Methodological and Statistical Background on a 2014 UPDATE to

The World's Technological Capacity to Telecommunicate Information

Martin Hilbert
University of California, (www.martinhilbert.net)

This technical note describes changes and new data sources that have been introduced during the 2014 update of the 1986-2007 estimation of the world's technological capacity to telecommunicate[1]. If not otherwise indicated, the methodological choices and sources outlined in the original 300 page methodological supporting information still apply and should be cited i.e. López & Hilbert (2011; 2012)[2]. The most important aspects are repeated in the following. The study includes 172 countries[3], corresponding to 99 % of the world's Gross National Income (GNI, in current US$), and 96 % of the world's population.

Fixed-line phones

The assumptions are unchanged[2]. Number of subscriptions is taken from ITU[4] and performance metrics are replicated in the following table. Ley-μ is used in Australia, Japan and United States only.

Optimally compressed transmission rates for fixed line telephony.

		Analog	Digital
		"Optimal"	"Optimal"
Bit rate [kbps]	Ley-A	8.63	12.44
Bite rate [kbps]	Ley-μ Australia, Japan, U.S.	7.97	11.56

Source: López & Hilbert, 2011; 2012.

Mobile telephony

Until 2007 (and for 2G and 2.5G mobile), the assumptions follow López & Hilbert (2011; 2012)[2]. We consider the differential start dates of data capacity in 2G phones (earliest 1992) and assume that all mobile phones have data capacity after 2002. In 2007, ITU[4] stared to account for "active mobile-broadband subscriptions", which was completed and harmonized with previous estimates. Broadband bandwidth performance is constructed by comparing and complementing input from Ookla's Netindex[5] and Akamai[6]. As usual, values for missing countries are estimated on basis of regional averages.

Broadband Internet

Most of the basic statistics for subscriptions are taken from ITU[4], with complements and corrections as outlined in López & Hilbert (2011; 2012)[2]. Performance estimations for dial-up and ISDN follow previous assumptions, as does broadband until 2007. From 2007 onward we use average bandwidth of countries reported by Ookla's NetIndex[5], which is seen "as the best of the currently available data sources for assessing the speed of ISP's broadband access service"[7]. NetIndex compiles the results of two bandwidth velocity meters (Speedtest.net and Pingtest.net) and in this way estimates the average upstream and downstream speed for countries worldwide (e.g. for 2010 an average of 179,822 tests per country per day for 160 countries). We fill-in missing values on vasis of regional averages and countries with comparable profiles, and correct cases where we suspect a bias in the measurement.

The assignment of this total average toward specific technologies follows some assumptions (which do affect any analysis related to the contribudion of different broadband technologies, but not the total bandwdith, which stays the same). We assume that users of FTTH/B, DSL and cable modem (CM) perform most speed tests. We estimate the offered fiber optic bandwidth on basis of a large variety of national fiber optic providers, creating national averages among the offered rates. Based on several other speed-tests, we assume that cable modem download speed is 3 times faster than DSL, and cable modem upload speed is 1.5 times faster than DSL.[8] Combined with the subscriber numbers, this gives us an equation with one unknown that can uniquely be solved for each country (in the following DSL performance for download):

ExcptValue [performance] =
= [% Fiber subsc.]*[Fiber perf.] + [% DSL subsc.]* [**DSL perf**.] + [% Cable subsc.]*3*[**DSL perf**.] =
= [National average bandwdith]

