SLAC-WP-095

The Emergence of the Internet and Africa

Les Cottrell SLAC

SLAC Colloquium, May 6th, 2013

Work supported in part by US Department of Energy under contract DE-AC02-76SF00515.

Agenda

- Brief history of the Internet and its goals,
  - how it has grown,
  - today's major challenges,
  - and future research.
- The impact of the Internet on development,
- Africa
  - How Africa has lagged the world,
  - Why does it matter?
  - Is the performance for Africa improving, will it catch up?

1961 Vision from the Bell Phone System

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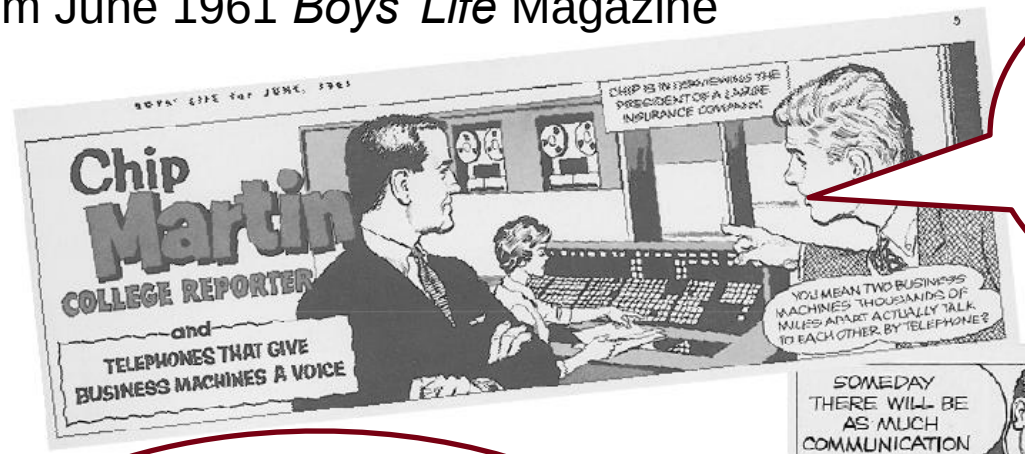
TeleGeography Research — The Authoritative Source for Global Telecom Statistics and Analysis

Data Traffic is Nothing New

Ad from June 1961 *Boys' Life* Magazine



You mean two business machines thousands of mile apart actually talk to each other by telephone

Someday there will be as much communication between business machines as between people

The Start of the Internet as we know it today

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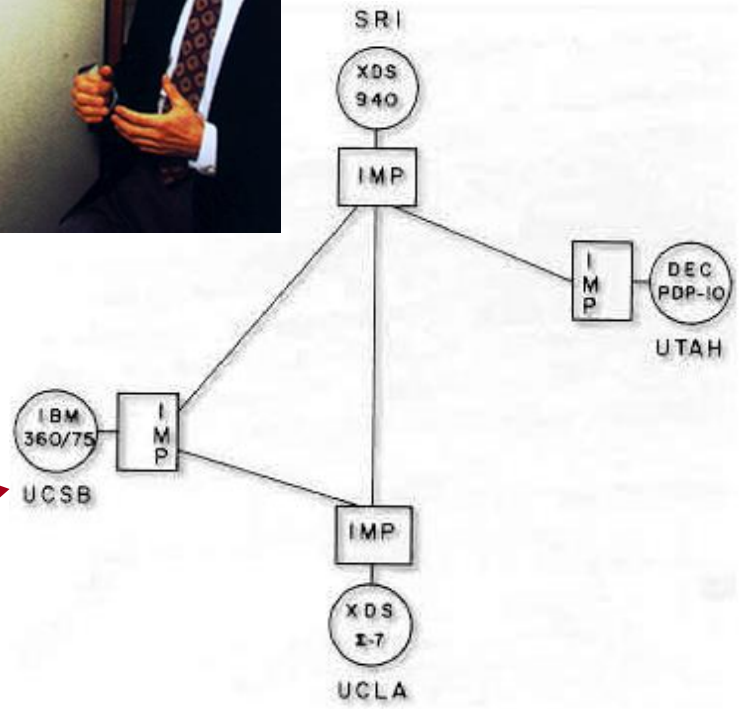
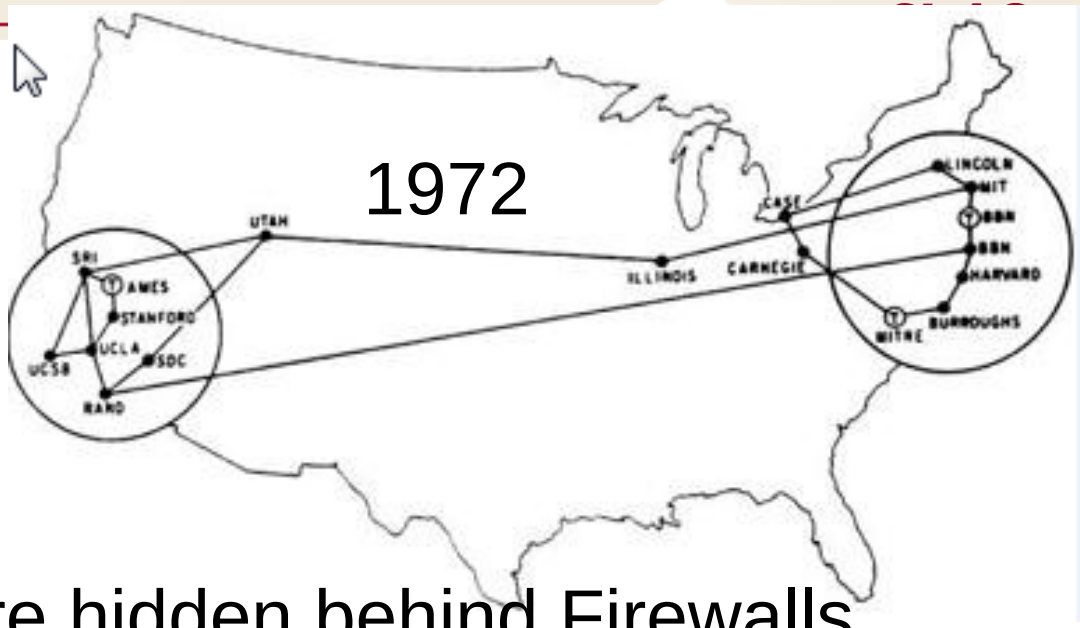
- 1965: Larry Roberts and Thomas Marill create the first wide area connection **via telephone lines**, turns out to be inefficient and costly.
- Kleinrock predicts that packet switching (developed by Baran, Davies, Kleinrock et. al.) more promising

1969: the original Internet created and had 4 nodes, UCLA, Stanford Research Institute, MIT, Utah, 50kbit backbone (today scaled up a billion times)



Early days



1983 400 nodes,

Now 750M (many more hidden behind Firewalls and home router/Network Address Translation devices (NAT) etc.)

Design Goals slide 1

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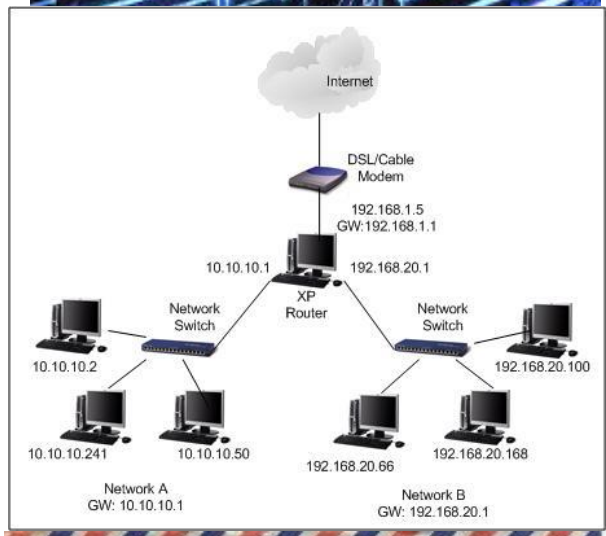
- Built as a **collaboration of global proportions**, independent stand on own, self managed autonomous systems, decentralized (chaotic, no central control/management cf. phone system),
- **Best effort**, no guarantees, recovery from losses, pipelining host flow control, checksums
- **non-proprietary** (c.f. IBM's System Network Architecture, Digital Equipment's network, Xerox Network Services, phone system …),

Design Goals 2

- **Little focus on security**
  - (if had: might never have happened),
- **simple black boxes** (routers connect nets)

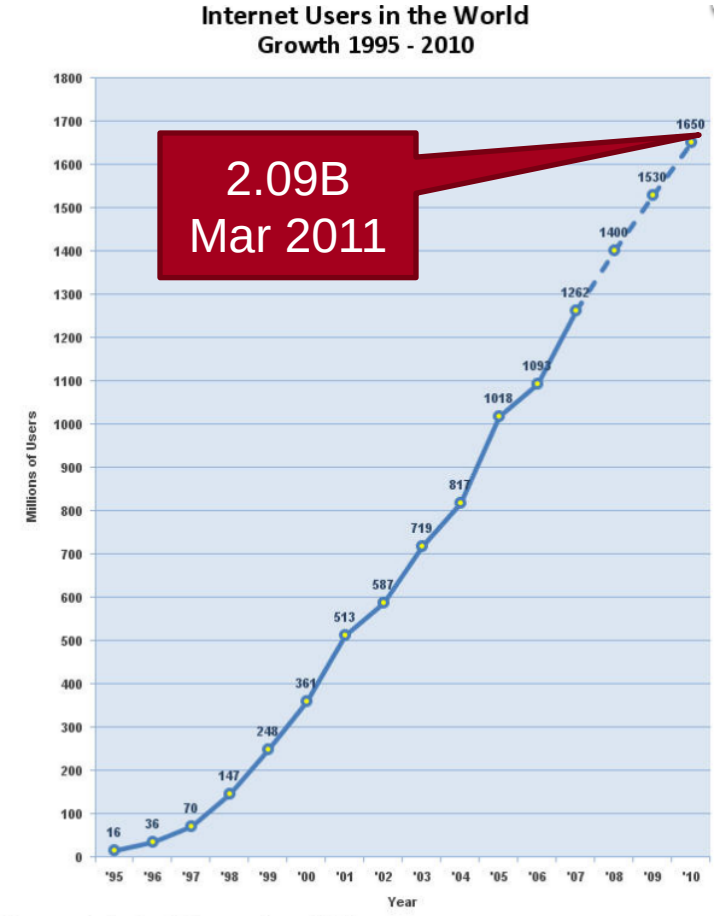
  do not retain information about the individual flows,
- **packets inside envelopes, layering**

  (independent of each other, i.e. middle layers don't know if lower layers are wireless, satellite, copper, fibre, upper layer independent of applications cf. purpose designed TV broadcast networks, cable networks, telephone network, only end device knows what contents mean).

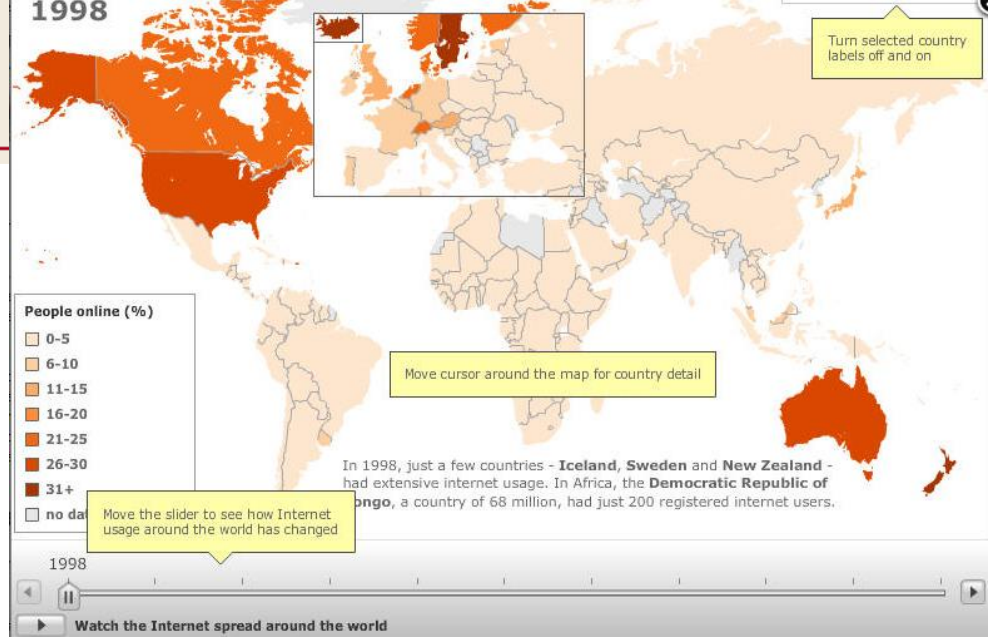


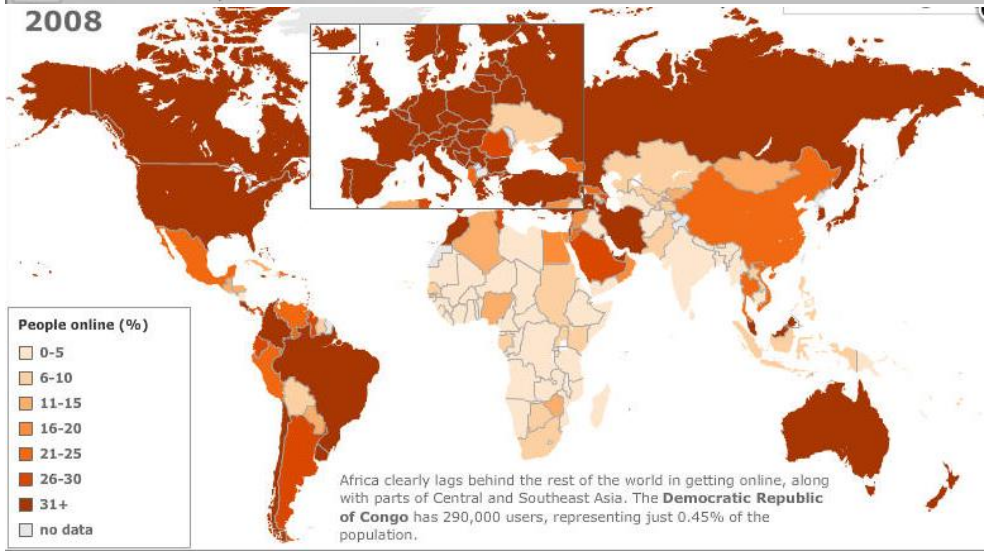
Growth: users

Factor of 6 in 10 years



Source: www.internetworldstats.com - January, 2008
Copyright © 2008, Miniwatts Marketing Group





Most future user growth from developing nations

Maps from http://news.bbc.co.uk/2/hi/technology/8552410.stm

Growth: Devices

August 2010: 12.5Billion devices plugged in to Internet

In 10 years factor 100 growth

- **cell phones & other new classes of consumer electronics** (eBooks, tablets, Internet TV, digital picture frames …), Internet of things, 99% of todays electronic devices are not on the Internet
- **Even bigger is machine to machine** (Internet of Things)
  - smart grids for energy management, smart cities, surveillance & public safety, traffic & parking control, cars, and sensor nets …).

