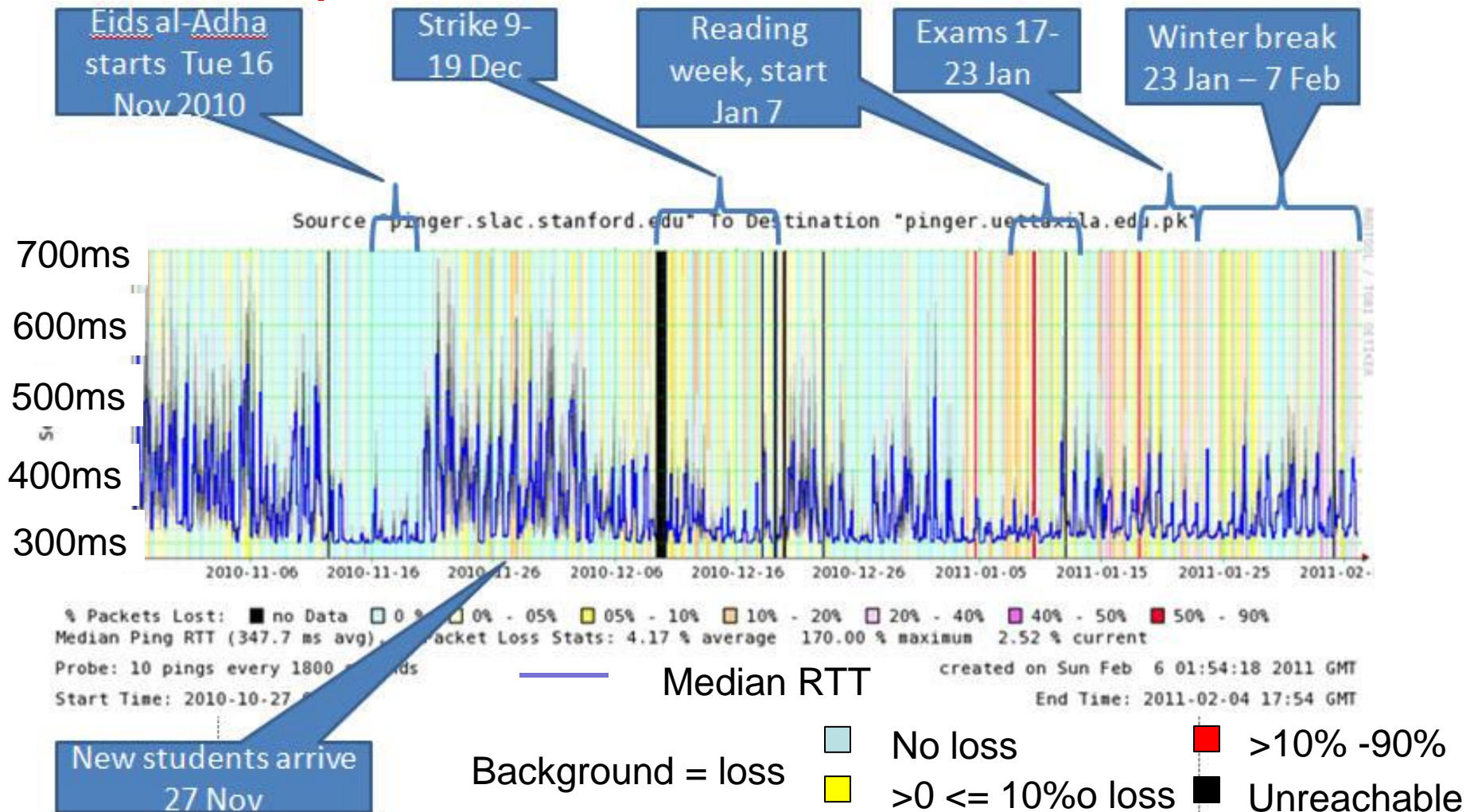
MOS Measured from SLAC to world regions



Important for VoIP

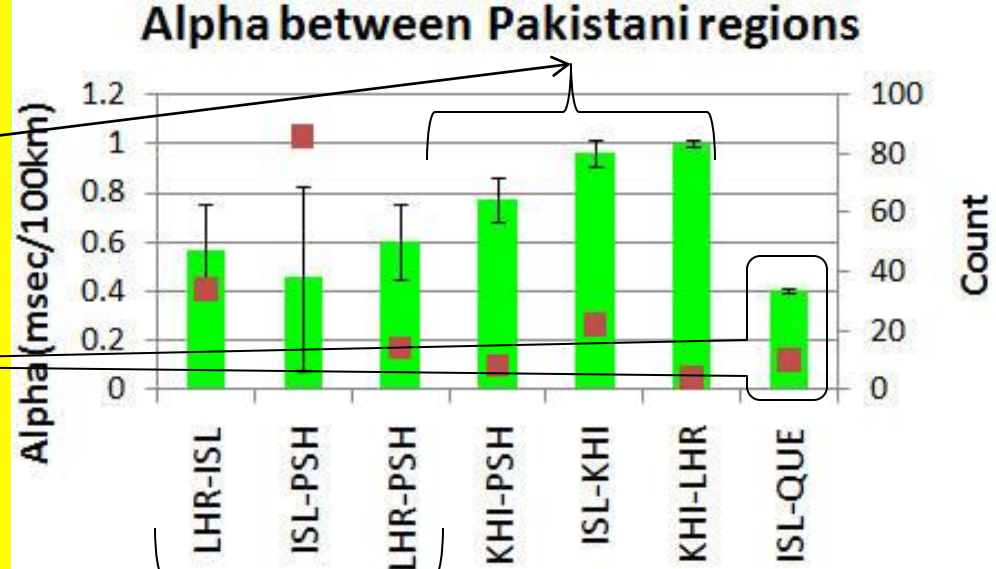
Correlation with Social Activity

- Between SLAC and Taxila U in Pakistan. Can correlate performance with activities