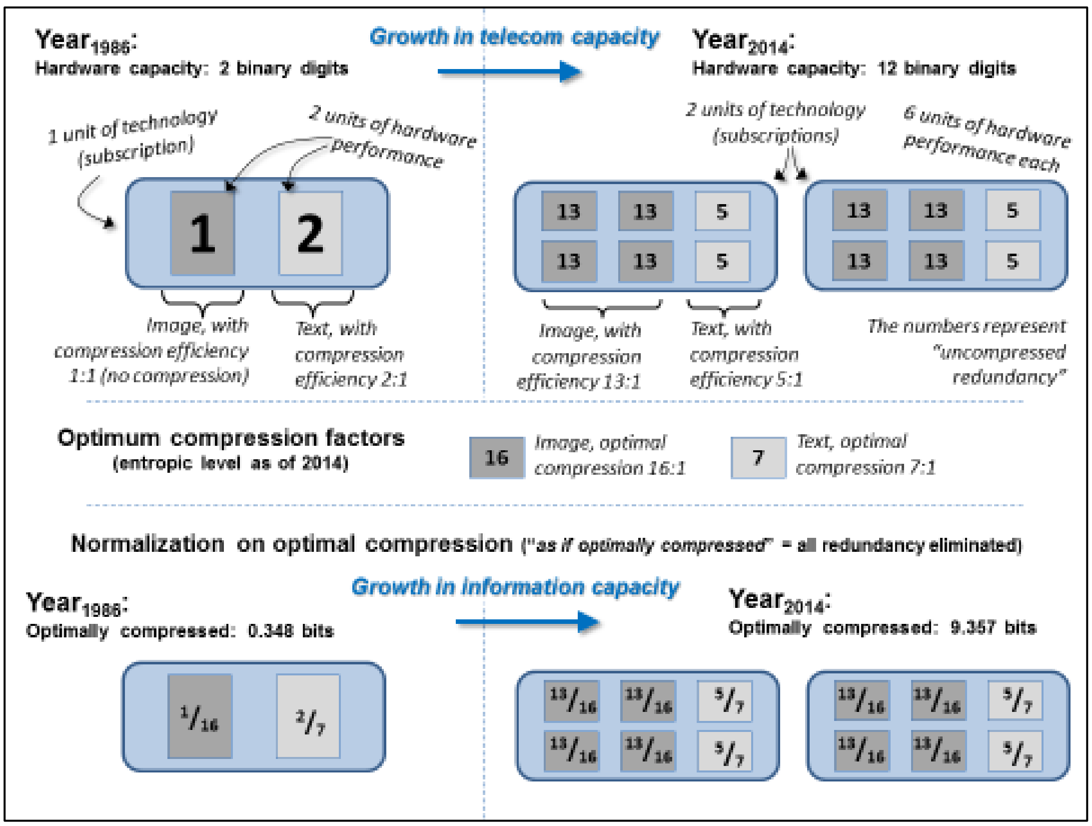
Tablets and Wearables

The number of tablets and wearables per world region is taken from the reports of Cisco[9], Statista[10] and Ericsson[11], while the number of per country is estimated on basis of the number of mobile phones per country (taking 2010 as the year of introduction of both tablets (i.e. the iPad) and wearables). After comparing the bandwidth for tablets and wearables presented in the above sources, it was decided to use the national 2G mobile phone bandwidth as an estimate for the bandwidth of wearables, and the mobile broadband bandwidth as an estimate for tablets.

Compression normalization

As explained in detail in Hilbert and López (2012)[12] the estimation of time series makes it indispensable to work with some reasonable normalization on compression rates, as compression algorithms have enable to send more information through the same hardware infrastructure over recent decades[13]. We normalize on "optimally compressed bits" ("as if all content were compressed with the best compression algorithms possible in 2014"). It would also be possible to normalize on a different standard (e.g. the most used compression algorithms in 2014), but the optimal level of compression has a deeper information theoretic conceptualization as it approaches the entropy of the source)[14]. For the estimation of compression rates of different content, justifiable estimates are elaborated for 7-years intervals (1986, 1993, 2000, 2007, 2014). We create estimates for both compression factors and the respective content distribution for those years, and interpolate linearly between them.

The following Figure gives a schematic example of the procedure. Assume one subscription with a bandwidth of 2 bits/second in 1986. Half of this installed hardware capacity communicated uncompressed images and the other half text that is compressed with a factor of 2:1 (which means that uncompressed content is reduced to half of its size, for example through some kind of zip, rar, or related standard). In 2014, we count with two subscriptions (growth in subscriptions), each of which counts with a hardware bandwidth of 6 bits/sec (growth in hardware performance). Two thirds of this content is used to communicate images, and one third to communicate text. By now, images are compressed with a factor of 13, and text with a factor of 5. According to leading technological and theoretical considerations, the optimal achievable lossless compression for images is a factor of 16:1, and text 7:1. This is used to normalize the result on “optimally compressed bits” (“as if all content were always compressed with the best compression algorithms possible in 2014”). This quantifies the amount of information transmitted over the channel, not merely the hardware capacity.