Growth: bandwidth

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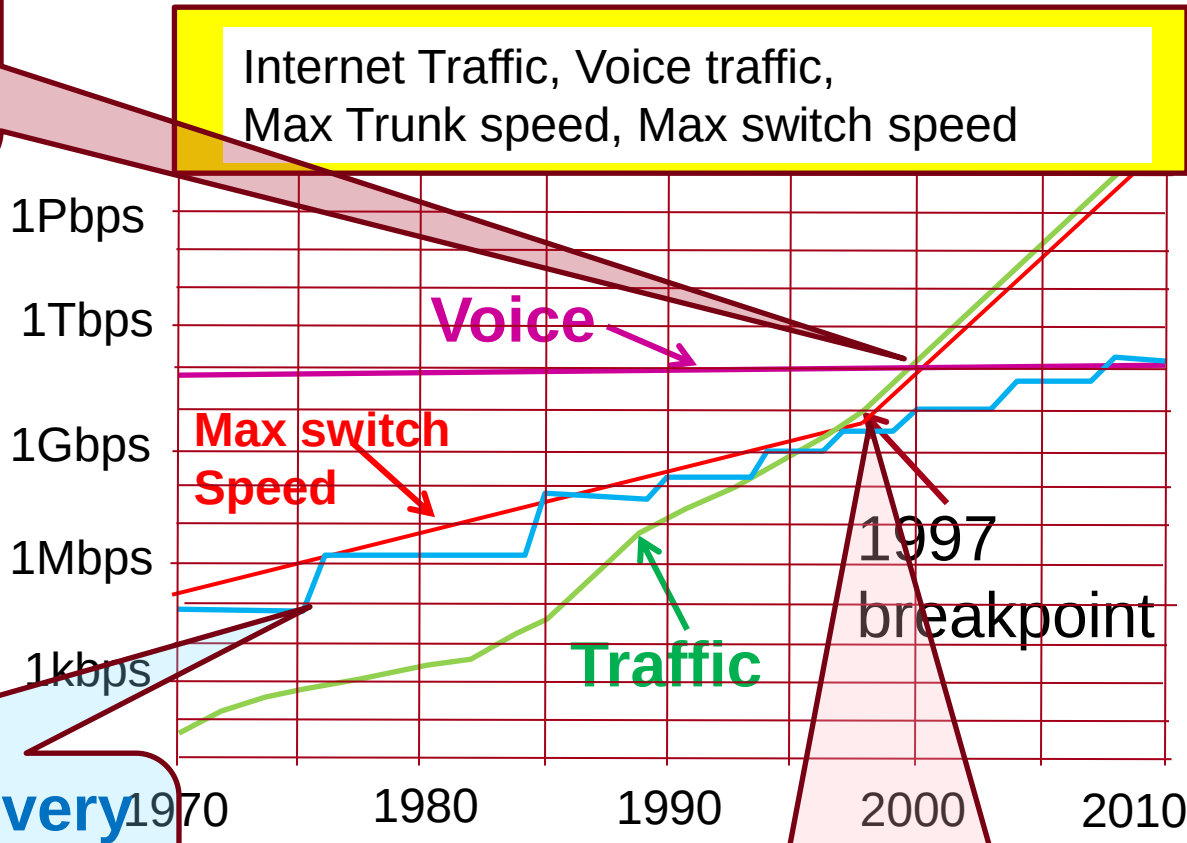
2000: data overtakes voice



Trunk speed doubles every 22 months, 50kps 1970 => 100Gbps today

1997: Multiplex multiple colors over single fibre

International Internet Bandwidth Growth 2005-2010

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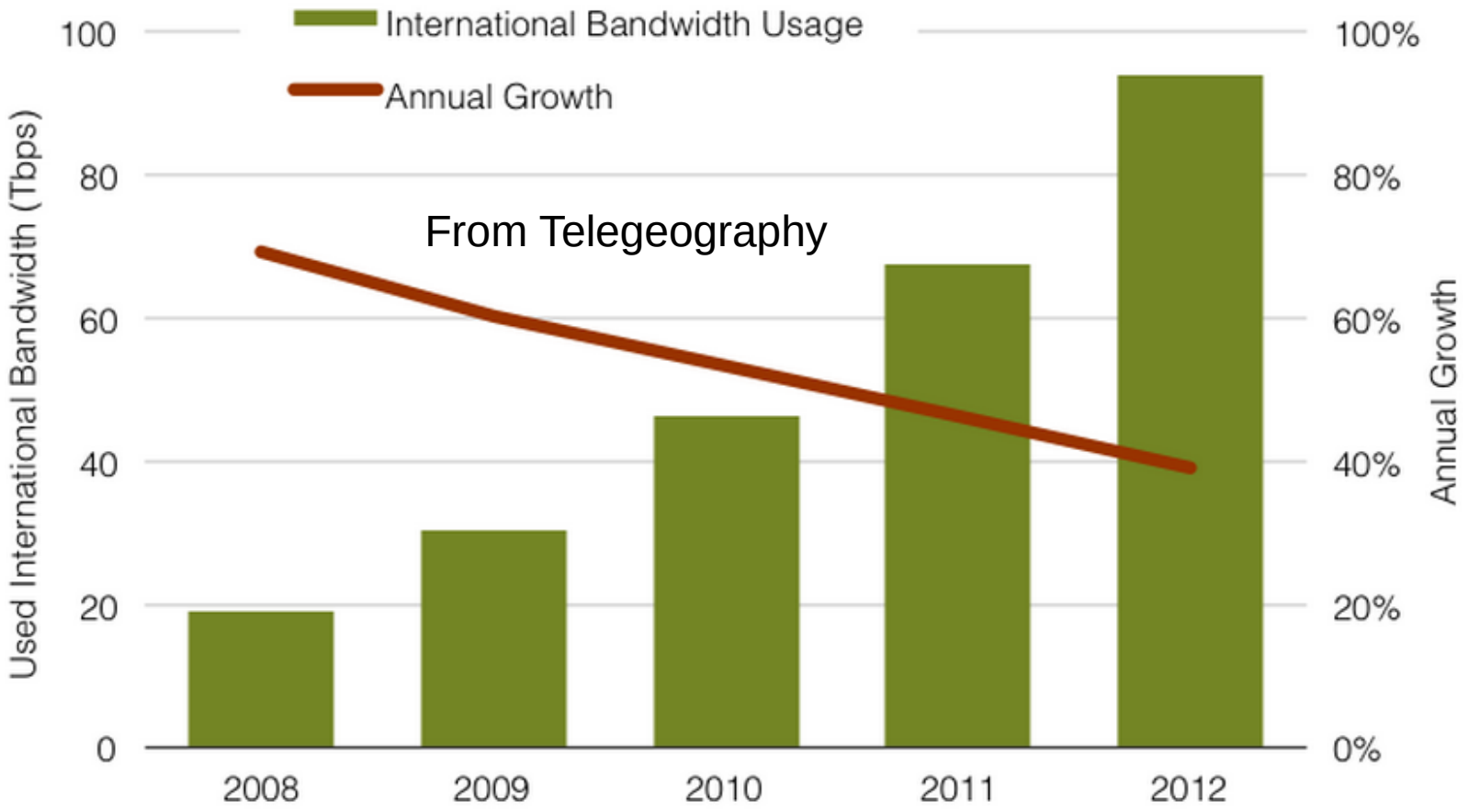
Annual growth > 50% in last few years

i.e. as much capacity added in 2012 as was available in 2008

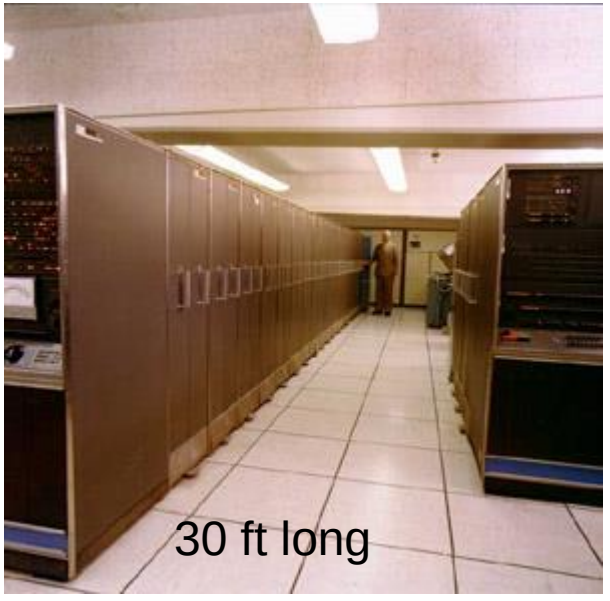


www.telegeography.com/research-services/global-bandwidth-research-service/index.html

Compare today with 50 years ago

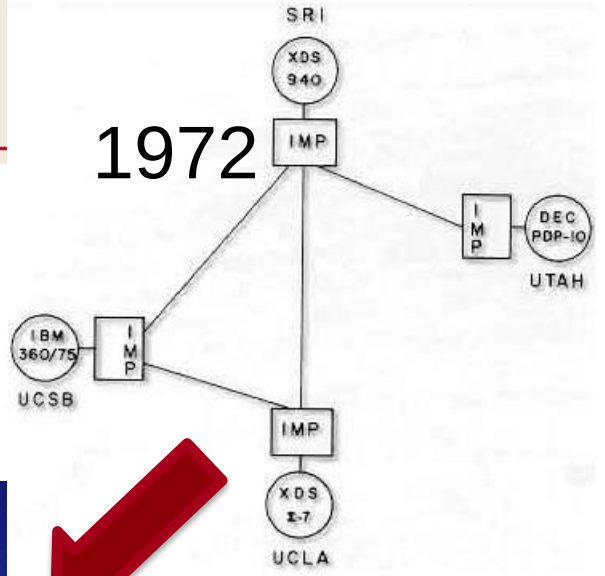
If we compare the IBM Stretch supercomputer of the early 1960's with today's smartphone we can see we have come a long way:

