94-812 Technology for International Development

Access

Networking

Mobile

Learning objectives

- Awareness of the underlying technology
- Knowledge of basic terminology
- Improved mental model of the Internet & mobile
- Personal calibration of global Internet access data

Access in Terms of Development

- Access to hardware
  - Computing devices
    - Desktop PCs, laptops
    - Mobile phones, tablets
- Access to software
  - Working (legal, supported) operating system software
  - Applications (office applications, content authoring applications…)
- Internet access
  - Broadband, dialup, satellite…
  - Wireless
  - At home vs community shared (e.g. at an Internet café)
- Access to information and services
  - For business, government services, entertainment, education, etc.
- Access to produce information and provide services
  - To use the technologies to create new information and provide it and/or services to others.

Hardware Access

- There has been plenty of activity:
  - Recycling hardware to developing countries
    - (Sometimes becomes dumping hazardous waste in countries)
  - ComputerReach (computerreach.org)
    - Reputable local (Pittsburgh) enterprise
    - Have placed > 9500 computers in 24 states and 30 countries
    - Work with local organizations in each location
  - Building cheap hardware
    - OLPC - http://laptop.org/
    - Aakash Low Cost Tablet (Datawind India)
    - Intel EduWise notebook, Classmate PC
    - Raspberry Pi
    - *State of ICTD Research* article found 50 such projects

Network Access

- Understanding the *layers* of a network is useful for understanding what network access means.
- Important network "Layers"
  - Application
    - Communicate email messages, web pages, Tweets, etc. reliably between devices.
  - Transport: TCP
    - Assemble unbounded set of IP messages into an ongoing, two-way, stream of information between any two devices on the Internet.
  - Internet: IP
    - Send single message hopping from network to network to get from device A to device B on any interconnected network.
  - Data link
    - Communicates information, messages made up of collections of 0's and 1's, across a single network.
      - E.g. Ethernet
  - Physical:
    - Gets signals from device A to B (computers, routers, printers) on a single network.
      - E.g. electrical signals on a wire, light pulses on a fiber, radio waves to a satellite
      - These signals represent 0's and 1's

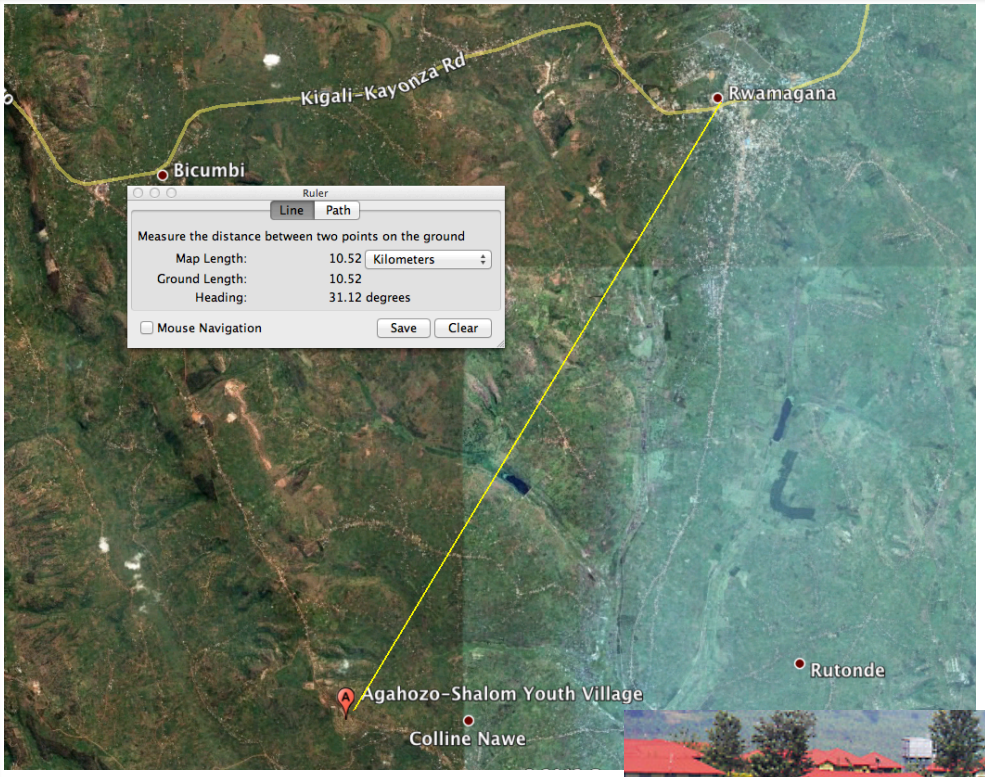
Physical and Data Link Network Layer

- How the data travels via cable or radio waves.

- The “Last Mile” problem is how does it get to your house village, business, school…
  - Copper loop: Dialup, DSL
  - Coaxial bus: Cable
  - Fiberoptic (e.g. Verizon FIOS)
  - Wireless: Wifi, wifi mesh, WiMax