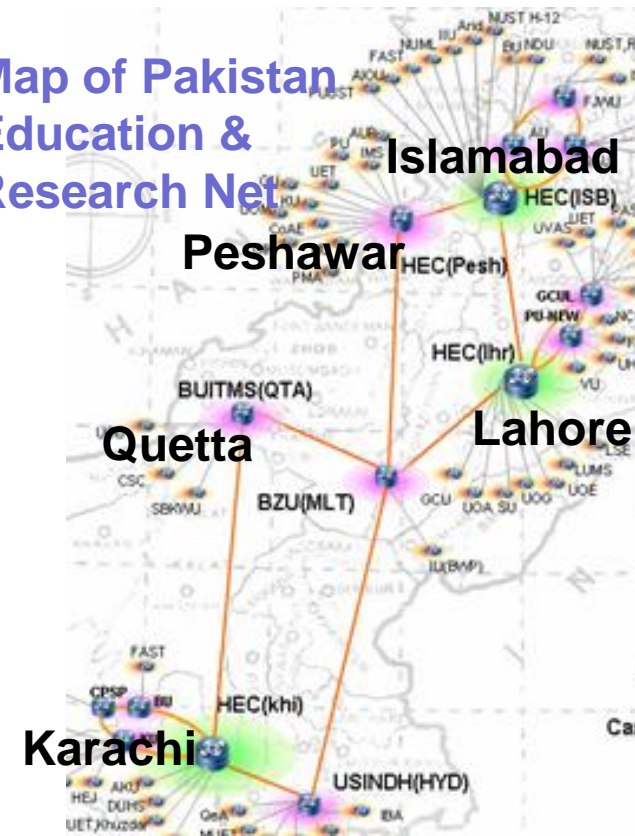


- The speed of light in fibre is roughly $0.66 \cdot c$
 - ‘c’ = speed of light in vacuum i.e. 299,792,458 m/s
- Using 300,000 km/s as ‘c’ this yields:
 - $RTD [km] = Alpha * min_RTT [ms] * 100 [km/ms]$
- *Alpha* is a way to derive Round Trip Distance (RTD) between two hosts (using minimum RTT).
- Or if we know the RTD
 - Large values of *Alpha* close to one indicate a direct path.
 - Small values usually indicate a very indirectly routed path.
- This assumes no queuing and minimal network device delays.

- **Direct links (alpha close to 1) for:**
 - Karachi and Lahore
 - Karachi and Islamabad
 - Karachi and Peshawar
- **Very indirect link between Islamabad and Quetta (low alpha).**
 - Route goes via Karachi in the south and then back northwards to Quetta.
- **More indirect links (lower alpha):**
 - Islamabad and Lahore
 - Islamabad and Peshawar
 - Lahore and Peshawar
 - Islamabad is a common element



Map of Pakistan Education & Research Net



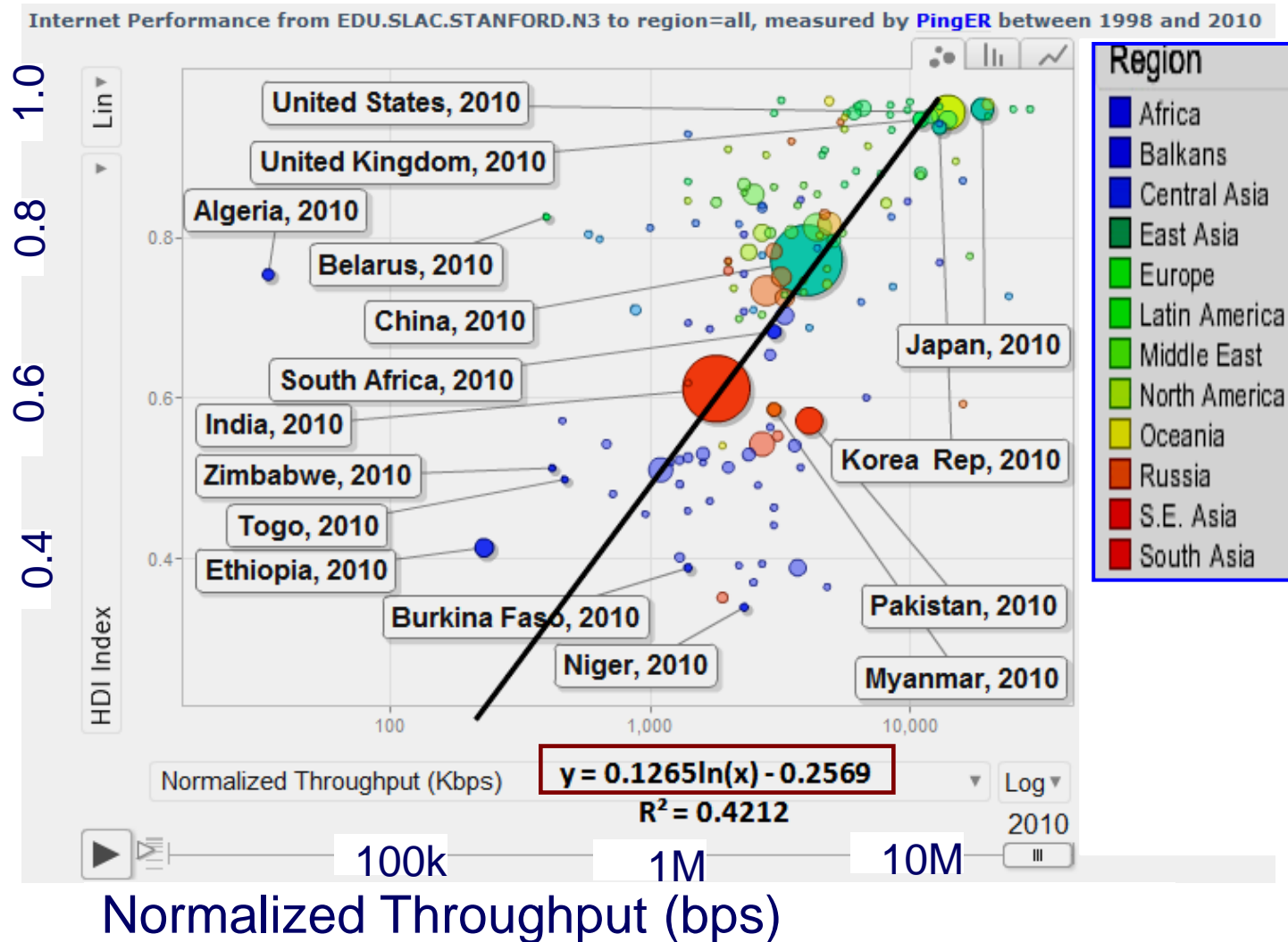
- **Islamabad's intra-city traffic experiences multiple hops (within a few square kms).**
- **Outbound Islamabad traffic also experiences a slightly indirect route (multiple hops).**
- **Traffic passing between Peshawar and Lahore shows a much more direct route.**