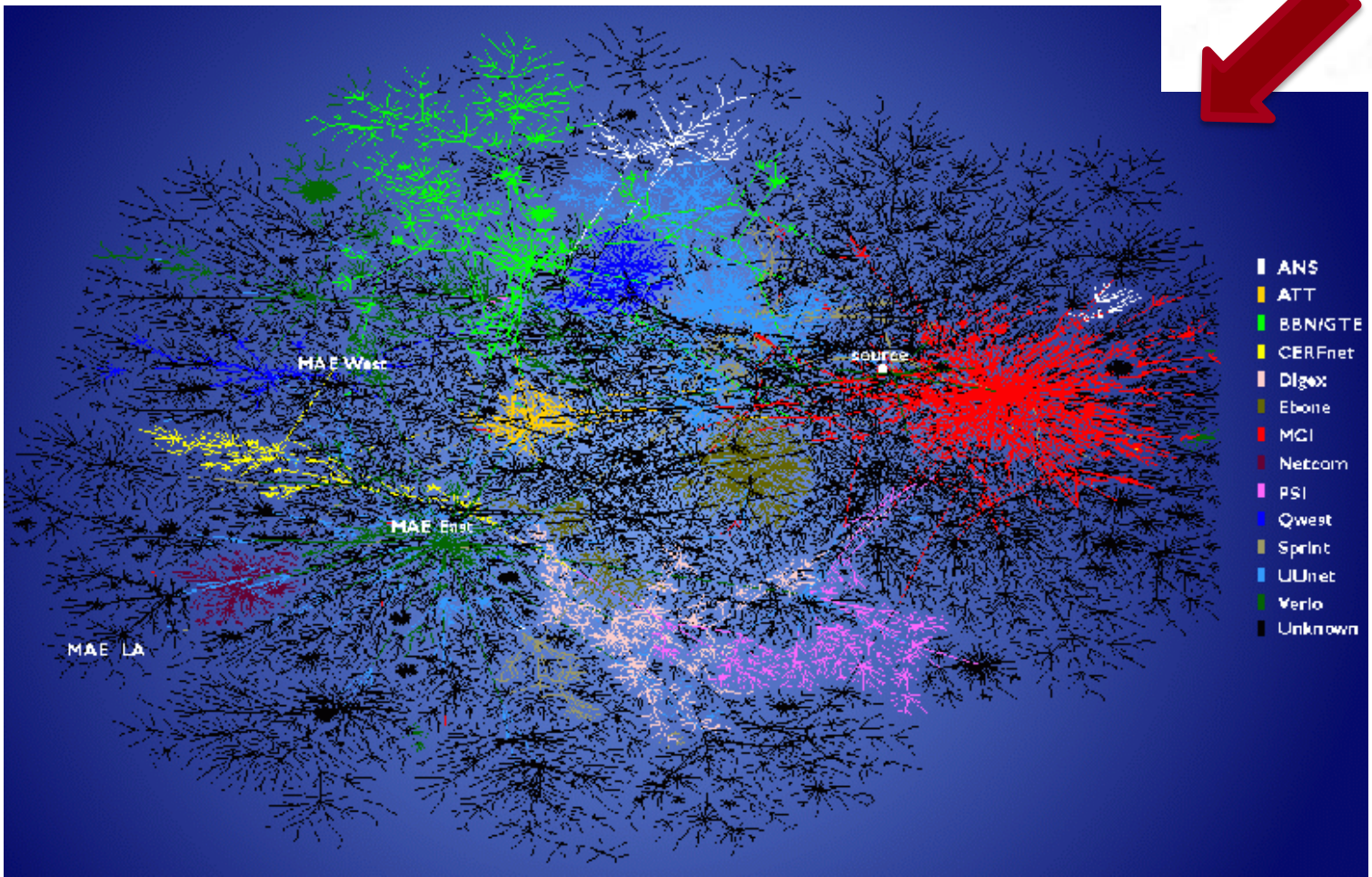
- Smartphone is much smaller, i.e. it fits in the hand versus 2500 sq feet;
- Smartphone weighs 5 oz. versus 40,000lbs;
- Smartphone uses 10,000 times less power;
- Smartphone ~ 3000 times more compute power
- Stretch $8M, smartphone few hundred $



30 ft long

Growth in connectivity





Amazing scalability Success

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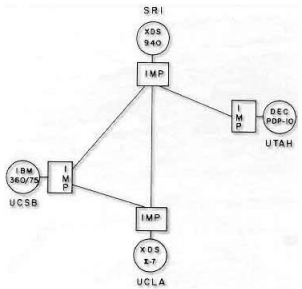
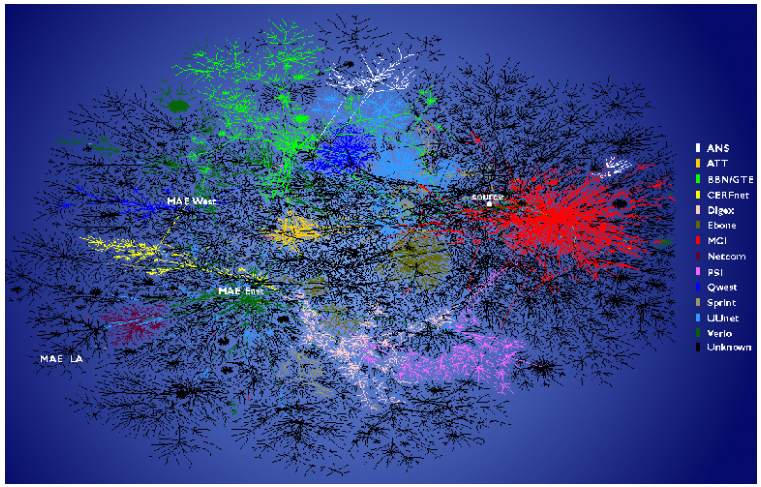
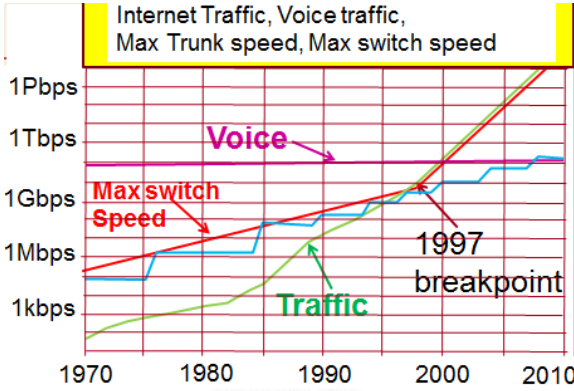
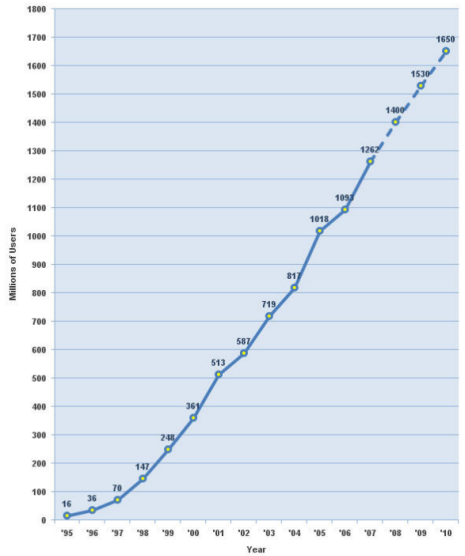
- The Internet has successfully scaled from a few users to over a billion and speed increases of seven orders of magnitude (56kbps=>100Gbps backbone)
- From a research and education network to a commercial network used worldwide







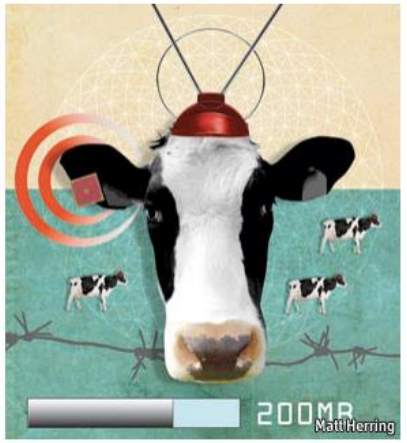


However there are challenges…

Challenge: demands for adddress space

- Internet **users in developing world**
- **Devices per person** (smart phones, tablets wearable devices…)
- **Monitoring** of equipment,  humans (e.g. medical), animals
- **Machine to machine** (typical car today has 16 IP addresses)
- Smart homes, smart cities, traffic, surveillance, safety, security, power grids …
- 99% of **electronics** in the world today still not connected to the internet.

Figure 4. Even Cows Will Have Sensors.



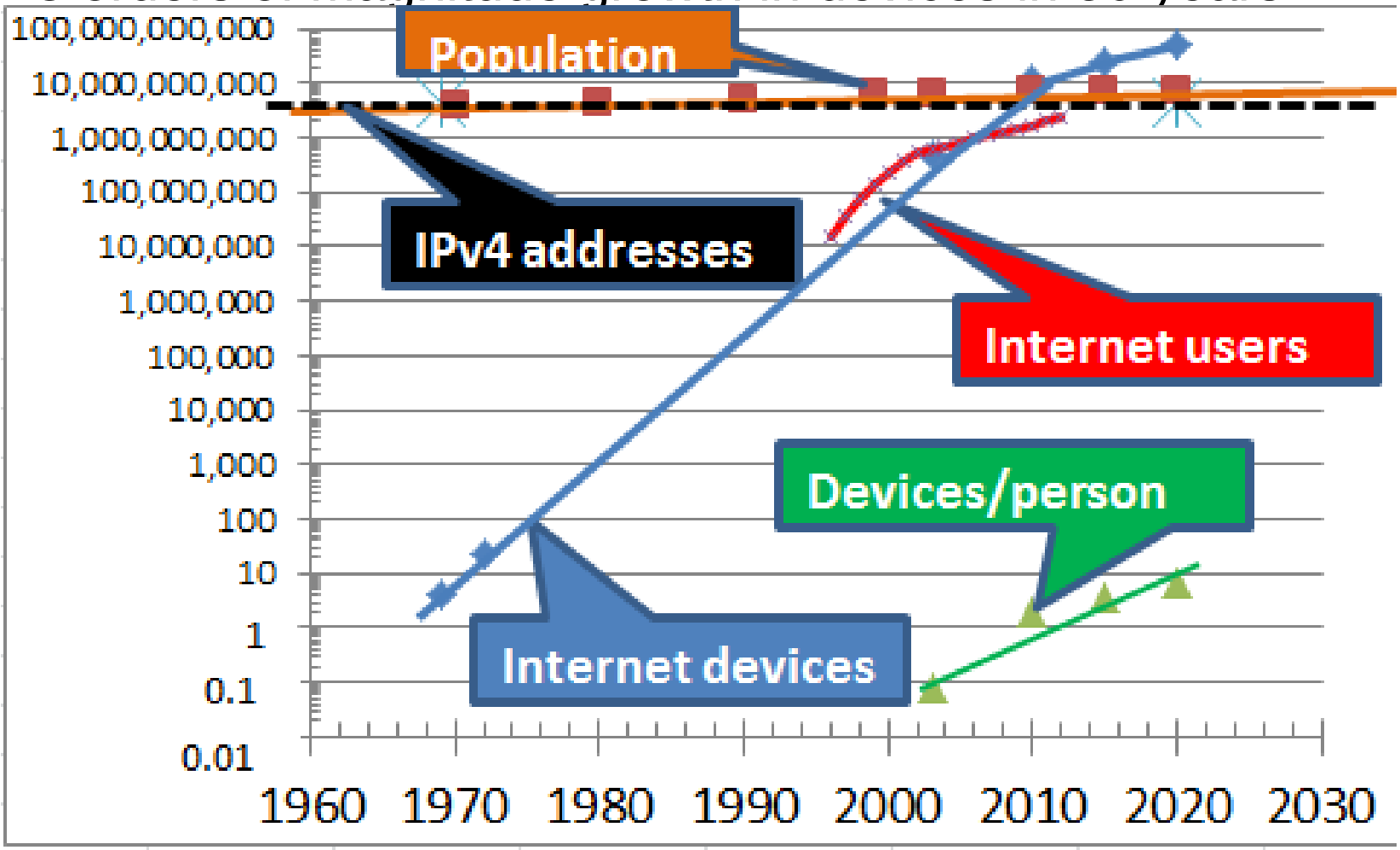
Source: *The Economist*, 2010.

The IPv6-Addressable Light Bulb Goes On Sale

GreenWave Reality and NXP launch 6LowPAN mesh-networked LED bulbs and home energy control platform.

Challenge: Internet growth

8 orders of magnitude growth in devices in 50 years



Population: Wikipedia
Internet Users: Internet World Stats
Devices/user: Cisco
Internet devices: Cisco

IPv4 devices = 2^32= 4.3B

Challenge: Mobility

Computers used to be big and did not move

As move need to change IP addresses

- Topology can change

Need persistence across links going up & down

- Delay & disruption tolerance (e.g. for space flights)

Mesh, sensor nets, self-organizing networks

- Bad guy may join, e.g. military position overrun, enemy gets device, pretends to be friend

Challenges: Trust – slide 1

Initial trust relationship badly broken

- Not everyone has everyone else's best interest in mind
- Organized crime, state sponsored intelligence gathering, cyber-warfare
- Akamai observed (3Q12) attack traffic originating from 180 unique countries/regions. China top ~33%, followed by US (13%) & Russia (5% traffic)

This is compounded with:

- Naïve OS', unpatched systems, browsers, users
- Routing mistakes (e.g. black holes)

Challenges: Trust – slide 3

Freedom of information vs privacy (e.g. wikileaks)

- Google/Yahoo … (has your emails), Facebook have a good idea of who your friends are where you live, work, spend your free time, your health, love life, political leaning
- Branching out into your realtime (Global Position System) to give your location
- Nowhere to hide anymore

Lack of tools for strong authentication needed for Grids & cloud computing

Prevalence of viruses, worms, malware, Trojan horses, Denial of Service

Challenge: SPAM

Unsolicited pitches for things such as drugs (> 60%), dating, stocks, malware (few %) …

US leads as source of spam

Sent by botnets

- Networks of compromised computers, millions worldwide
- Located mainly in Europe (esp East), Russia, US and India

88% of all email, 150B emails/day (Cisco)

