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Why the Digital Dividend will not close the Digital Divide

A major European case study highlights the problem

Technological advance makes it possible to use broadcasting frequencies more efficiently. All over the world, terrestrial broadcasting infrastructure is being updated to switch from legacy analog to digital television. For the same broadcasting coverage less spectrum is required, and a "Digital Dividend" – the freed spectrum – is to be distributed. Many options on how to make best use of these frequencies are being discussed and have to be weighed against each other.

Distribution of spectrum is further complicated by the need to provide adequate protection or alternative solutions for incumbent users affected by the change in spectrum allocation. A political goal which is driving the Digital Dividend discussion particularly in Germany, the USA and Australia is to close the so called "Digital Divide", which refers to the widening gap between people with access to the Internet and those without. Especially in rural areas, the absence of high data rate ("broadband") Internet access contributes to a widening of the gap.

In this article, we would like to answer the questions "Can the Digital Dividend close the Digital Divide or mitigate it?" and suggest, in consequence, economically feasible options for reassignment of frequencies.[1]

Digital Divide and Digital Dividend

Digital Divide: Economic and social Impact

The availability of modern information and communication technology has fundamentally changed human communication behavior and social interaction. Moreover, the possibility to overcome spatial distances in combination with the ubiquitous presence of information had a massive positive impact on economic growth, leading to the creation of the information society[2]. Information and communication technologies are essential in the process of economic growth, social interaction and enhancing the standard of living[3]. The OECD identified a positive correlation between the availability of broadband and growth in GDP[4]. In consequence, broadband was already regarded as a "General Purpose Technology"[5] in 2007. Today, being offline means being excluded from the information society. This phenomenon is referred to as the Digital Divide.

Consequences of a widening Digital Divide are harsh, not only for offliners, but for entire nations. It can not only increase social injustice, but also lead to new inequalities and distortions among the entire population. That is why there is broad consent about the fact that adequate countermeasures have to be taken in order to fulfill governmental duties of care, responsibility and preservation of equal opportunities for every member of society[6].

Digital Dividend and Options for Reassignment

Compared to analog transmission, digital terrestrial broadcasting allows the transmission of television signals with higher spectral efficiency, i.e., for the same number of broadcast television programs, only a fraction – about one third to one sixth depending on the level of compression and standard – of the spectrum

1 See e.g. D21 (2008), Digitale Dividende nutzen!. http://www.initiatived21.de/presseinformationen/ digitale-dividende-nutzen. Accessed 10th March 2010.
2 See Picot, A./Reichwald, R./Wigand, R. (2008), Information, Organization and Management. Springer. Berlin, p. 132.
3 See e.g. Pohjola, M. (2001), Information Technology, Productivity, and Economic Growth: International Evidence and Implications for Economic Development. Oxford University Press. UK. 2001.
4 See OECD (2008), OECD Information Technology Outlook 2008: Highlights. Paris. OECD Publishing. 2008.
5 See OECD (2007), Broadband and the Economy. Paris. OECD Publishing. 2007, p. 9.
6 See Kubicek, H., Welling, S. (2001). Vor einer digitalen Spaltung in Deutschland? Annäherung an ein verdecktes Problem von wirtschafts- und gesellschaftspolitischer Brisanz. in: Medien- & Kommunikationswissenschaft. 48(4). S. 497-517, p. 497.