Text:

In 2014, most text is still compressed with compression algorithms similar to the most common use of RAR in combination with ZIP. However, they evolved and RAR5 (introduced in 2013) achieves better compression rates that RAR3.7 used in 2007. Performance depends on file size and required speed, but we estimate an average improvement from 4.7 in 2007 to 4.9 in 2014.[15] The optimal level of compression improved from a 6.6 to 7.2, which is achieved by algorithms like durilca' kingsize and cmix v6.[16]

Images:

JPEG has increased its standard as the dominant market leader (being also the standard for images on mobile phone services, a dominant source of images). We keep the previous assumption, but instead of a market share of GIF 36 % vs. JPEG 64 %, we assume a market share of 95 % JPEG. This leads to a compression factor of 37.7 for low quality for 2014 (from 27.6 in 2007; optimum stays 48), 22.8 for medium quality (from 17.6 in 2007; optimum stays 32), and 13.4 for high quality (from 11.3 in 2007; optimum stays 16). We take a simple average for quality, and therefore get average compression factor of 18.8 for 2007; 24.6 for 2014; and a factor of 32:1 as optimal compression.

Sound:

For audio (including VoIP services) we recognize the increasing adoption of MPEG-4 AAC and AACv2, while the market share of MP3 is shrinking. We estimate an average compression rate of 20 for 2014, up from merely average 8.7 for average quality for audio voice in 2007 (6.8, 8.2 and 11.0 in low, medium, high quality audio/voice in 2007), and we adopt the optimum level of mobile communication of 32 for both mobile and fixed-line audio (as they have merged) (up from 24). For traditional telephony, during the period from 2007 to 2014 important improvements have been achieved for the quality of voice. However, this has not reduced size. We therefore use the same assumption for 2014 as we did in 2007.

Video:

H.265/MPEG-HEVC improved on H.264/MPEG-AVC during the period from 2007 to 2014. We follow a comparative assessment[17] and take the improvement of some 41 %, increasing compression from a factor of 60 to 85. As before, given the critical importance of video compression and the importance of centralized compression through streaming services like YouTube and Netflix, we assume that the optimal compression algorithm is also the most used one.

		1986	*1993*	*2000*	*2014*	*Optimal*
Basic	***Text / compressed***	2.2	2.9	4.6	4.9	**7.2**
	Image	1.0	7.0	11.2	24.6	**32.0**
	Sound	1.0	1.0	10.5	20.0	**32.0**
	Video	1.0	20.0	27.0	85.0	**85.0**

compression factor per type of content

Distribution of content:

The distribution of content is estimated on basis of a variety of sources, but mainly Sandvine (2014)[18].

Traffic distribution for services per region for 2014, based on Sandvine (2014)[18]