- Due to spam filters only 20% of mail received by users is spam

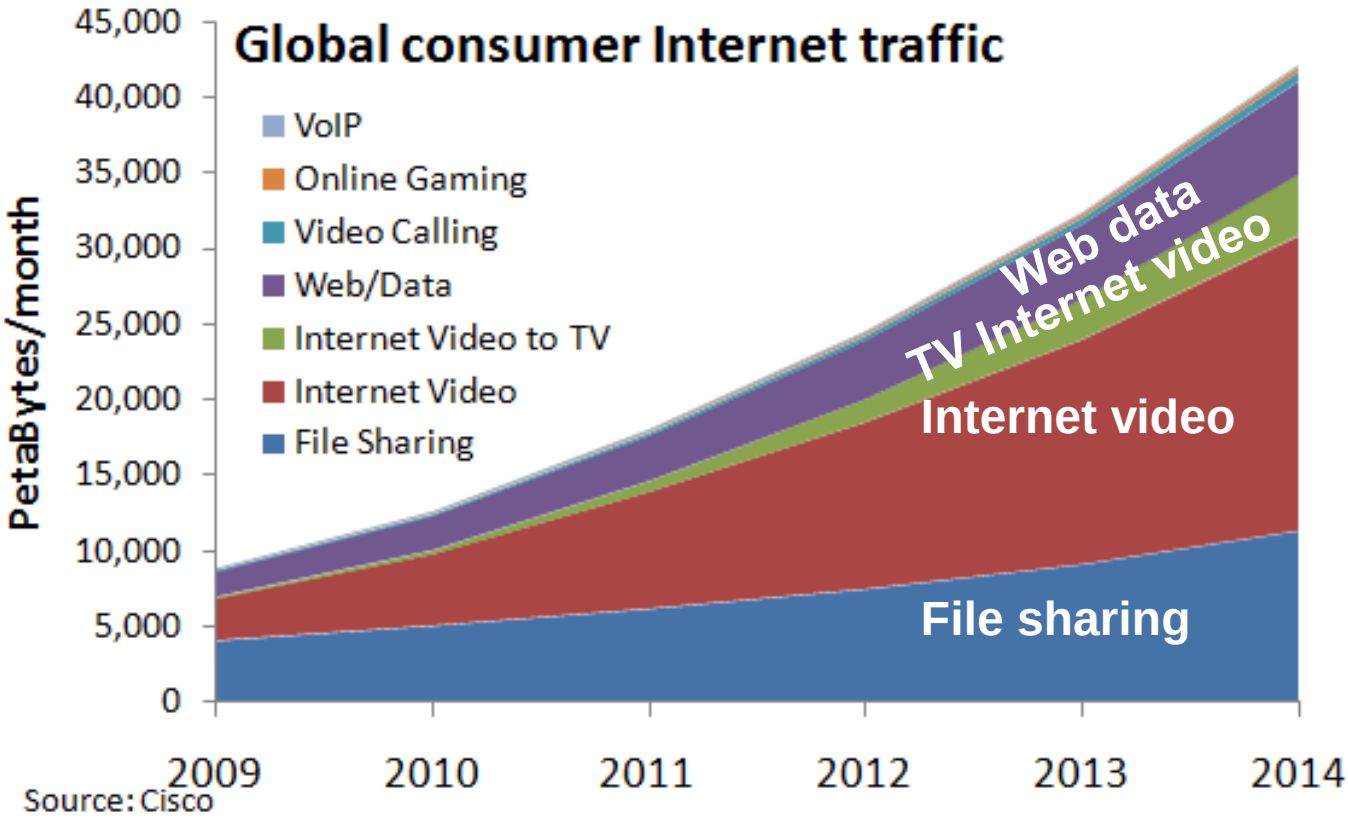
Huge Annual losses due to viruses for a typical 1,000-user organization will amount to over $158,000 (Radicati Group).

Challenges: Capacity and net neutrality

What are the drivers?

Can Capacity keep up with demand

- Does this lead ISP inspecting limiting traffic by customer
- Leading to loss of net neutrality



principle that Internet service providers and governments should treat all data on the Internet equally, not discriminating or charging differentially by user, content, site, platform, application, type of attached equipment, and modes of communication- Wikipedia

Challenge: How to change it

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Despite the new Internet Protocol (version 6 or IPv6) being > 15 years old, it carries < 2% traffic

How to redo a functioning production network critical to the global economy while it continues to run

- "*Creation was completed in 6 days, but no installed user base*"
- The Internet has been smoothly taking over from the phone network
- How does it happen next time?

Internet NG – slide 1

To borrow from John Lennon: *"Imagine there's no latency, no spam or phishing, a community of trust. Imagine all the people, able to get online from anywhere at any time".*

The goal is audacious:

- To create an Internet **without so many security breaches**, with **better trust and built-in identity management**.
- Researchers are trying to build an Internet that's **more reliable, higher performing** and better able to manage **exabytes** of content.
- And they're hoping to build an Internet that **extends connectivity to the most remote regions of the world, perhaps to other planets**.

Internet NG – slide 2

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Future InterNet Design (FIND) funded by NSF to get and implement a vision for 2020

- Launched 50 projects ($0.5-1M) in 2006, now (2010) being narrowed down to 2-4 with up to $9M
- Similar initiative from Europe

Internet's Impact on development

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- Brief history of the Internet and its goals,
  - how it has grown,
  - today's major challenges,
  - and future research.
- **The impact of the Internet on development,**
- Africa
  - How Africa has lagged the world,
  - Why does it matter?
  - Is the performance for Africa improving, will it catch up?

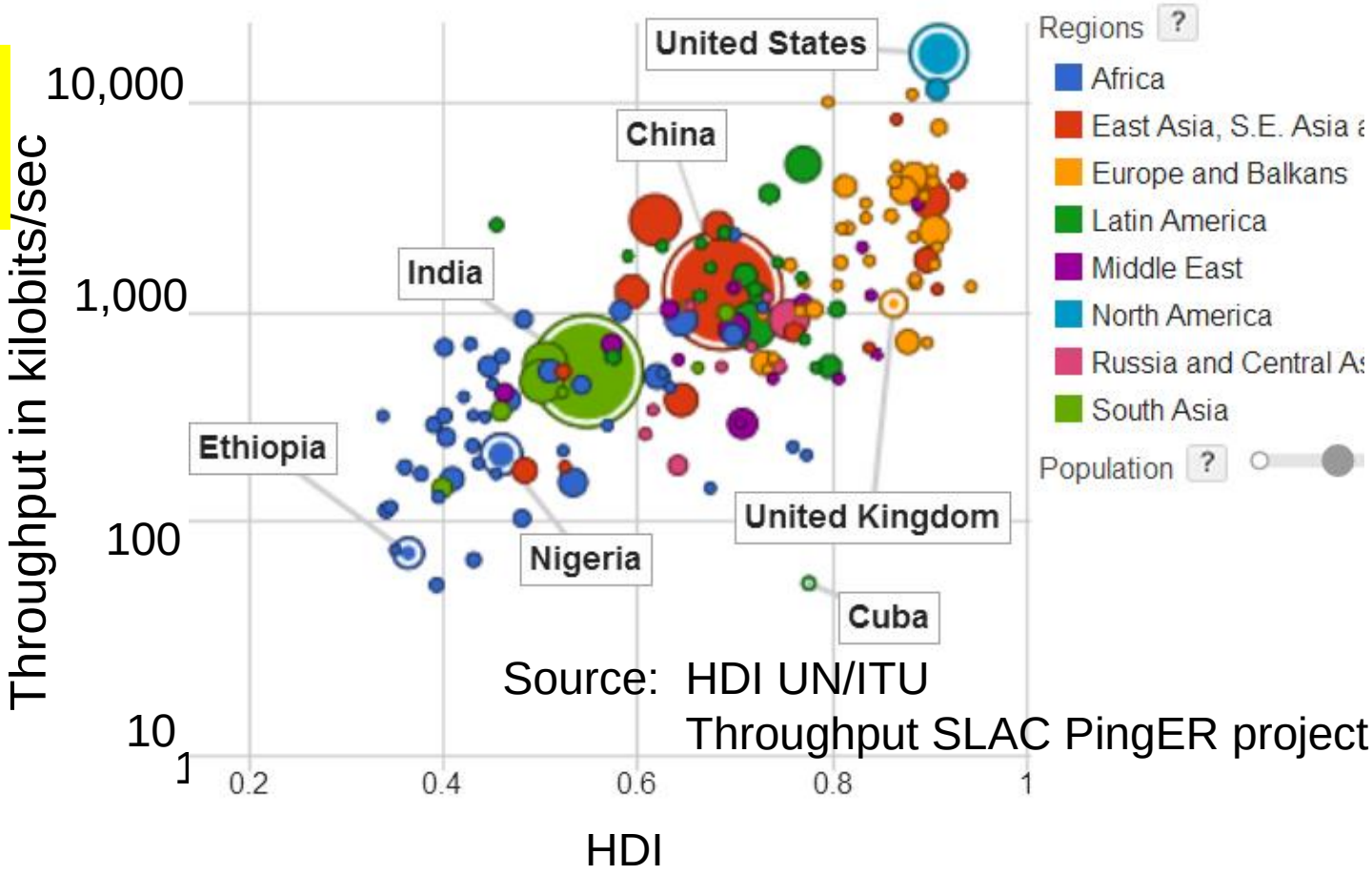
How does the Internet assist development?

- Investment in information technology plays the role of a **"facilitator"** that allows other innovations to take place. http://findarticles.com/p/articles/mi_m1093/is_3_45/ai_86517828/
- World Bank / IFC report: for every 10% increase in high-speed Internet connections there is an increase in economic growth of 1.3 percentage points. http://www.infodev.org/en/Article.522.html
- Example: Uganda 15% increase in price of maize based on improved farmer bargaining power. www.itu.int/ITU-D/.../S1-01-NG-ICT_Indicators-Tim_Kelly.pptx
- A study reported by Akamai showed that 80 new jobs are created for every 1,000 new broadband connections

Human Development Index (HDI)

- HDI from United Nations (UN) International Telecommunications Union (ITU)
  - composite statistic of life expectancy, education, and income

Top right = Good
Note correlation
Africa (blue) behind



Source: HDI UN/ITU
Throughput SLAC PingER project

Africa

- Brief history of the Internet and its goals,
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- The impact of the Internet on development,
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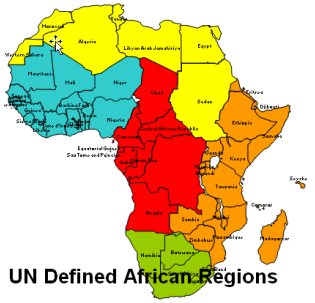
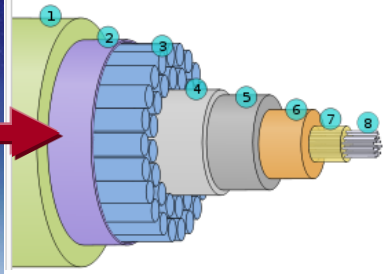
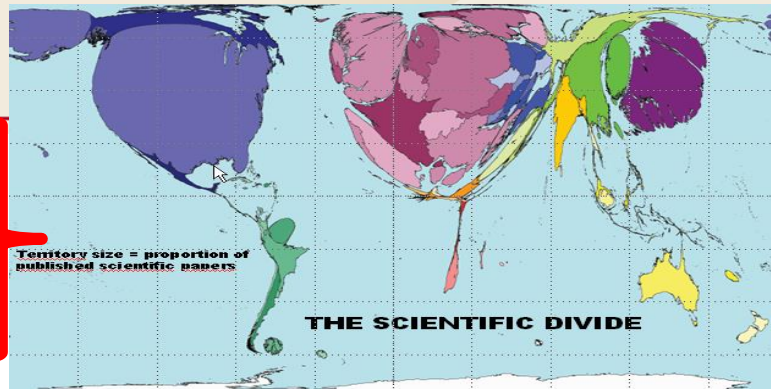
  - How Africa has lagged the world,
  - Why does it matter?
  - **What has soccer got to do with it?**
  - Is the performance for Africa improving, will it catch up?



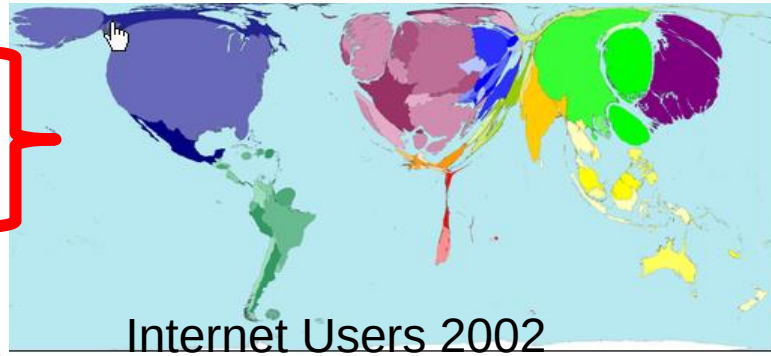


Why does it matter to Africa

- African scientists **isolated**
- **Lack critical mass**



- Need **network** to collaborate but it is terrible



So we have: Brain **drain**

Instead we need:

- Brain **gain**, tap diaspora
- **Blend in distance learning**
- **Provide leadership, train trainers**

Cartograms from:
www.geog.qmw.ac.uk/gbhgis/conference/cartogram.html

Why is Africa important?

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Africa is Huge

~ 1B people, over 1000 languages,multi climates

Developed world market saturated, Africa big opportunity

African technology industry is growing at ~ 20% annually.

Africa demonstrates massive consumer appetite for technology,

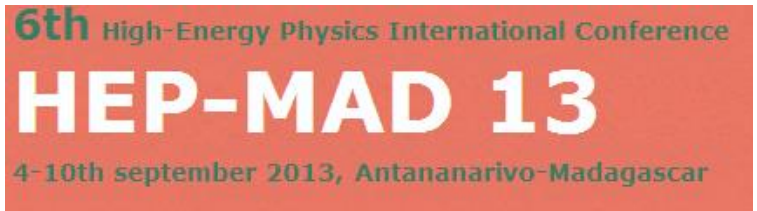
e.g. mobile users set to reach 735 million by the end of 2012 (GSMA.)

