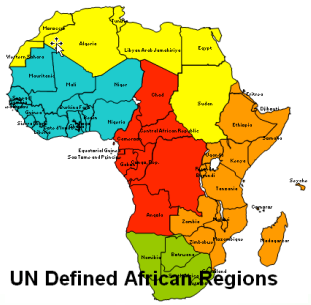


Internet Connectivity in Africa

Prepared by: ***Les Cottrell****SLAC*,

Shahryar Khan[NIIT/SLAC], *Jared Greeno*[SLAC]

Internet & Grids in Africa:

An Asset for African Scientists for the Benefit of African Society,

10-12 December 2007, Montpellier, France

www.slac.stanford.edu/grp/scs/net/talk07/montpellier-dec07.ppt

Summary

- Why do we Measure?
- Methodology of measuring Internet performance
- Overall Internet performance of the world today
- Validation against other measurements
- **Africa**
  - Performance, Routing, Costs, Difficulties
- Conclusions & further information

Why?

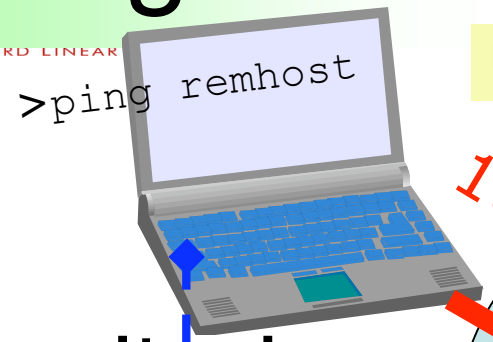
- In the Information Age Information Technology (IT) is the major productivity and development driver.
- Travel & the Internet have made a global viewpoint critical
- One Laptop Per Child ($100 computer)
  - New thin client paradigm, servers do work, requires networking (Google: “Negroponte $100 computer”)
  - Enables “Internet Kiosk & Cafe” can make big difference
- So we need to understand and set expectations on the accessibility, performance, costs etc. of the Internet

Methodology

- Use PingER:
  - Arguably the world's most extensive Active E2E Intern Monitoring project

PingER Methodology

Uses ubiquitous ping



Monitoring host

Once a Day

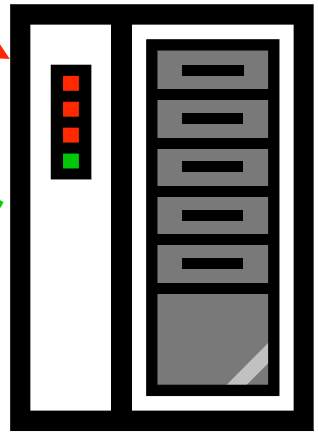
Data Repository @ SLAC

Internet

10 ping request packets each 30 mins

Ping response packets

Remote Host (typically a server)

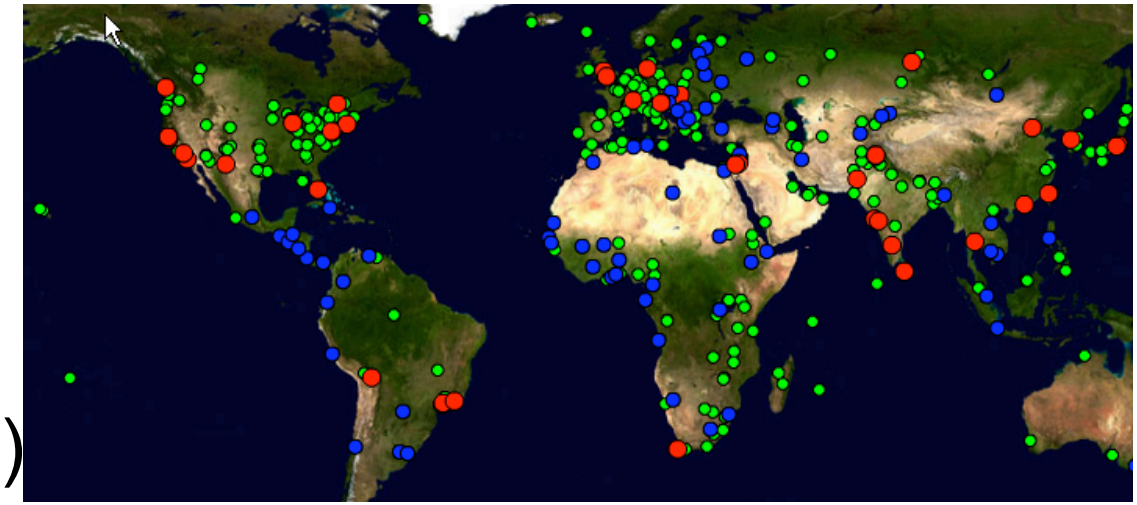


Measure Round Trip Time & Loss

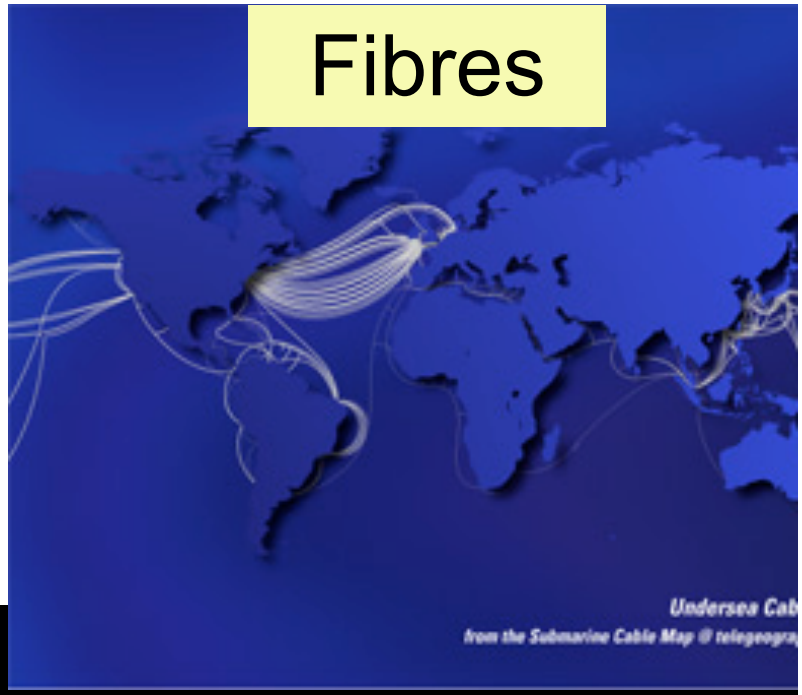
PingER Deployment

- PingER project originally (1995) for measuring network performance for US, Europe and Japanes HEP community - now **mainly R&E sites**
- Extended this century to measure Digital Divide:
  - Collaboration with **ICTP Science Dissemination Unit** http://sdu.ictp.it
  - ICFA/SCIC: http://icfa-scic.web.cern.ch/ICFA-SCIC/
- >150 countries (99% world's connected populatio
  - 40 in Africa

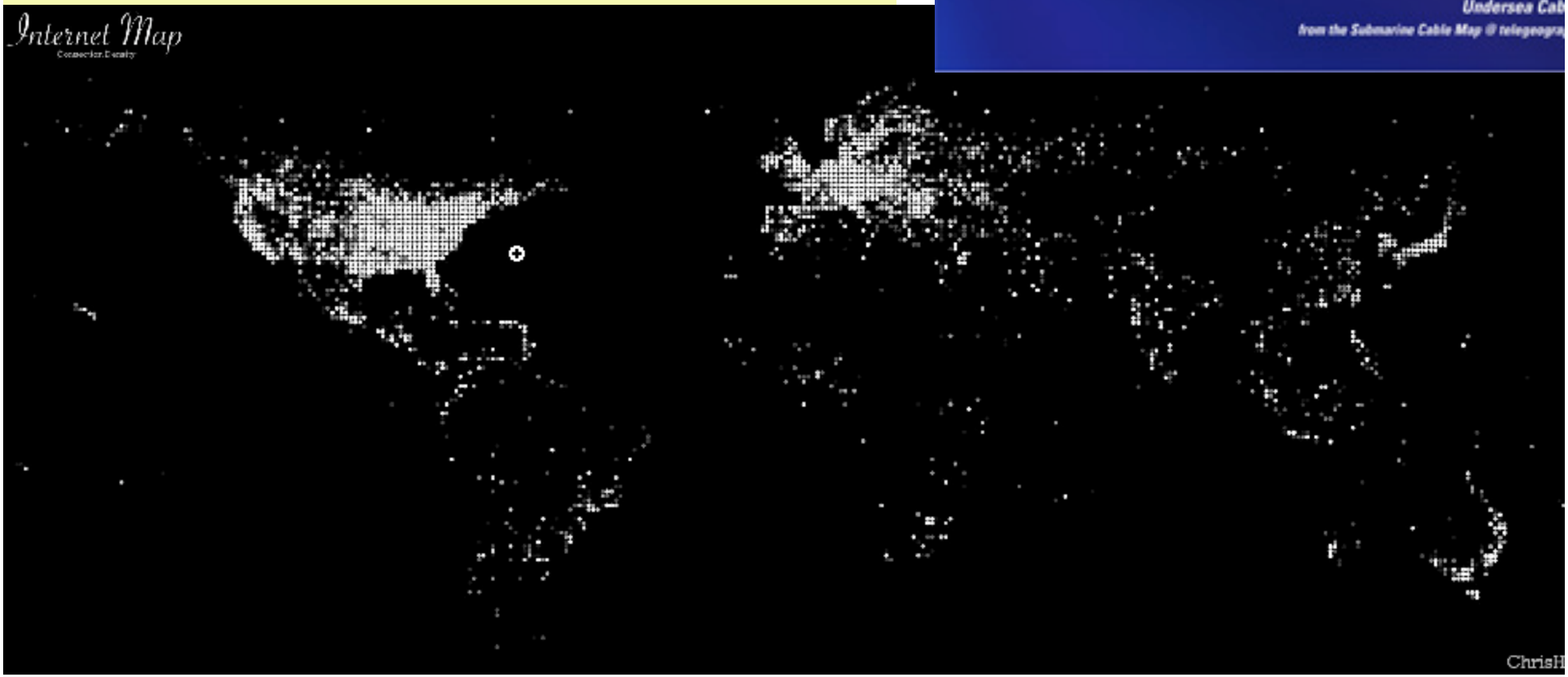
- Monitor (40 in 14 countries)
- Beacons ~ 90
- Remote sites (~700)



World Status

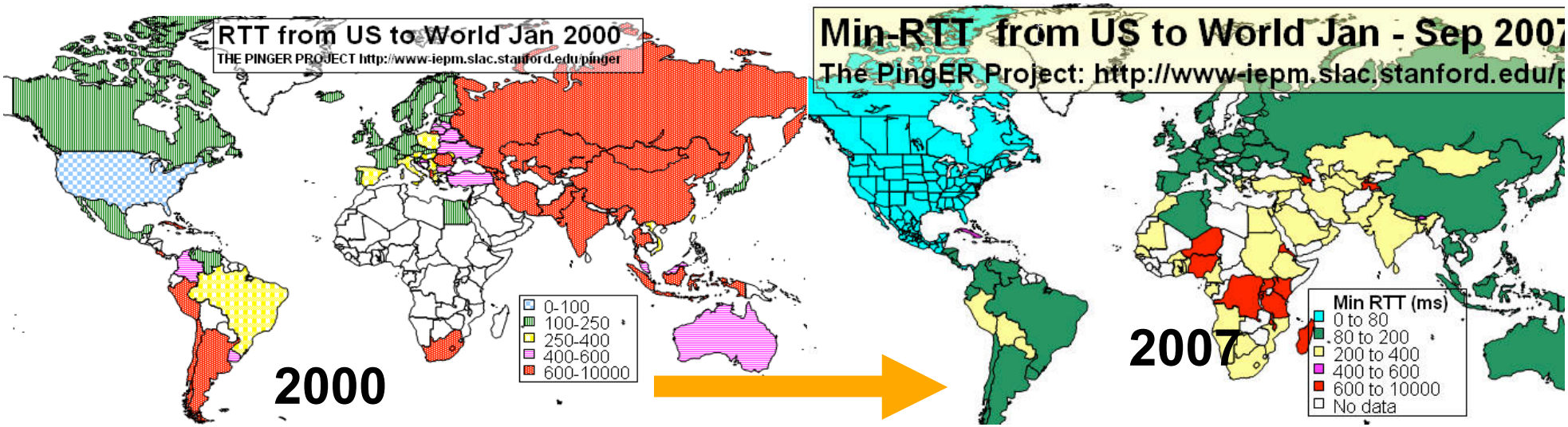


- Internet city connections



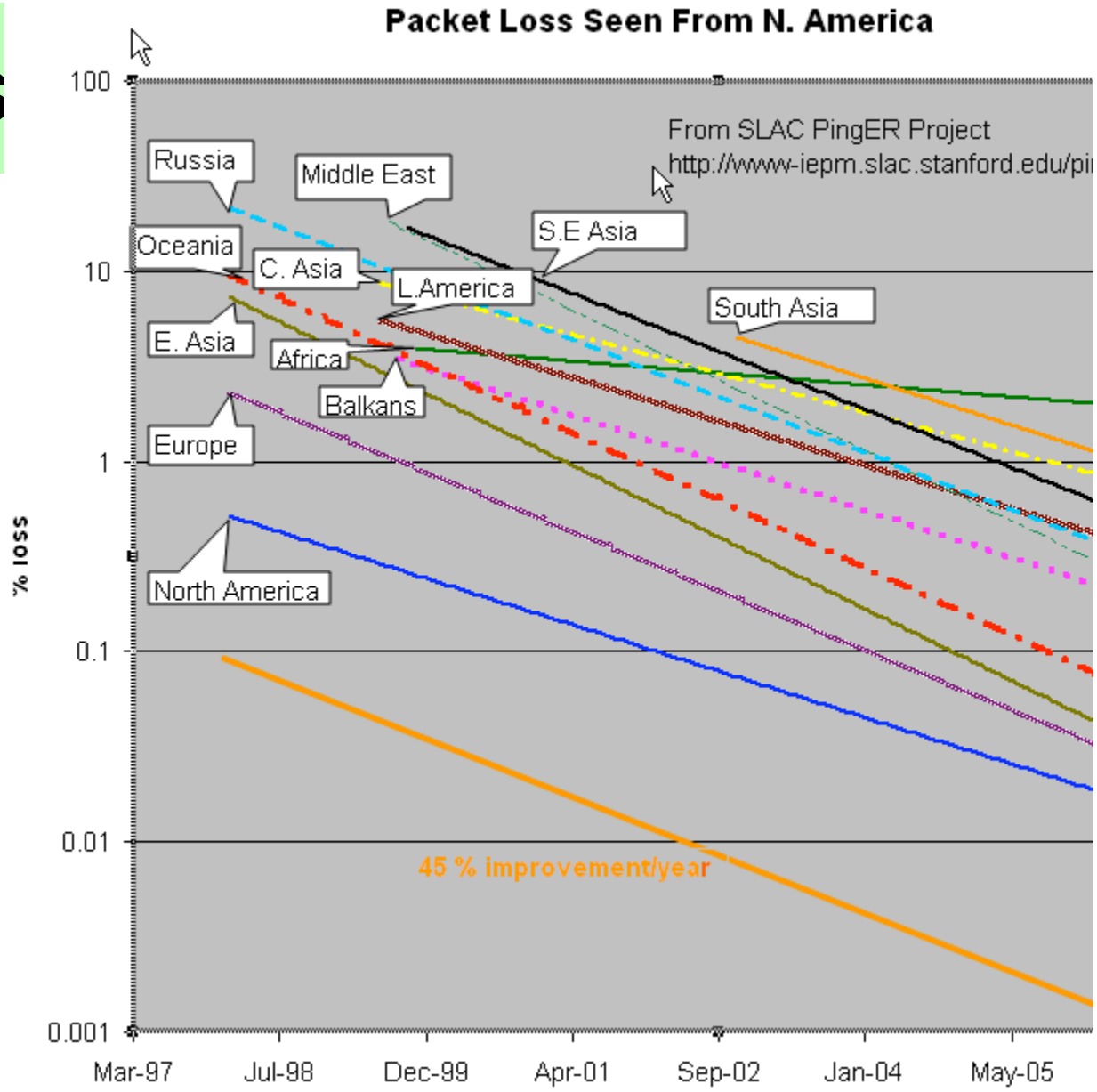
World Measurements: Min RTT from US

- Maps show increased coverage
- Min RTT indicates best possible, i.e. no queuing
- >600ms probably geo-stationary satellite
- Between developed regions min-RTT dominated by distance
  - Little improvement possible
- Only a few places still using satellite for international access, mainly Africa & Central Asia



Trends:Losses

- Mainly distance independent
- Big impact on performance, time outs etc.
- Losses > 2.5 % have big impact on interactivity, VoIP etc.