A failed wind-powered wifi experiment in Nauru

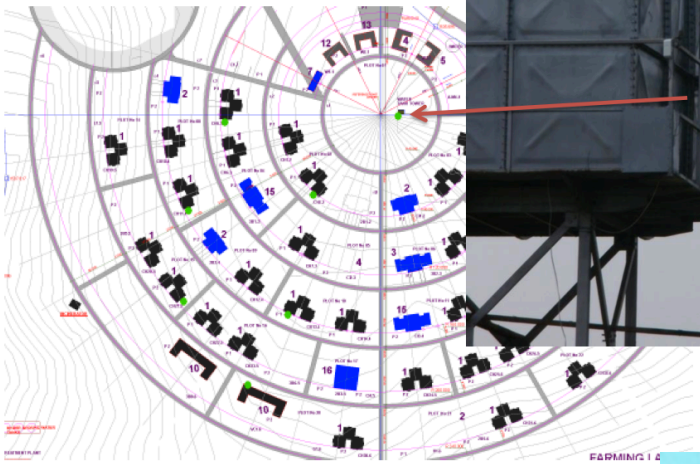
The last 10km in Rwanda



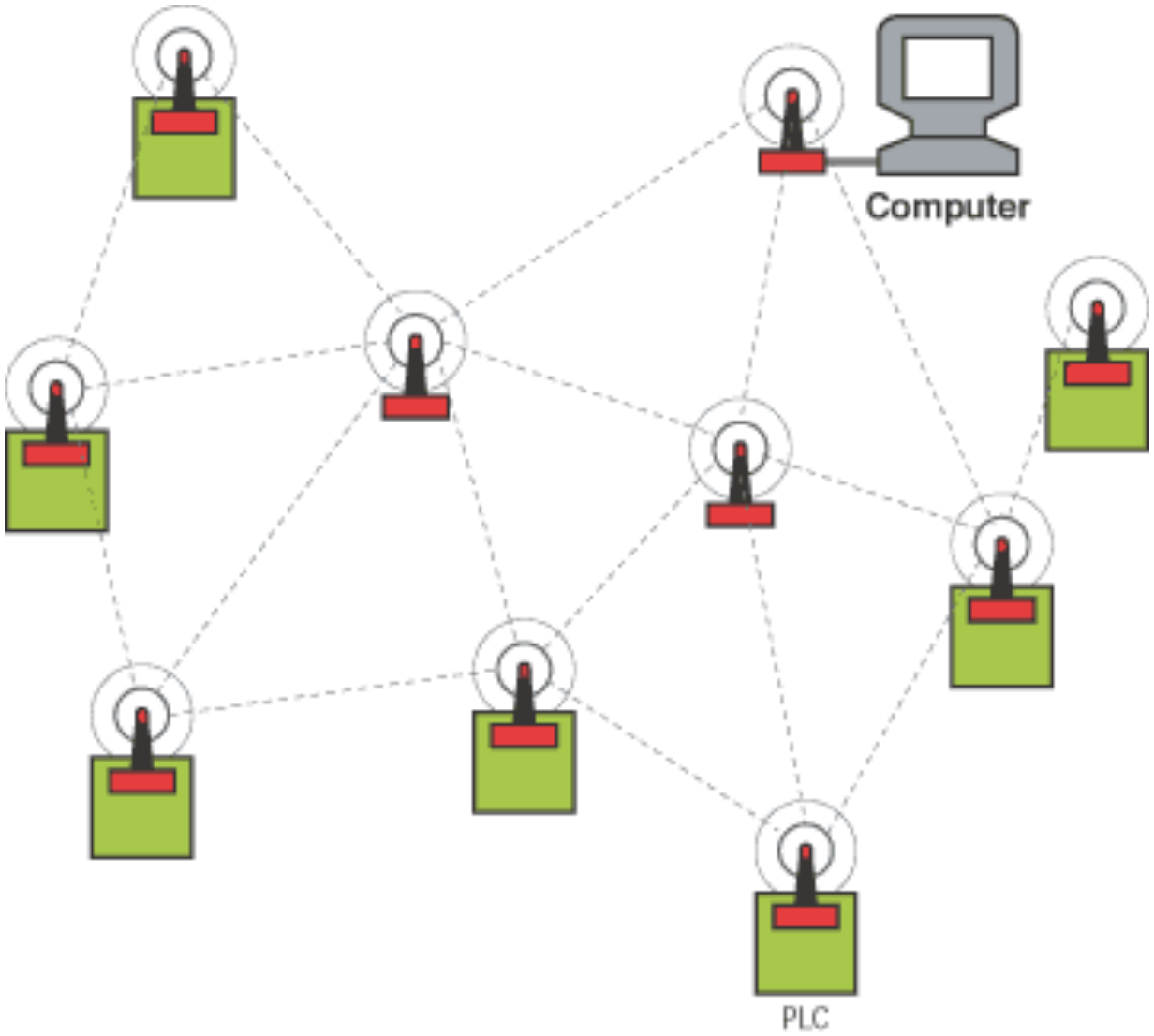
IP	10.10.30.2
Mac	00:15:6D:AB:22:7F
Manufacturer	Ubiquiti Networks
Channel	1
Frequency (Mhz)	2.4
Antenna	Omnidirectional

Measurements (dBm)	Average
50 ft.	-70
100 ft.	-72

Residence



Wifi Mesh



Source: http://www.green-wifi.com

Source: http://www.sensorsmag.com/networking-communications/standards-protocols/wireless-mesh-networks-968

WiMax

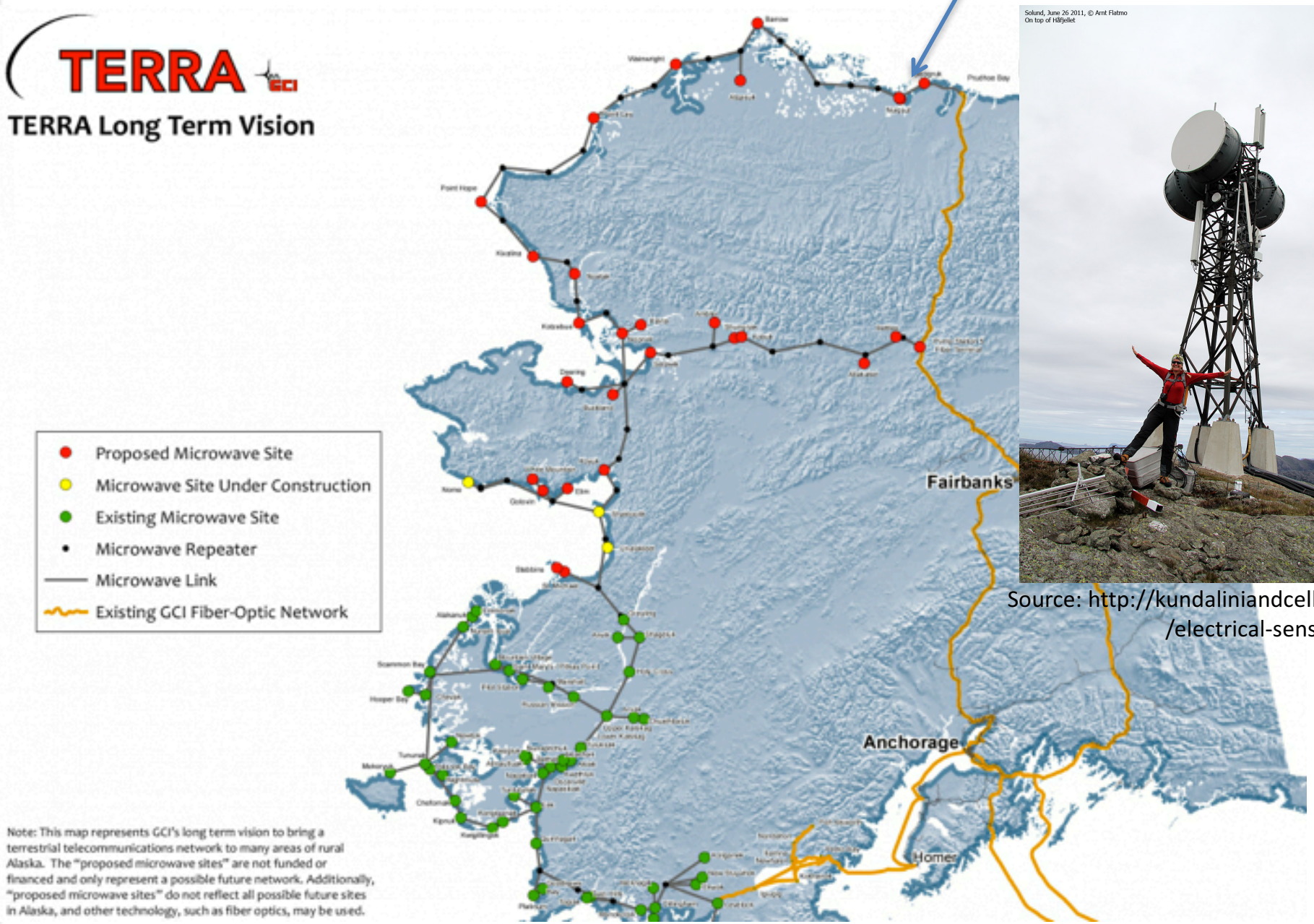
- Similar to wifi in functionality
  - High speed internet access
- Much longer distances:
  - Wifi: 100 feet (depending on conditions)
  - WiMax: 30 miles (depending on conditions)

Backhaul / Internet Backbone

- Last Mile networks are assembled and *backhauled* to larger collection points
- The Internet backbone is made up of the very top layer, very high speed, very long distance, networks (major commercial and government).
- Technologies at the Physical / Data Link layer:
  - Fiber-optic
  - Copper Cable
  - Microwave
  - Satellite

Microwave in Rural Alaska

30 miles Nuiqsut to Oooguruk



Source: http://kundaliniandcelltowers.com/electrical-sensitivity.html

Source: http://terra.gci.com/maps-locations/terra-vision-map

Laying cable

- Terrestrial
  - Long distance cables often laid along railroad rights of way
    - http://www.youtube.com/watch?v=OtmKECNb78k
  - Africa terrestrial:
    - http://www.africabandwidthmaps.com/fibrereach/
- Undersea:
  - https://youtu.be/iipPJdqdljY?t=124 (until 9:50)

