PingER End to End Internet measurements: what we learn

Les Cottrell\textsuperscript{SLAC},

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Outline

• 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

> ping remhost

Monitoring host

Once a Day

Internet

Remote Host (typically a server)

Ping response packets

Data Repository @ SLAC

Measure Round Trip Time & Loss

10 ping request packets each 30 mins

10 ping request packets each 30 mins
Coverage

- 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
Losses

- 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
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.

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

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

Derived throughput $\sim 8 \times 1460 / (\text{RTT} \times \sqrt{\text{loss}})$

Mathis et al.

Feb 1992
Mean Opinion Score

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

Important for VoIP

MOS Measured from SLAC to world regions

From the PingER project (http://www-iepm.slac.stanford.edu/pinger/)
Correlation with Social Activity

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

- Eids al-Adha starts Tue 16 Nov 2010
- Strike 9-19 Dec
- Reading week, start Jan 7
- Exams 17-23 Jan
- Winter break 23 Jan – 7 Feb

![Graph showing correlation with social activity](image)

- Background = loss
- No loss
- >0 <= 10%o loss
- >10% -90%
- Unreachable
The speed of light in fibre is roughly $0.66 \times c$.

- $c$ = speed of light in vacuum i.e. 299,792,458 m/s

Using 300,000 km/s as $c$ this yields:

- $RTD[km] = \text{Alpha} \times \text{min}_RTT[ms] \times 100 [\text{km/ms}]$

**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

• 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
- Bkg color=loss Smoke=jitter
• **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

1000ms
Lost connection
200=>400msms

Reduced To Fraction

SLAC = www.tanta.edu.eg
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.
Japanese Earthquake

• 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
More Information

• By the way; the PingER measurement engine was IPv6 compliant back in 2003

• We are working on the analysis, presentation etc.

• PingER Home site

• Annual report:

• 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

• 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