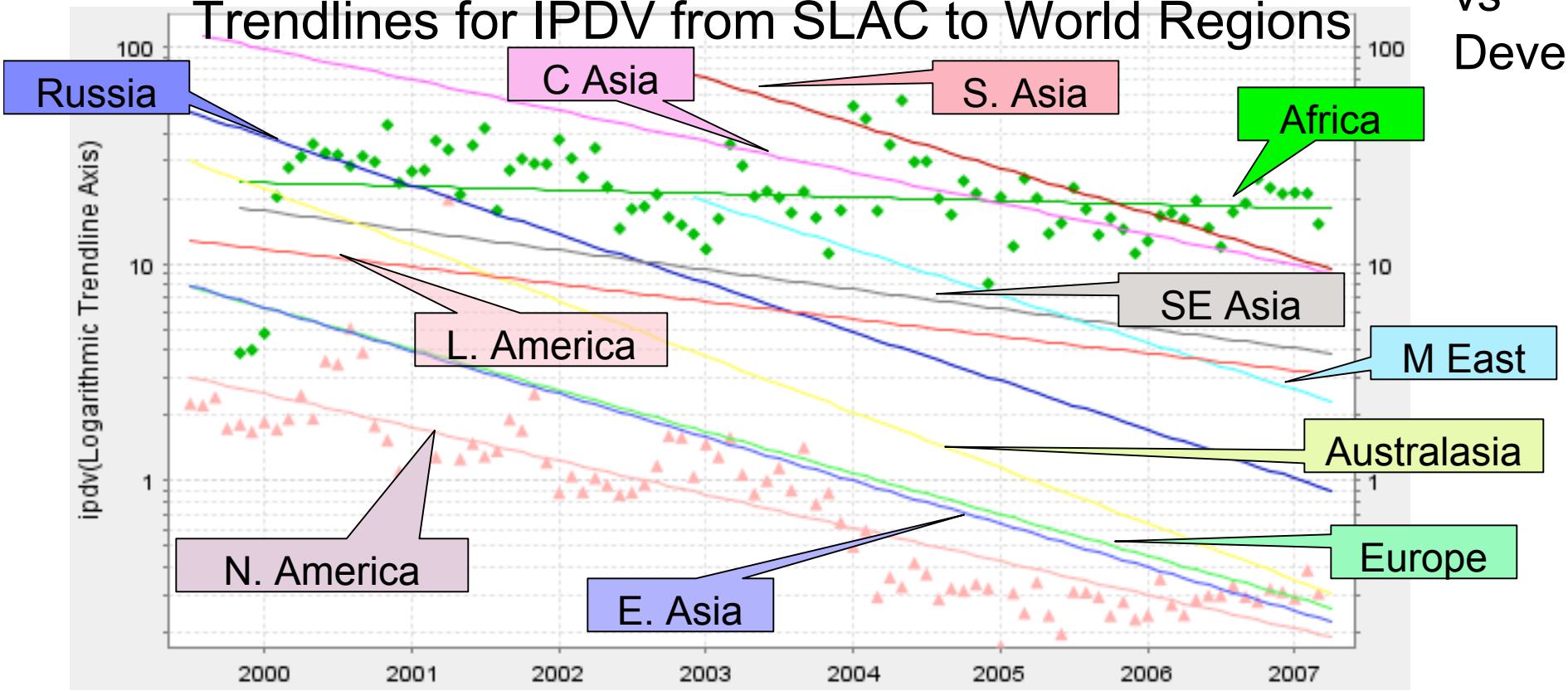


- N. America, Europe, E. Asia, Oceania < 0.1%
- Underdeveloped 0.3- 2% loss, Africa worst.

Jitte

- ~ Distance independent
- Calculated as Inter Packet Delay Variation (IPDV)
  - IPDV = $Dr_i = R_i - R_{i-1}$
- Measures congestion
- Little impact on web, email
- Decides length of VoIP codec buffers, impacts streaming
- Impacts (with RTT and loss) the quality of VoIP

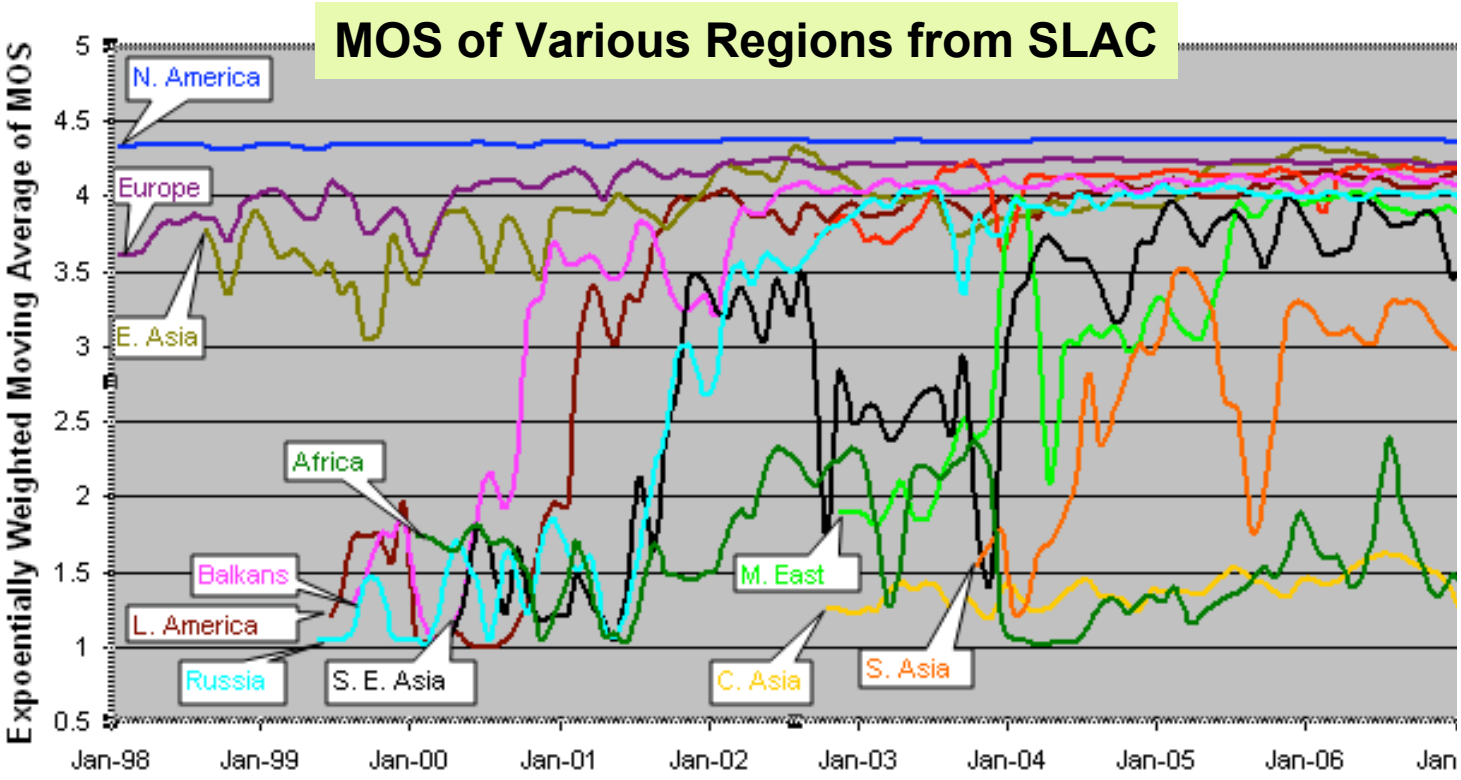
Usual division Develop vs Develop



VoIP & MOS

- Telecom uses Mean Opinion Score (MOS) for quality
  - 1=bad, 2=poor, 3=fair, 4=good, 5=excellent
  - With VoIP codecs best can get is 4.2 to 4.4
  - Typical usable range 3.5 to 4.2
  - Calc. MOS from PingER: RTT, Loss, Jitter (www.nessoft.com/kb/50
  - Africa & C. Asia not possible, S. Asia with patience OK

Improvements very clear, often due to move from satellite to land line.
Similar results from CERN (less coverage)

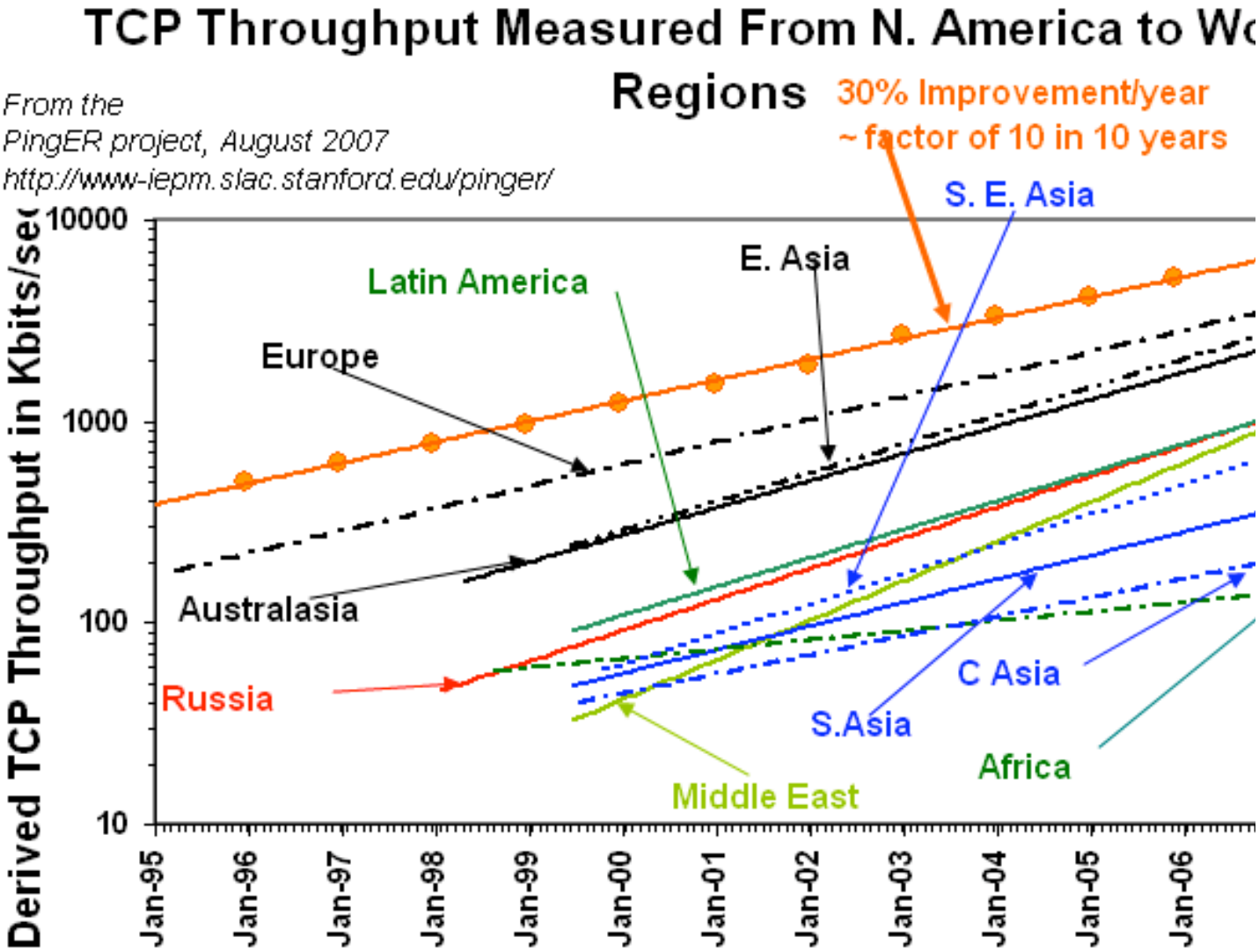


World throughput

Derived throughput ~ 8 * 1460 /(RTT * sqrt(loss
Mathis et. al

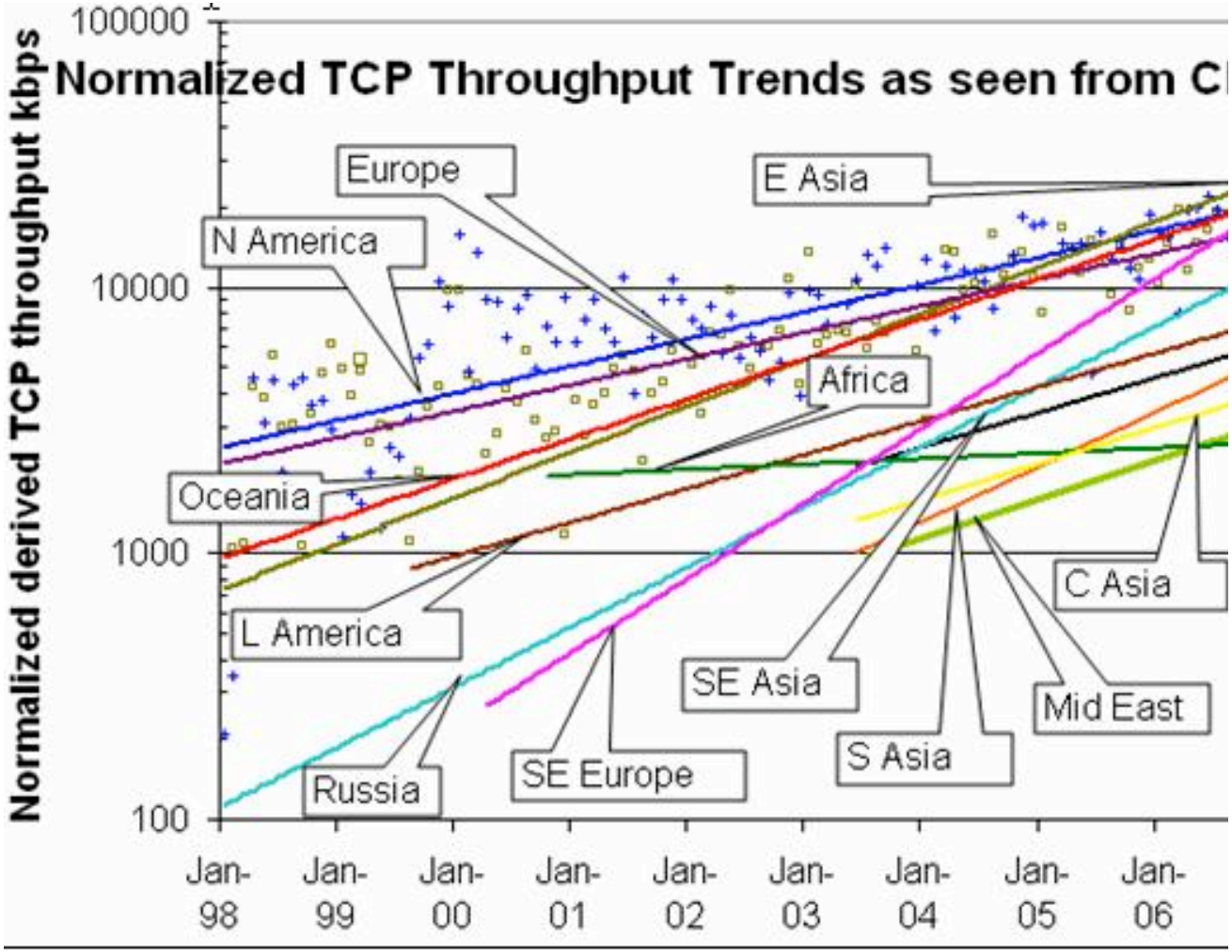
Behind Europe
6 Yrs: Russia, Latin America
7 Yrs: Mid-East, SE Asia
10 Yrs: South Asia
11 Yrs: Cent. Asia
12 Yrs: Africa

South Asia, Central Asia, and Africa are in Danger of Falling Even Farther Behind



Similar Results from Europe

- EU, US/CA, Oceania, E. Asia lead
- SE Europe, Russia catching up
  - S. Asia. Mid East, C. Asia poor
  - Africa poor and falling behind
  - Working on ICTP analysis

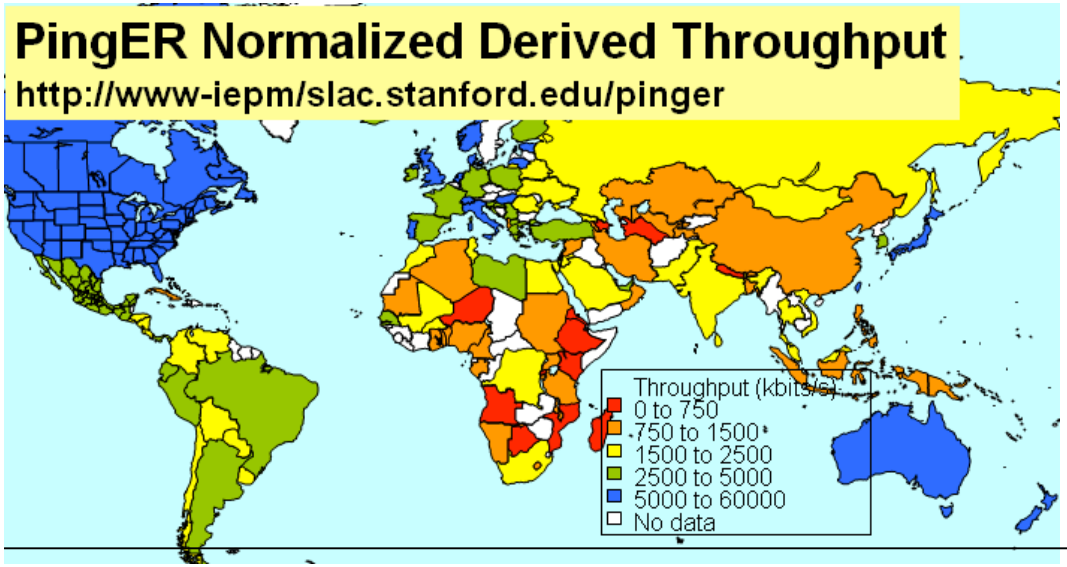


Validation

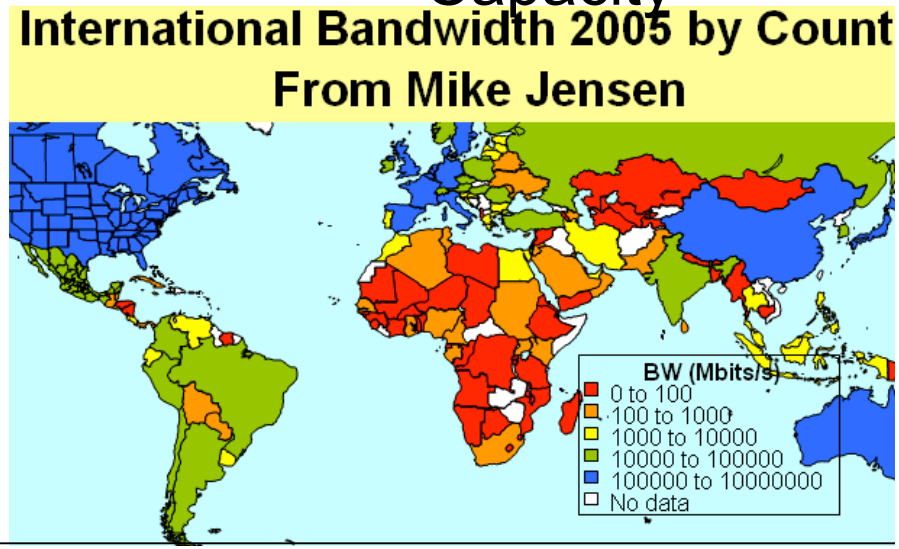
- Many indices from ITU, UNDP, CIA, World Bank try to classify countries by their development
  - Difficult: what can be measured, how useful is it, how well defined, how changes with time, does it change country to country, cost of measuring, tak time to gather & often out of date, subjective
  - Typically use GDP, life expectancy, literacy, education, phone lines, Interne penetration etc.
  - E.g. HDI, DOI, DAI, NRI, TAI, OI .. In general agree with one another (R^2~0.
- Given importance of Internet in enabling development in the Information age some metrics we can measure:
  - International bandwidth
  - Number of hosts, ASNs
  - PingER Internet performance
- See if agree with development indices.
  - If not may point to bad PingER data or illuminate reasons for differences
  - If agree quicker, cheaper to get, continuous, not as subjective
  - Working to extend PingER coverage (120=>156 countries, 45 in Africa)