Maps

- Undersea Cables:
  - http://www.submarinecablemap.com/
  - Where do they go?
  - ?Who owns them?
- Satellite Coverage:
  - http://www.intelsat.com/flash/coverage-maps/index.html

Palau Undersea Cable - 2017

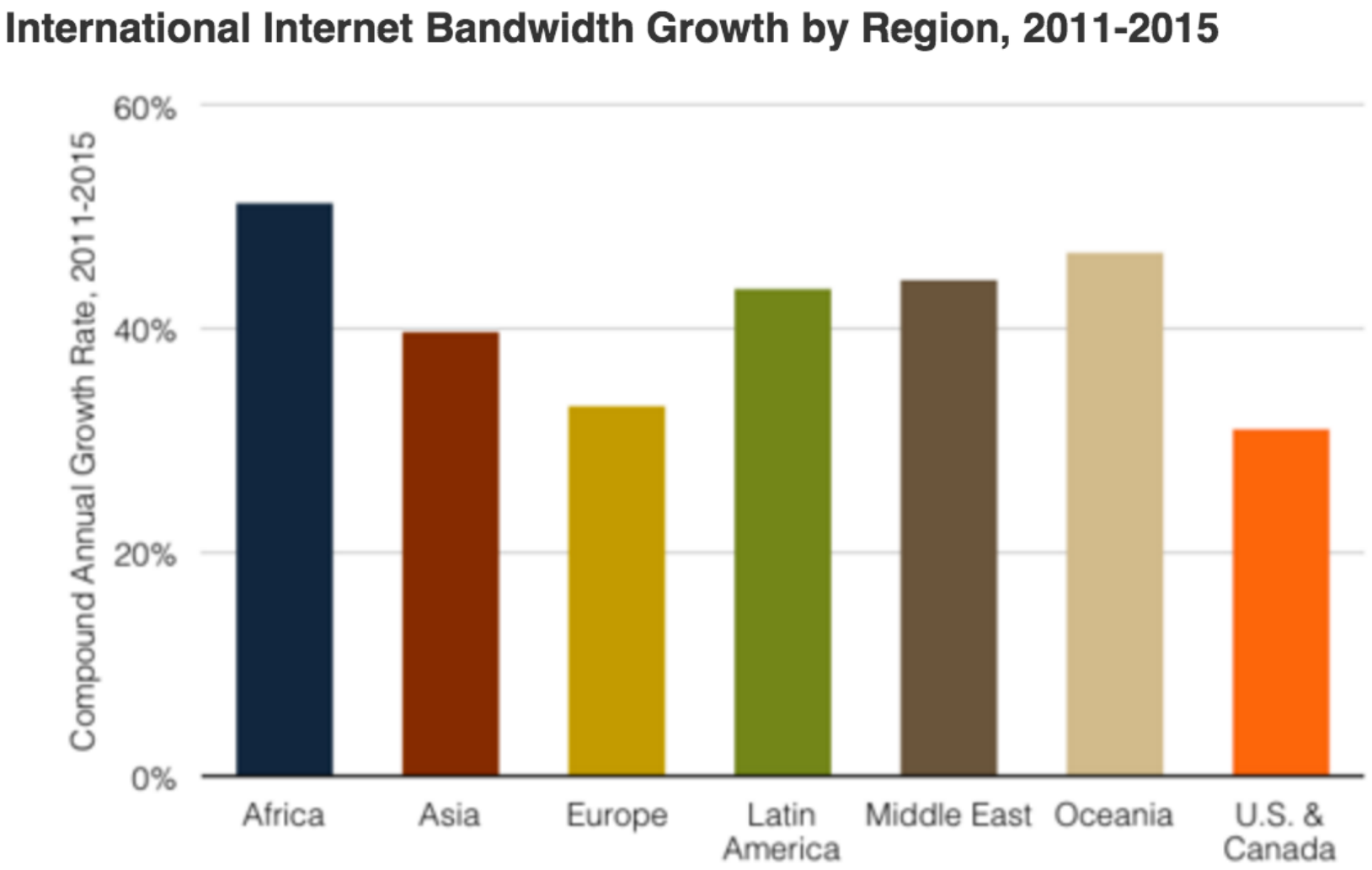
Palau Undersea Cable - 2017

Palau Undersea Cable - 2017

Palau Undersea Cable - 2017

Palau Undersea Cable - 2017

Bandwidth growth



Source: TeleGeography
https://www.telegeography.com/research-services/global-internet-geography/

Normalized to Netflix

- Netflix is 36% of North American Internet traffic
  - http://fortune.com/2015/10/08/netflix-bandwith/
- Bandwidth to Africa is only 2900Gbps
  - https://www.telegeography.com/press/press-releases/2015/08/26/african-internet-capacity-growth-continues-to-lead-world/index.html
- Netflix standard definition requires 0.7Gbps
- Therefore 10M people watching Netflix in Africa could totally consume their incoming bandwidth
  - There are 1.2B people in Africa
  - 0.8% of the population watching Netflix would use up 100% of the bandwidth
- BTW, Netflix is not a big player in Africa.
  - Nollywood films are more popular, and are not on Netflix (techcrunch)
  - As of Jan 2016, it is in Africa, source Netflix via techcrunch.com
  - They have a Point of Presence in South Africa, so some video traffic need not come from abroad.

Internet Layer

- Fiber, satellite, etc create individual networks.
  - (Physical and data link layers)
- How are these interconnected to create one ***Internet***?
  - (IP layer)

Routers

- The Internet is an interconnection of all these networks
- ***Routers*** provide switching and intelligently direct information toward its destination.
- Because it is massively interconnected, there are multiple routes a given packet of information can take.
  - Was originally designed this way during the Cold War to withstand a nuclear attack.
  - Routers share information with each other so that each can make smart decisions on where to send any packet of data.

Internet Protocol (IP)

- Internet Protocol (IP) is the protocol that manages getting a packet of data to its destination.
- Routing is an IP-level activity.
- IP address is a (unique) numerical address of all devices connected to the Internet
  - E.g. 128.2.55.120
  - E.g. when at my desk, my laptop has 2 of them
    - it has wired and wifi capability, so is on 2 networks

Transport Protocol: TCP

- Other part of TCP/IP, which you might have heard of.
- TCP/IP together is what makes it easy to build applications that send data from one place to another reliably
  - E.g. www, email, Skype (UDP)
- IP moves small packets of data from device A to B
- TCP moves whole streams of information (files, email messages, movies) from A to B (via IP) by breaking it up into IP packets and reassembling at the destination.

Move to NY analogy

- Roads and highways
  - Physical Network (fiber, satellite, etc)
- Uber
  - IP – Internet Protocol
  - Hire a car to go from here to New York
- UberMove (fictional)
  - TCP – Transport Protocol
  - Breaks your furniture, clothing, books, etc into boxes that fit into multiple Uber cars, sends them all out independently to NY, everything reassembled there.

Application Protocols

- Above IP and TCP ride application protocols:
  - IMAP & POP – receive email
  - SMTP – send email
  - FTP – file transfer
  - RTP – stream audio and video
  - HTTP – web
  - And many others…

The Role of Standards

- TCP and IP are standards.
  - Once adopted, many could build upon them.
  - Like a language, if you have a group that shares a language, communication can flourish.
- Similarly, the WWW was not engineered.
  - No one laid out a detailed plan for where all the pieces would be.
- Rather, 3 simple standards were defined:
  - HTTP – to get info from one place to another
  - URL – to uniquely address that info
  - HTML – to be able to display and link info
- A lot of additional standards have been built upon this initial success.

Standards Takeaway Message

- Systems don't always need to be engineered
  - E.g. like a database
- They can ***evolve*** when a ***good*** set of ***open standards*** are ***agreed upon***.
  - All words in bold-italic are critical.