Normalized TCP Throughput in 2010 vs. UN Human Development Index (HDI)

UNDP HDI:

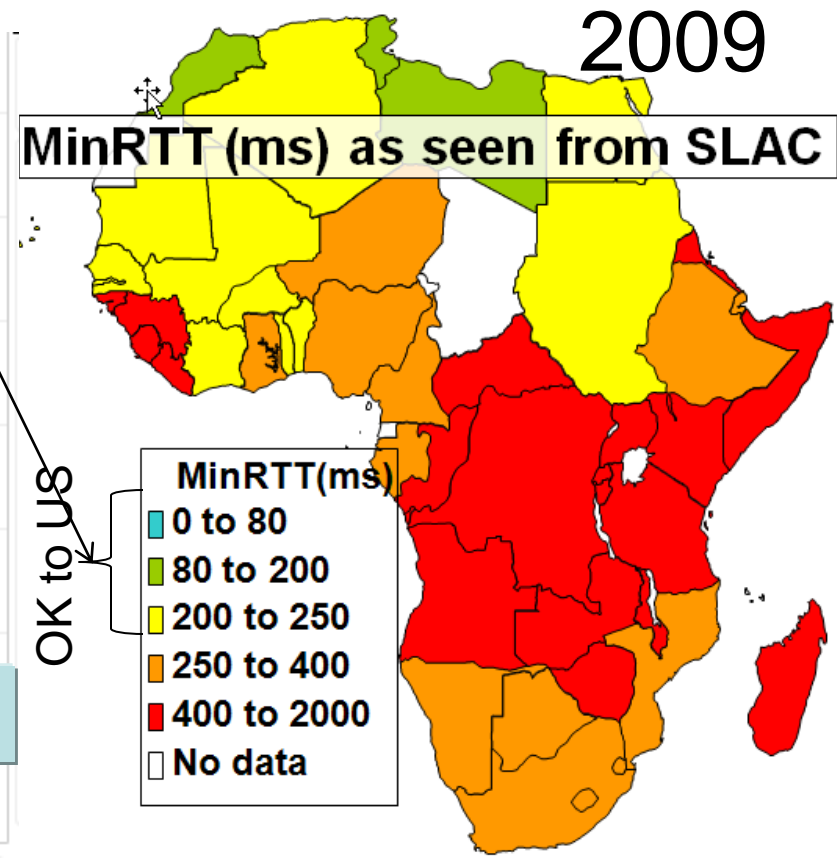
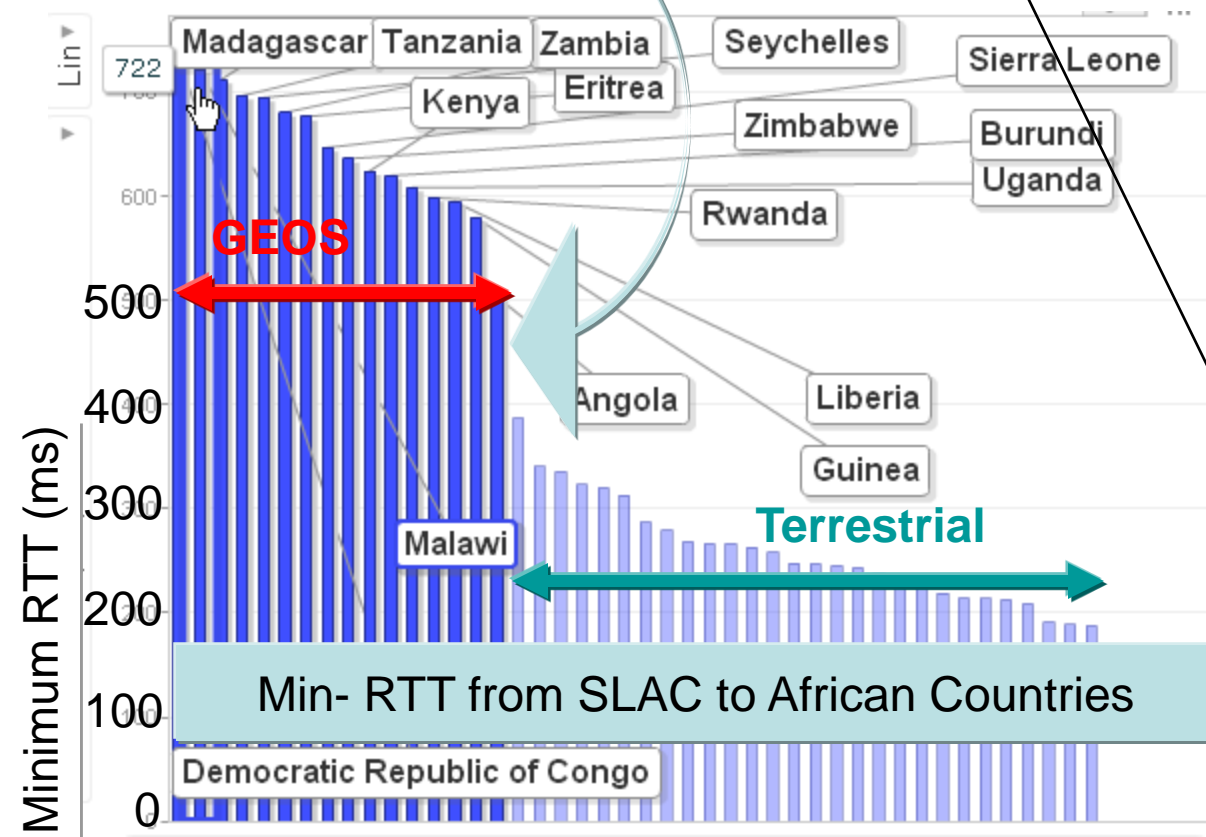
- ◆ A long and healthy life, as measured by life expectancy at birth
- ◆ Knowledge as measured by the adult literacy rate (with 2/3 weight) and the combined primary, secondary and tertiary growth enrollment ratio (with 1/3 weight)
- ◆ A decent standard of living, as measured by GDP per capita