Science Opportunities: Square Kilometre Array (SKA)

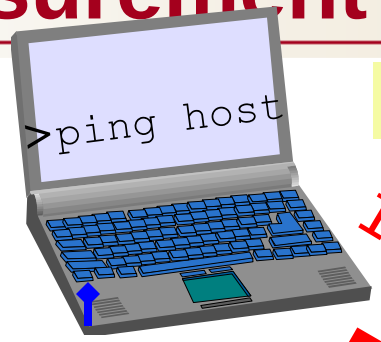
- Build in Sub-Saharan states with cores in South Africa and Australia,
- €1.5 billion, construction start 2016, initial observations 2019

Examples of Other Scientific Opportunities

- Aug 30, 2012: **CERN donated 220 computer servers** from CERN to the Kwame Nkrumah University of Science and Technology in Ghana.
- Strategic plan for a **synchrotron light source in southern Africa** championed by SLAC's own Herman Winick
- **Drugs from rain-forest, environment studies, geo-physics**
- Six **HEP International Conferences in Madaga**scar



Measurement Mechanism: PingER



Uses ubiquitous ping

Monitor Host

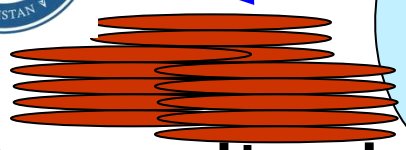
Once a Day

10 ping request packets each 30 mins

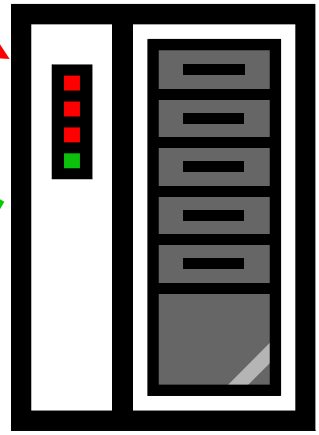
Ping response packets

Internet

Remote Host (typically web server)



Repositories



Measure Round Trip Time & Loss

Deployment of PingER hosts

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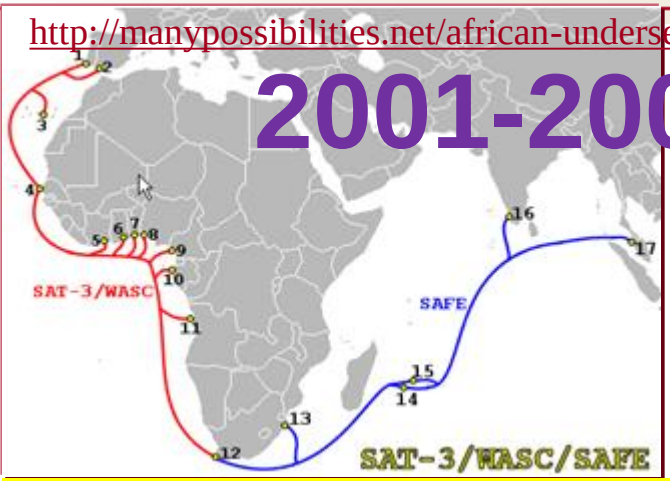
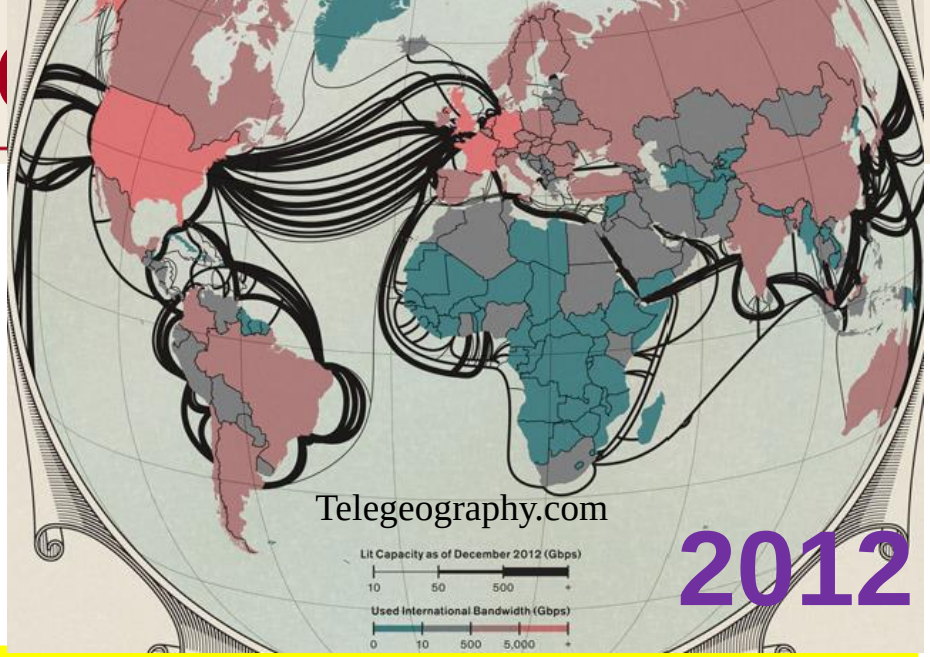
- Monitors > 90 in 23 countries, 4 in Africa
- Beacons monitored by most monitors (~100)
- Remote sites monitored by some monitors (~750)

African Submarine C

http://manypossibilities.net/african-undersea-cables/





1 cable, W Coast only, No competition (340Gb/s)

- **Future Cables promise more connectivity:**
- Cable capacity increase from 0.34Tb/s in 2008 to 87.5 Tb/s by 2014 (factor ~300)
- Investment of $6T

World Cup S Africa 2010 led to many submarine cables connecting Africa to rest of the world

More Capacity, shorter RTT, competition

Still worst off continent

Examples of impact of terrrestrial links, 2009

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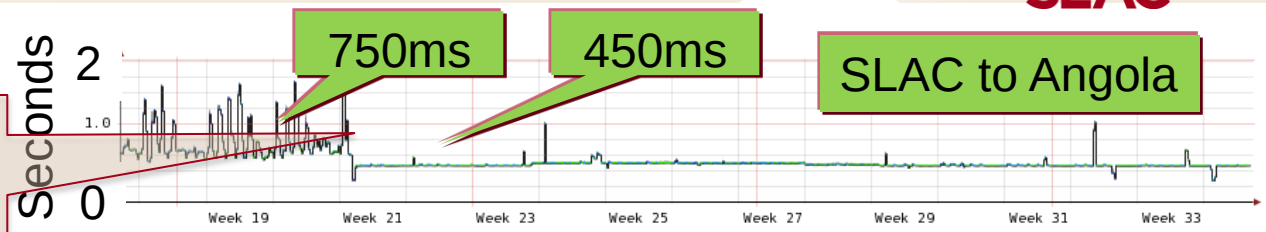
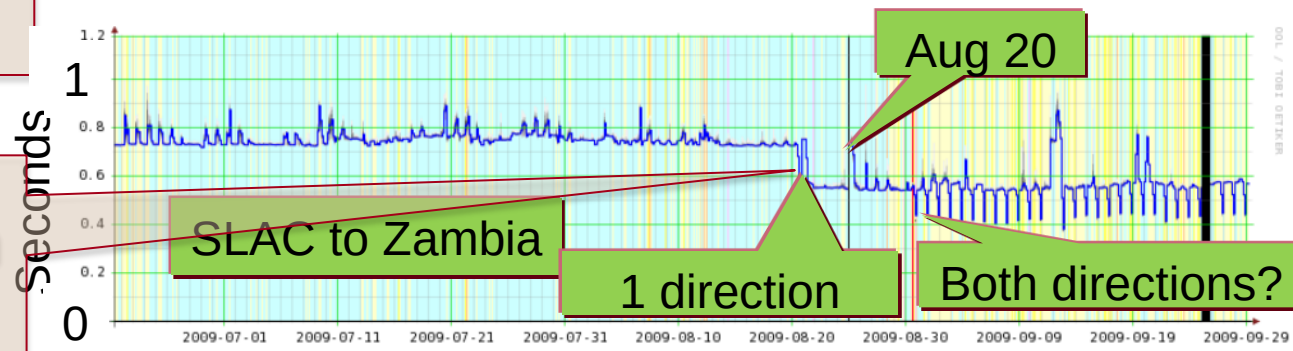
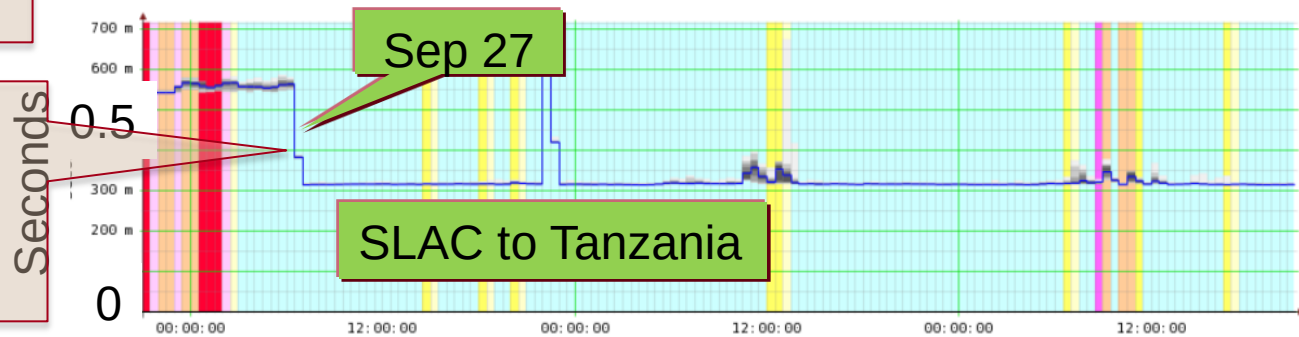
Angola step mid-May + more stable