FIXED	Upstream		Downstream	MOBILE	Upstream		Downstream
North America							
BitTorrent	37%	Netflix	44%	Facebook	40%	YouTube	22%
HTTP	22%	YouTube	17%	SSL	19%	Facebook	17%
SSL	10%	HTTP	15%	HTTP	18%	HTTP	16%
Netflix	10%	iTunes	5%	YouTube	6%	MPEG	11%
YouTube	8%	SSL	4%	Instagram	5%	SSL	8%
Skype	3%	BitTorrent	4%	BitTorrent	3%	GoogleMarket	6%
Facebook	3%	MPEG	4%	MPEG	3%	PandoraRadio	6%
FaceTime	2%	Facebook	3%	PandoraRadio	2%	Netflix	6%
Dropbox	2%	AmazonVideo	2%	Gmail	2%	Instagram	4%
iTunes	2%	Hulu	2%	iCloud	2%	iTunes	4%
	100%		100%		100%		100%
Europe							
BitTorrent	45%	YouTube	26%	Facebook	27%	HTTP	25%
HTTP	14%	HTTP	24%	HTTP	20%	YouTube	23%
YouTube	10%	BitTorrent	15%	SSL	13%	Facebook	18%
SSL	8%	SSL	8%	YouTube	12%	SSL	8%
Skype	6%	Facebook	5%	BitTorrent	7%	MPEG	6%
Facebook	6%	RTMP	5%	Skype	7%	Netflix	5%
eDonkey	5%	MPEG	5%	iTunes	5%	iTunes	5%
Dropbox	3%	Netflix	4%	Instagram	3%	GoogleMarket	4%
MPEG	2%	FlashVideo	3%	MPEG	3%	BitTorrent	4%
iTunes	2%	iTunes	3%	Snapchat	3%	Instagram	3%
	100%		100%		100%		100%
Latin America							
BitTorrent	27%	YouTube	36%	Facebook	33%	Facebook	22%
YouTube	20%	HTTP	18%	SSL	17%	YouTube	18%
HTTP	17%	SSL	14%	BlackBerry	15%	HTTP	17%
Facebook	11%	BitTorrent	9%	HTTP	12%	BlackBerry	11%
SSL	11%	Facebook	7%	WhatsApp	8%	SSL	10%
Ares	5%	Netflix	6%	YouTube	4%	GoogleMarket	7%
MPEG	3%	MPEG	4%	Gmail	3%	Instagram	4%
Skype	2%	FlashVideo	3%	Twitter	3%	MPEG	4%
FlashVideo	2%	RTMP	2%	Ares	3%	WhatsApp	3%
Netflix	2%	GoogleMarket	2%	Skype	3%	Twitter	3%
	100%		100%		100%		100%
Asia Pacific							
BitTorrent	59%	YouTube	35%	HTTP	28%	HTTP	26%
QVoD	14%	BitTorrent	24%	Facebook	19%	YouTube	20%
YouTube	7%	HTTP	13%	SSL	19%	MPEG	15%
RTSP	5%	RTSP	8%	BitTorrent	9%	Facebook	10%
Thunder	4%	Facebook	5%	YouTube	6%	SSL	8%
HTTP	4%	MPEG	4%	Skype	5%	Dailymotion	5%
Skype	3%	QVoD	4%	MPEG	5%	GoogleMarket	4%
Facebook	2%	RTMP	2%	WhatsApp	4%	HTTPliveStream	4%
SSL	1%	FlashVideo	2%	Dropbox	3%	Instagram	4%
PPStream	1%	SSL	2%	Instagram	3%	iTunes	3%
	100%		100%		100%		100%
Africa							
BlackBerry	32%	HTTP	41%	BitTorrent	31%	HTTP	31%
HTTP	23%	BlackBerry	19%	HTTP	24%	YouTube	19%
WAPv2	13%	WAPv2	8%	YouTube	11%	BitTorrent	15%
SSL	9%	OperaMini	6%	SSL	11%	Facebook	9%
WhatsApp	7%	WhatsApp	5%	Facebook	9%	SSL	9%
Facebook	5%	SSL	5%	Skype	7%	MPEG	5%
OperaMini	4%	GoogleMarket	5%	MPEG	2%	FlashVideo	4%
BitTorrent	3%	YouTube	4%	FlashVideo	2%	Skype	3%
Skype	3%	Facebook	4%	iTunes	1%	iTunes	3%
Yahoo!Mail	3%	BitTorrent	2%	Dropbox	1%	GoogleMarket	2%
	100%		100%		100%		100%

Assumptions of 2014 content distribution for traffic flow services recorded by Sandvine (2014)[18]