Review

- Physical networks send signals interpreted as 0/1
- Data Link protocols send messages of 0/1 as information on a single network.
- IP, operating in computers and routers, interconnect these networks into an internetwork (Internet) getting small data packets from one place to its destination
- TCP moves larger streams of information from source to destination computers.
  - So TCP/IP provides a standard way to have applications communicate across the Internet.
- Applications communicate information, over TCP, specific to their purpose (email, web sites, etc).

Cellular

- Only so many radio channels are available for mobile communication

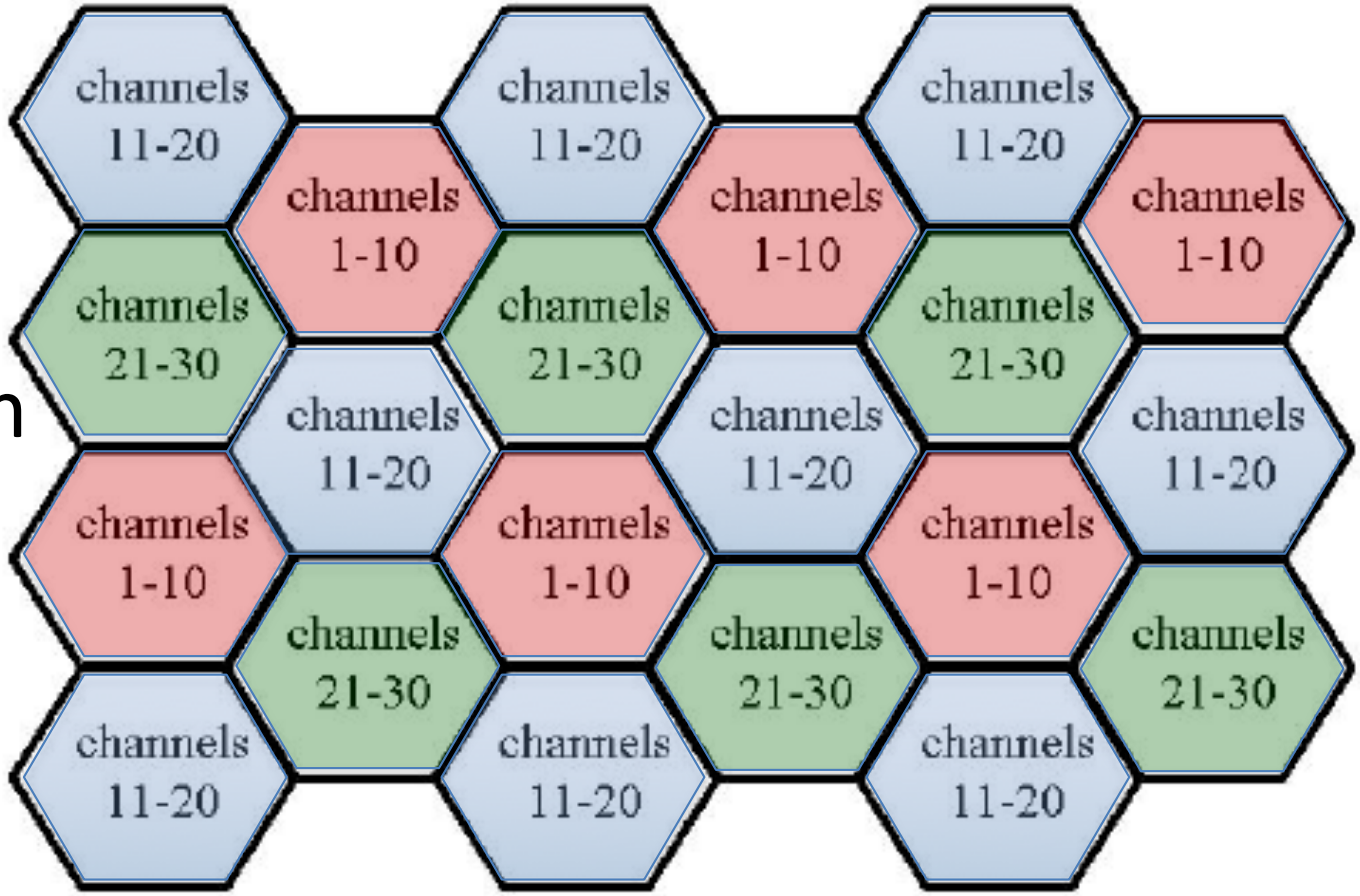
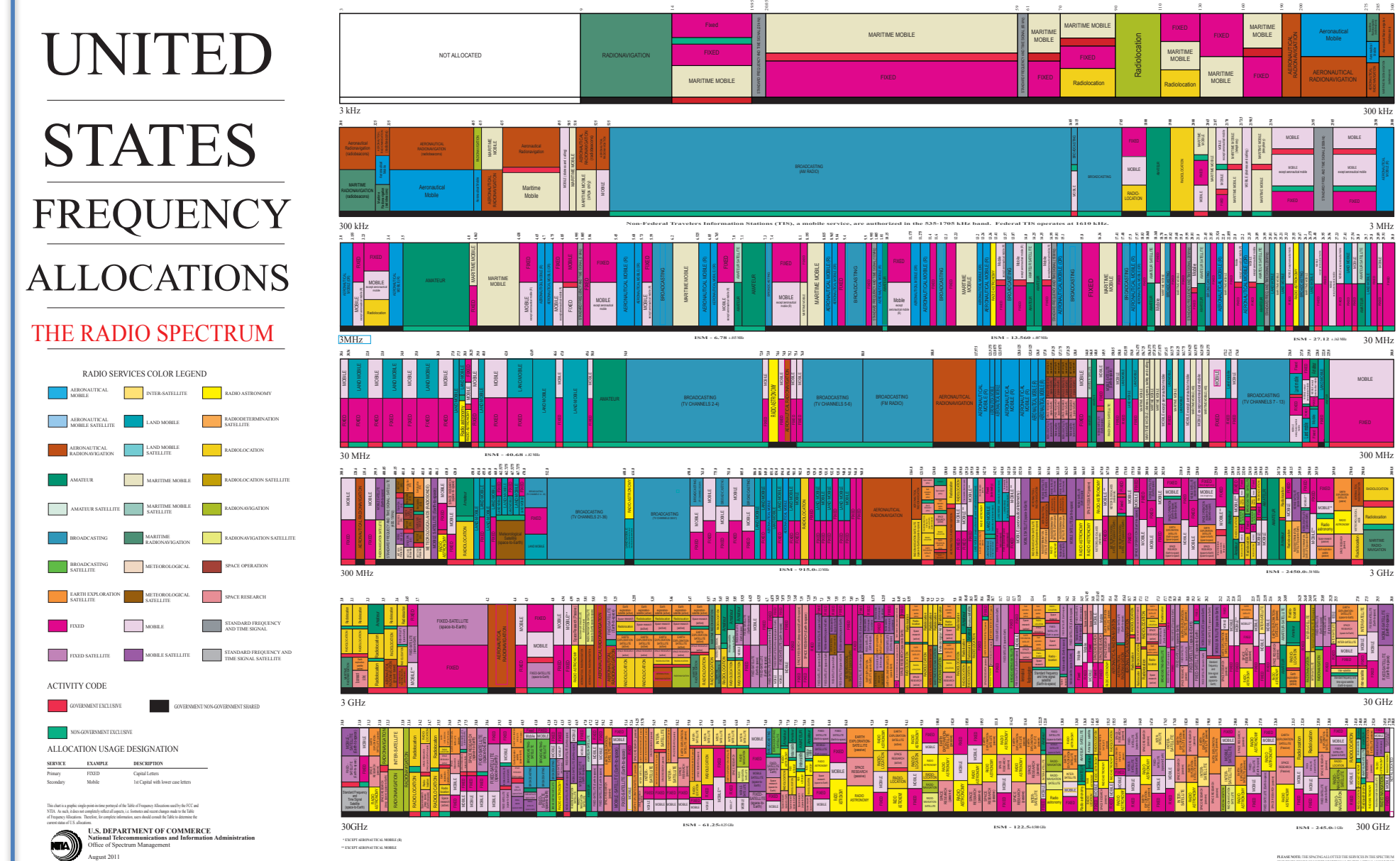