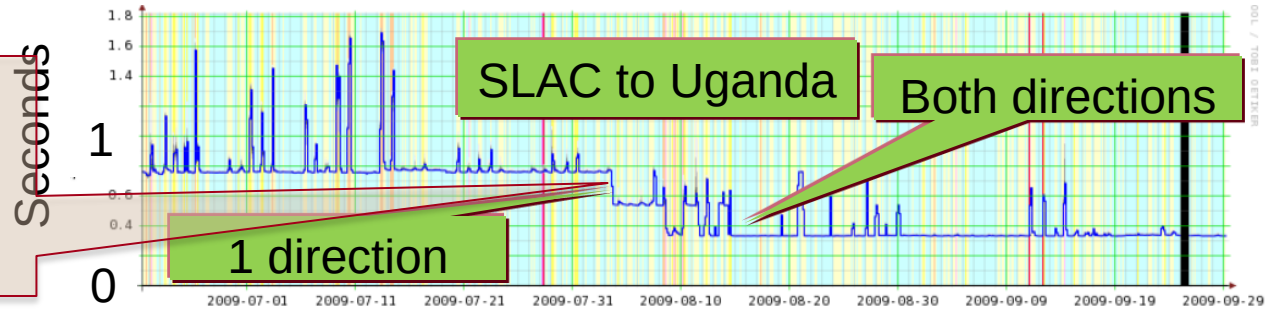
Zambia one direction 720>550ms



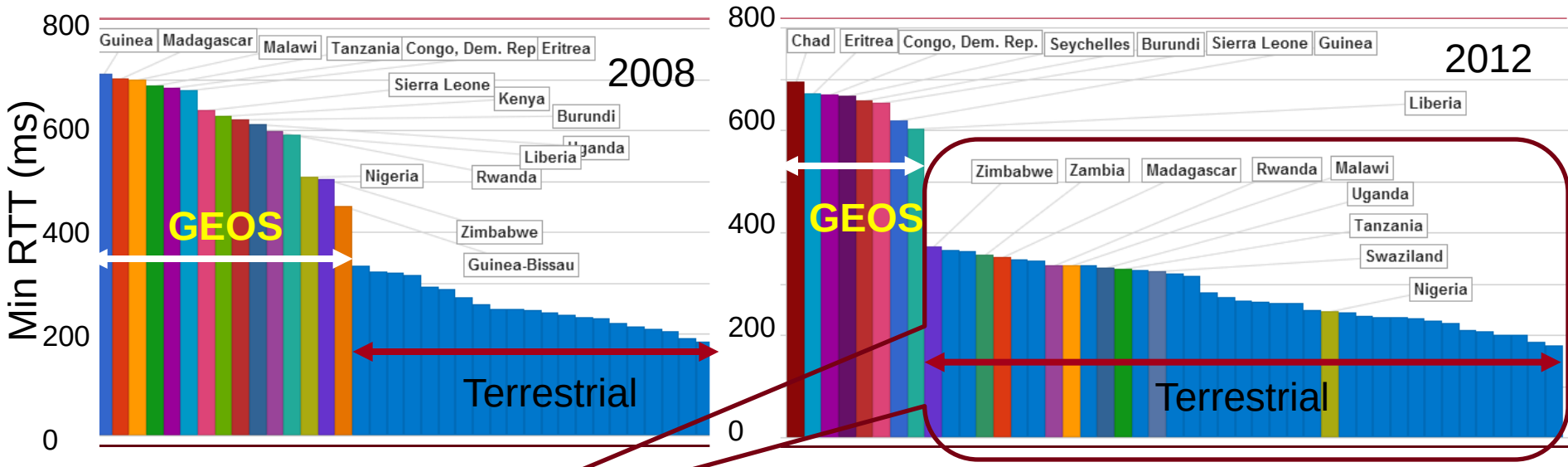
Tanzania 700>400ms fixes losses too



Uganda (inland via Kenya) 2 step process

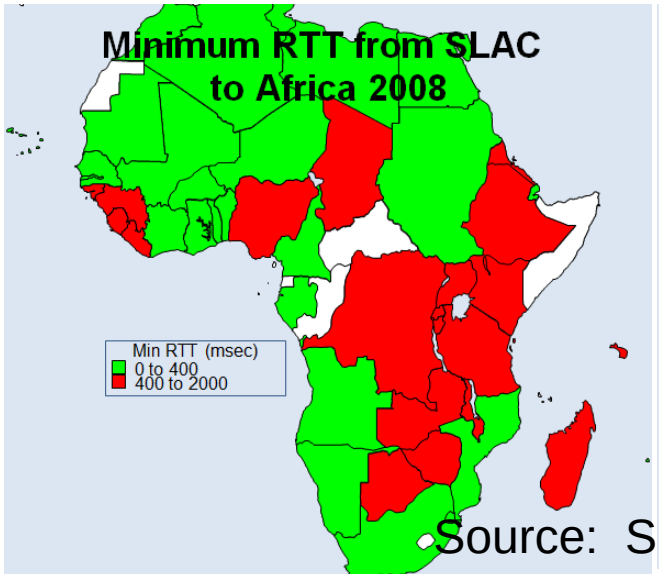


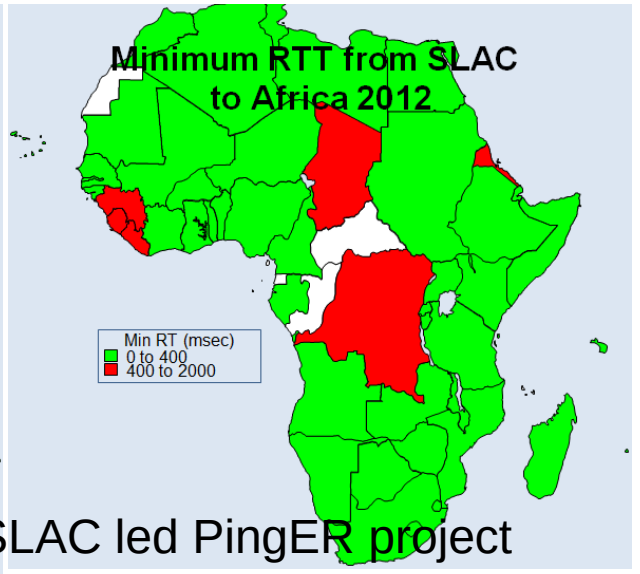
Comparison in minimum RTT from SLAC to African Countries in 2008 and 2012.



Minimum RTT from SLAC to African Countries 2008 vs. 2012

Note the countries that have gone from GEOS to terrestrial



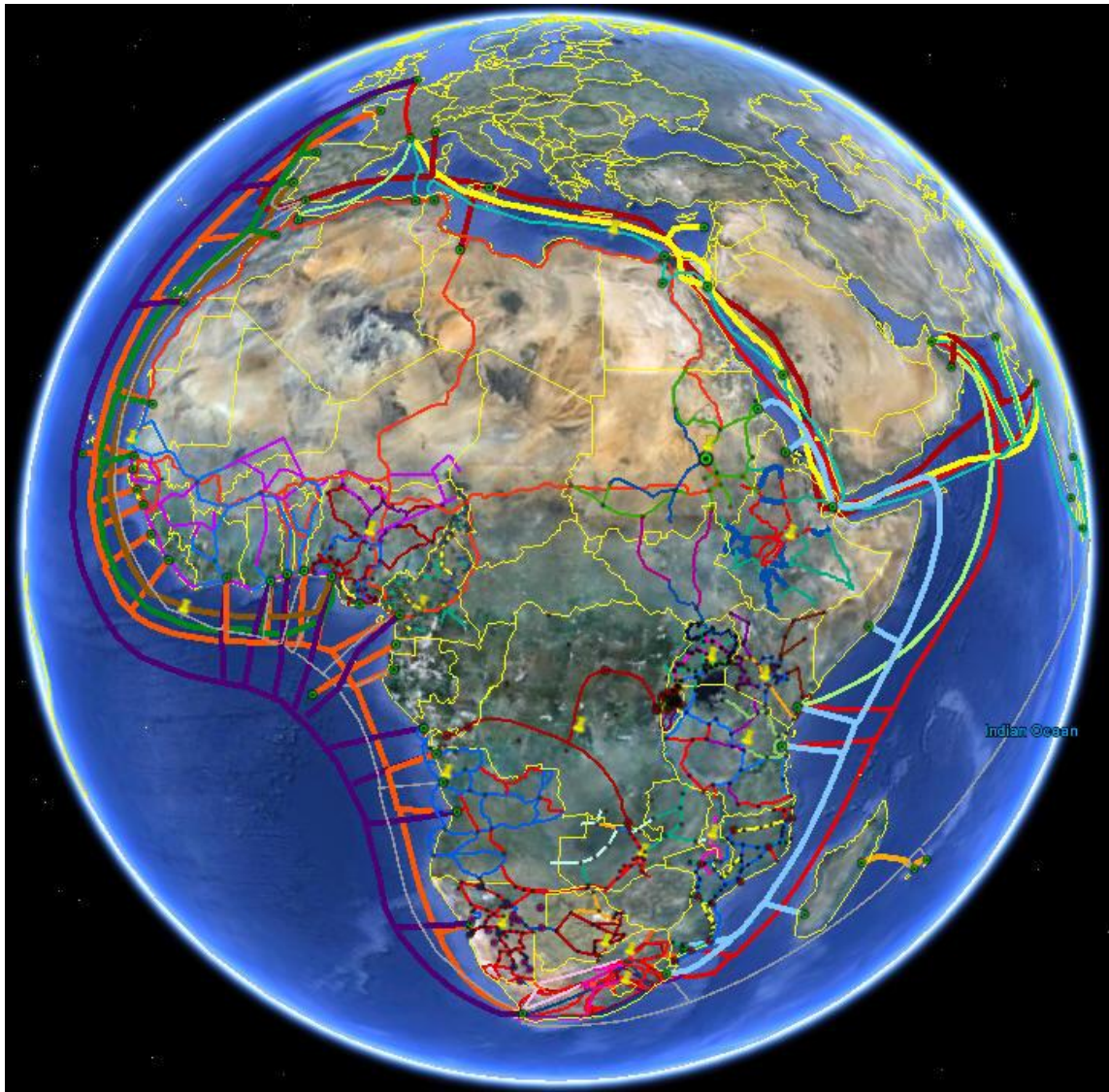


Source: SLAC led PingER project

Intra Africa Optical Fibre Network

Just as important as the submarine cables serving the coasts, are the tens if not hundreds of millions of dollars being invested in new terrestrial fiber to move this capacity inland.

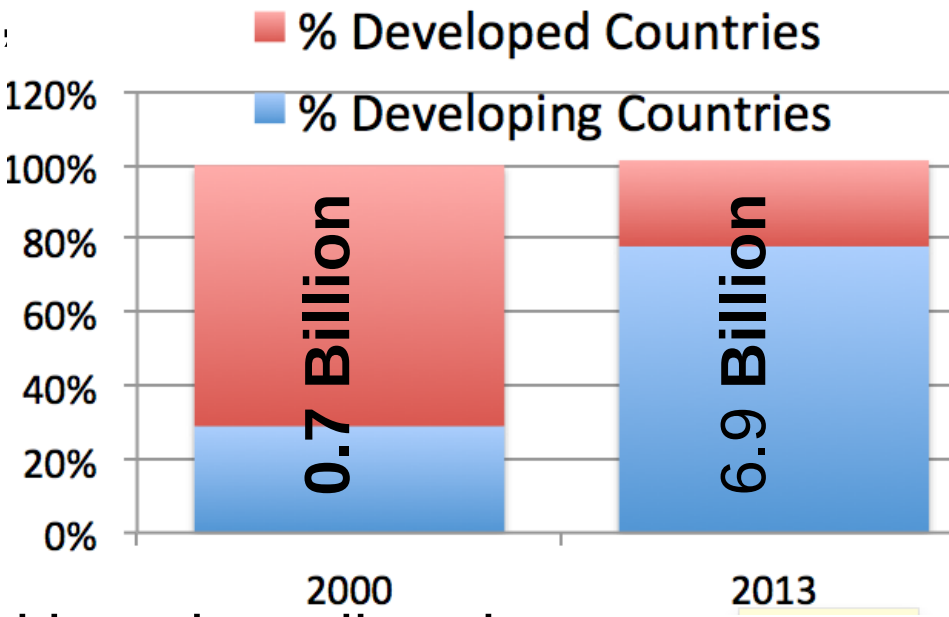
http://www.ubuntunet.net/fibre-map



How to reach the rest of Africa

WiFI & Mobile to the rescue, overlay cell network with fibre net

- Mobile phones huge in developing world.

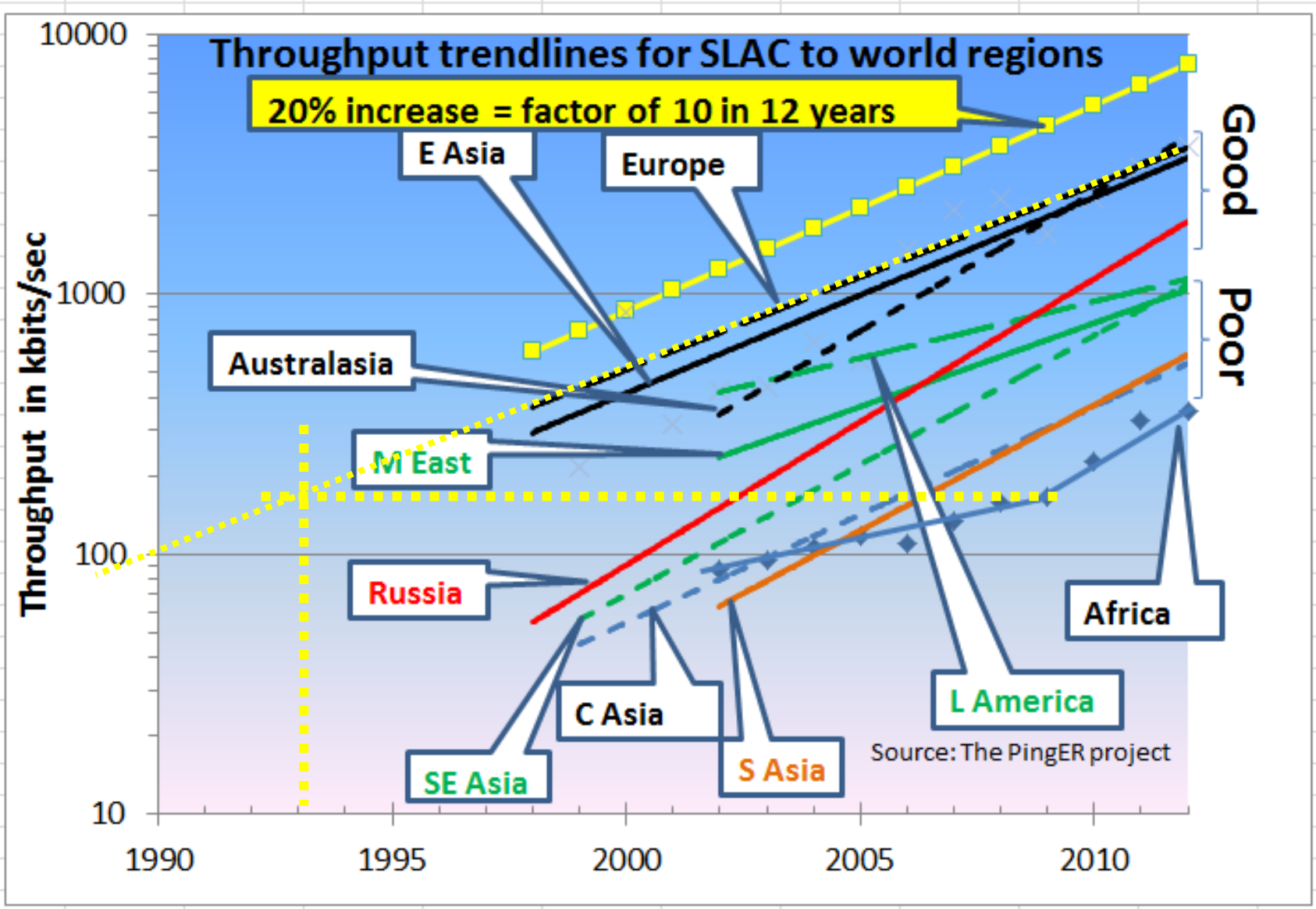


Also O3B

- Refers to population of world without broadband
- Constellation of 8 Medium Earth Orbit satellites at altitude 8000km
- Min RTTs factor of 4 less than GEOS
  - ~125ms, similar to inter-continent land lines
- Backed by SES World Skies, HSBC, Google…
- Launch 2013