	Text	Image	Sound	Video	Compressed
HTTPliveStreaming	0%	0%	2%	98%	0%
FlashVideo	0%	0%	2%	98%	0%
RTSP	0%	0%	2%	98%	0%
PPStream	0%	0%	2%	98%	0%
QVoD	0%	0%	2%	98%	0%
Netflix	0%	0%	5%	95%	0%
YouTube	0%	0%	5%	95%	0%
MPEG	0%	0%	5%	95%	0%
AmazonVideo	0%	0%	5%	95%	0%
Hulu	0%	0%	5%	95%	0%
BitTorrent	5%	3%	5%	85%	2%
Ares	5%	3%	5%	85%	2%
Dailymotion	5%	3%	5%	85%	2%
eDonkey	5%	3%	5%	85%	2%
Thunder	5%	3%	5%	85%	2%
Skype	0%	0%	30%	70%	0%
FaceTime	0%	0%	30%	70%	0%
Dropbox	15%	15%	15%	55%	0%
iTunes	1%	3%	50%	46%	0%
Snapchat	25%	30%	5%	40%	0%
WhatsApp	25%	30%	5%	40%	0%
RTMP	25%	30%	5%	40%	0%
HTTP	30%	31%	2%	35%	2%
BlackBerry	30%	31%	2%	35%	2%
Gmail	30%	31%	2%	35%	2%
Yahoo!Mail	30%	31%	2%	35%	2%
iCloud	30%	31%	2%	35%	2%
GoogleMarket	55%	10%	15%	20%	0%
Twitter	40%	35%	5%	20%	0%
Facebook	30%	40%	10%	20%	0%
WAPv2	60%	20%	10%	10%	0%
OperaMini	60%	20%	10%	10%	0%
SSL	70%	15%	5%	0%	10%
Instagram	5%	95%	0%	0%	0%
PandoraRadio	0%	0%	100%	0%	0%

The global content distribution that results from this methodology for 2014 is roughly reconfirmed by the global content estimates of Cisco Systems[9], with the advantage that we now have a breakdown at the regional level (see Table).

Distribution of content type in % per region and Uplink / Downlink

FIXED						MOBILE					
North America DL	**1986**	**1993**	**2000**	**2007**	**2014**	***North America DL***	**1986**	**1993**	**2000**	**2007**	**2014**
Text/compressed	96	92	49	35	9	***Text/compressed***	100	100	100	40	20
Image	4	3	25	20	7	***Image***	0	0	0	26	18
Sound	0	5	19	6	7	***Sound***	0	0	0	6	14
Video	0	0	7	39	77	***Video***	0	0	0	27	48
North America UL	**1986**	**1993**	**2000**	**2007**	**2014**	***North America UL***	**1986**	**1993**	**2000**	**2007**	**2014**
Text/compressed	96	92	46	25	19	***Text/compressed***	100	100	100	40	32
Image	4	3	21	7	11	***Image***	0	0	0	26	31
Sound	0	5	27	12	7	***Sound***	0	0	0	6	8
Video	0	0	6	55	63	***Video***	0	0	0	27	26
Europe DL	**1986**	**1993**	**2000**	**2007**	**2014**	***Europe DL***	**1986**	**1993**	**2000**	**2007**	**2014**
Text/compressed	96	92	49	35	18	***Text/compressed***	100	100	100	40	22
Image	4	3	25	20	13	***Image***	0	0	0	26	19
Sound	0	5	19	6	6	***Sound***	0	0	0	6	8
Video	0	0	7	39	63	***Video***	0	0	0	27	51
