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Communication Quantity

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An increasing share of the world's data capacity is centralized in "the cloud." The gatekeeper to obtain access to this centralized capacity is telecommunication access. Telecommunication channels are the necessary (but not sufficient) condition to provide access to the mass of the world's data storage.

In this inventory we mainly follow the methodology of what has become a standard reference in estimating the world's technological information capacity: Hilbert and López (2011). The total communication capacity is calculated as the sum of the product of technological devices and their bandwidth performance, where the latter is normalized on compression rates. We measure the "installed capacity" (not the effectively used capacity), which implies that it is assumed that all technological capacities are used to their maximum. For telecommunication, this describes the "end-user bandwidth potential" ("if all end-users would use their full bandwidth"). This is merely a "potential," because in reality, negative network externalities create a trade-off in bandwidth among users. For example, estimating that the average broadband connection is 10 Mbps in a given country does not mean that all users could use this average bandwidth at the same second. The network would collapse. The normalization on software compression rates is important for the creation of meaningful time series, as compression algorithms have enable to send more information through the same hardware infrastructure over recent decades (Hilbert 2014a; Hilbert and López 2012a). We normalize on "optimally compressed bits" as if all content were compressed with the best compression algorithms possible in 2014 (Hilbert and López 2012b). For the estimation of compression rates of different content, justifiable estimates are elaborated for 7-year intervals (1986, 1993, 2000, 2007, 2014). The subscriptions data stem mainly from ITU (2015) with completions from other sources. One of the main sources for internet bandwidth is NetIndex (Ookla 2014), which has gathered the results of end-user-initiated bandwidth velocity tests per country per day over recent years (e.g., an average 180,000 test per day already in 2010 through Speedtest.net and Pingtest.net). For more see Hilbert (2015) and López and Hilbert (2012).

Figure 1a looks at the total telecommunication capacity in optimally compressed kbps in terms of global income groups (following the classification of the World Bank of 2015). The world's installed telecommunication capacity has grown with a compound annual growth rate of 35% during the same period, (from 7.5 petabites to 25 exabits). The last three decades show a gradual loss of dominance of global information capacities for today's high-income countries. High-income

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countries dominated 86% of the globally installed bandwidth potential, but merely 66% in 2013. It is interesting to compare this presentation with the more common method to assess the advancement approximation in terms of the number of telecommunication subscriptions (Fig. 1b). Both dynamics are quite different, which stems from the simple fact that not all subscriptions are equal in their communicational performance. This intuitive difference is the main reason why the statistical accounting of subscriptions is an obsolete and very often misleading indicator. This holds especially true in an age of Big Data, where the focus of development is set on informational bits, not on the number of technological devices (for the complete argument, see Hilbert (2014b, 2016)).

Comparing these results with the global shares of Gross National Income (GNI) and population (Fig. 1c, d), it becomes clear that the diffusion dynamic of the number of subscriptions follows existing patterns in population distribution. Especially the diffusion of mobile phones during recent decades has contributed to the fact that both distributions align. The number of subscriptions reaches a saturation limit at about 2–2.5 subscriptions per capita worldwide, and therefore leads to a natural closure of the divide over time. On the contrary, communication capacity in kbps (and therefore access to the global Big Data infrastructure) follows the signature of economic capacities. After only a few decades, both processes align impressively well. This shows that the digital divide in terms of data capacity is far from being closed but is rather becoming a structural characteristic of modern societies, which is as persistent as the existing income divide (Hilbert 2014b, 2016).

Figure 1a also reveals that the evolution of communication capacities in kbps is not a monotone process. Increasing and decreasing shares between high income and upper middle income countries suggest that the evolution of bandwidth is characterized by a complex nonlinear interplay of public policy, private investments, and technological progress. Some countries in this income range seem to (at least temporarily) do much better than their economic capacity would suggest. This is a typical signature of effective public policy.

Figure 2 shows the same global capacity in optimally compressed kbps per geographic regions (following the World Bank classification of 2015). Asia has notably increased its global share at the expense of North America and Europe, with a share of less than a quarter of the global capacity in 1986 (23%) and a global majority of 51% in 2013 (red-shaded areas in Fig. 2). Figure 2 reveals that the main driver of this expansion during the early 2000s were Japan and South Korea, both of which famously pursued a very aggressive public sector policy agenda in the expansion of fiber optic infrastructure in the early 2000s. The more recent period since 2010 is characterized by the expansion of bandwidth in both China and Russia. Notably, most recent broadband policy efforts in the USA seems to show some first detectable effects on a macrolevel, as North America has started to return its tendency of a shrinking global share during recent years.