Table 1: Comparison of Reassignment Options

	Cellular wireless communication	Other broadband services	Terrestrial broadcasting	Wireless media equipment	Consumer equipment/ WLAN
Licensing	Individual allocation/ countrywide	Individual allocation, possibly localized	Individual allocation, possibly sharing with low power devices	General authorization	General authorization
Transmission power	Medium power	Low to medium power	High power	Low power	Low power
Approximate cell radius/ communication range	<30km	<30km	50-100km	<5km	<1km

is needed[7]. This fact is known as the Digital Dividend: for the same number of television channels less spectrum is required and the respective frequencies can be made available for other uses. However, as this spectrum is a scarce good and all technologically useful spectrum has been already been assigned to a certain purpose and to specific users, if spectrum is subject to reassignment, demand usually exceeds supply[8]. Spectrum access rights are then redistributed according to a reward procedure, e.g., an auction, lead by the respective regulatory body. The time scale of such spectrum auctions and reassignment for new purposes spans from months to years. Regarding the Digital Dividend, the frequency band from 790 MHz to 862 MHz was identified for co-primary IMT use as a result of the World Radio Conference 2007[9]. To make use of this Digital Dividend, various options are discussed to redistribute the respective frequencies.

From a spectrum regulatory view point, three approaches are possible in principle: an individual allocation for a closed user group, a general authorization for public use, or a primary and secondary assignment of spectrum to both a closed user group and a general allocation (spectrum sharing).

These options can be associated with existing or new services and affect each of the market participants; some options are mutually exclusive. Five major market participants and services are under consideration: Mobile cellular communication, other broadband services, terrestrial broadcast services, wireless media equipment (wireless audio/video) and consumer equipment and wireless local area networks. The options and the possible regulatory approaches are shown in Table 1.[10]

Using the Digital Dividend to mitigate the Digital Divide

Rural areas are lacking high performance wired communication infrastructure[11]. This is not only the case in developing countries but also in industrialized nations. The Digital Dividend was identified quickly by political stakeholders with broad consent to yield the spectrum needed to provide wireless broadband Internet access in rural areas, where high wired infrastructure costs and small market size still hinder the development of broadband Internet access[12]. The major reasons brought forward to support this approach are rollout speed, convenience, and significantly reduced infrastructure cost.

The Relationship between Reach, Speed, Frequency and Transmission Power

The achievable data rate in a network setup ultimately depends on the available signal strength at the receiver and, if the signal strength if high enough, the available transmission bandwidth. The available signal strength at the

7 See ETSI standard EN 300 744, Framing structure, channel coding and modulation for digital terrestrial television.

8 See Bundesnetzagentur (2009a), Entwurf zur Anhörung - Entwurf einer Entscheidungen der Präsidentenkammer der Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen über die Verbindung der Verfahren zur Vergabe von Frequenzen in den Bereichen 790 bis 862 MHz sowie 1710 bis 1725 MHz und 1805 bis 1820 MHz mit dem Verfahren zur Vergabe von Frequenzen in den Bereichen 1.8 GHz, 2 GHz und 2.6 GHz für den drahtlosen Netzzugang zum Angebot von Telekommunikationsdiensten - Anhörung nach §§ 55 Abs. 9, 61 Abs. 1 TKG. Federal Network Agency of Germany. Bonn., p. 8f.

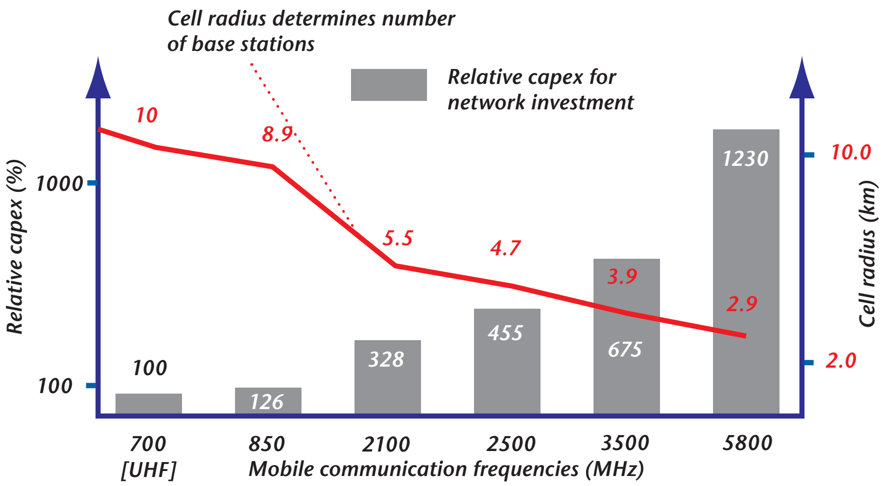
9 See ITU Radio Regulations.