Figure 6: Reusing spectrum with the cellular concept [22]

Image source: *How America's Fragmented Approach to Public Safety Wastes Money and Spectrum*
http://web.si.umich.edu/tprc/papers/2005/438/Peha_Public_Safety_Communications_TPRC_2005.pdf

US Spectrum



Source: http://www.ntia.doc.gov/files/ntia/publications/spectrum_wall_chart_aug2011.pdf

Cellular

Theory

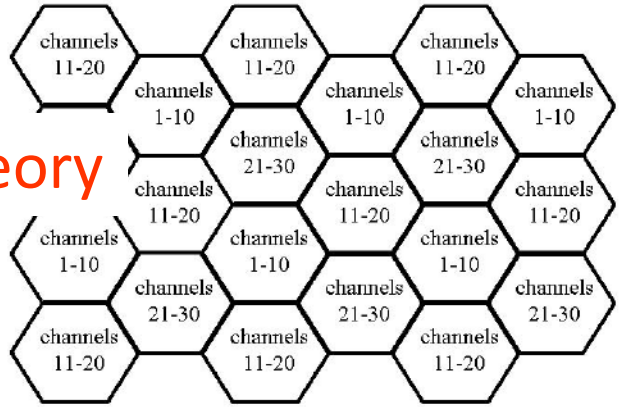
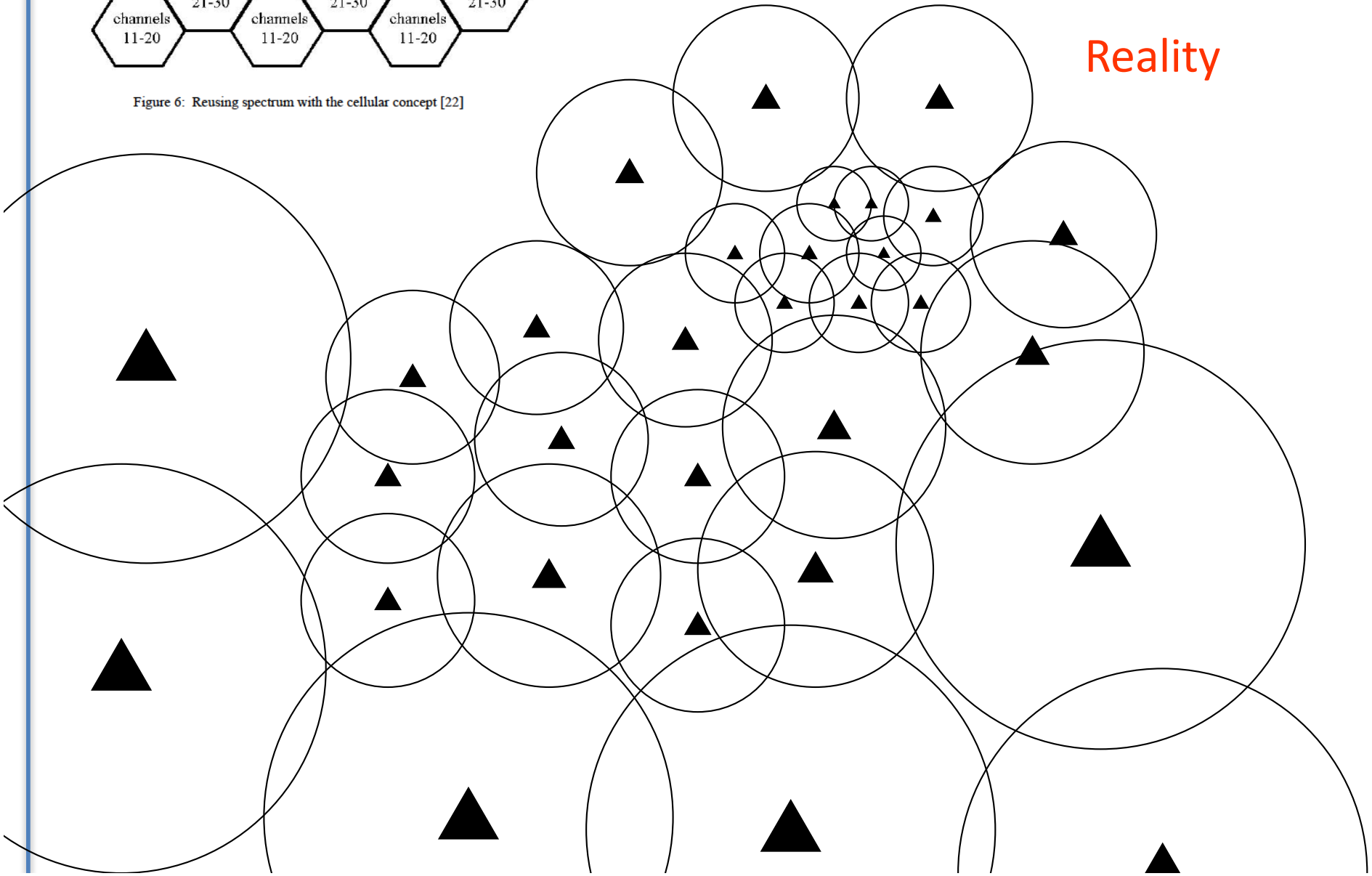


Figure 6: Reusing spectrum with the cellular concept [22]

Reality



Voice & Data

- CDMA – Verizon, and backhaul elsewhere
- GSM, most of the world

- Mobile Broadband:

Second generation (2G) from 1991:

Speeds in kbit/s	*down and up*
• GSM CSD	9.6
• *CDPD*	up to 19.2
• GSM GPRS (2.5G)	56–115
• GSM EDGE (2.75G)	up to 237

Third generation (3G) from 2001:

Speeds in Mbit/s	*down*	*up*
• UMTS W-CDMA	0.4	
• UMTS HSPA	14.4	5.8
• UMTS TDD	16	
• CDMA2000 1xRTT	0.3	0.15
• *CDMA2000 EV-DO*	2.5–4.9	0.15–1.8
• GSM EDGE-Evolution	1.6	0.5

Fourth generation (4G) from 2006:

Speeds in Mbit/s	*down*	*up*
• HSPA+	21–672	5.8–168
• Mobile WiMAX (802.16)	37–365	17–376
• LTE	100–300	50–75
• LTE-Advanced:		
• while moving at high speeds	100	
• while stationary or moving at low speeds	up to 1000	
• *MBWA (802.20)*	80	