Africa was 19 yrs behind Europe in 2009

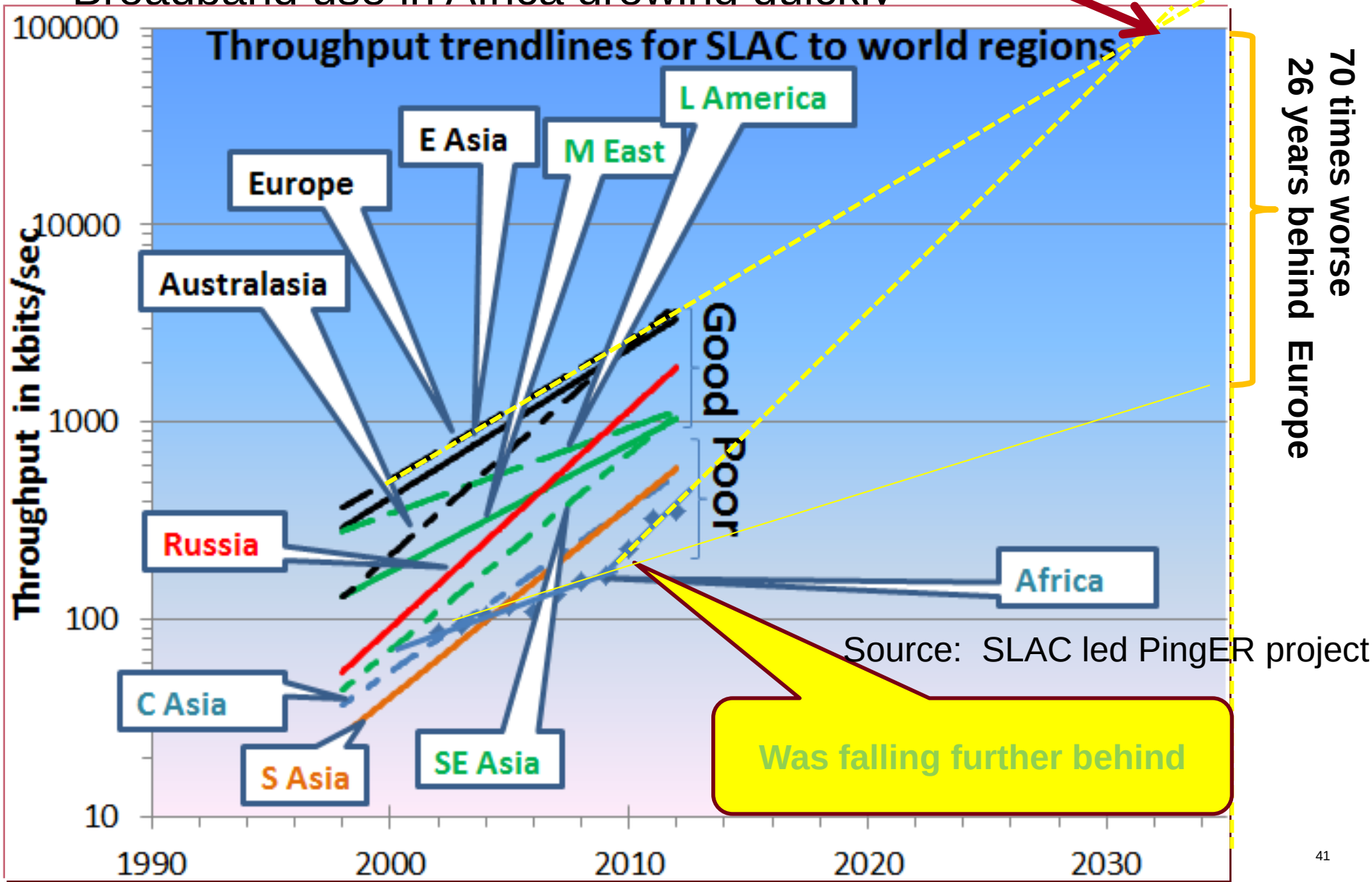
Developed nations in black, Russia, S. E. Asia catching up, Africa worst



Africa might catch up with Europe in 20 years at current rate of improvement

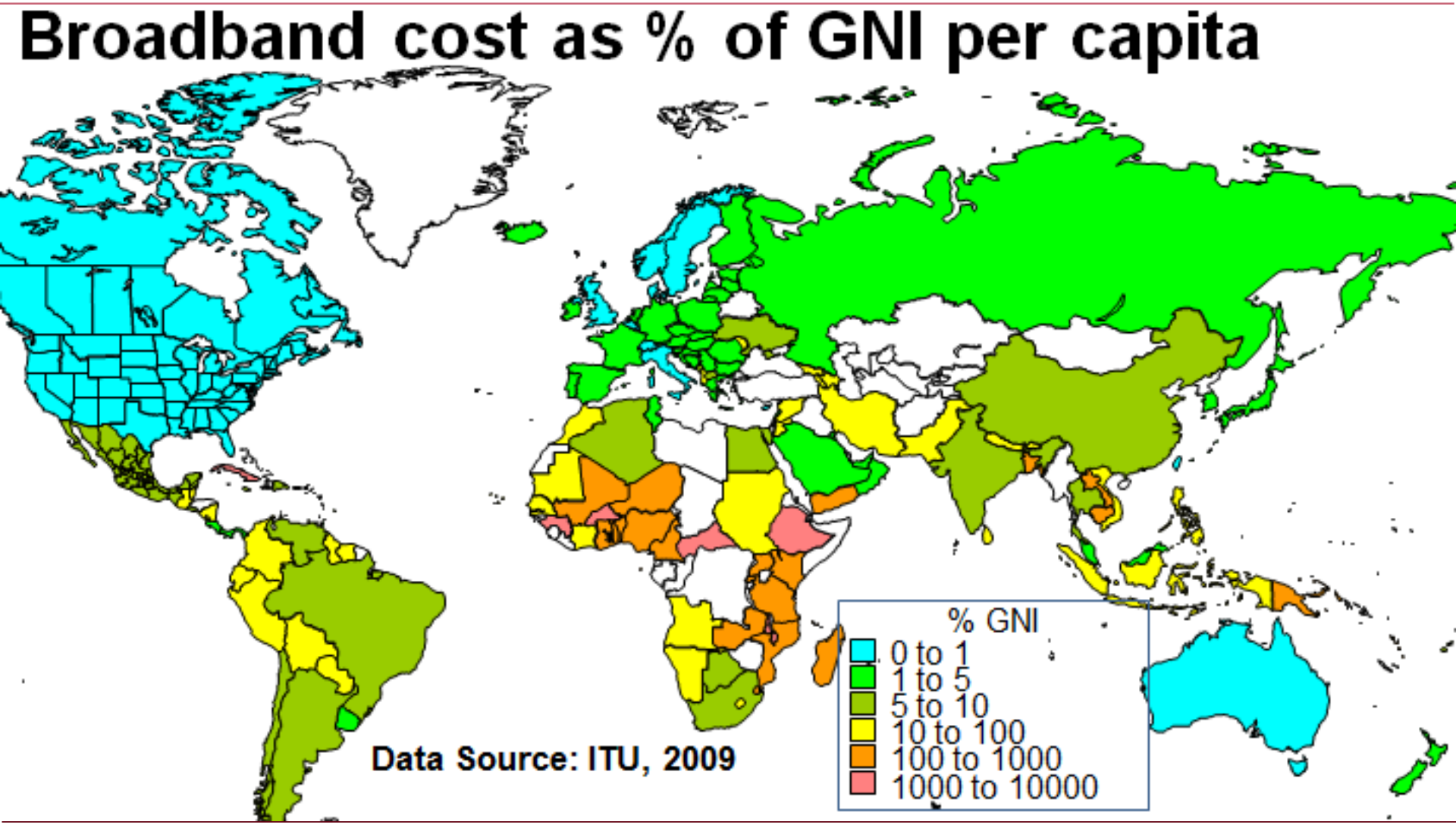
SLAC

- Broadband use in Africa growing quickly



Africa Broadband costs vs rest of the world

SLAC

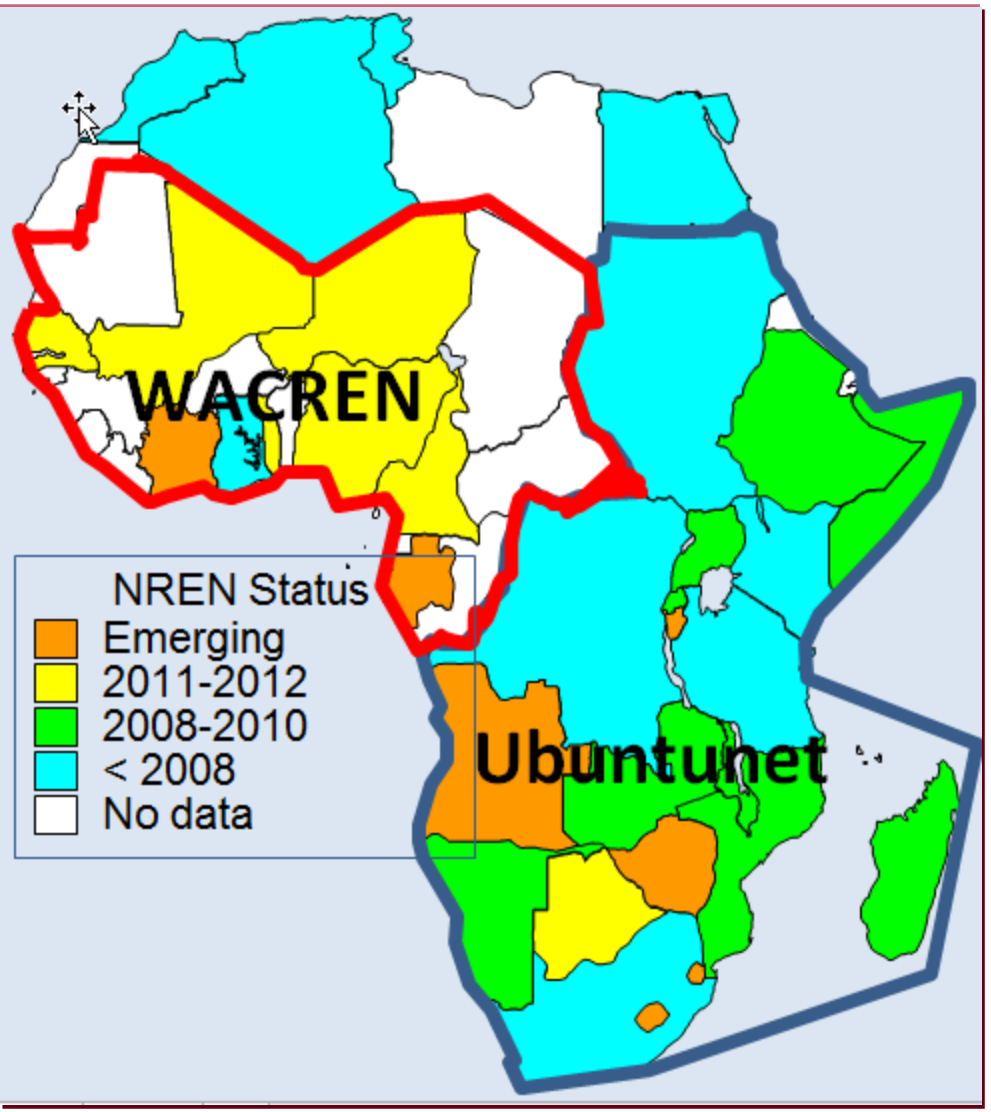


Prices and Governance

By 2011 prices had dropped only factor of 2

- Alternative fibre often owned by electricity companies, pipelines and not allowed to sell, lease or operate – needs deregulation and is happening
- Business model: Internet Service Providers sell to large corporations, governments, education, NGOs
- Need to move to serving multitude of small customers to recover costs from the move from high => low prices

National Research and Education Networks



- National Research and Education Networks (NRENS) provide:
  - leadership, training, and
  - leverage in contract negotiation

- N. Africa connected via EUMED to Europe.
- Also Arab States Research and Education Network formed 2011

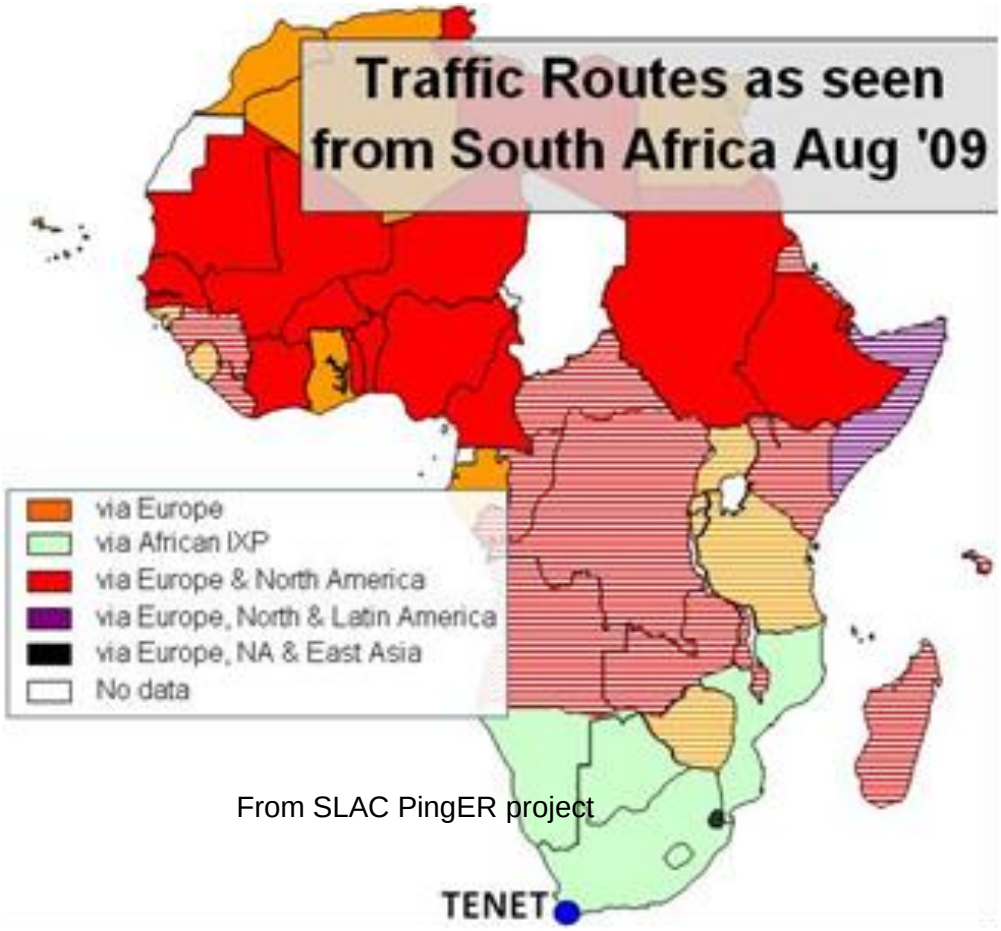
- With connection to GÉANT going live end 2012, UbuntuNet will provide sub-Saharan Africa with infrastructure for global, and regional research collaboration and e-learning