10 See power allocations in Frequenznutzungsplan, Bundesnetzagentur (2008), Frequenznutzungplan. April 2008. www.bnetza.de 10th March 2010. Power and range are approximate estimates, based on current mobile communications standards. See e.g. 3GPP (2009), as above, and IEEE (2009a). IEEE 802.11, Wireless Local Area Network Working Group. http://grouper.ieee.org/groups/802/11/. Accessed 10th March 2010.

11 See Picot/Grove Picot, A., Grove N. (2009), Flächendeckende Breitbandversorgung im internationalen Vergleich: Strategien für den Glasfaserausbau in ländlichen Gebieten, Infrastrukturrecht Vol. 6, 11/2009, p.315 – 326.

12 See e.g. D21 (2008), ibidem.

Figure 1 Relative capital expenditure and required number of base stations



receiver is given by the transmission power of the base station and the distance between base station and receiver. High available signal strength and a large bandwidth allow for high data rates. In consequence and under the assumption of constant transmission power, high data rates are possible close to the transmitter, while the achievable rate declines with distance. Most importantly, if the wireless standard is cell-based, which implies that all receivers listen to a base station, the transmission bandwidth has to be shared among all users in the coverage area of a cell[13]. This directly leads to another aspect of the relationship between reach and speed: if the cell has to serve a high number of users, the individual data rate is low. For a given wireless standard, the maximum traffic per cell is constant. This is why cell density and cell size are directly related to user density.

Another aspect to be taken into account are the frequency dependent propagation characteristics of electromagnetic waves. Generally speaking, higher frequencies propagate worse in space for omnidirectional communication and suffer higher attenuation by physical objects[14]. Hence, for large cells lower frequencies, e.g., frequencies in the UHF band, are better suited.

On the other hand, higher frequencies allow a more focused or directed emission of radiation, making them ideal for use in areas with high user and hence cell density. Figure 1[15] shows the number of base stations required for mobile operators to cover an area of 314 km², which can be achieved with a single cell of 10 km radius at 700 MHz. At 5.8 GHz, approximately 12 cells of 2.9 km radius are needed for the same coverage[16]. These cells are, however, able to support 12 times more users. From an MNOs viewpoint, the Digital Dividend frequencies are hence especially suited for large cell sizes and at comparatively low user density.

The fourth and last aspect which influences reach and speed of wireless links is the transmission power allowance for the allocated frequency range. This factor does not only influence directly the maximum distance between sender and receiver, the transmission power moreover correlates negatively with the bandwidth available per region and user.

In addition, wireless broadband technologies are inherently less reliable due to the physical nature of the free space propagation of electromagnetic waves compared to wired technologies. Transmission speeds have historically been slower by orders of magnitude. On short range (several meters to several dozen meters), wireless transmission with comparatively high data rates - several hundred MBps to several GBps – will be possible in the near future with technologies based on the IEEE 802.11 (WLAN) and IEEE 802.15 family of standards[17]. It is, however, much harder to attain data rates in the order of 100 Mbps and faster in omnidirectional cell-based communication access networks.