Some Other World Views

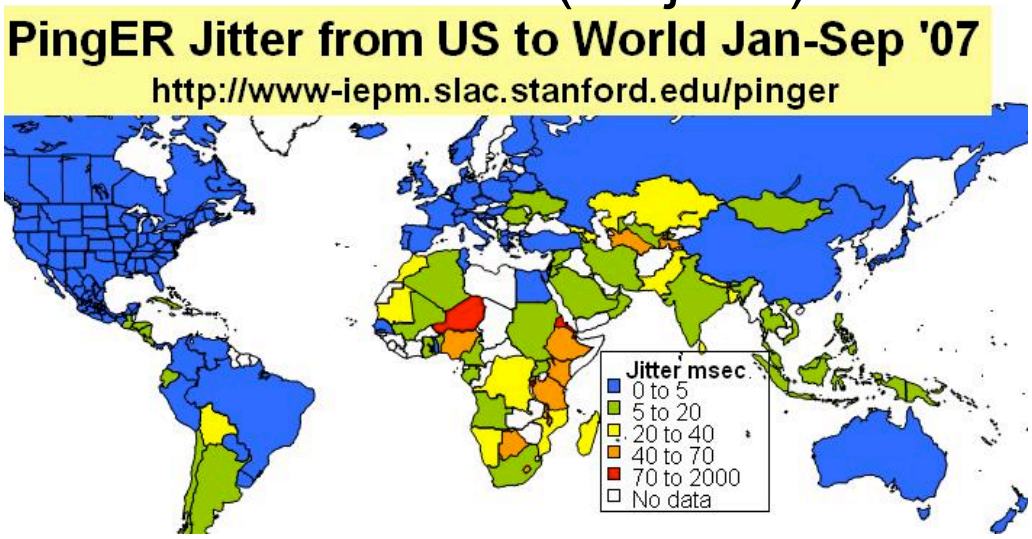
Data Transfer



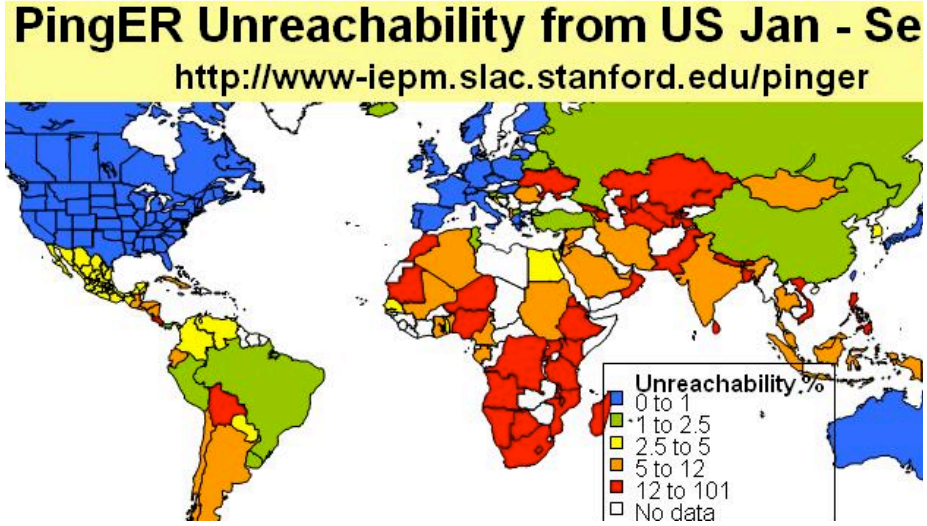
Capacity



Voice & video (de-jitter)



Network & Host Fragility



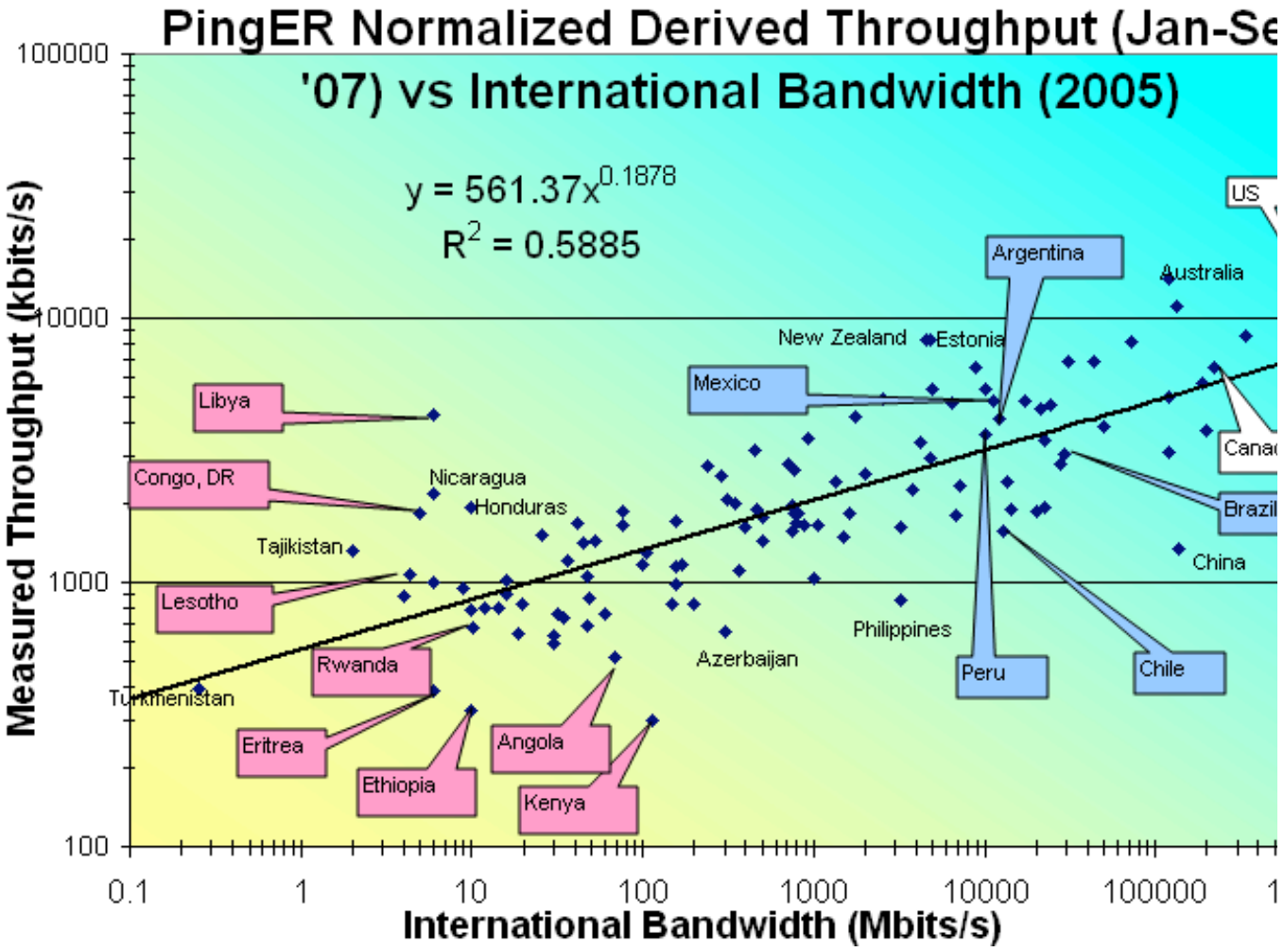
Thru vs Int. BW

Derive: thru ~ 8 * 1460 /(RTT * sqrt(lo
Mathis et. al

norm_thru = thru * min_RTT(rem_region) / min_rtt(mon_regio

- Hard to get to countries (E. Africa, C Asia)
- Last mile not good (China)
- ’07 vs ’05 (Aus & NZ)
- Emphasize Internet deploy (Estonia)
- Host choice (Congo, Libya)

Good Correlat



PingER vs Speedtest

- www.zdnet.com.au/broadband/results.htm
  - Application sends known amount of data between your computer and serve
  - Measures throughput saves results by country, ISP
    - About 30 countries have <= 3 attempts

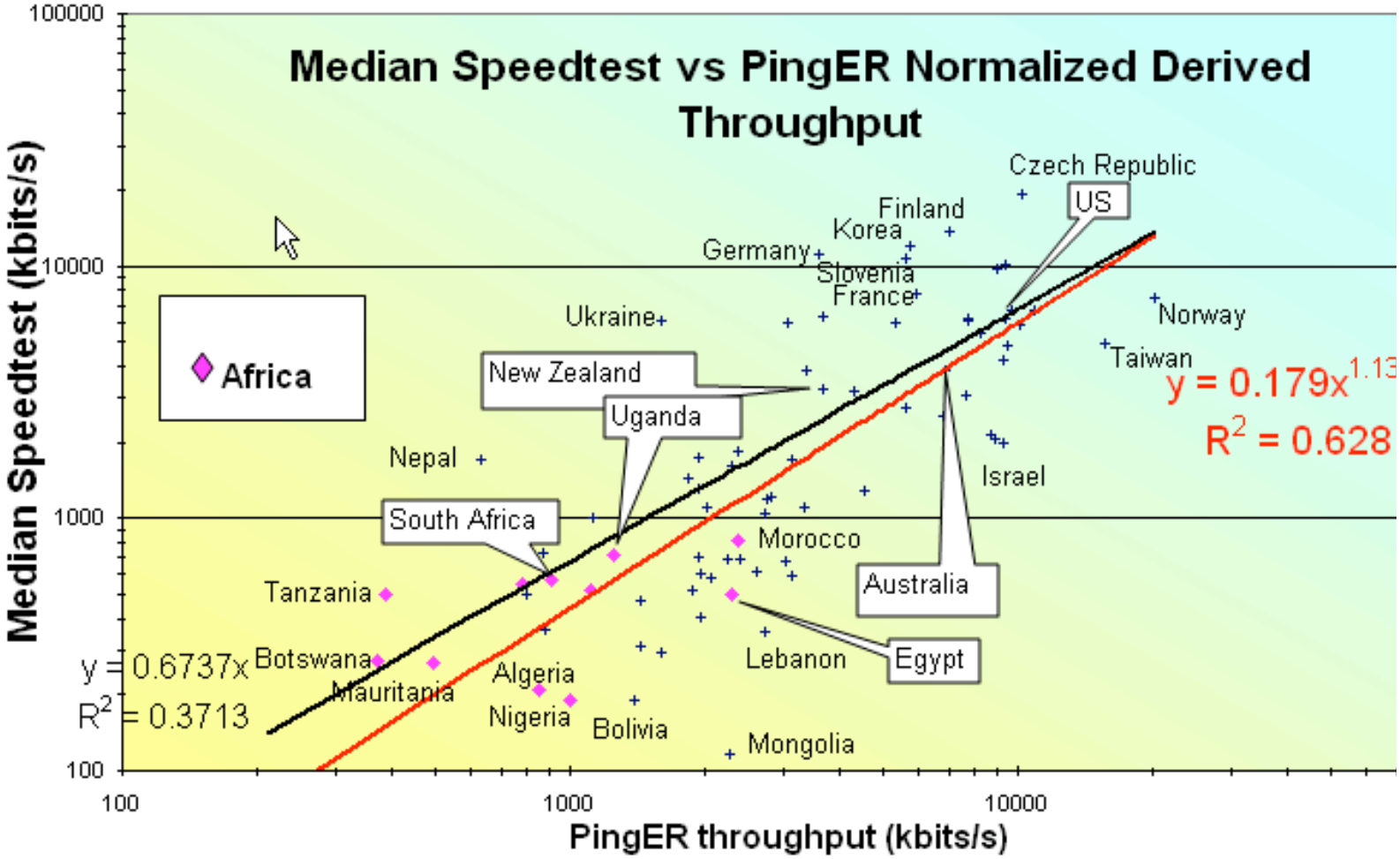
Server in Aus.

AU&NZ agree

Absolute values agree

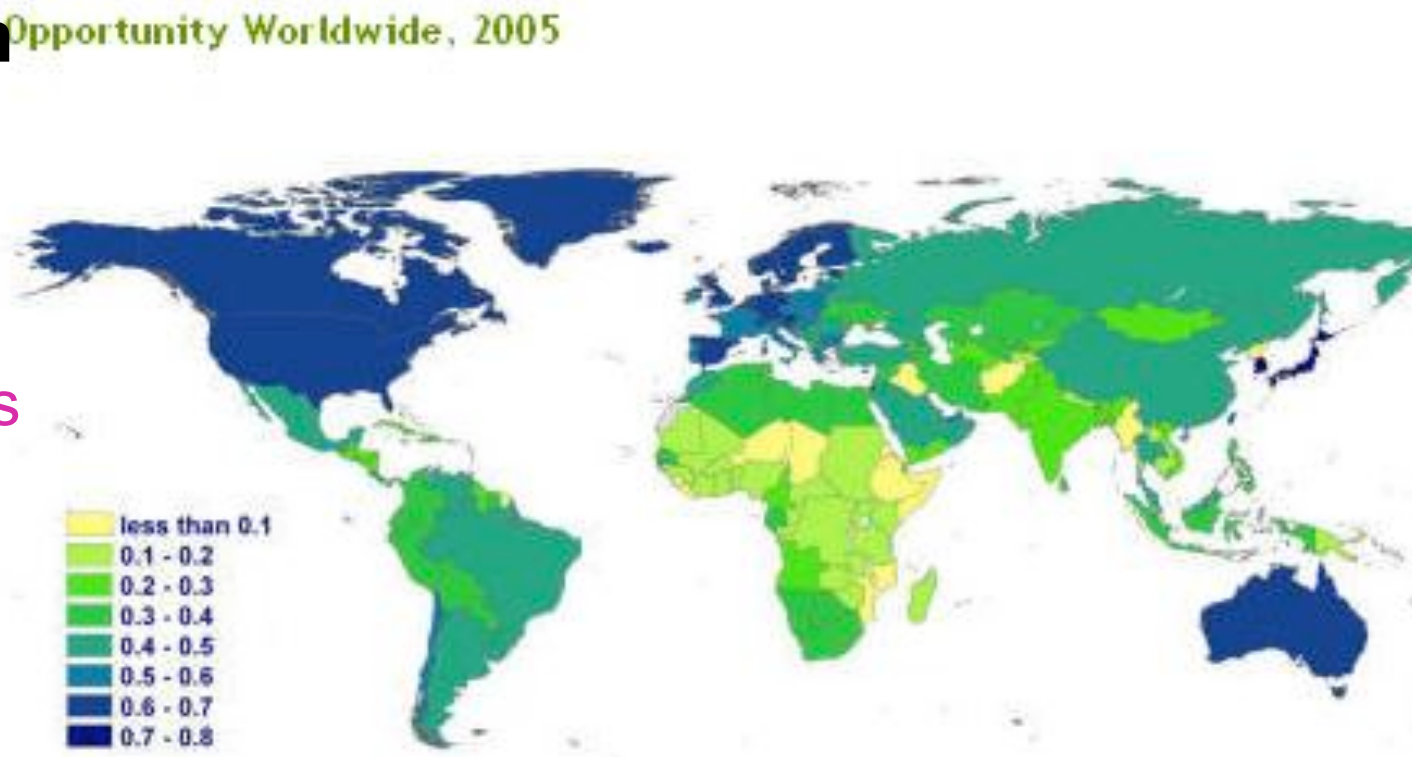
Strong Correlation

Africa (magenta) worst off



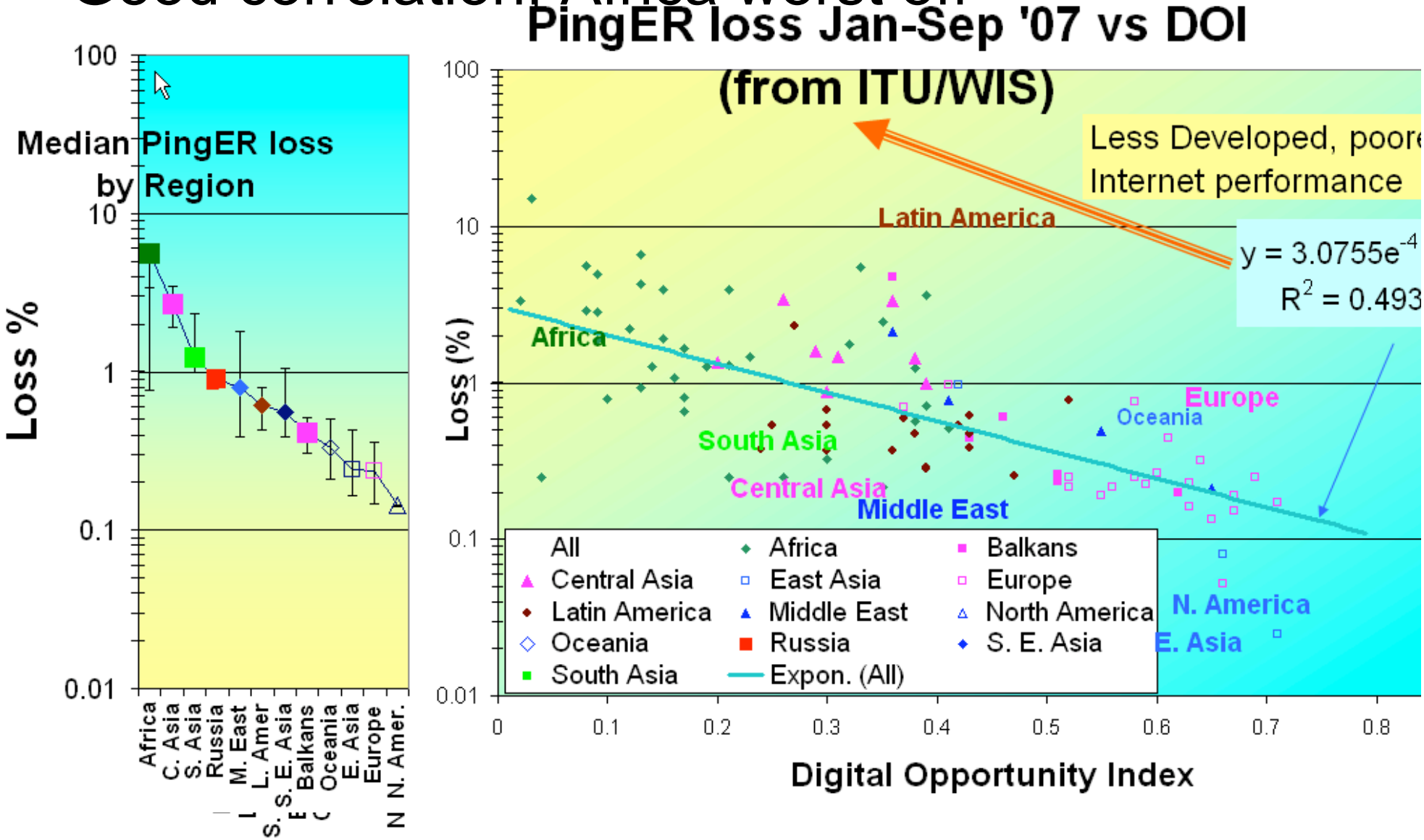
Digital Opportunity Index (ITU 2006)