Source: https://en.wikipedia.org/wiki/Mobile_broadband

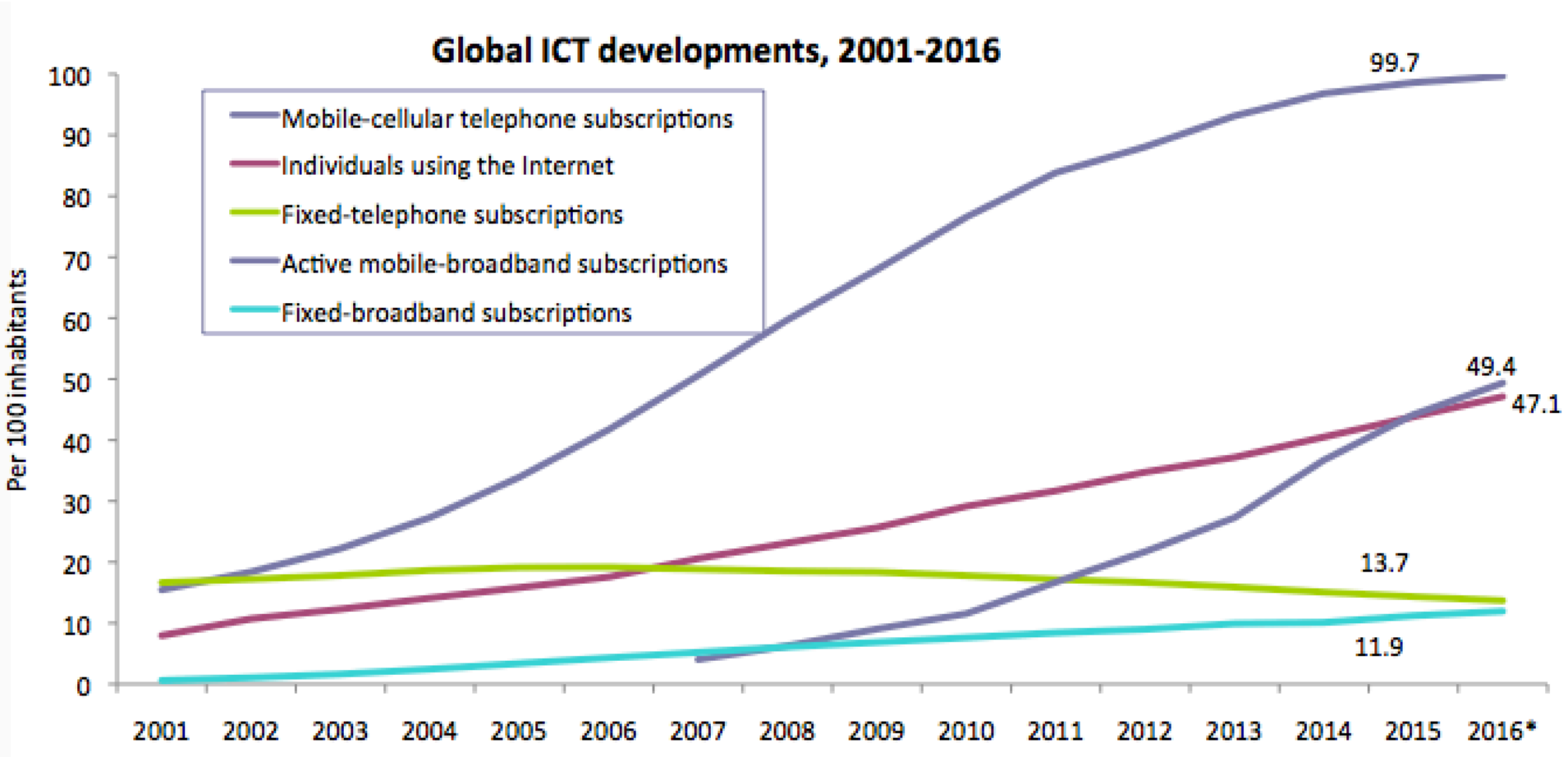
Stats….

- The following are International Telecommunications Union (ITU) statistics
- Source: http://www.itu.int/ITU-D/ict/statistics/

Stats....

- The International Telecommunications Union (ITU) collects useful statistics on fixed and mobile broadband penetration globally.
- Review interesting highlights at:
  - http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2013.pdf
- And here is an interesting way to explore data per country:
  - http://www.itu.int/net4/itu-d/icteye/
- They also have tabular data if you want to do analysis.

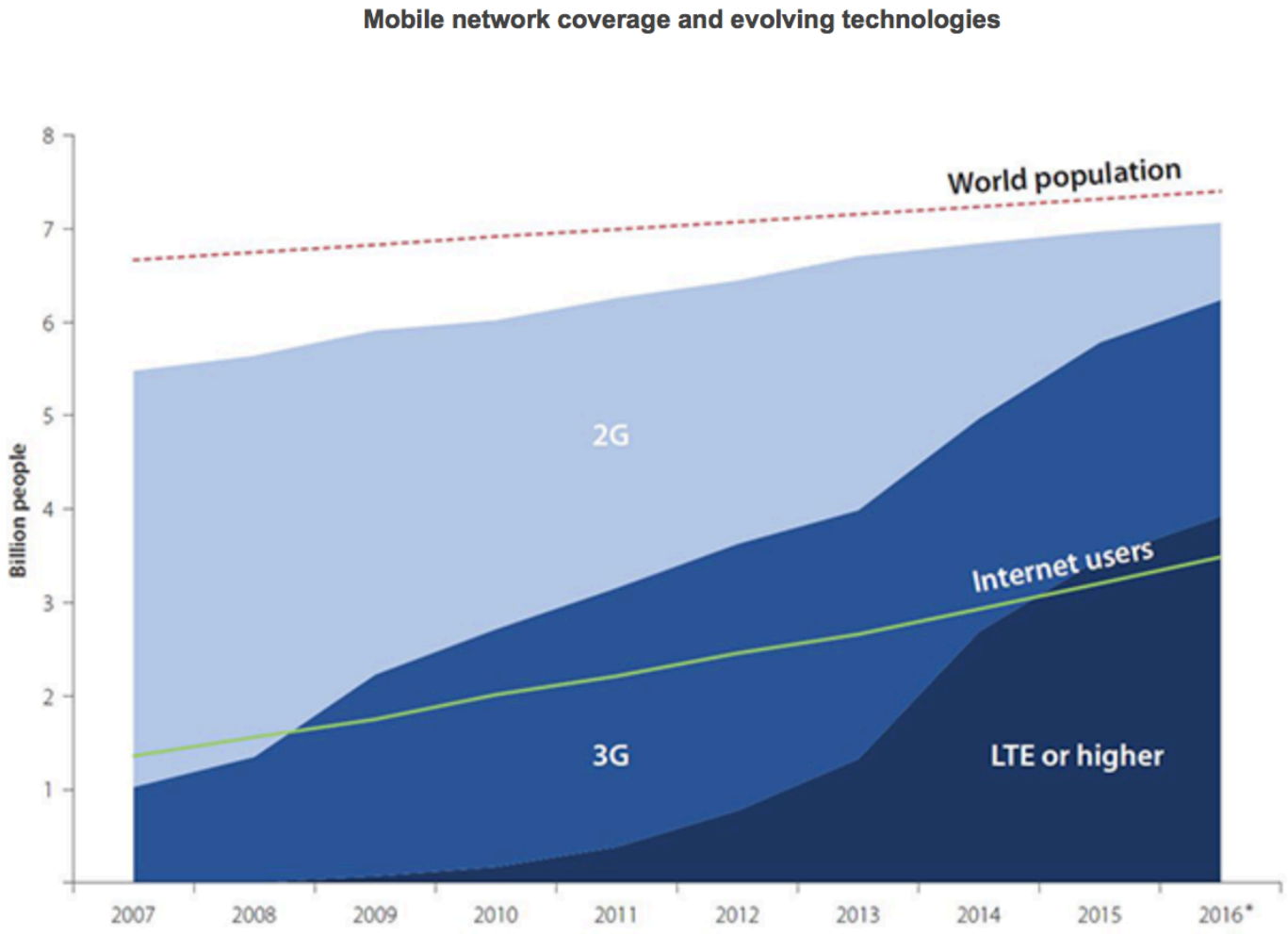
ITU Access Statistics



Note: * Estimate
Source: ITU World Telecommunication /ICT Indicators database

Source: http://www.itu.int/en/ITU-D/Statistics/Documents/statistics/2016/Stat_page_all_charts_2016.xls