Traceroutes within Africa 2009

SLAC

Despite having NRENs & terrestrial fibres along both East & West coasts of Africa connecting to most maritime countries, still most inter-African routes went via Europe and N America

Not only did this add large delays, but also resulted in costly inter-continental rates



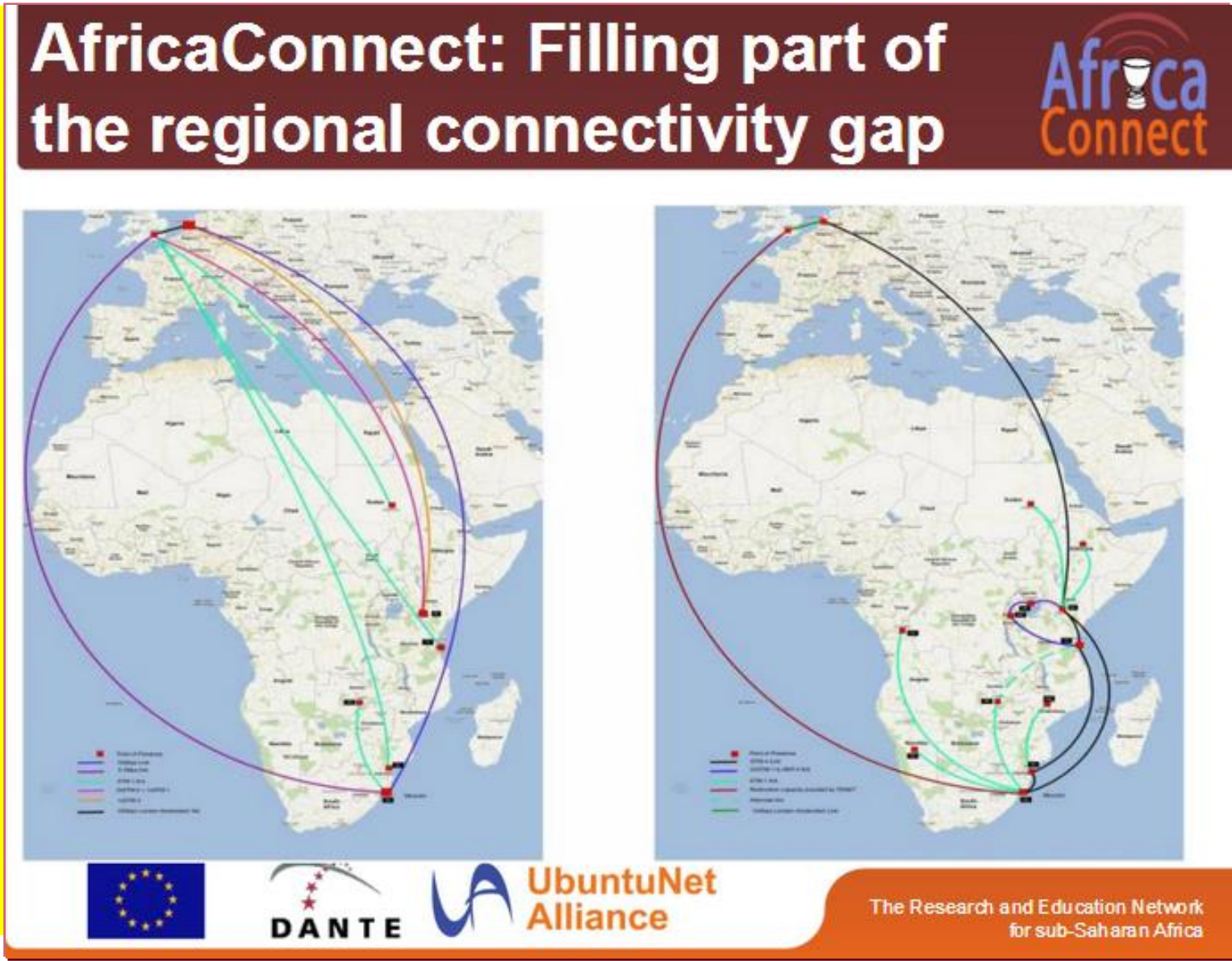
From SLAC PingER project

Setting up International eXchange Points for better connectivity

SLAC

Connections between African countries no longer via Europe or USA.

Much reduced Round Trip Times



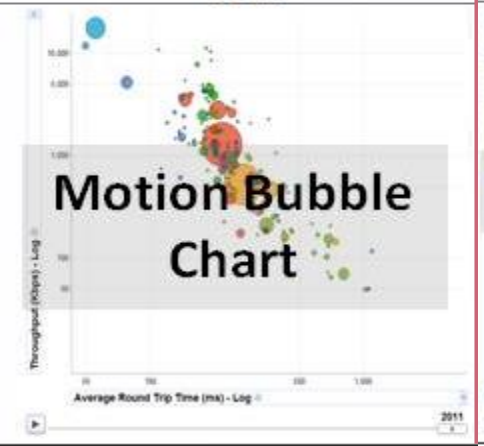
Demonstration

SLAC

Interactive demonstrations of the data mining capabilities of public data sources provided by organizations such as the United Nations and the International Telecommunications Union coupled with monitoring data from PingER

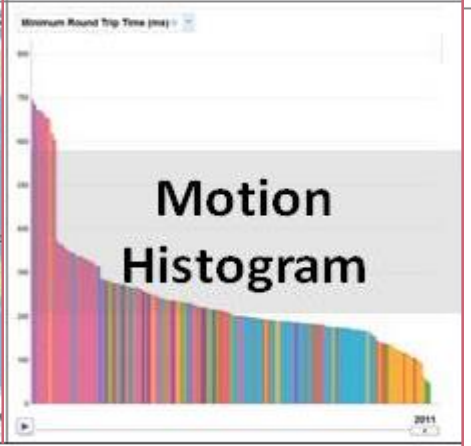
http://www-iepm.slac.stanford.edu/pinger/explorer.html

Motion (time) bubble (size=population) chart for world countries colored by region showing throughput vs average RTT.

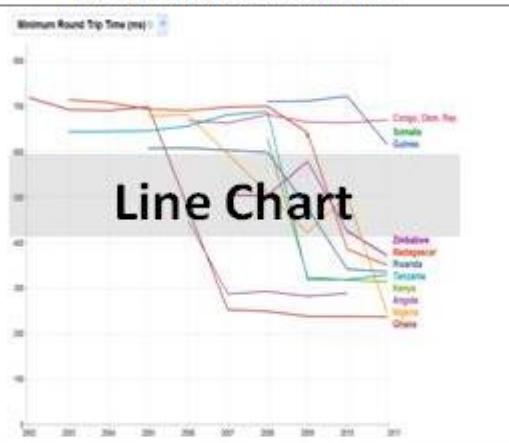


Motion (time) world map of minimum RTT by color with bubble size indicating population.

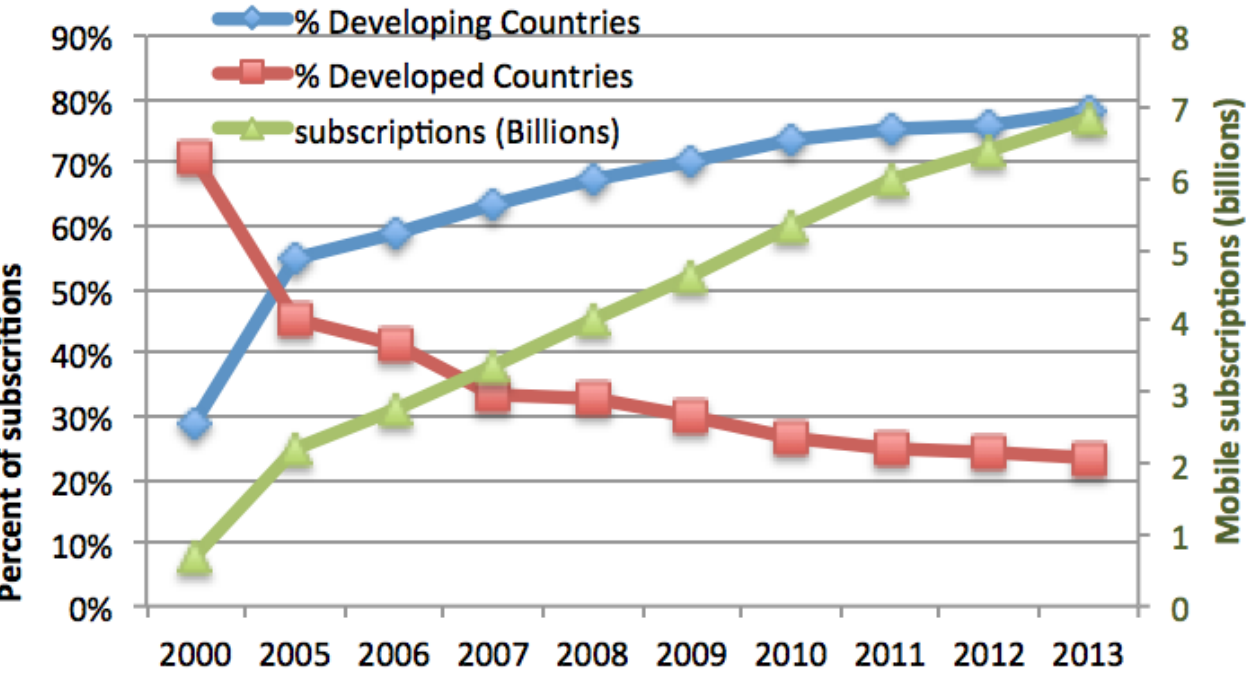
Bar chart of the minimum RTT for all the countries of the world colored by region with time as motion.

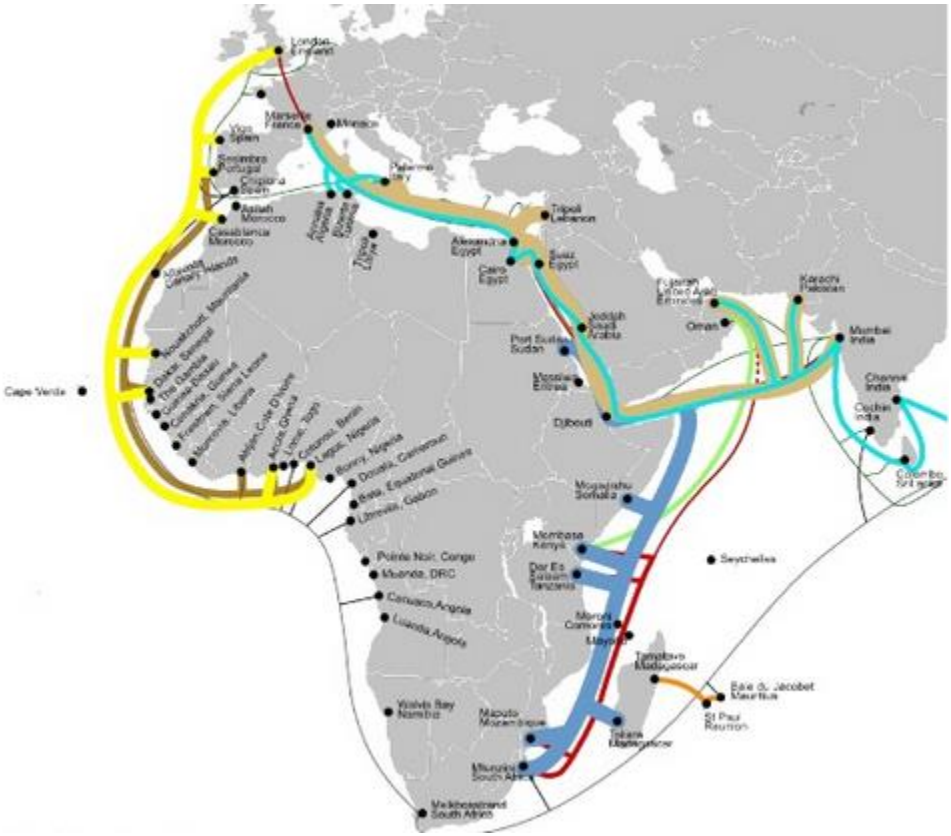


Minimum RTT time series for selected countries. Note sudden drop offs from >450ms to < 450ms ms as countries moved from Geo-stationary satellite to terrestrial connections.



That’s it folks, Questions


% Developing Countries
% Developed Countries
subscriptions (Billions)
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent of subscritions
8
7
6
5
4
3
2
1
0
Mobile subscriptions (billions)
2000
2005
2006
2007
2008
2009
2010
2011
2012
2013


Cape Verde
Djibouti
Seychelles