- 180 countries, recent (data 2005, announce 2006), full coverage 2004-2005, 40 leaders have 2001-2005
- 11 indicators:
  - (Coverage by mobile telephony, Internet tariffs, #computers, fix line phones, mobile subscribers, Internet users)/population
- **Working with ITU** to see if PingER can help.
  - Add countries
    - 130>150
  - Increase coverage



Correlation Loss vs DOI

- Good correlation, Africa worst off



African Situation

- Access to the internet is so desirable to students in Africa that they spend considerable time and money to get it. Many students surveyed, with no internet connection at their universities, resorted to private, fee-charging internet cafes to study and learn.
  www.arp.harvard.edu/**Africa**HigherEducation/Online.html

Internet Café in G

- **Survey (IHY meeting Ethiopia in November '07)** of **leading** Universities in 17 countries (will repeat with more clarity):
  - Each had tens of 1000's of students, 1000 or so staff
  - Best had 2 Mbits, worst dial up 56kbps
  - Often access restricted to faculty
- School in a secondary town in an East Coast country with networked computer lab spends 2/3rds of its annual budget to p for the dial-up connection.
  - Disconnects

Many systemic factors: Electricity, import duties, skills, disease, protectionist policies, corruption.
915M people 14% world population, 3.6% of world internet users, mainly in cities

Africa

~ 3x lower penetration than any other region
huge potential market

Huge growth

RNET USAGE AND POPULATION STATISTICS

	tion Est.)	Population % of World	Internet Usage, Latest Data	% Population (Penetration)	Usage % of World	Usa Grov 2000-
Africa	915,210,928	14.1 %	32,765,700	3.6 %	3.0 %	62
Asia	3,667,774,066	56.4 %	394,872,213	10.8 %	36.4 %	24
Europe	807,289,020	12.4 %	308,712,903	38.2 %	28.4 %	19
Middle East	190,084,161	2.9 %	19,028,400	10.0 %	1.8 %	47
North America	331,473,276	5.1 %	229,138,706	69.1 %	21.1 %	11
Latin America/Caribbean	553,908,632	8.5 %	83,368,209	15.1 %	7.7 %	36
Oceania / Australia	33,956,977	0.5 %	18,364,772	54.1 %	1.7 %	14
WORLD TOTAL	6,499,697,060	100.0 %	1,086,250,903	16.7 %	100.0 %	20

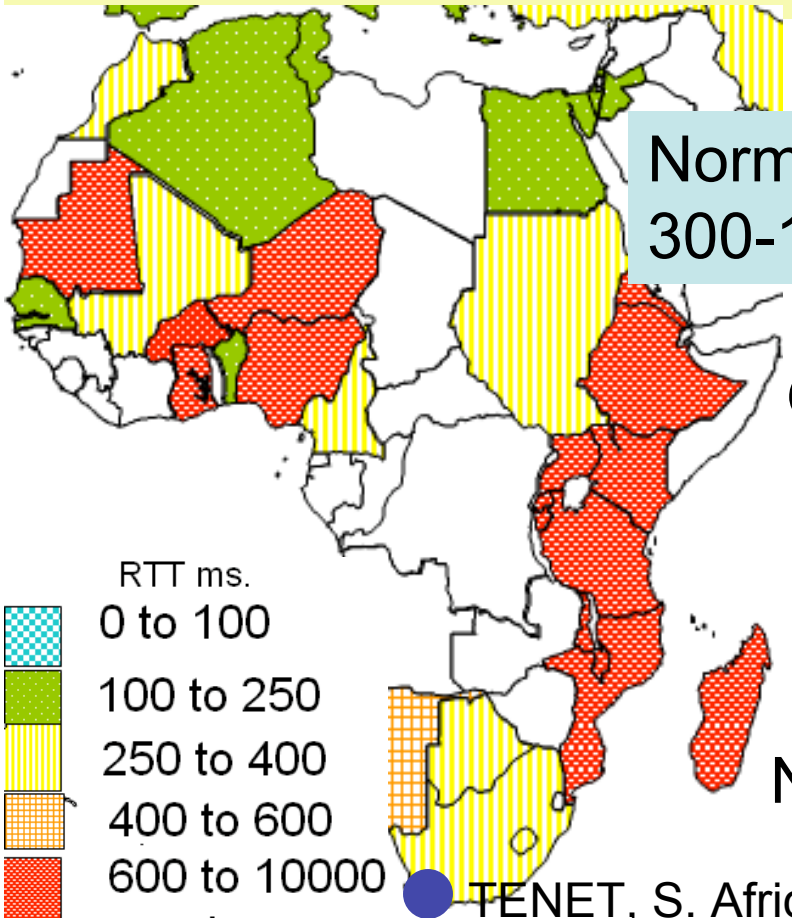
NOTES: (1) Internet Usage and World Population Statistics were updated for Sept. 18, 2006. (2) CLICK on each world region for detailed regional inform
(3) Demographic (Population) numbers are based on data contained in the world-gazetteer website. (4) Internet usage information comes from data put
by Nielsen//NetRatings, by the International Telecommunications Union, by local NICs, and other other reliable sources. (5) For definitions, disclaimer,
navigation help, see the Site Surfing Guide. (6) Information from this site may be cited, giving due credit and establishing an active link back to
www.internetworldstats.com. © Copyright 2006, Miniwatts Marketing Group. All rights reserved w

http://www.internetworldstats.

Satellites vs Terrestrial

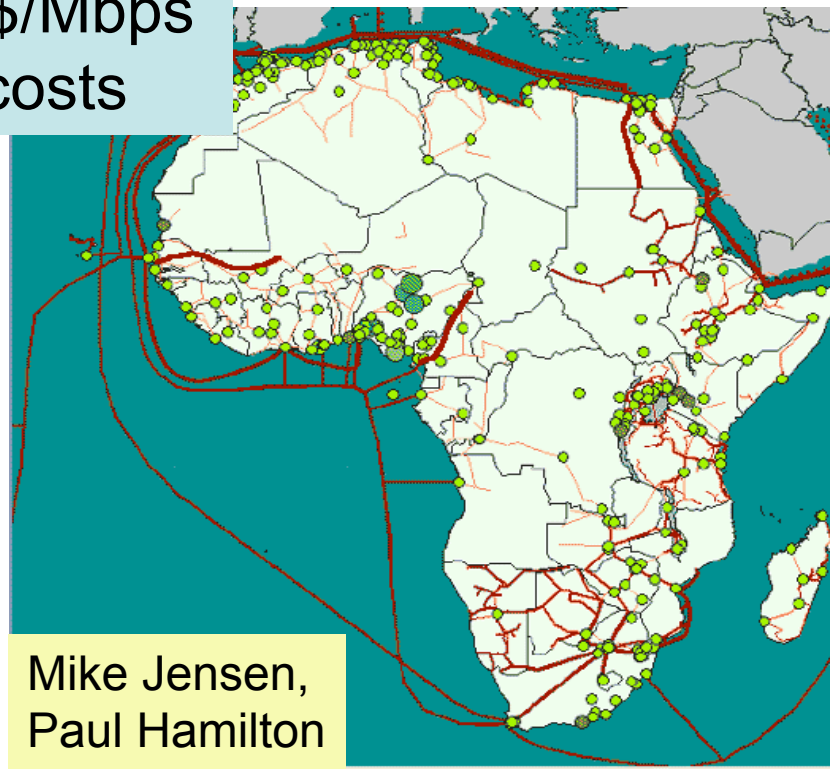
- Terrestrial links via SAT3 & SEAMEW (Med & W. Africa)
  - monopoly bandwidth is sold for $4.5K-12K per Mbps/mo
  - Equal satellite prices

PingER min-RTT measurements from S. African TENET monitoring station



Normal Satellite $/Mbps 300-1000x fibre costs

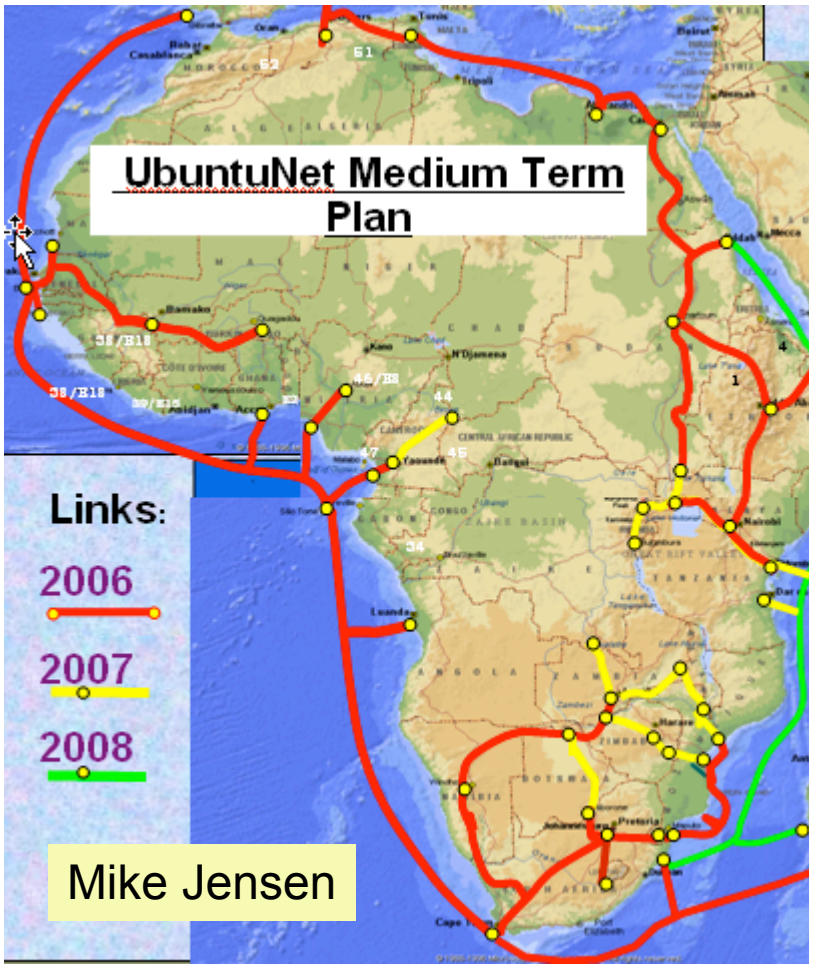
Only 14 of 49 Sub-Saharan countries have fibre NEPAD '04



Mike Jensen, Paul Hamilton

Fibre Links Future

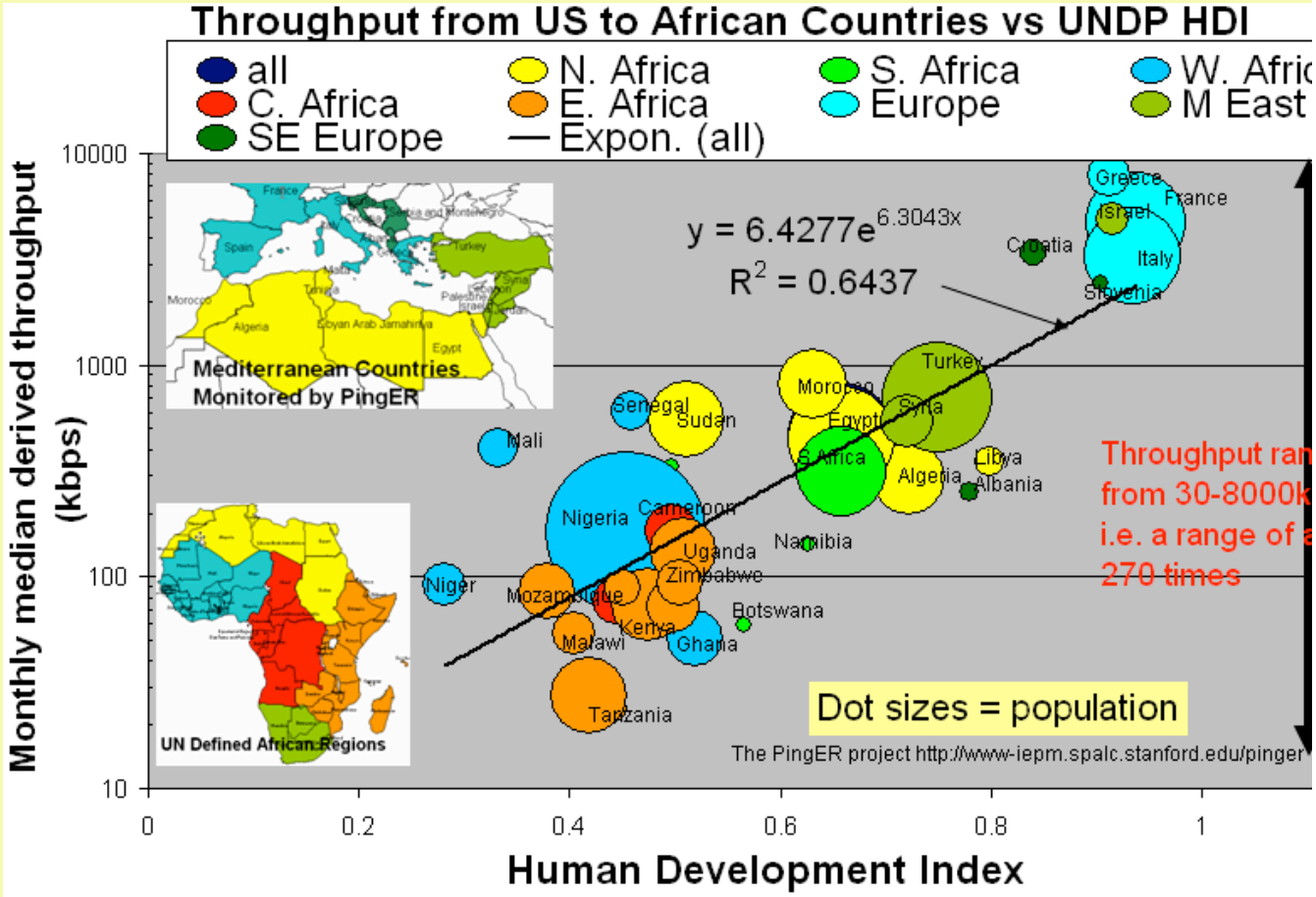
- SAT3 connects eight countries on the W coast of the continent to Europe and the Far East. Operating as a car of monopoly state-owned telecommunication providers, prices have barely come down since it began operating i 2002
  - SAT-3 shareholders such as Telecom Namibia, which has no landing point of its own find it cheaper to use satellite
- Will EASSy follow suit?
- Another option to EASSy: since Sudan and Egypt are now connected via fibre, and the link will shortly extend to Ethiopia, there are good options for both Kenya and Uganda/Rwanda and Tanzania to quickly link to the backbones via this route



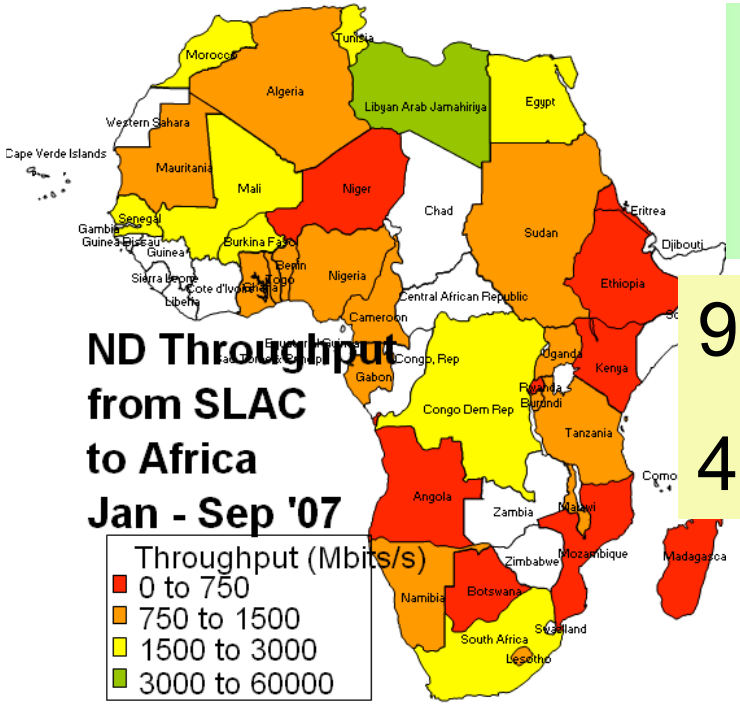
Mediterranean. & Africa vs HD

HDI related to GDP, life expectancy, tertiary education e

- There is a good correlation between the 2 measures
- N. Africa has 10 times poorer performance than Europe
- N. Africa several times better than say E. Africa
- E. Africa poor, limited by satellite access
- W. Africa big differences, some (Senegal) can afford SAT3 fibre others use satellite
- Great diversity between & within regions