A Clear Correlation Between the UNDP HDI and the Throughput

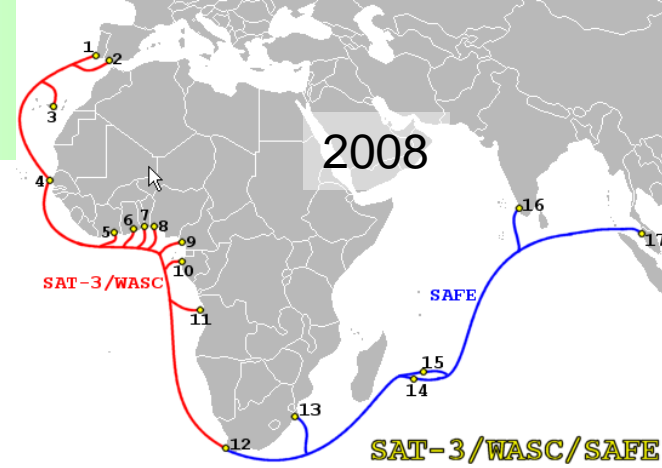
Why does Fibre matter: Satellite & Min-RTT for Africa

- GEOS (Geostationary Earth Orbit Satellite)
 - good coverage, but expensive in \$/Mbps
 - broadband costs 50 times that in US, >800% of monthly salary c.f. 20% in US
 - AND long delays min RTT > 450ms which are easy to spot
 - N.b. RTTs > 250ms v. bad for VoIP



What is happening

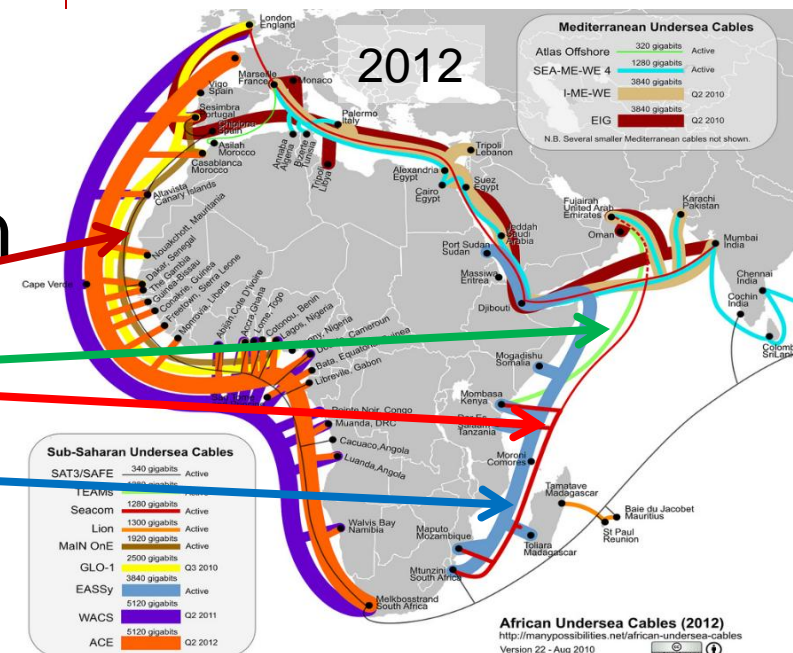
- Up until July 2009 only **one** submarine fibre optic cable to sub-Saharan Africa (SAT3) costly (**no competition**) & only **W. Coast**



- 2010 Football World Cup** => scramble to provide fibre optic connections to S. Africa, both E & W Coast



- Multiple providers = competition
- New Cables: **Seacom**, **TEAMs**, **Main one**, **EASSy**, already in production



manypossibilities.net/african-undersea-cables

Impact: RTT etc.