Europe UL	**1986**	**1993**	**2000**	**2007**	**2014**	***Europe UL***	**1986**	**1993**	**2000**	**2007**	**2014**
Text/compressed	96	92	46	25	16	***Text/compressed***	100	100	100	40	26
Image	4	3	21	7	10	***Image***	0	0	0	26	23
Sound	0	5	27	12	7	***Sound***	0	0	0	6	9
Video	0	0	6	55	67	***Video***	0	0	0	27	41
Latin America DL	**1986**	**1993**	**2000**	**2007**	**2014**	***Latin America DL***	**1986**	**1993**	**2000**	**2007**	**2014**
Text/compressed	95	86	44	35	21	***Text/compressed***	100	100	100	40	30
Image	5	8	29	21	12	***Image***	0	0	0	26	26
Sound	0	6	20	5	5	***Sound***	0	0	0	6	6
Video	0	1	7	39	63	***Video***	0	0	0	27	39
Latin America UL	**1986**	**1993**	**2000**	**2007**	**2014**	***Latin America UL***	**1986**	**1993**	**2000**	**2007**	**2014**
Text/compressed	95	86	43	27	20	***Text/compressed***	100	100	100	40	36
Image	5	8	26	11	12	***Image***	0	0	0	26	28
Sound	0	6	24	10	6	***Sound***	0	0	0	6	6
Video	0	1	7	52	62	***Video***	0	0	0	27	29
AsiaPacific DL	**1986**	**1993**	**2000**	**2007**	**2014**	***AsiaPacific DL***	**1986**	**1993**	**2000**	**2007**	**2014**
Text/compressed	95	86	44	35	9	***Text/compressed***	100	100	100	40	21
Image	5	8	29	21	8	***Image***	0	0	0	26	18
Sound	0	6	20	5	4	***Sound***	0	0	0	6	6
Video	0	1	7	39	79	***Video***	0	0	0	27	55
AsiaPacific UL	**1986**	**1993**	**2000**	**2007**	**2014**	***AsiaPacific UL***	**1986**	**1993**	**2000**	**2007**	**2014**
Text/compressed	95	86	43	27	7	***Text/compressed***	100	100	100	40	32
Image	5	8	26	11	4	***Image***	0	0	0	26	24
Sound	0	6	24	10	5	***Sound***	0	0	0	6	7
Video	0	1	7	52	84	***Video***	0	0	0	27	38
Africa DL	**1986**	**1993**	**2000**	**2007**	**2014**	***Africa DL***	**1986**	**1993**	**2000**	**2007**	**2014**
Text/compressed	95	86	44	35	37	***Text/compressed***	100	100	100	40	22
Image	5	8	29	21	26	***Image***	0	0	0	26	15
Sound	0	6	20	5	5	***Sound***	0	0	0	6	7
Video	0	1	7	39	32	***Video***	0	0	0	27	56
Africa UL	**1986**	**1993**	**2000**	**2007**	**2014**	***Africa UL***	**1986**	**1993**	**2000**	**2007**	**2014**
Text/compressed	95	86	43	27	39	***Text/compressed***	100	100	100	40	21
Image	5	8	26	11	26	***Image***	0	0	0	26	14
Sound	0	6	24	10	5	***Sound***	0	0	0	6	7
Video	0	1	7	52	30	***Video***	0	0	0	27	58