Expressed in installed kbps per capita (per inhabitant), we can obtain a clearer picture about the increasing and decreasing nature of the evolving digital divide in terms of bandwidth capacity. First and foremost, Fig. 3a shows that the divide continuously increases in absolute terms. In 2003, the average inhabitant of high-income countries had access to an average of 100 kbps of installed bandwidth potential, while the average inhabitant of the rest of the world had access to merely 9 kbps. In absolute terms, this results in a difference of some 90 kbps. As shown in Fig. 3a, this divide increased with an order of magnitude every 5 years, reaching almost 900 kbps in 2007 and over 10,000 kbps by 2013. This increasing divide in absolute terms is important to notice in the context of a Big Data world, in which the amount of data is becoming a crucial ingredient for growth.

In relative terms, this results in an increasing and decreasing evolution of the divide over time. Figure 3b contrasts this tendency with the monotonically decreasing tendency of the digital divide in terms of telecommunication subscriptions. It shows that the divide in terms of data capacities is much more susceptible to both technological change and technology interventions. The decreasing divide during the period until 2000 is explained by the global diffusion of narrowband internet and

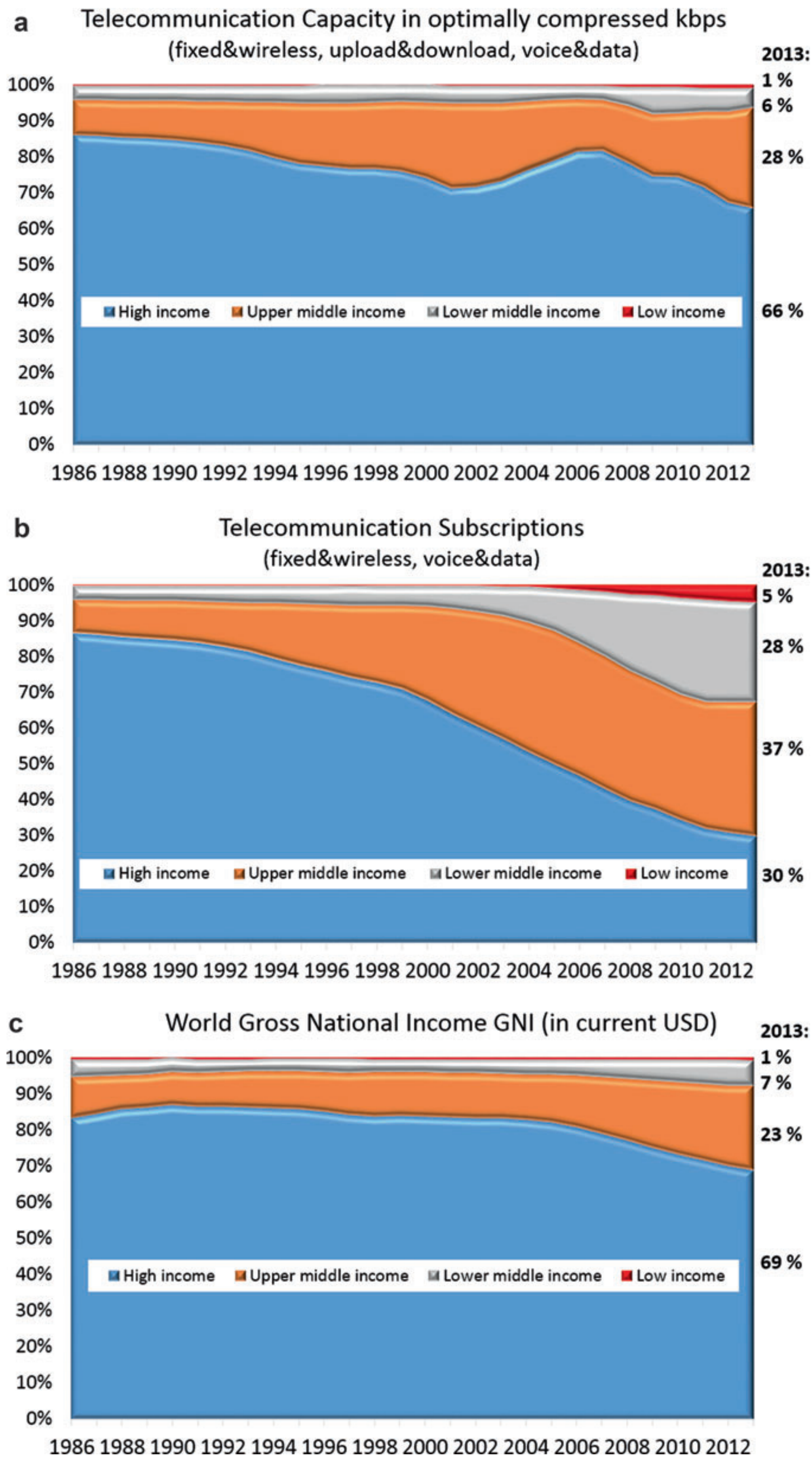
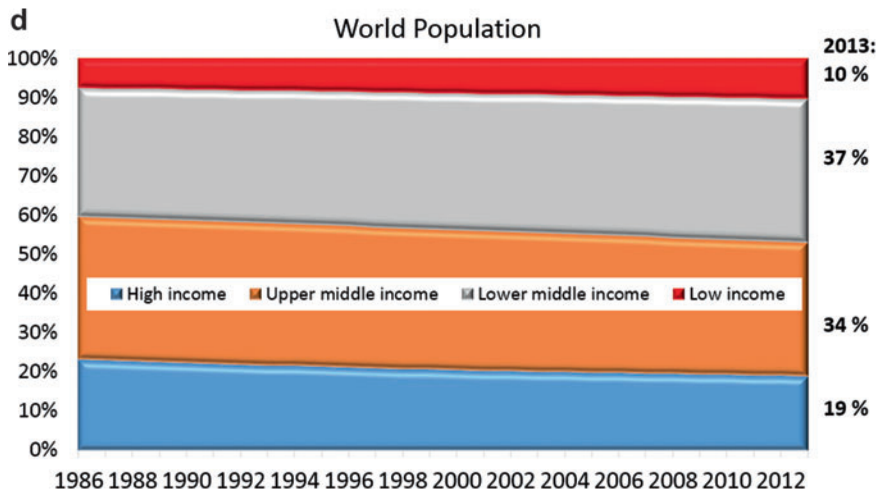
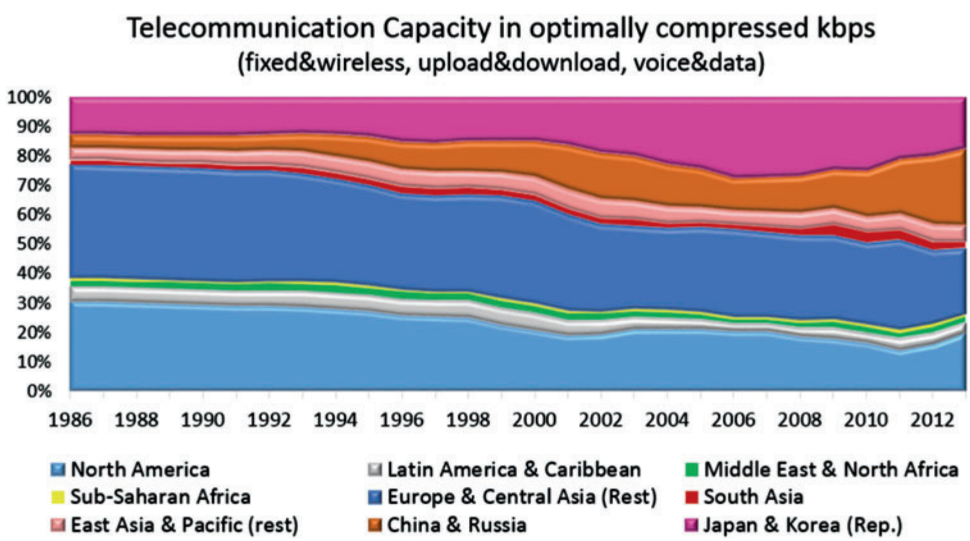