ITU Access Statistics



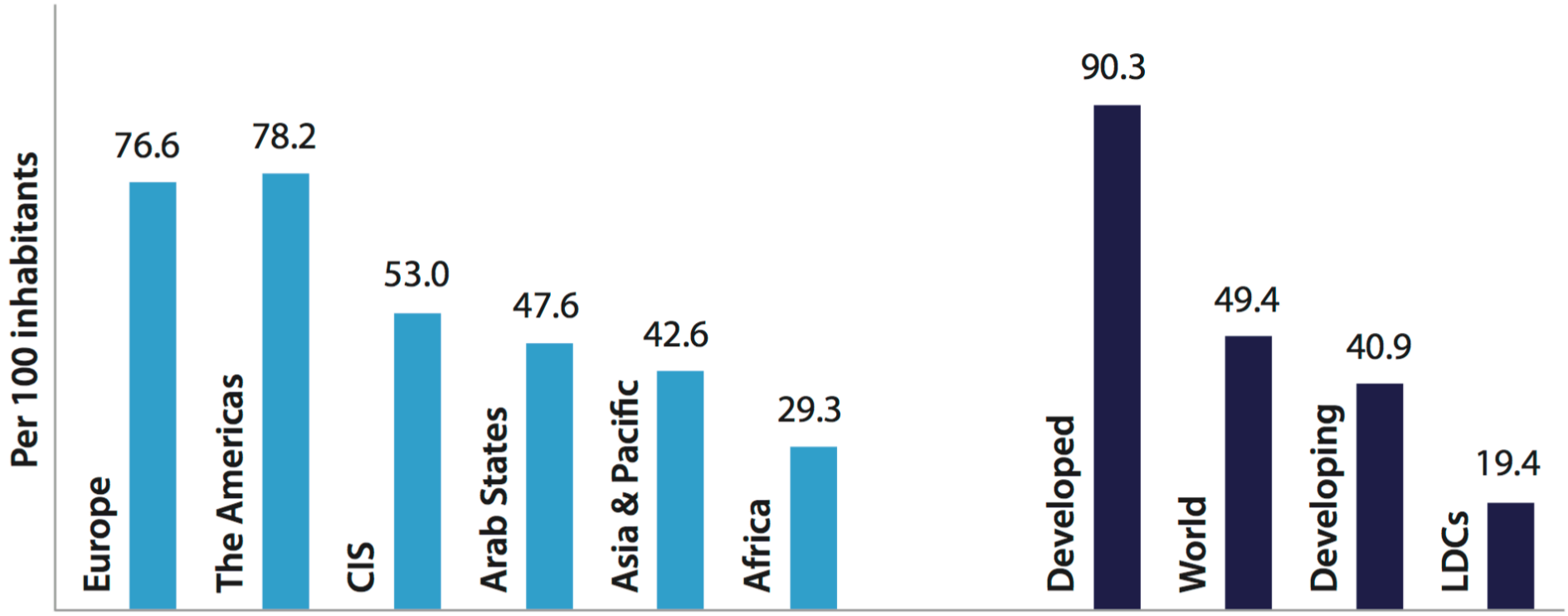
Note: * Estimates. Mobile network coverage refers to the population that is covered by a mobile network.

Source: ITU.