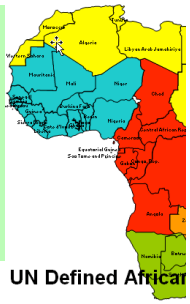


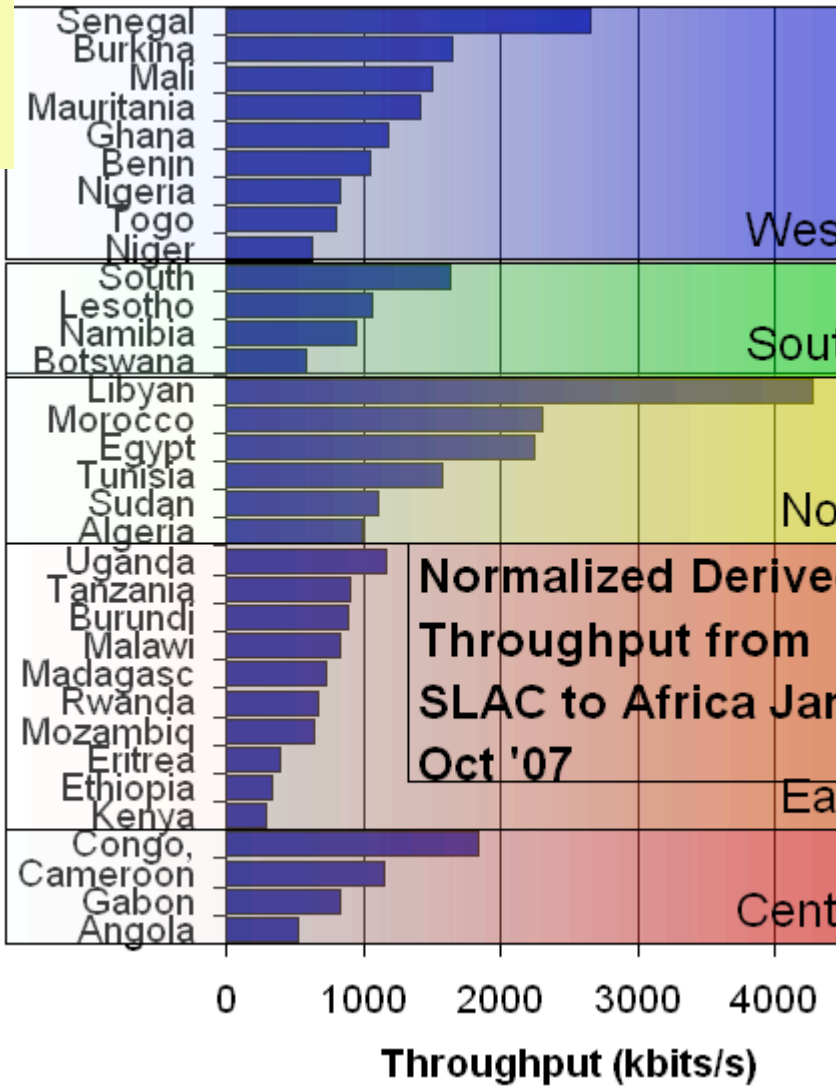
Divide within Divide: Africa Throughput



99 hosts

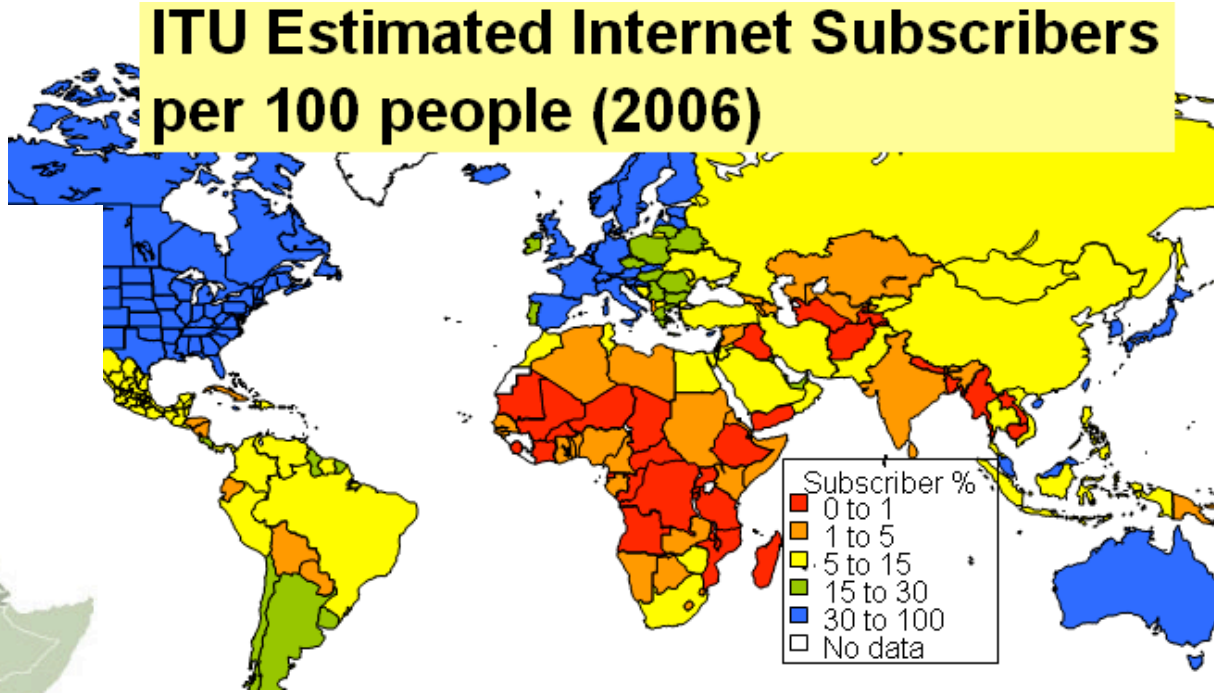
45 Countries

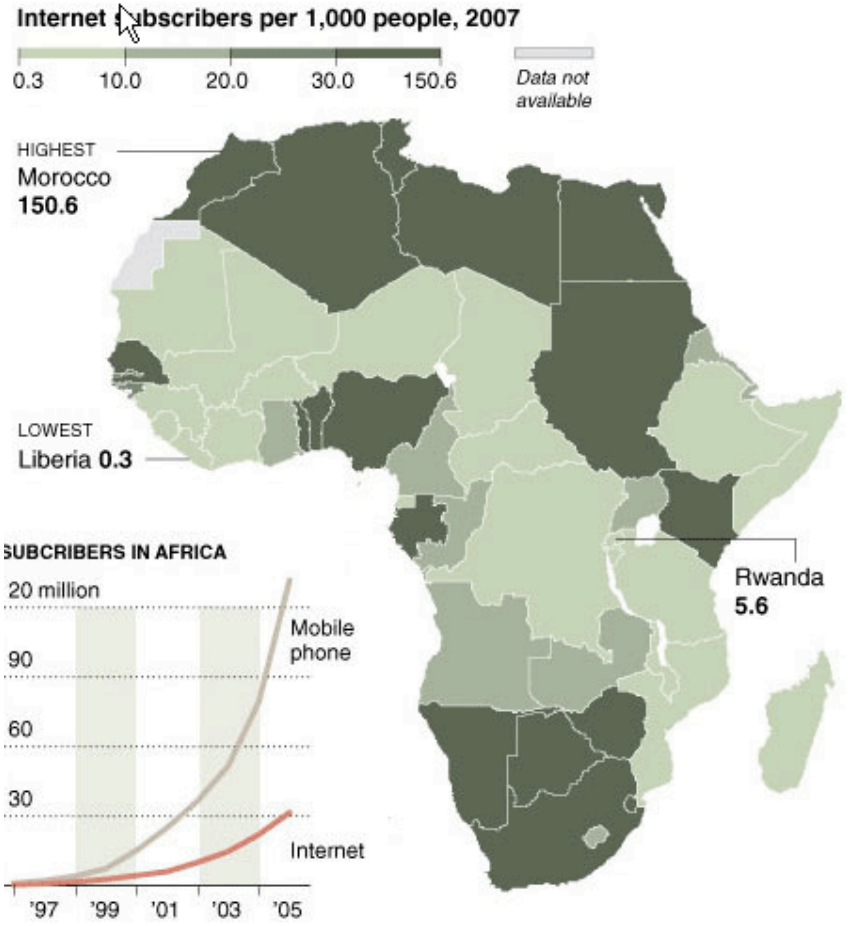




- Overall Loss performance is poor to bad
- Factor of 10 difference between Angola & Libya
- N Africa best, E Africa worst
- Big differences within regions
- In 2002, BW/capita ranged from 0.02 to over 40bps - a factor of over 1000

Subscribers /people





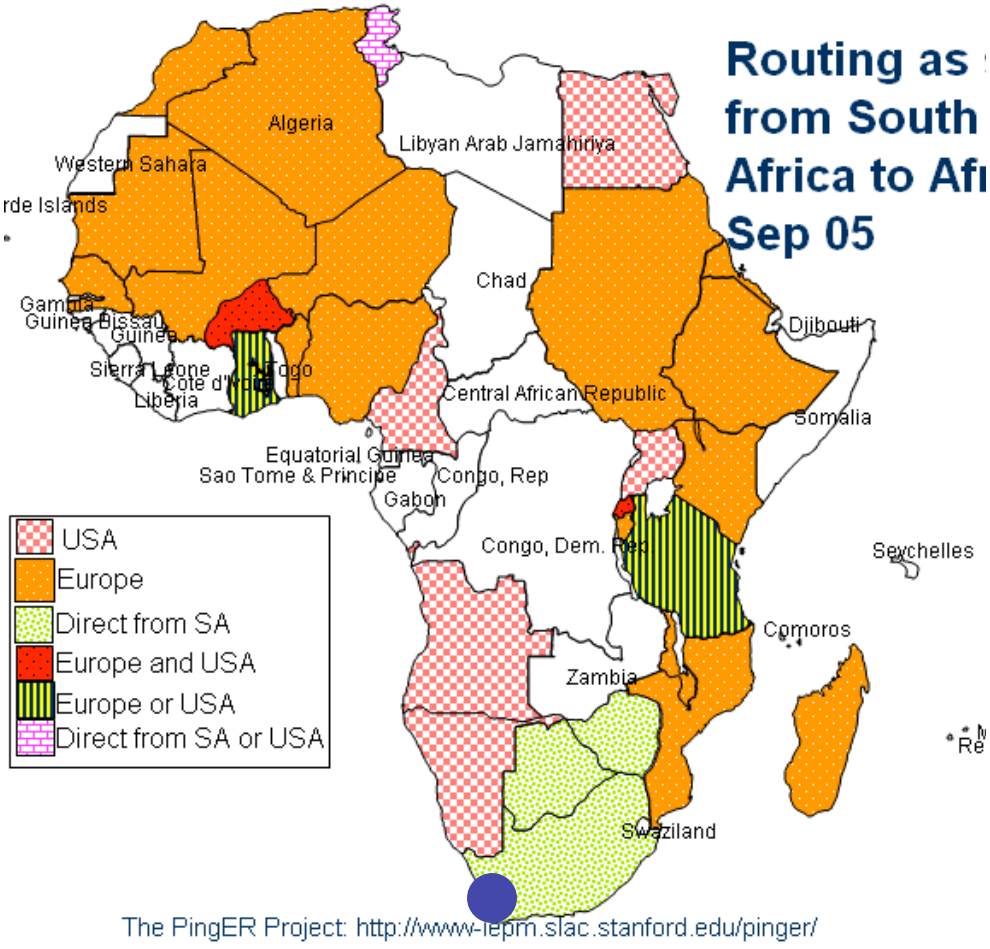
from the New York Times ,"Africa Offline: Waiting for the Web", July 22, 2007
data from the World Bank, Miniwatts Marketing Group

Subscribers / 100 people

- OECD median=27+-0.7
- ITU Africa 3.34+-3.1

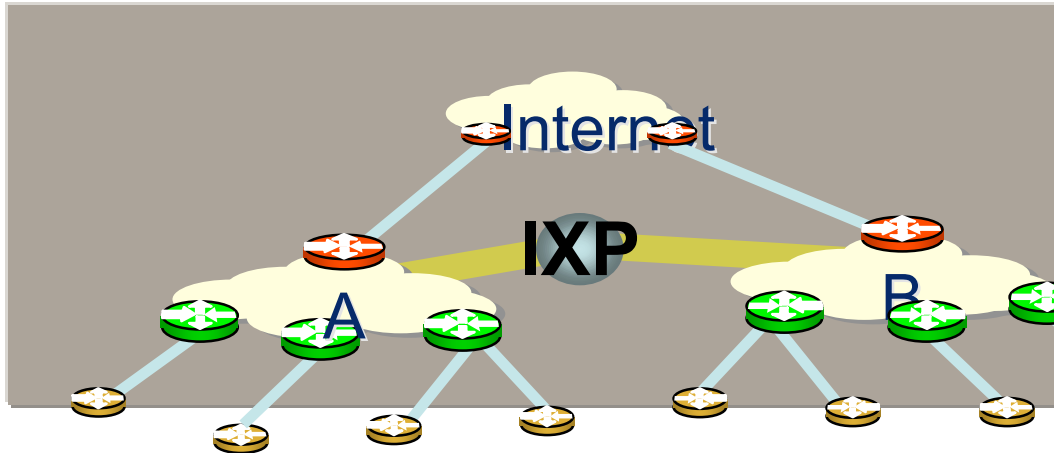
Routing from S Africa

- **Seen from TENET Cape Town ZA**
- **Only Botswana & Zimbabwe are direct**
- **Most go via Europe or USA**
- **Wastes costly international bandwidth**
- **Need IXPs in Africa**



IXPs a Major Issue for African Interne

- International bandwidth prices are biggest contributor to high costs
- African users effectively subsidise international transit providers!
- Fibre optic links are few and expensive → reliance on satellite connectivity
- High satellite latency → slow speed, high prices
- Growth of Internet businesses is inhibited
- In 2003 10 out of 53 countries had IXPs, now 16
- More IXPs → lower latency, lower costs, more usage
- Both national and regional IXPs needed
- Also needed: regional carriers, more fibre optic infrastructure investment



•*Américo Muchanga*
americo@uem.mz,

•*25 September 2005*

But there are Obstacles

- Users (universities, countries) need to band together to leverage influence, get deals
  - E.g. Ubuntunet, Bandwidth Initiative
- Current providers (cable and satellite) have a lot t loose
- Many of these have close links to regulators and governments (e.g. over 50% of ISPs in Africa are government controlled)
- Regulatory regimes on the whole closed and resistant to change
- Sometimes ISPs themselves are unwilling to co-operate

Costs compared to West

- Sites in many countries have bandwidth< US residence
  - "10 Meg is Here", www.lightreading.com/document.asp?doc_id=104415

	Down stream	Up stream	$/Mo	$/Mb / mo
Sep-03	1.5	0.128	62.91	$41.94
Mar-04	2	0.128	41.23	20.61
Jul-04	3	0.256	41.23	13.74
Jan-05	3	0.256	52.05	17.35
Mar-06	3	0.256	32.46	10.82
Sep-06	10	1	60.47	6.04
Mar-07	10	1	86.38	8.63

Bandwidth in Africa is hundreds of
times more expensive than in Europe
N. America

OECD: median=$16/Mbps/mo
Japan=$3.09/Mbps/mo
OECD study on Broadband Nov 2007

- Africa: $5460/Mbps/r
  - W Africa $8K/Mbps/m
  - N Africa $520/Mbps/
(IDRC study Jan 2005)

Bandwidth Initiative: Coalition of 11 African Universities (MZ, TZ, U
GH, NG, KY) + four major US Foundations to provide satellite thru
Intelsat at 1/3 cost ($7.3K/Mbps/m => $2.23K)

1 yr of Internet access > average annual income of most African
Survey by Paul Budde Communications (OECD 2.5%, US 1.45%)

Conclusions

- **Poor performance affects data transfer, multi-media, VoIP, IT development & country performance / development**
- **DD exists between regions, within regions, within countries, between age groups…**
- **Decreasing use of satellites**, expensive, but still neede for many remote countries in Africa and C. Asia
- **Last mile problems, and network fragility**
- **International Exchange Points (IXPs) needed**
- Internet performance (**non subjective, relatively easy/quick** to measure) **correlate strongly** with economic/technical/development indices
  - Increase coverage of monitoring to understand Internet performance
- **Africa worst by all measures** (throughput, loss, jitter, D international bandwidth, users, costs …) **and falling further behind.**

More Information

- Thanks:
  - **Incentive**: ICFA/SCIC, Monique Petitdidier, ICTP, ITU
  - **Funding**: SLAC/HEP, Pakistan HEC
  - **Effort**: SLAC, ICTP (Trieste), FNAL, Georgia Tech, administrat at over 40 monitoring sites
- **Need your help to improve African coverage**
- ITU/WIS Report 2006 & 2007 (or Google: "WSIS Report 2007")
  - www.itu.int/osg/spu/publications/worldinformationsociety/**2007**/report.html
- Higher Education in Sub-Saharan Africa
  - www.arp.harvard.edu/AfricaHigherEducation/Online.html
- PingER
  - www-iepm.slac.stanford.edu/pinger, sdu.ictp.it/pinger/africa.htn
  - www.slac.stanford.edu/xorg/icfa/icfa-net-paper-**jan07**/
- Speedtest: http://www.speedtest.net/
- Case Study (in progress):
  - confluence.slac.stanford.edu/display/IEPM/**Sub-Sahara+Case+Study**

Extra Slides

Africa PingER Sites

Algeria (8/1)	Angola (4/1)	Benin (2/1)	Botswana (2/0)	Burkina Fas
Burundi (1/0)	Cameroon (4/1)	Cape Verde (1/0)	Congo, Dem Rep (2/0)	Djibouti (1/1
Egypt (3/1)	Eritrea (2/0)	Ethiopia (2/1)	Gabon (2/1)	Gambia (1/1)
Ghana (3/1)	Guinea-Bissau (1/0)	Ivory Coast (2/1)	Kenya (2/0)	Lesotho (2/1
Liberia (1/0)	Libya Arab Jamahiriya (1/1)	Madagascar (3/0)	Malawi (2/0)	Mali (1/1)
Mauritania (2/1)	Mauritus (1/0)	Morocco (2/1)	Mozambique (2/1)	Namibia (2/1
Niger (1/0)	Nigeria (1/0)	Rwanda (3/1)	Senegal (1/1)	Seychelles (
Sierra Leone (2/0)	South Africa (8/1)	Sudan (3/1)	Swaziland (1/0)	Tanzania (3/
Togo (2/1)	Tunisia (3/1)	Uganda (4/0)	Zambia (1/0)	Zimbabwe (

Leading

Country	Population	Int'l BW Mbps	Int'l BW / capita (bps)	Internet Users	Internet users/ 1000 capita	BW (bps)/ Internet User	DC Ra
Egypt	82,073,660.00	**3784**	46.105	1000000	12.1842	3784	
South Africa	43,743,316.00	881.5	20.152	**1012500**	**23.1464**	870.617	
Senegal	12,938,350.00	775	**59.899**	19351	1.49563	**40049.6**	
Cameroon	18,569,348.00	155	8.3471	6500	0.35004	23846.2	
Nigeria	**139,070,856.00**	150	1.0786	350000	2.5167	428.571	
Kenya	38,213,024.00	113.39	2.9673	80000	2.09353	1417.38	
Uganda	31,621,980.00	100	3.1624	8000	0.25299	12500	
Burkina Faso	14,866,133.00	76	5.1123	14238	0.95775	5337.83	
Cote d'Ivoire	18,465,326.00	55.42	3.0013	13747	0.74448	4031.43	
Benin	8,349,959.00	47	5.6288	6396	0.76599	7348.34	
Niger	13,364,797.00	30	2.2447	3117	0.23322	9624.64	
Mozambique	21,379,584.00	18.5	0.8653	25000	1.16934	740	
Ethiopia	78,697,922.00	10	0.1271	12155	0.15445	822.707	
Namibia	2,067,433.00	9	4.3532	19000	9.19014	473.684	