- As sites move their routing from GEOS to terrestrial connections, we can expect:
 - Dramatically reduced Round Trip Time (RTT), e.g. from 700ms to 350ms – seen immediately
 - Reduced losses and jitter due to higher bandwidth capacity and reduced contention – when routes etc. stabilized
- Dramatic effects seen in leading Kenyan & Ugandan hosts

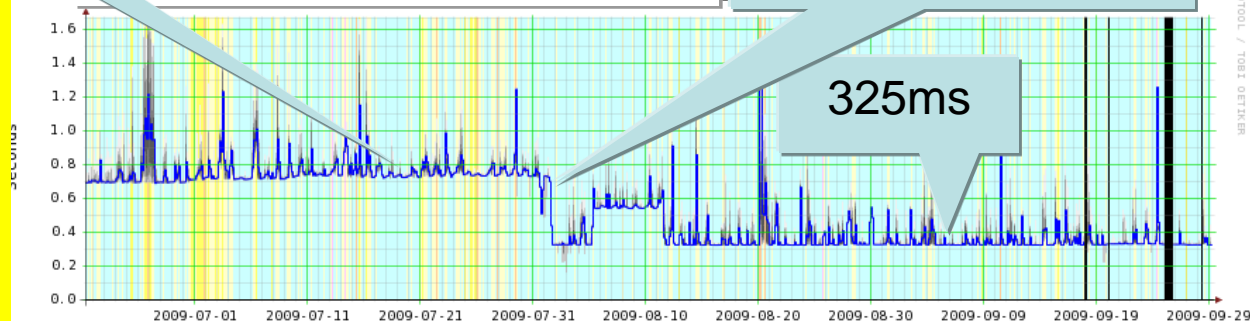
- RTT improves by factor 2.2
- Losses reduced
- Thruput $\sim 1/(RTT * \sqrt{\text{loss}})$ up factor 3

720ms

Median RTT SLAC to Kenya

Big jump Aug 1 '09
23:00hr

325ms

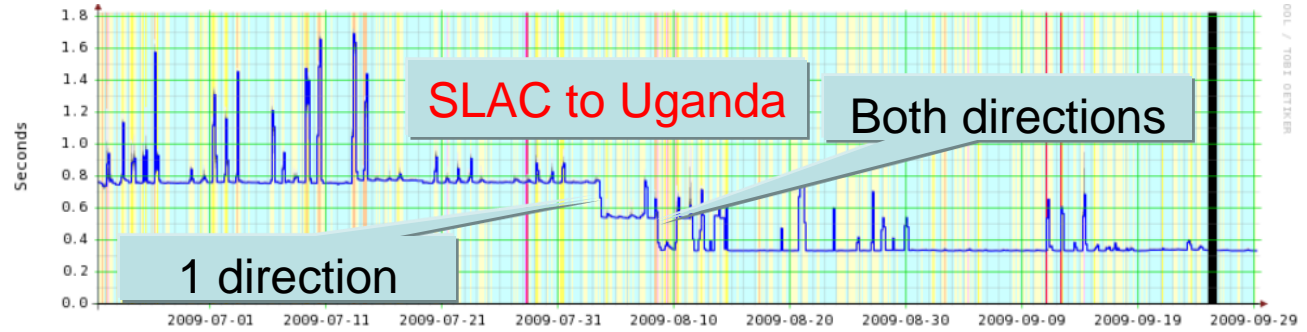
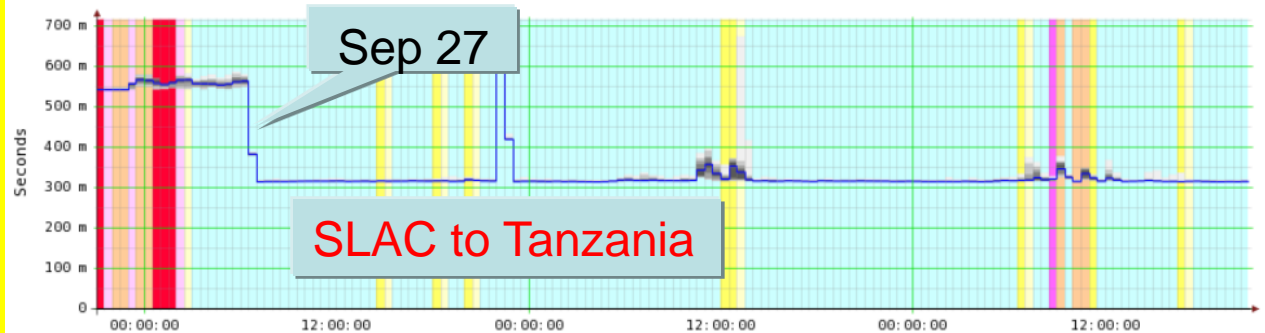
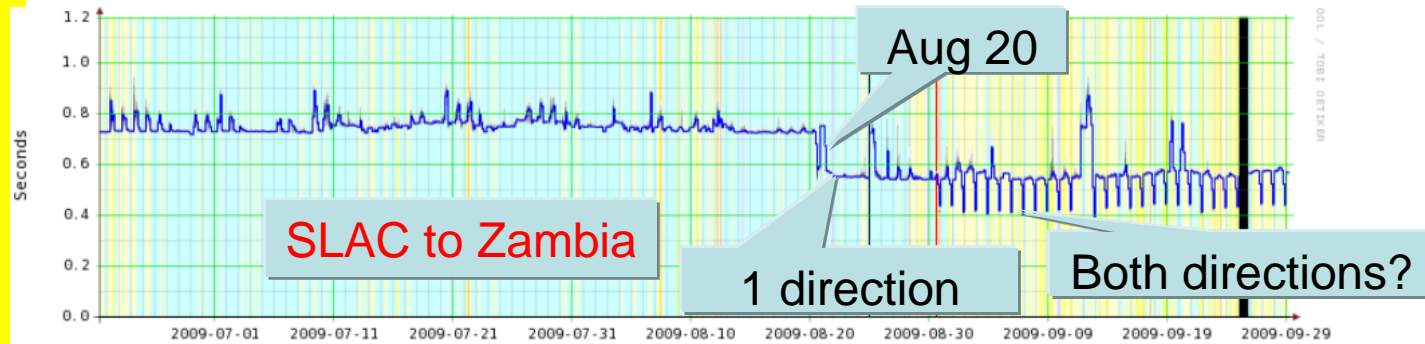
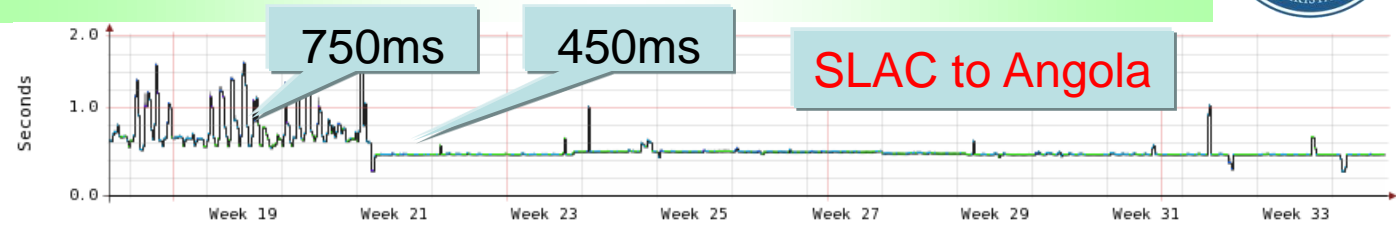