Fig. 1 (continued)



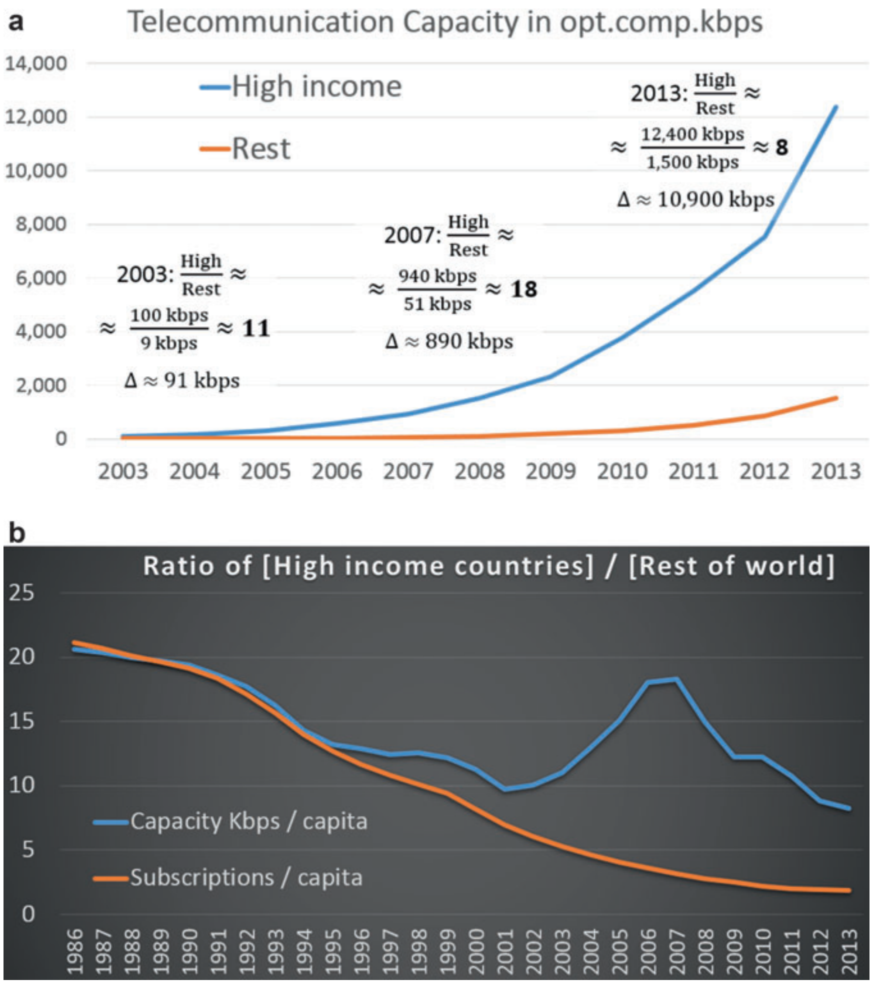
Communication Quantity, Fig. 1 International income groups: (**a**) telecommunication capacity in optimally compressed kbps; (**b**) telecommunication subscriptions; (**c**) World Gross National Income (GNI, current USD); (**d**) World population



Communication Quantity, Fig. 2 Telecommunication capacity in optimally compressed kbps per world region

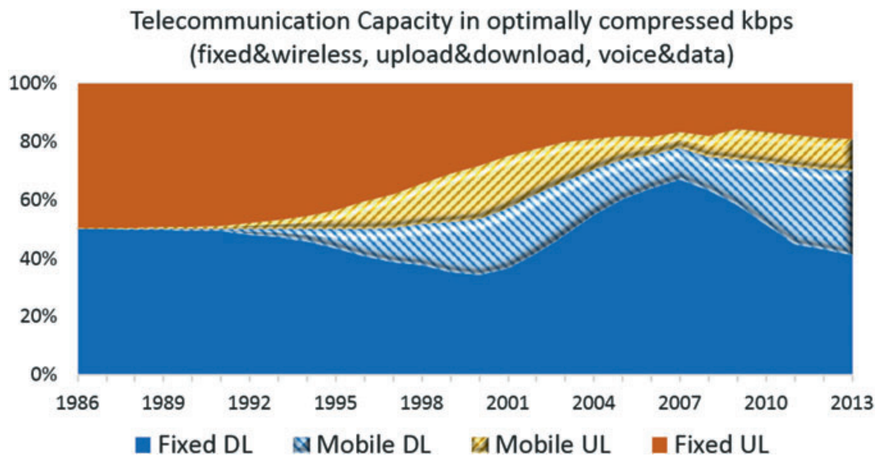
2G telephony. The increasing nature of the divide between 2001 and 2008 is due to the global introduction of broadband for fixed and mobile solutions. The most recent decreasing nature of the divide is evidence of the global diffusion of broadband. The digital divide in terms of data capacities is a continuously moving target, which opens up with each new innovation that is introduced into the market (Hilbert 2014b, 2016).

Finally, another aspect with important implications for the Big Data paradigm is the relation between uplink and downlink capacity. Uplink and downlinks show the potential of contribution and exploitation of the digital Big Data footprint. Figure 4 shows that the global telecommunication landscape has evolved from being a media of equal up- and downlink, toward to more download heavy medium. Up until 1997, global



Communication Quantity, Fig. 3 (**a**) Telecommunication capacity per capita in optimally compressed kbps: high-income groups (World Bank classification) versus rest of world. (**b**) Ratio of telecommunication capacity per capita in high-income countries versus rest of world, and of subscriptions per capita

telecommunication bandwidth potential was equally split with 50% up- and 50% down-link. The introduction of broadband and the gradual introduction of multimedia video and audio content changed this. In 2007, the installed uplink potential was as little as 22%. The global diffusion of fiber optic cables seems to reverse this trend, reaching a share of 30% uplink in 2013. It can be expected that the share of effectively transmitted bits through this installed bandwidth potential leads to an even larger share of fixed-line broadband (for more in these methodological differences, see Hilbert and López (2012a, b)).



Communication Quantity, Fig. 4 Telecommunication capacity in optimally compressed kbps per uplink and downlink

Further Readings

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