Scenario Cases

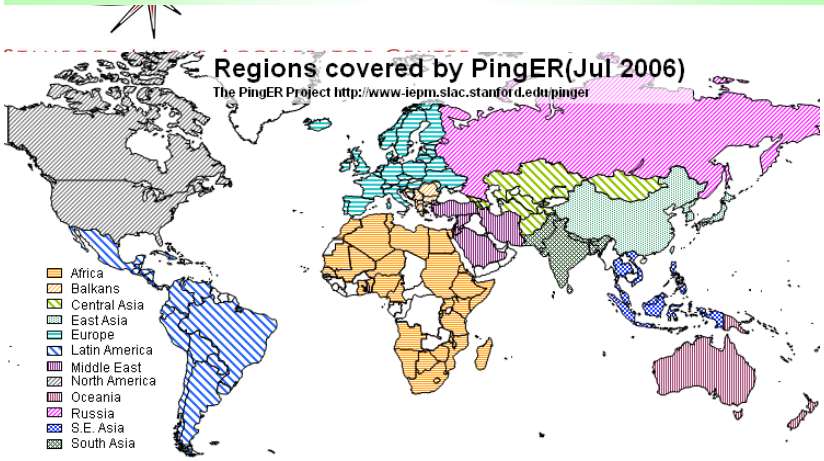
1. School in a secondary town in an East Coast country with network computer lab spends 2/3rds of its annual budget to pay for the dia up connection.
   - Disconnects
2. Telecentre in a country with fairly good connectivity has no connectivity
   - The telecentre resorts to generating revenue from photocopies PC training, CD Roms for content.
3. Primary health care giver, somewhere in Africa, with sonar machine, digital camera and arrangement with national academic hospital and/or international health institute to assist in diagnostics. After 10 dial-up attempts, she abandons attempts to connect

Heloise Emdon,
Acacia Souther
Africa

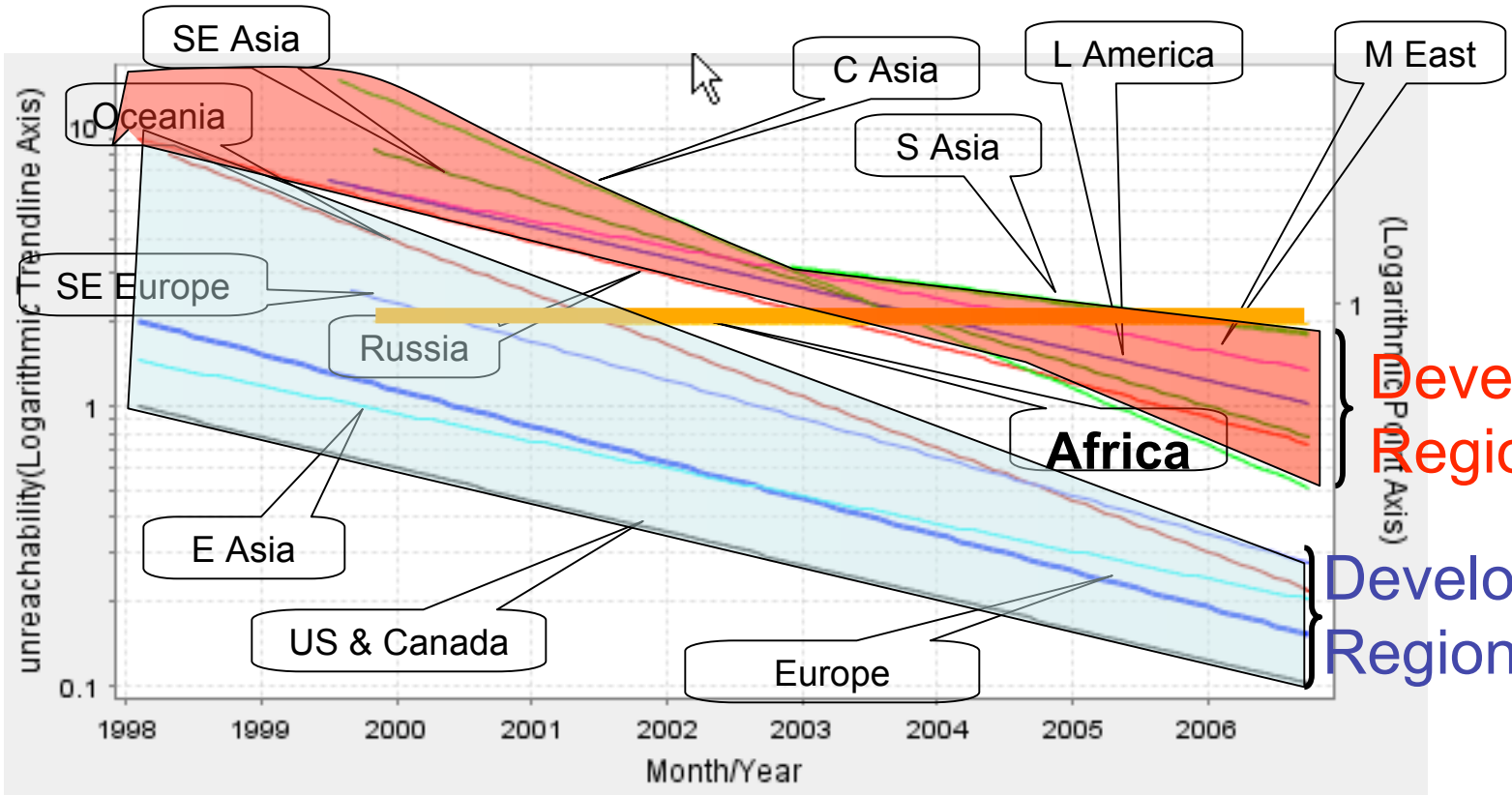
UNDP Global Meeting for IC
Development, Ottawa 1(
July

4. Sep 05, international fibre to Pakistan fails for 12 days, satellite backup can only handle 25% traffic, call centres given priority. **Research & Education sites cut off from Internet for 12 days**

Unreachability



- All pings of a set fail ≡ unreachable
- Shows fragility, ~ distance independent
- Developed regions US, Canada Europe, Oceania, E Asia lead
  - Factor of 10 improvement in 8 yea
- Africa, S. Asia followed M East & America worst off

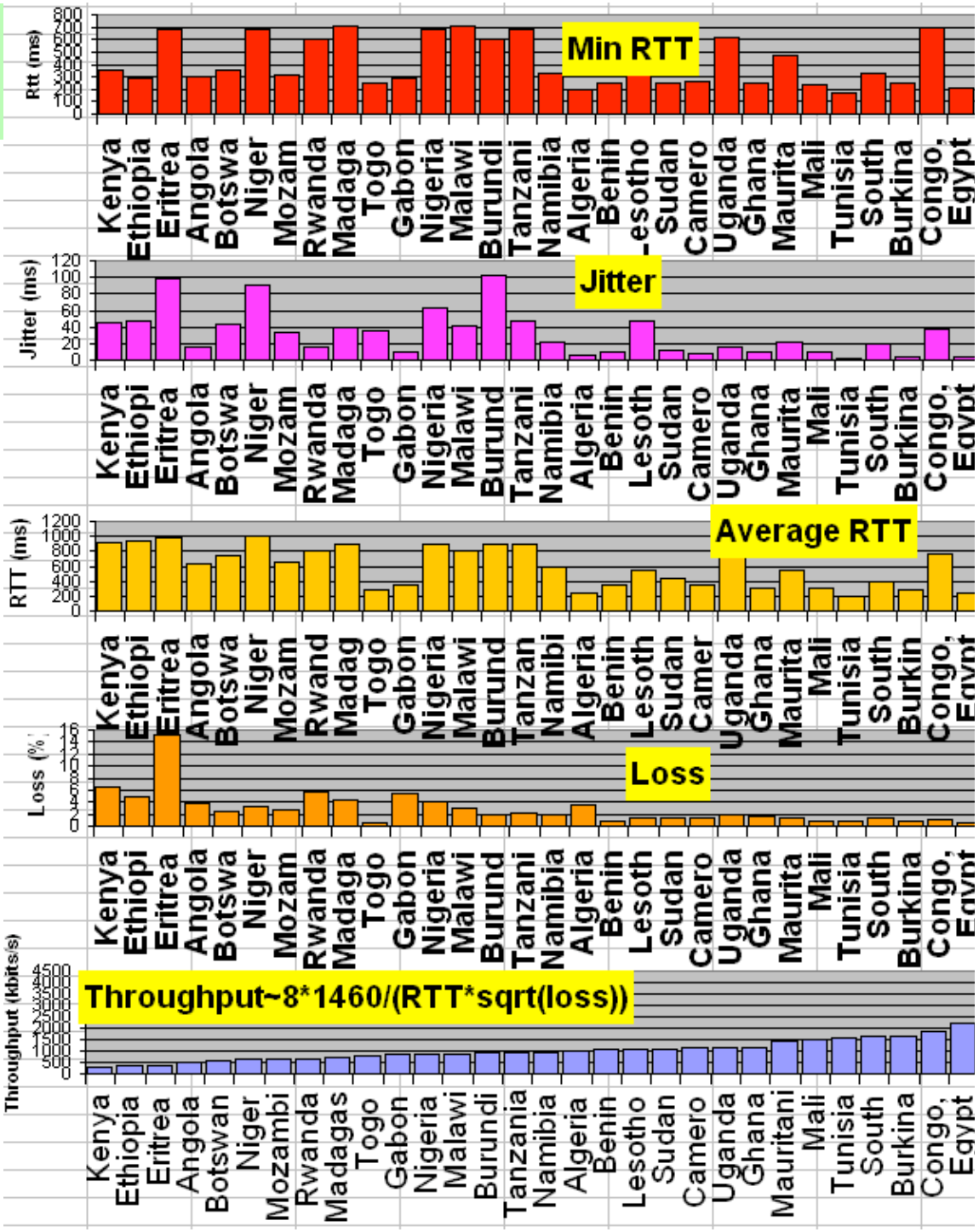


- **Africa N improvir**

Throughput

- Derive from:

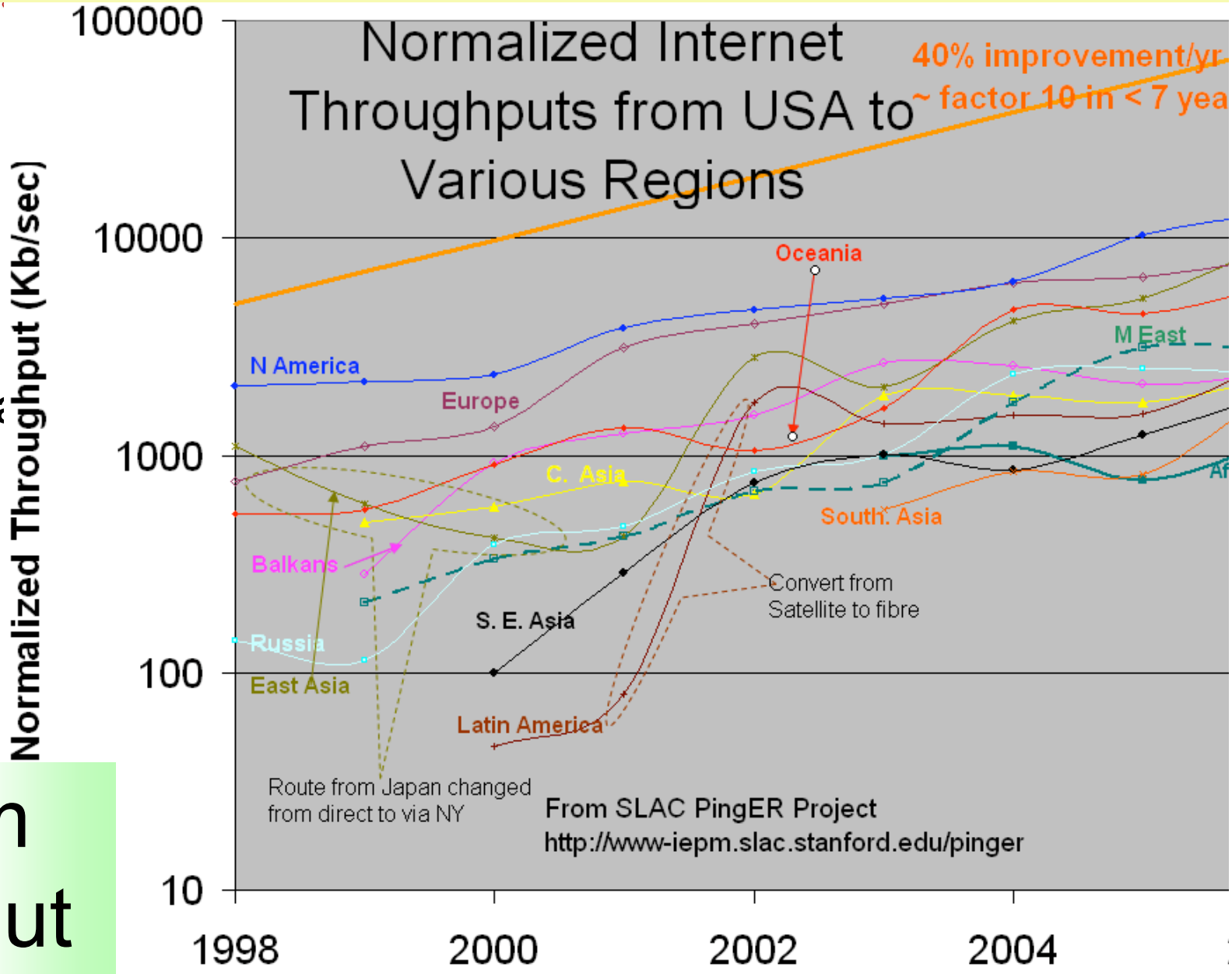
$$\text{Thru} \sim \frac{8 * 1460}{(\text{RTT} * \sqrt{\text{loss}})}$$



Thru = 1460 / (RTT*sqrt(loss)) Mathis et. al

Norm_thru = thru * min_rtt(remote_region)/min_rtt(monitoring_region

- Note step changes
- Africa v. poor
- S. Asia improving
- N. America, Europe, E Asia, Oceania lead

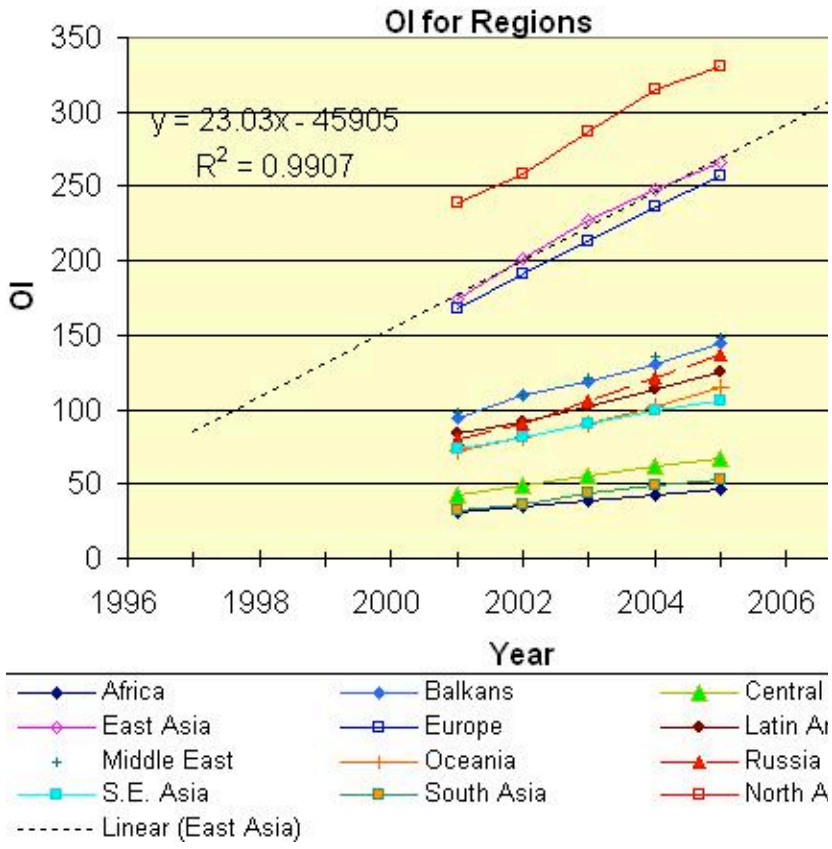


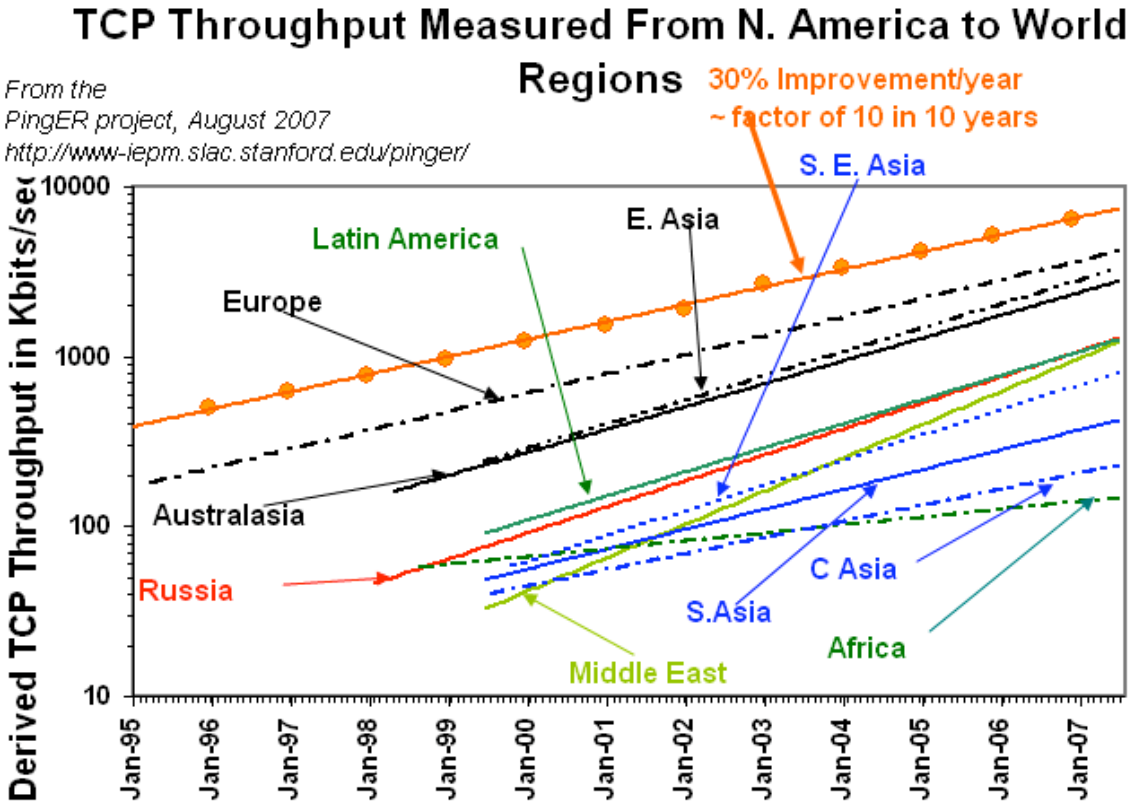
Norm Thruput

World thruput vs ITU-OI

Behind Europe
- 6 Yrs: Russia, Latin America
- 7 Yrs: Mid-East, SE Asia
- 10 Yrs: South Asia
- 11 Yrs: Cent. Asia
- 12 Yrs: Africa