- Bkg color=loss Smoke=jitter



Other countries

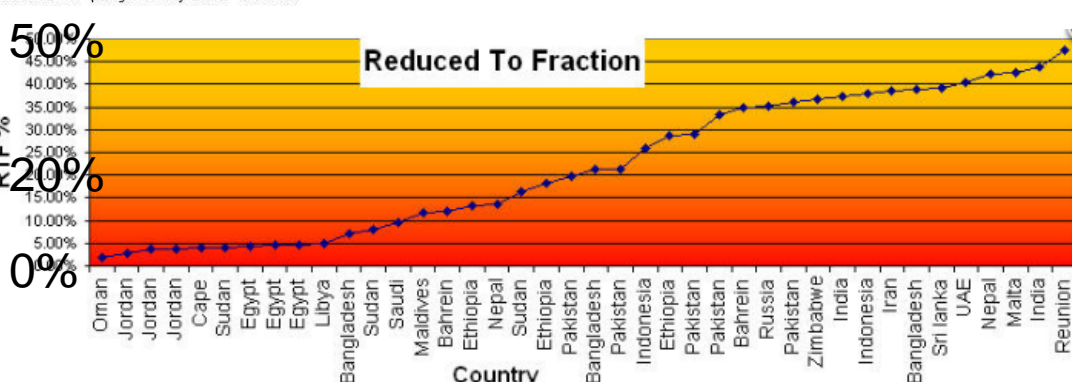
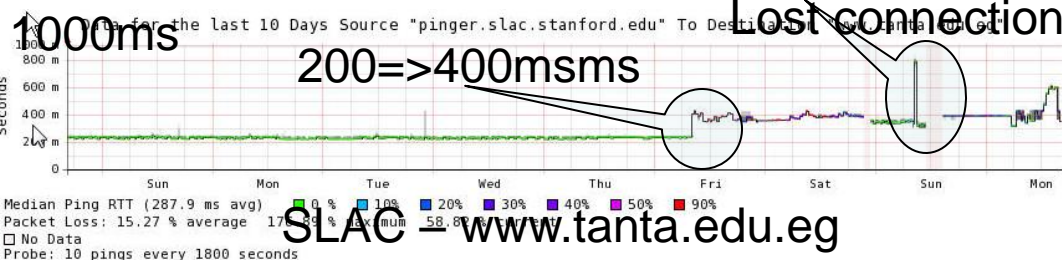
- **Angola** step mid-May, more stable
- **Zambia** one direction reduce 720>550ms
 - Unstable, still trying?
- **Tanzania**, also dramatic reduction in losses
- **Uganda inland** via Kenya, 2 step process
- Many sites still to connect