[1] The original project covered the period 1986-2007 and resulted in a series of publications, among them:

Hilbert, M., & López, P. (2011). The World's Technological Capacity to Store, Communicate, and Compute Information. *Science*, 332(6025), 60 –65. http://doi.org/10.1126/science.1200970
M. Hilbert, "What Is the Content of the World's Technologically Mediated Information and Communication Capacity: How Much Text, Image, Audio, and Video?," *The Information Society*, vol. 30, no. 2, pp. 127–143, 2014.
M. Hilbert, "How much information is there in the 'information society'?," *Significance*, vol. 9, no. 4, pp. 8–12, 2012.
M. Hilbert, "How much of the global information and communication explosion is driven by more, and how much by better technology?," *J Assn Inf Sci Tec*, vol. 65, no. 4, pp. 856–861, Apr. 2014.
M. Hilbert, "Technological information inequality as an incessantly moving target: The redistribution of information and communication capacities between 1986 and 2010," *J Assn Inf Sci Tec*, vol. 65, no. 4, pp. 821–835, Apr. 2014.
[2] López, P., & Hilbert, M. (2011). Supporting Online Material: The World's Technological Capacity to Store, Communicate, and Compute Information. *Science*, 332(6025), 60 –65. http://doi.org/10.1126/science.1200970
López, P., & Hilbert, M. (2012). Methodological and Statistical Background on The World's Technological Capacity to Store, Communicate, and Compute Information (online document). Retrieved from http://www.martinhilbert.net/WorldInfoCapacity.html
[3] Albania, Algeria, Andorra, Angola, Antigua and Barbuda, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belgium, Belize, Benin, Bermuda, Bhutan, Bolivia, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cameroon, Canada, Cape Verde, Central African Rep., Chad, Chile, China, Colombia, Comoros, Congo, Congo (Democratic Republic of the), Costa Rica, Cote d'Ivoire, Croatia, Cyprus, Czech Republic, Denmark, Djibouti, Dominica, Dominican Rep., Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Estonia, Ethiopia, Fiji, Finland, France, Gabon, Gambia, Georgia, Germany, Ghana, Greece, Greenland, Grenada, Guatemala, Guinea, Guyana, Honduras, Hong Kong, China, Hungary, Iceland, India, Indonesia, Iran (Islamic Rep. of), Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kiribati, Korea (Rep. of), Kuwait, Kyrgyzstan, Lao P.D.R., Latvia, Lebanon, Lesotho, Liberia, Liechtenstein, Lithuania, Luxembourg, Macao, China, Madagascar, Malawi, Malaysia, Mali, Malta, Mauritania, Mauritius, Mexico, Moldova, Mongolia, Morocco, Mozambique, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Puerto Rico, Romania, Russia, Rwanda, Saint Kitts and Nevis, Saint Lucia, Samoa, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sri Lanka, St. Vincent and the Grenadines, Sudan, Suriname, Swaziland, Sweden, Switzerland, Syria, Taiwan, Tajikistan, Tanzania, Thailand, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Uganda, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Uzbekistan, Vanuatu, Venezuela, Viet Nam, Yemen, Zambia, Zimbabwe,
[4] ITU (International Telecommunication Union). (2014). World Telecommunication/ICT Indicators Database. Geneva: International Telecommunication Union. Retrieved from http://www.itu.int/ITU-D/ict/statistics/
[5] Ookla. (2015). NetIndex source data. Retrieved from http://www.netindex.com/source-data/
[6] Akamai. (2015). The State of the Internet (Quarterly Report). Retrieved from http://www.akamai.com/stateoftheinternet/
[7] Bauer, S., Clark, D., & Lehr, W. (2010). Understanding broadband speed measurements. Presented at the 38th Research Conference on Communication, Information, and Internet Policy (TPRC), Arlington, Virginia. http://people.csail.mit.edu/wlehr/Lehr-Papers_files/bauer_clark_lehr_2010.pdf
[8] FTTH Council (2010). Rural Utilities Services Workshop - FTTH Deployment Status Update. October 2010, Retrieved November 2011, from http://www.ftthcouncil.org/en/content/ftth-council-presentations-to-rural-utilities-service-workshop-october-2010; http://s.ftthcouncil.org/files/rus_workshop_-_ftth_status.pdf
Organisation for Economic Co-Operation and Development (OECD). (2011). OECD communications outlook 2011 – Information and communications technologies. Retrieved November 2011, from: http://213.253.134.43/oecd/pdfs/browseit/9305011E.PDF
UltTex Speed Tester (2006). 3100 speed test results for 2005-2006 by type of technology. Retrieved November 2010, from: http://ult-tex.net/speed/results.pl?view_usa=All
[9] Cisco Systems. (2015). Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update 2014–2019 White Paper. Retrieved from http://cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white_paper_c11-520862.html

[10] Statista. (2014). Statistics and Market Data on Mobile Internet & Apps. Retrieved September 3, 2014, from www.statista.com/markets/424/topic/538/mobile-internet-apps/
[11] Ericsson. (2015). Ericsson Mobility Report (OpenArticle). Retrieved from http://www.ericsson.com/mobility-report
[12] Hilbert, M., & López, P. (2012). How to Measure the World's Technological Capacity to Communicate, Store and Compute Information? Part II: measurement unit and conclusions. International Journal of Communication, 6, 936–955.
[13] Hilbert, M. (2014). How much of the global information and communication explosion is driven by more, and how much by better technology? Journal of the Association for Information Science and Technology, 65(4), 856–861. doi:10.1002/asi.23031
[14] Shannon, C. (1948). A Mathematical Theory of Communication. Bell System Technical Journal, 27, 379–423, 623–656. doi:10.1145/584091.584093
[15] Softonic. (2013). WinRar 5.0 - is it really better than 7-zip? Retrieved April 12, 2015, from http://features.en.softonic.com/winrar-5-0-is-it-really-better-than-7-zip
[16] Mahoney, M. (2015). Large Text Compression Benchmark. Retrieved from http://mattmahoney.net/dc/text.html
[17] Grois, D., Marpe, D., Nguyen, T., & Hadar, O. (2014). Comparative assessment of H.265/MPEG-HEVC, VP9, and H.264/MPEG-AVC encoders for low-delay video applications (Vol. 9217, p. 92170Q–92170Q–10). http://doi.org/10.1117/12.2073323
[18] Sandvine. (2014). 2014 Global broadband phenomena (Research Report). Sandvine Incorporated. Retrieved from https://www.sandvine.com/trends/global-internet-phenomena/