Source: http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2016.pdf

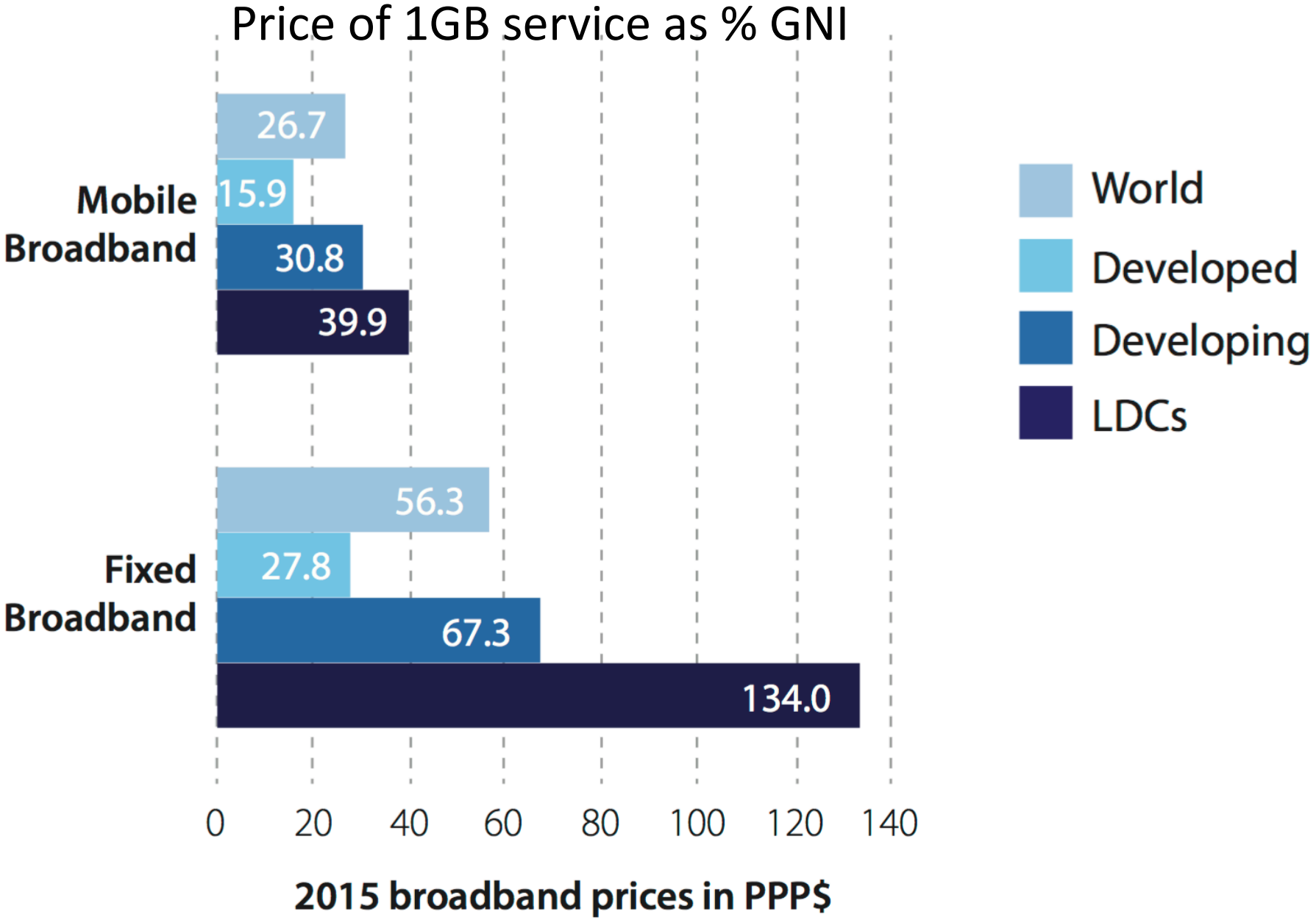
ITU Access Statistics

Mobile-broadband subscriptions



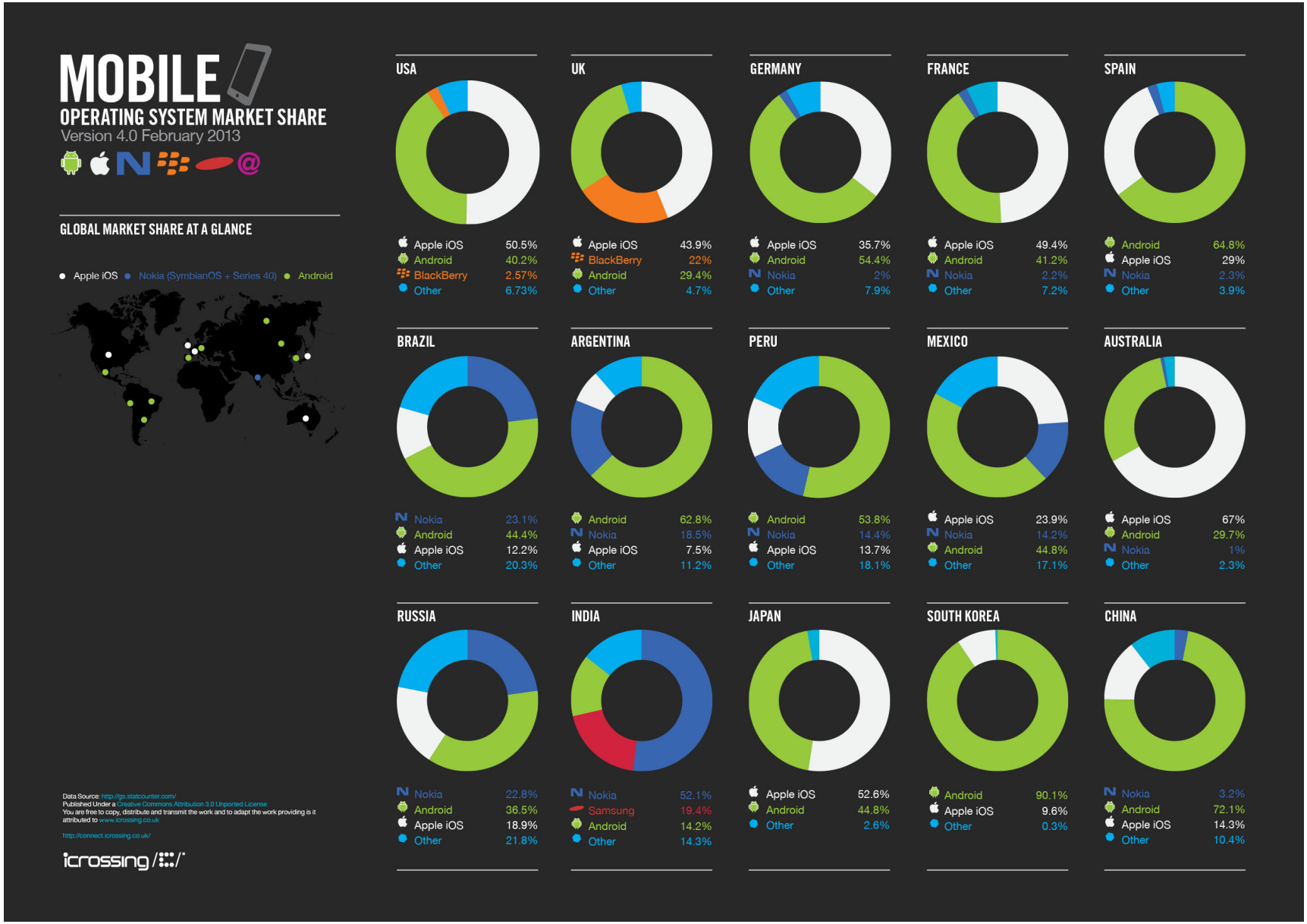
Source: http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2016.pdf

Mobile broadband is cheaper than fixed



Source: http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2016.pdf

Mobile use varies by country

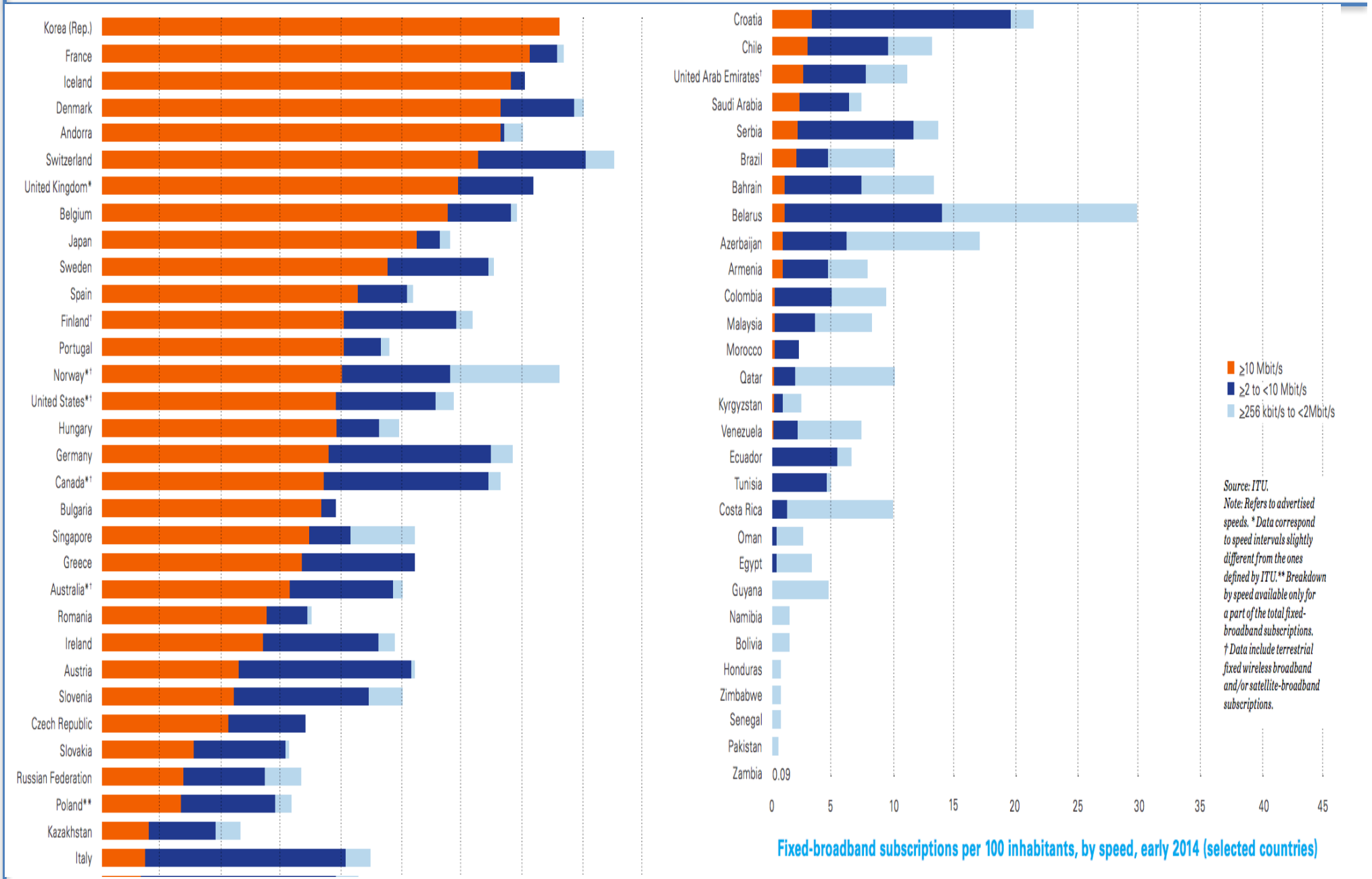


Source: http://connect.icrossing.co.uk/wp-content/uploads/2013/01/iCrossing_2013_Mobile_Market_Share.gif
Data from StatCounter

Bottom Line

- In the foreseeable future, mobile devices will be the most prevalent way that people access the Internet.
- So if you are thinking about technology for development, mobile is the platform that will reach the most individuals.

Broadband speed by country



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