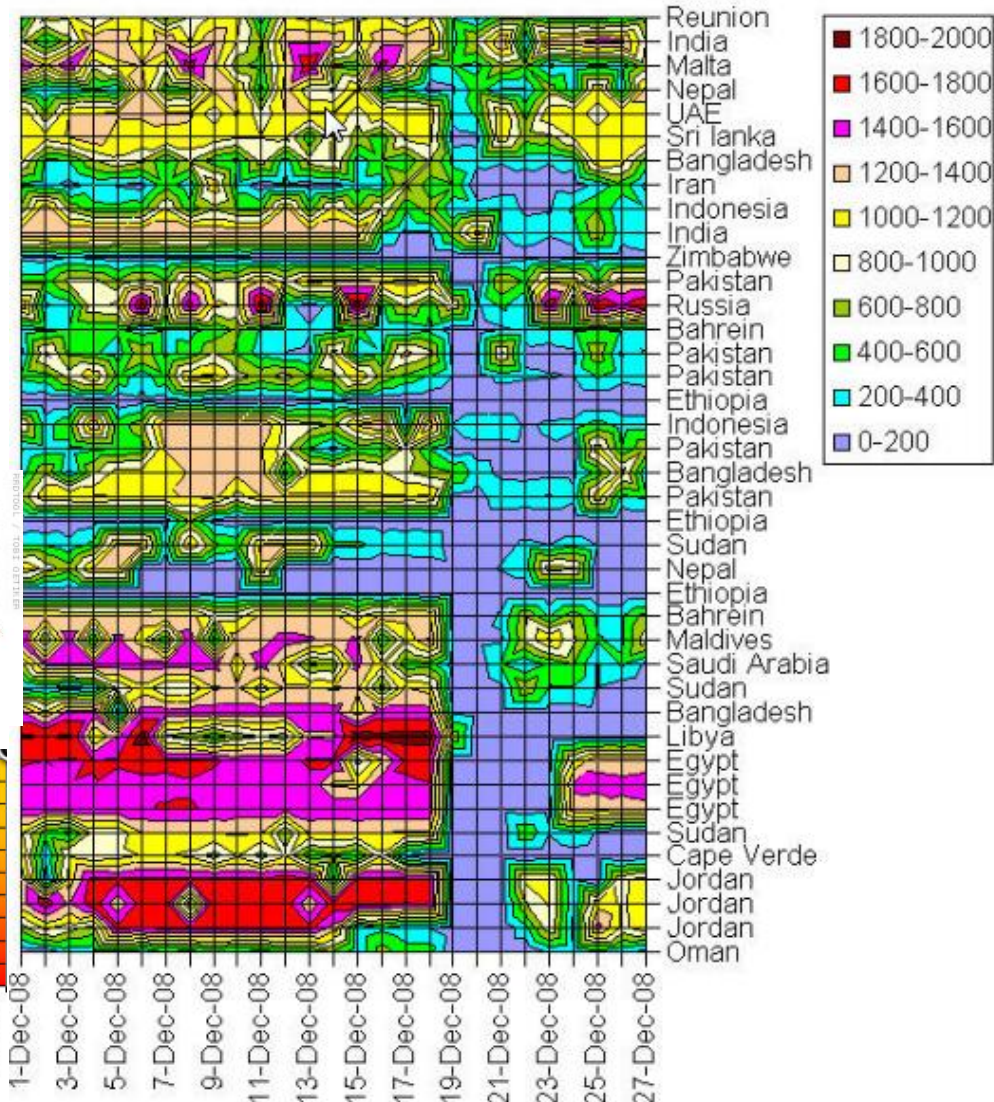
Impact of Fibre cuts Dec 2008

- Not only for competition
- Need redundancy
- Mediterranean Fibre cuts
 - Jan 2008 and Dec 2008
 - Reduced bandwidth by over 50% to over 20 countries

- New cable France-Egypt Sep 1 '10



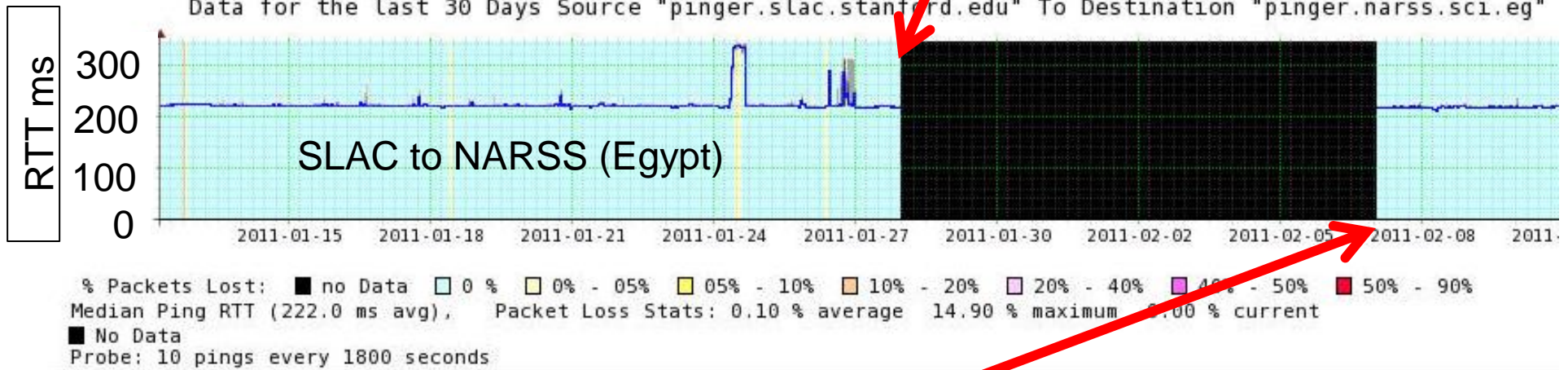
Derived TCP Throughput in kbits/sec from SLAC to Hosts in Countries Affected by the Mediterranean Fibre Cable Cuts December 2008