South Asia, Central Asia, and Africa are in Danger of Falling Even Farther Behind





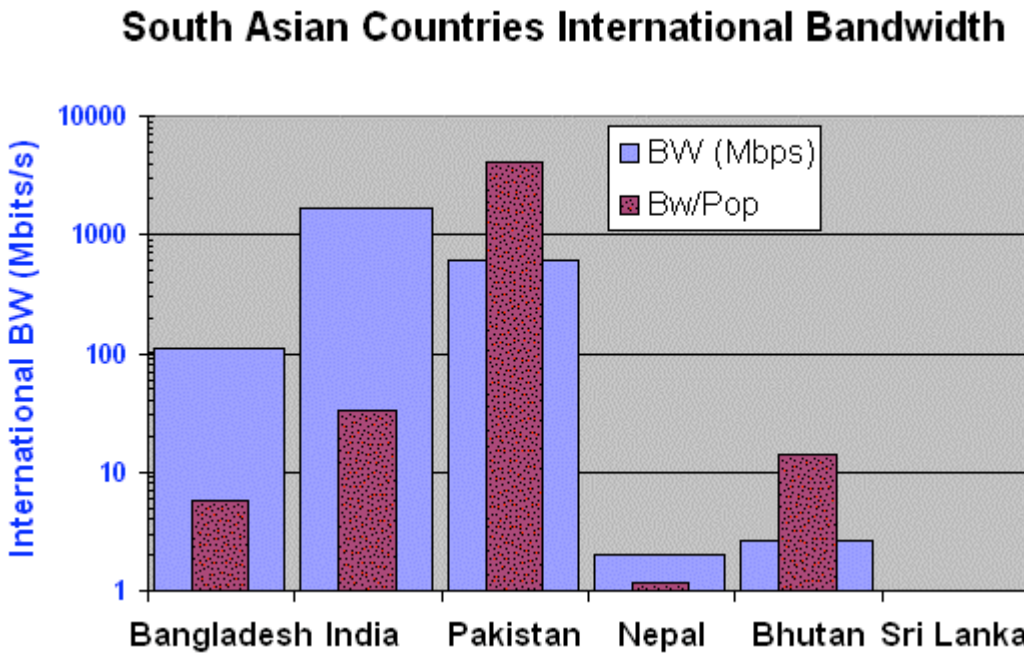
Overall (Aug 06)

- ~ Sorted by Average throughput
- Within region performance better (black ellipses)
- Europe, N. America, E. Asia generally good
- M. East, Oceania, S.E. Asia, L. America acceptable
- C. Asia, S. Asia poor, **Africa bad** (>100 times worse)

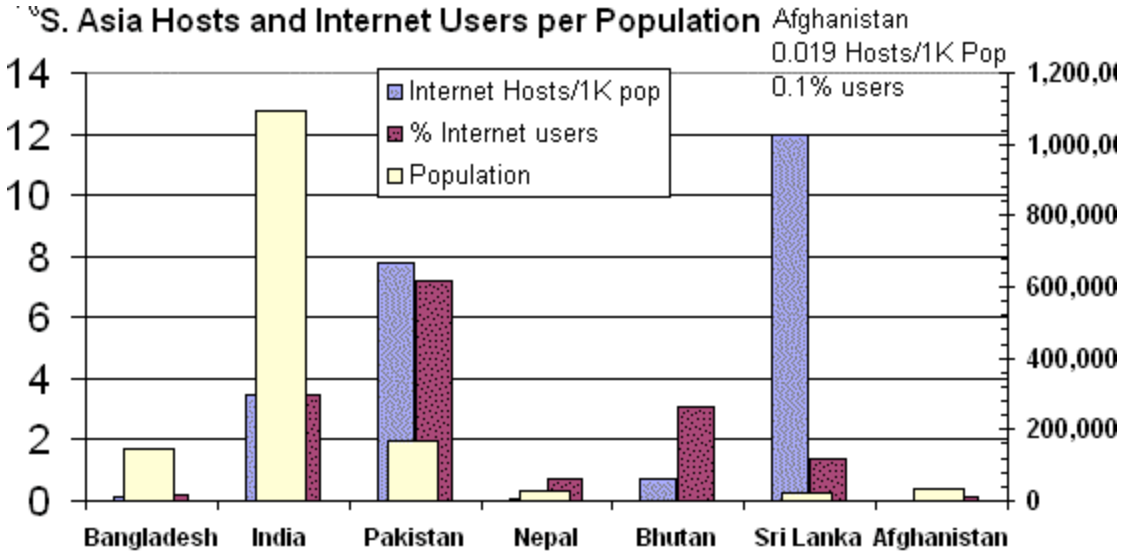
Monitored Country	Monitoring Country Top Level Domain ==========													
	CH	DE	HU	UK	CA	US	JP	CN	RU	BR	IN	PK	ZA	A
Europe	35585	9178	12880	16239	2083	2080	1220	986	493	794	1084	1017	169	
Balkans	6107	5214	8114		1917	1363			466	826	1554	969	121	
N America	2244	2095	2171	2939	12356	31365	1971	1472	337	1120	771	809	322	
E Asia	1138	1110	1188	1373	1658	1804	40000	4096	457	553	876	572	175	
Russia	4338	424	411	521	333	1191	2920		2865	219	199	239	103	
S Asia	771				689	521				48	1537	2697	93	
M East	802					1131								
Africa	1489	1869	1822	1597	855	496	581		320	399	200	231	369	
L America	905	436	433	532	918	1306	425		138	4350	236	375	138	
SE Asia	581					950								
Oceania	930	794	943		1340	1333			220	491	477	458	101	
C Asia	516					601								
Median	4617	2640	3495	3877	2461	3678	7853	2185	787	1026	770	818	177	
	Europe				N America		E Asia		RU	BR	S Asia		ZA	

Bandwidth & Internet use

- Note Log scale for BW
- India region leader
- Pakistan leads bw/pop
- Nepal very poor

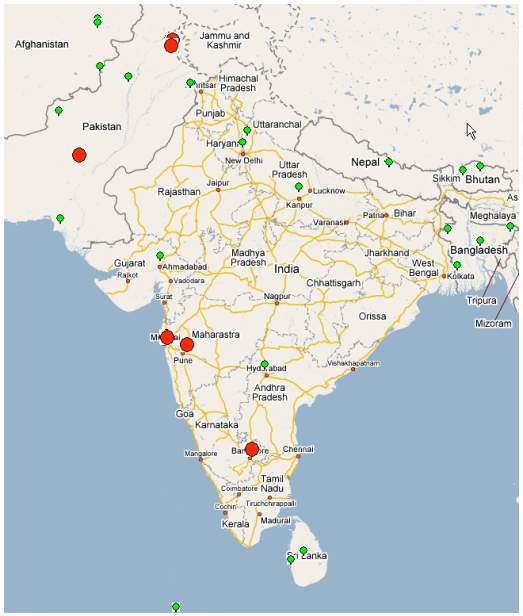


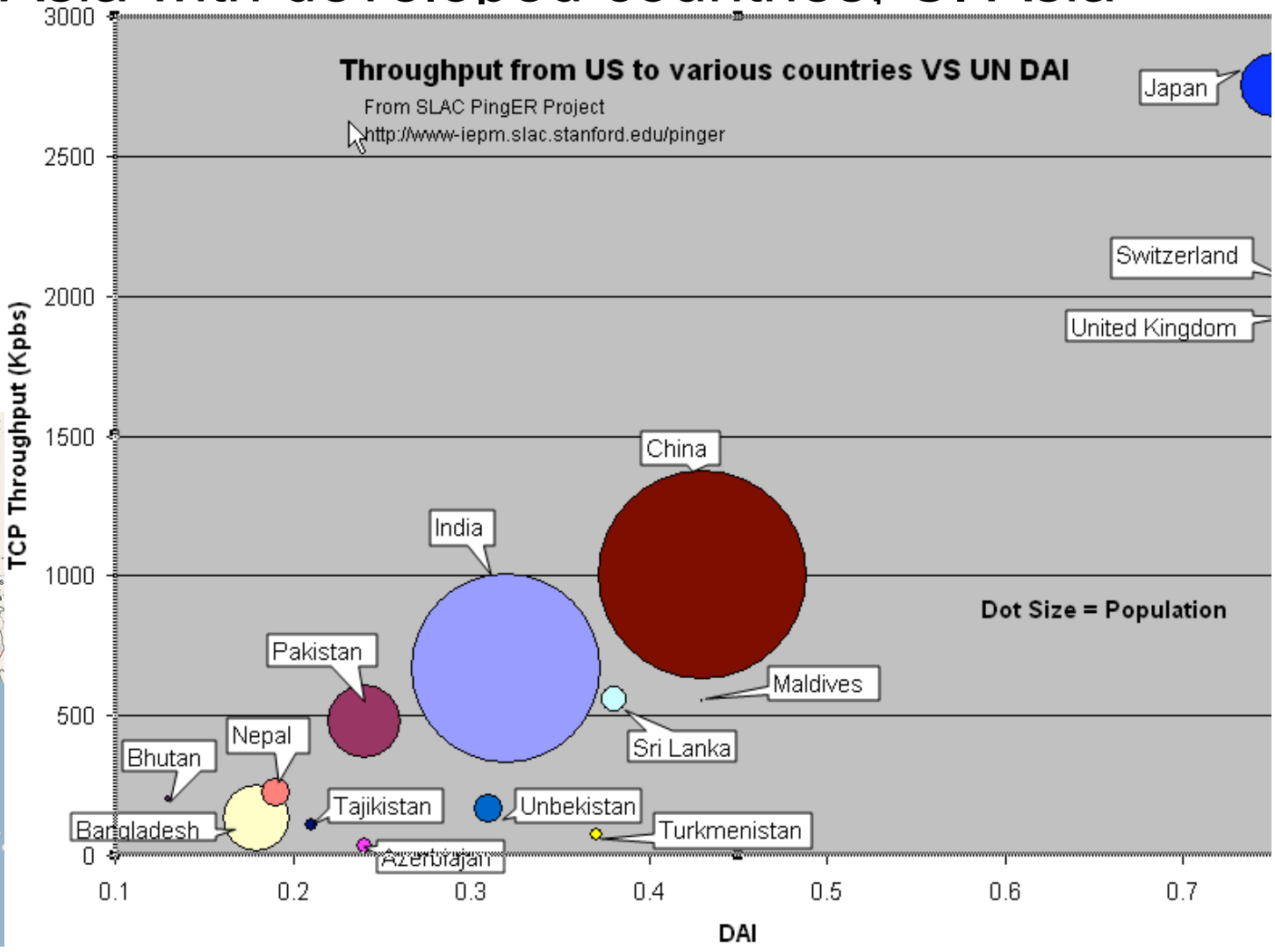
- Pakistan leads % users
- Sri Lanka leads hosts%%
- Pakistan leads bw/pop
- Nepal, Bangladesh, Afghanistan very poor



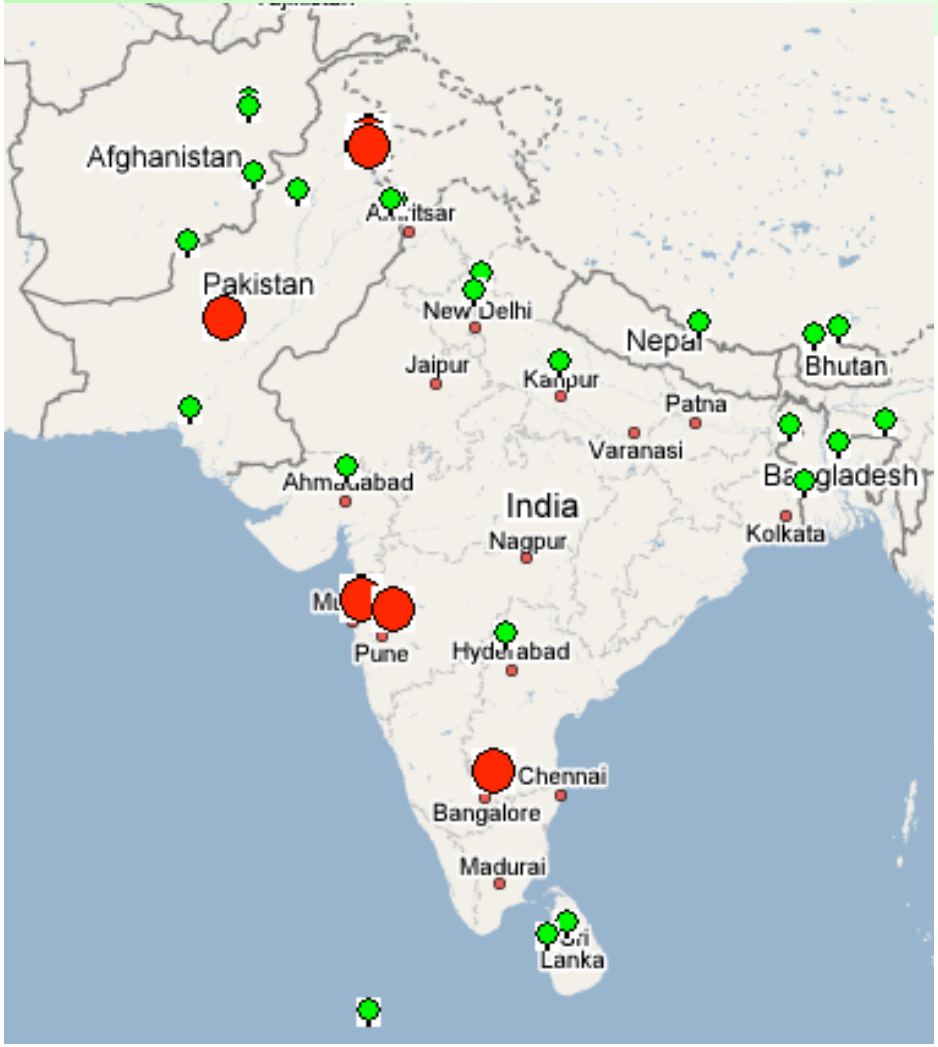
DAI vs. Thru & S. Asia

- More details, also show populations
- Compare S. Asia with developed countries, C. Asia

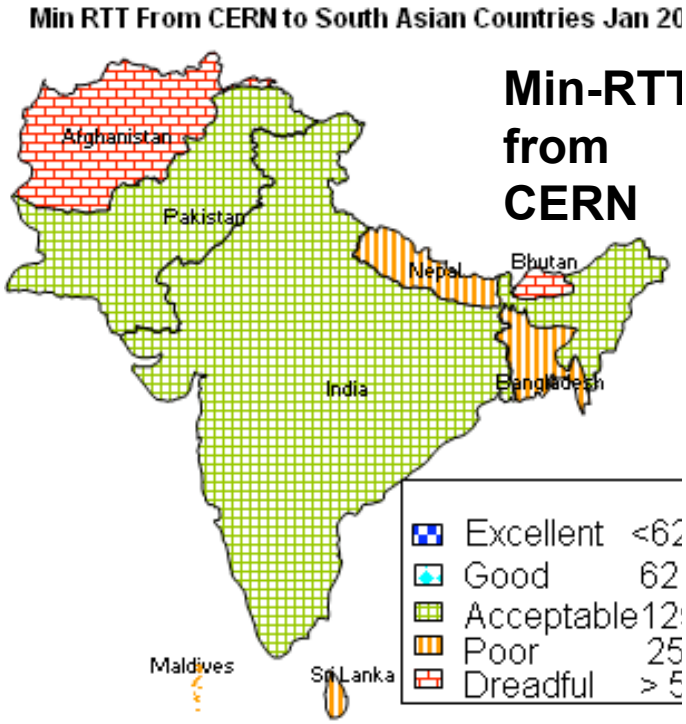


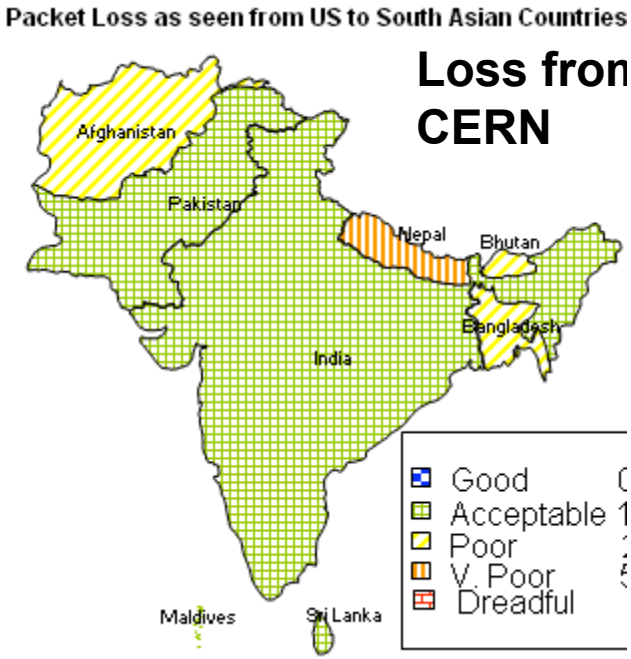


S. Asia Coverage



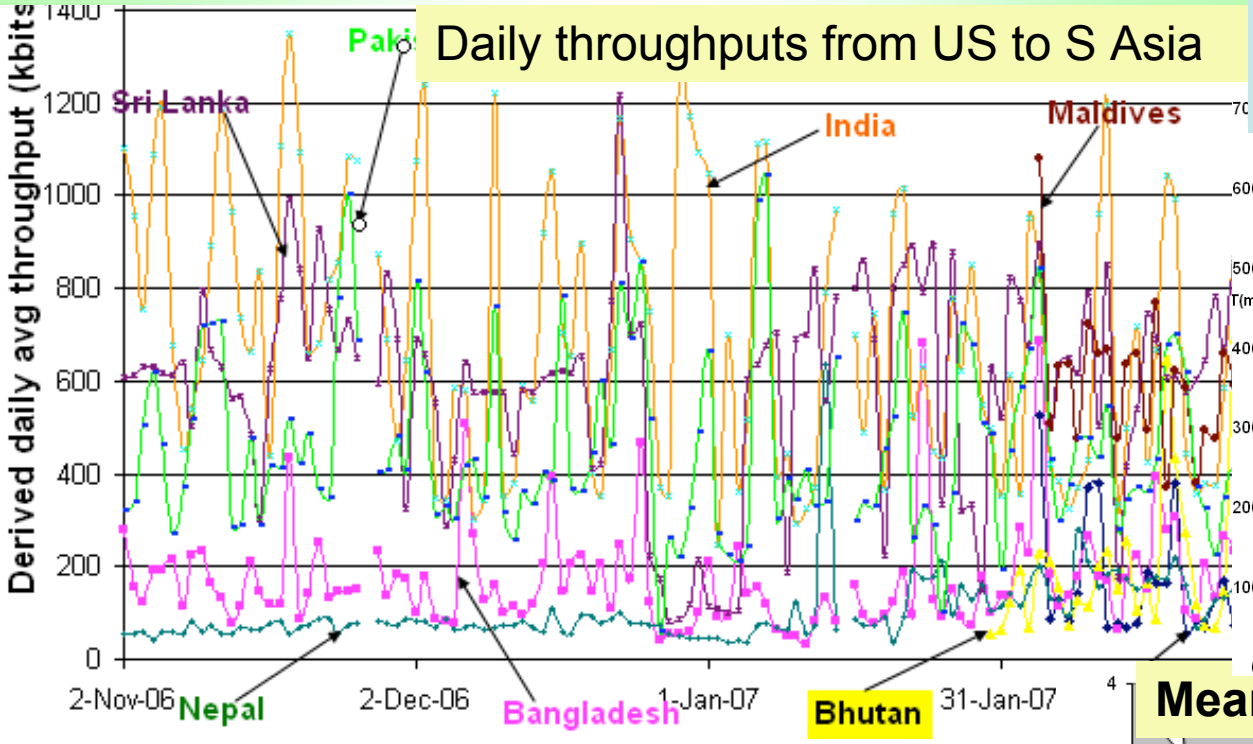
- Monitor 44 hosts in region.
- 6 Monitoring hosts

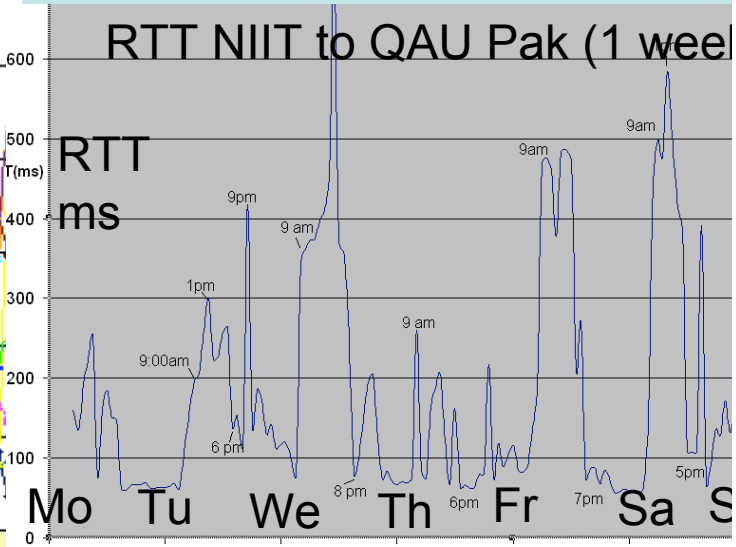




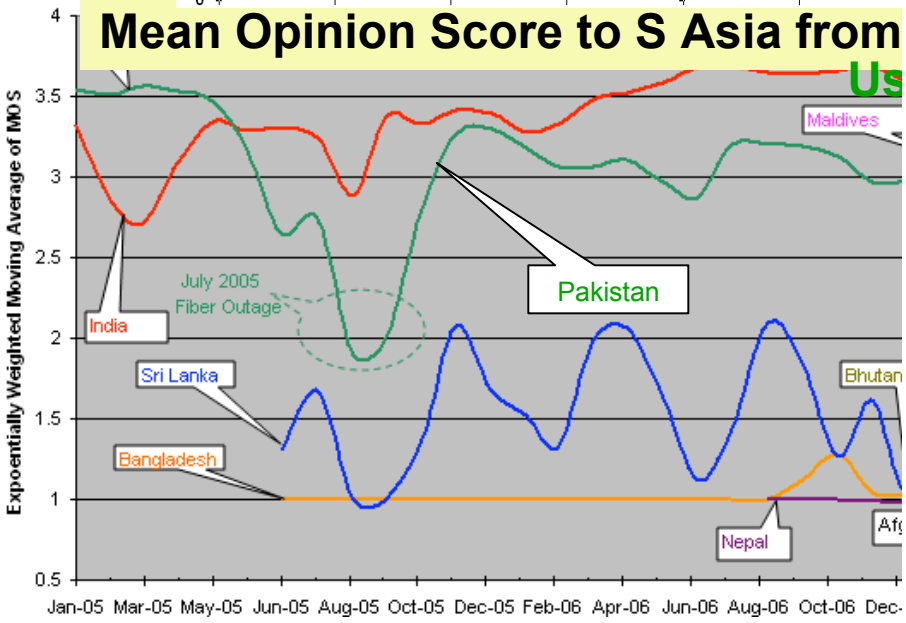
S Asia MOS & thruput

- weekend vs. w'day
  day vs night = **heav**
  congestion



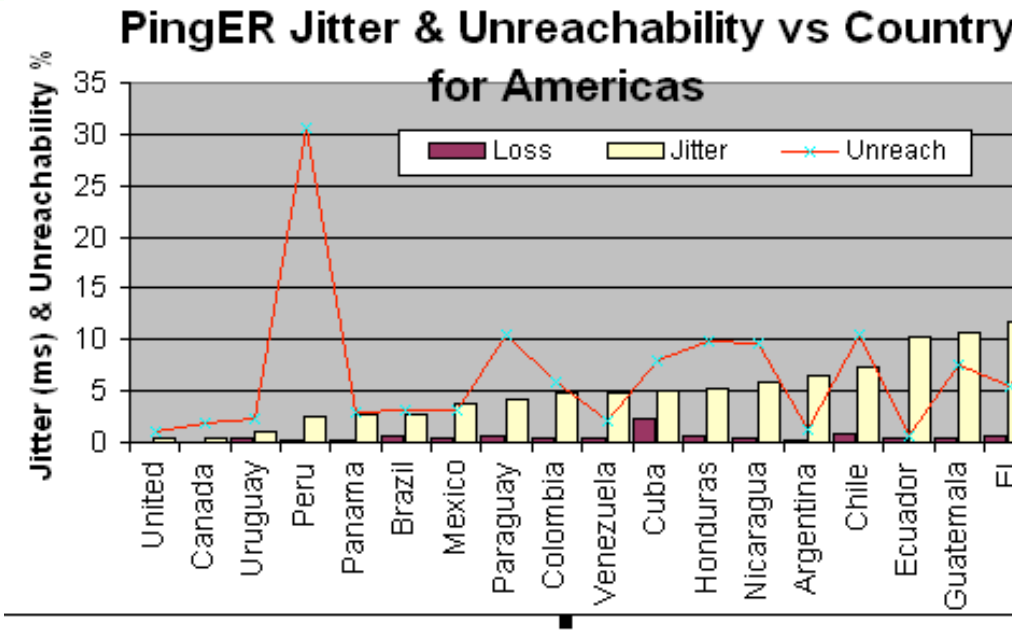


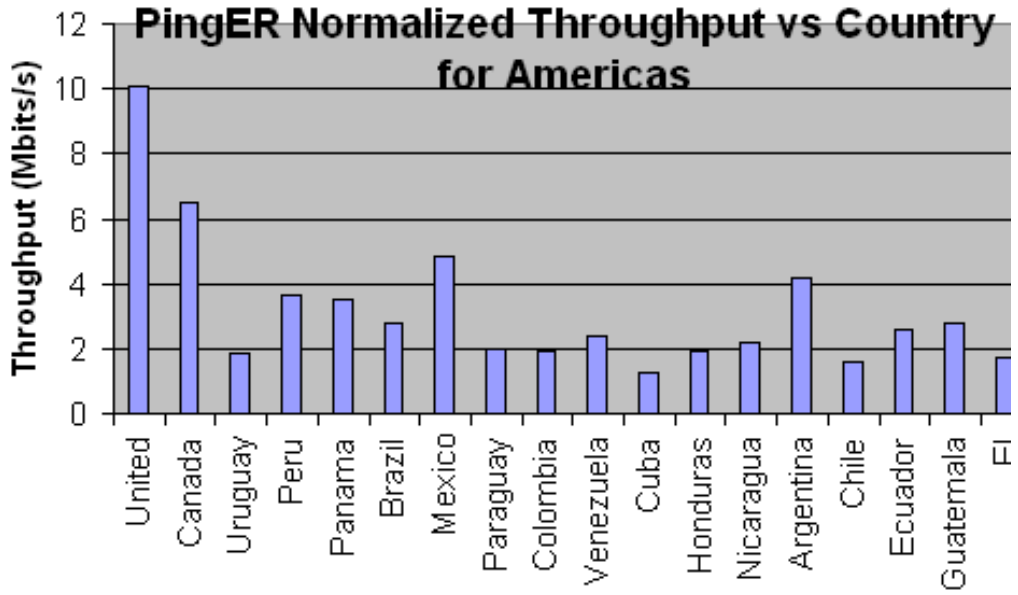
- Last mile problems
- Divides into 2
  - India, Maldives, Pakistan, Sri Lanka
  - Bangladesh, Nepal, Bhutan, Afghanistan



Americas

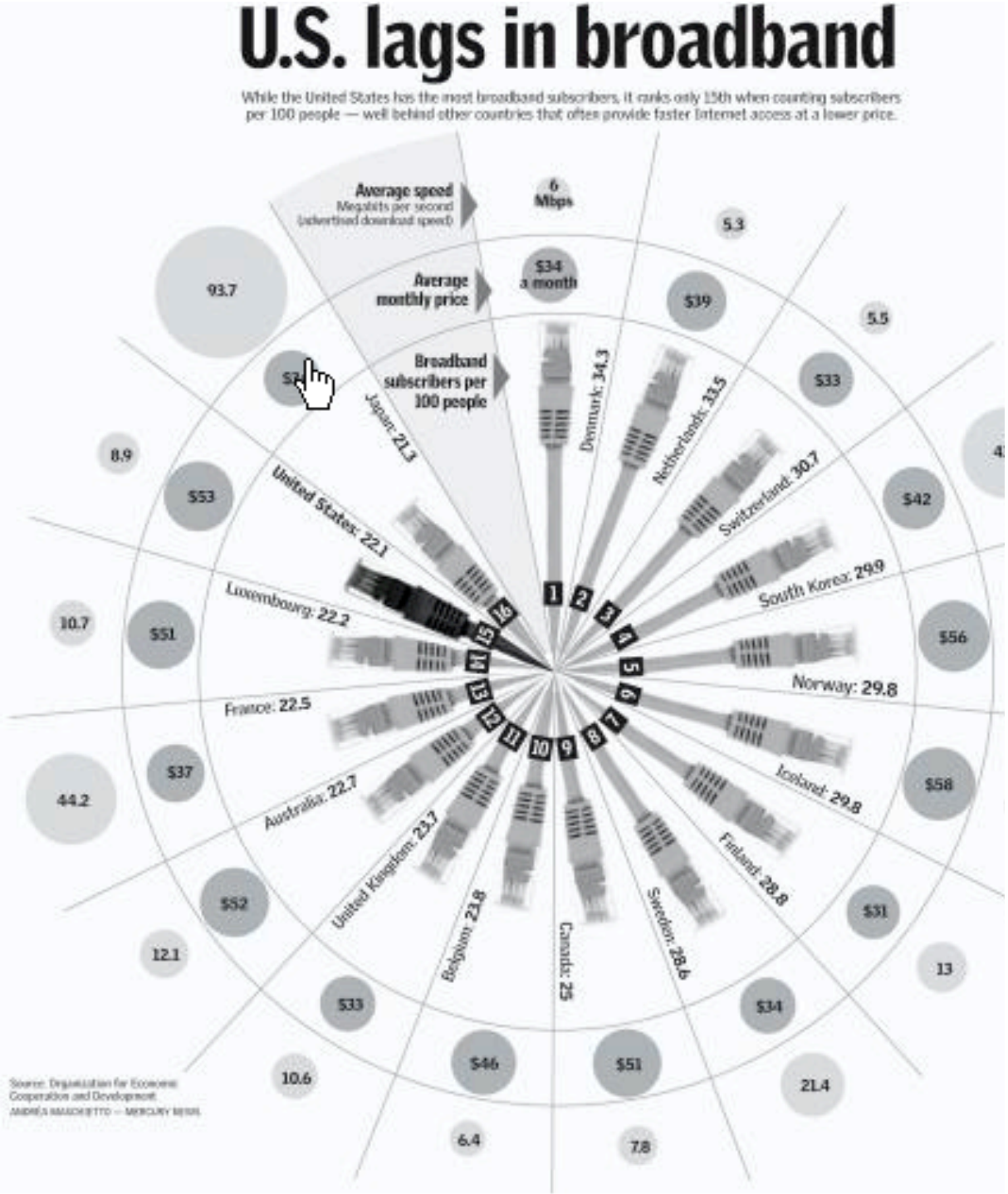
- Cuba poor throughput due to satellite RTTs and high losses
- US & Canada lead





OECD Broadband

- Graphic from San Jose Mercury, 11/22/07

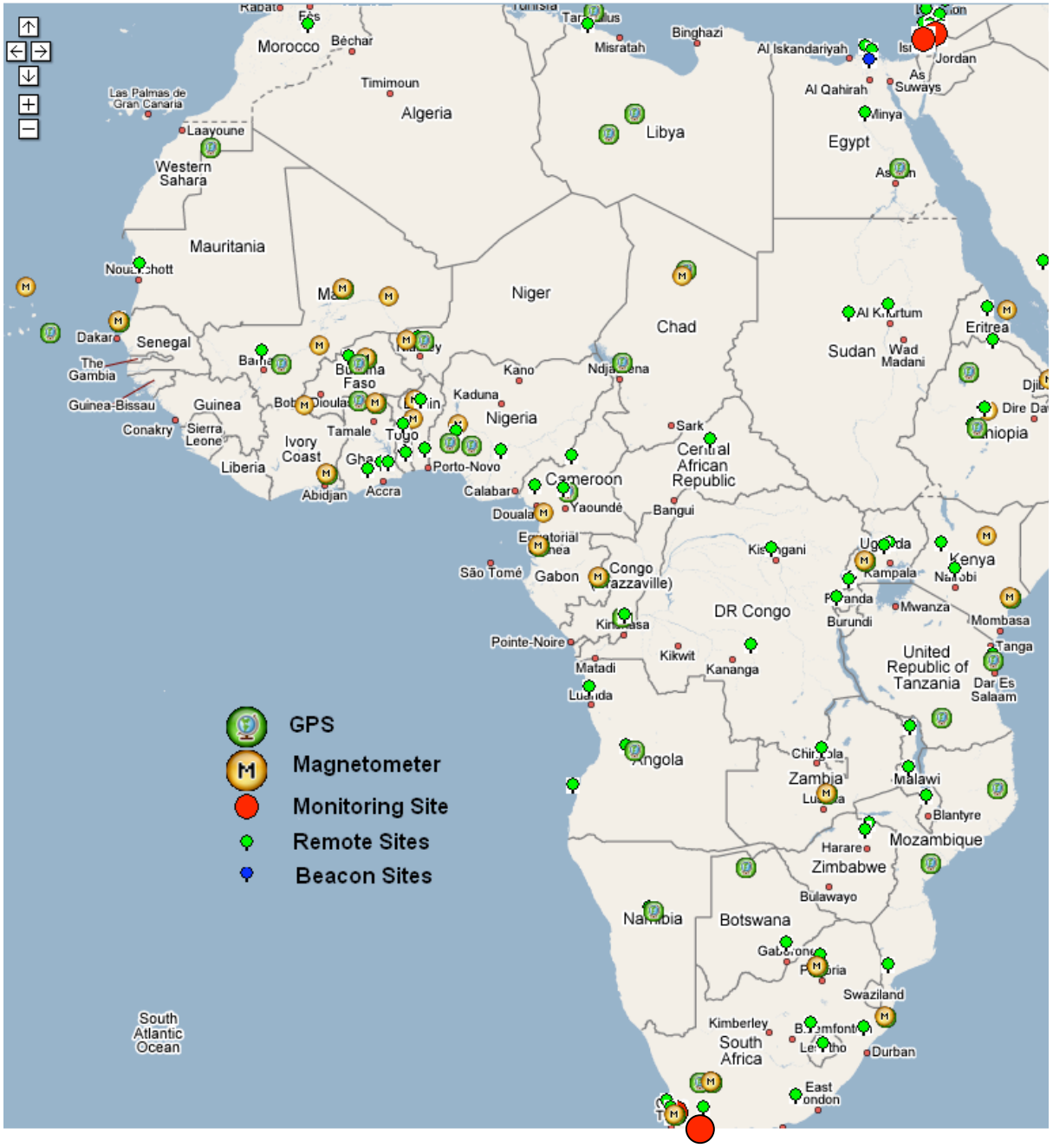


IHY Sites & PingER

Google maps

- Zoom, pan etc.

- IHY coordinates from Monique Petitdidier (CNRS)
- SIDs from Deborah Scherrer (Stanford)
- To come: Barbara Thompson (NASA)



www.slac.stanford.edu/comp/net/wan-mon/viper/ihy_googlemap.htm

- Automate uploading etc. via Internet