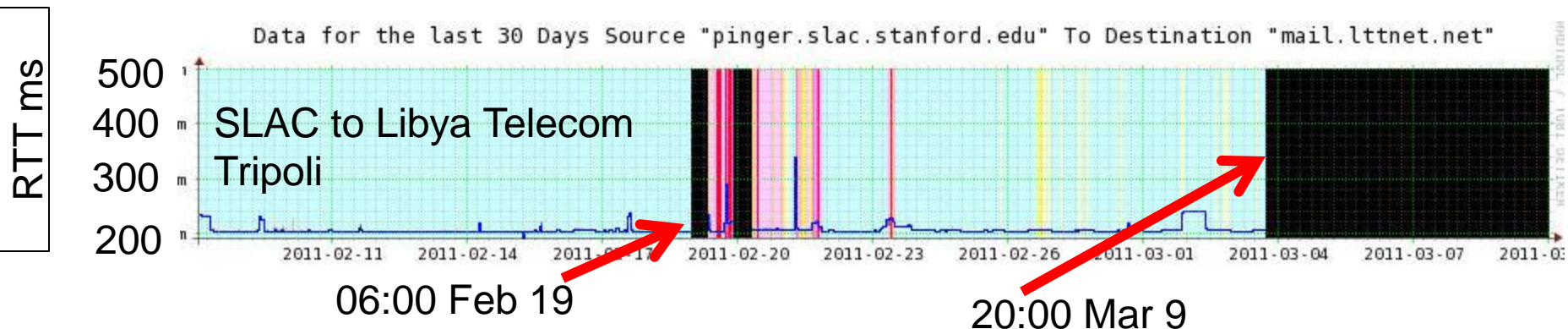
Recent Internet shutdowns



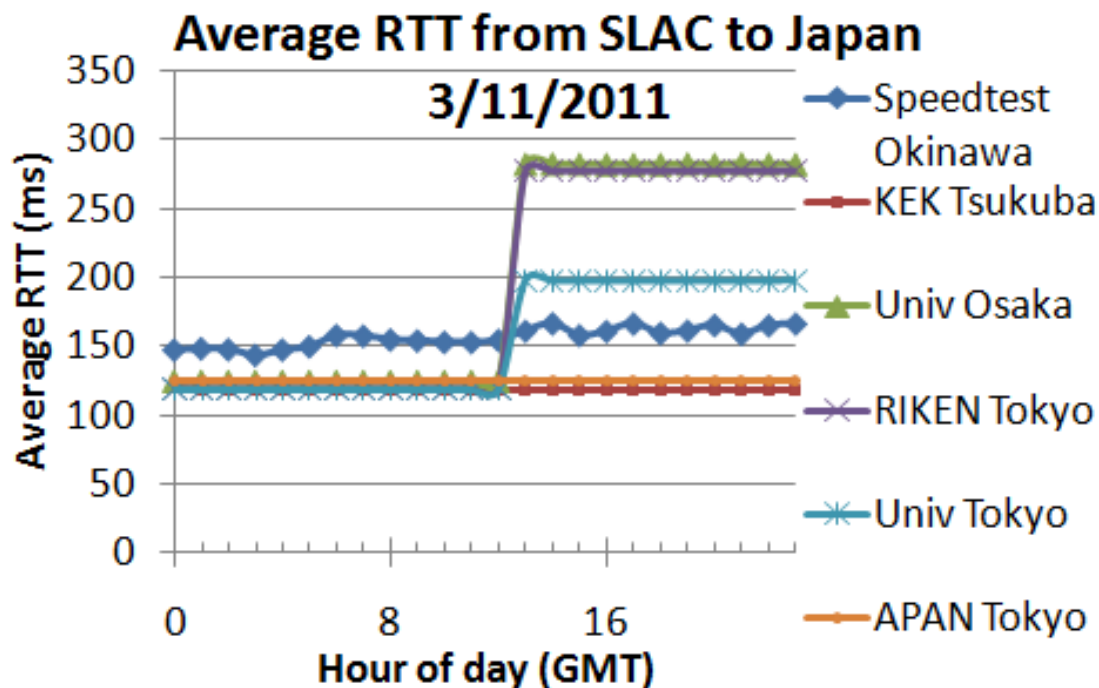
- SLAC lost connectivity to the National Authority for Remote Sensing and Space Science (NARSS) in Cairo between 11:30 pm Jan 27, and midnight 30 minutes later



- NAARS could be seen again from SLAC between midnight and 1:00am February 7th, 2011



- SLAC monitors 6 Japan hosts
 - None went down
 - 3 RTTs had big RTT increase



- Monitoring from host at RIKEN
 - All Japanese hosts have constant RTT
- Monitoring sites around world looking at RIKEN:
 - No effect: from Africa, E. Asia, Europe, L. America, M. East
 - Big effect from N. America to RIKEN
 - Canada 163ms=>264ms, US 120ms=>280ms
 - India CDAC Mumbia no effect, Pune 380ms=> 460ms, VSNL Mumbia 360ms=>400ms
 - Sri Lanka no effect
 - Pakistan – depends on ISP
- It depends on the route, westbound from US OK, Eastbound big increases

- By the way; the PingER measurement engine was IPv6 compliant back in 2003
- We are working on the analysis, presentation etc.
- PingER Home site
 - <http://www-iepm.slac.stanford.edu/pinger/site.html>
- Annual report:
 - <http://www.slac.stanford.edu/xorg/icfa/icfa-net-paper-jan11/report-jan11.doc>
- Case Studies:
 - <https://confluence.slac.stanford.edu/display/IEPM/PingER>

Compare PingER with ICT

Development Index (IDI) from ITU

- IDI = ICT readiness + usage + skills
- Readiness (infrastructure access)
 - phone (cell & fixed) subscriptions, international BW, %households with computers, and % households with Internet access
- Usage (intensity of current usage)
 - % population are Internet users, %mobile, and fixed broadband users
- Skills (capability)
 - Literacy, secondary & tertiary education

PingER throughput & IDI

- Positive correlation between PingER throughput & IDI, especially for populous countries
- PingER measurements automatic
- No army of data gatherers & statisticians
- More up to date
 - IDI 2009 index for 2007 data
- Good validation
- Anomalies interesting