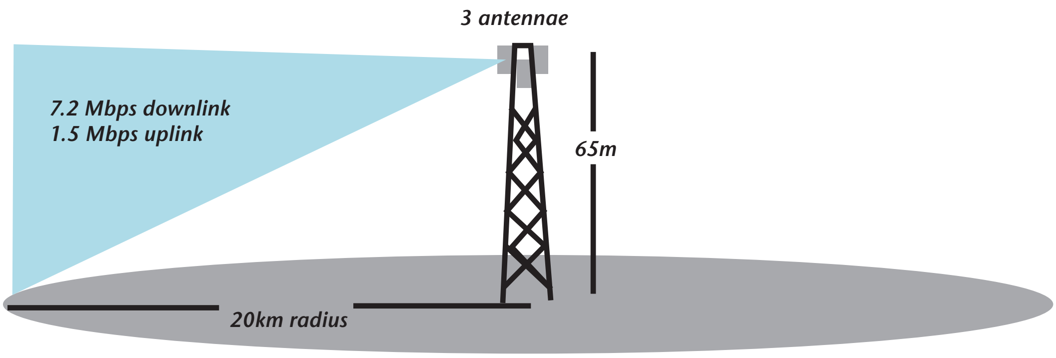
Summing up, the relationship between reach, speed, frequency and transmission has the following basic implications: When using the Digital Dividend for broadband access in rural areas, a high transmission power allowance (or large cell size in a cellular network) will provide the potential to overcome wide distances and provide even remote households with Internet access. The price to be paid for the high level of coverage is the data rate individually available. As explained above, the data rate available per user will be low, as a reuse of frequencies is not possible in wide areas.

13 See Geng, N., Wiesbeck, W (1998). Planungsmethoden für die Mobilkommunikation. Springer.

14 See Geng/Wiesbeck (1998), ibidem.
15 According to Krämer, M. (2009), Die Evolution von Mobilfunknetzen in Deutschland im Rahmen der Digitalen Dividende- Die Sicht von E-Plus. Presentation at 10th ZFTM Workshop. 6th of May 2009. Duisburg and Forge, S., Blackman C., Bohlin E. (2007). The Mobile Provide - Economic Impacts of Alternative Uses of the Digital Dividend. Study of SCF Associates. Bucks, p. 9.
16 See Forge/Blackman/Bohlin (2007), ibidem, p. 8f.

17 See IEEE 802.15 WG.

Figure 2 Wireless broadband pilot setup in Grabowhofe



Case Study: Wireless Broadband in Grabowhöfe, Germany

The theoretical analysis showed major restrictions for wireless broadband provisioning. By combining these theoretical results with information gained from the first pilot project in Grabowhöfe, Germany, valuable implications for the future use of the Digital Divide spectrum can be derived.

Project Description

Grabowhöfe is a small town located in Mecklenburg-Western Pomerania, Eastern Germany. It consists of 1065 inhabitants living on 31.12 km^2 [18]. Broadband wired access is not available there yet.

Project Realization[19]: Three project partners, the Ministry of Economy, Labour and Tourism of Mecklenburg-Western Pomerania, the E-Plus Mobilfunk GmbH & Co KG and the Ericsson GmbH created a joint pilot project in order to test the feasibility of the Digital Dividend for serving broadband to rural citizens. 50 test users in Grabowhöfe were selected in order to test the wireless broadband access in a testing period lasting until the beginning of 2010. The service and the equipment required for usage are provided free of charge to the participants. In consequence, the pilot project also provides insights about the demand side, which can be matched with the data of wireline broadband access technologies.

Technical Specification[20]:The infrastructure consists of three antenna arrays, located on one existing mast owned by E-Plus Mobilfunk GmbH & Co KG. The broadcast equipment used is provided by Ericsson and mounted at the radio mast in a height of 65 meters. The coverage of this setup is a maximum area of 20 kilometers around the radio mast[21]. A schematic view of the setup is shown in Figure 3.

The frequencies used are in the range of the Digital Dividend from 790 MHz – 862 MHz. Based on the UMTS HSDPA technology of Ericsson, data rates of 7.2 Mbps uplink and 1.5 Mbps downlink per user are realized.

Project Evaluation

The project has to be evaluated from two perspectives, including the acceptance and usage by participating consumers and the technological capacity possible. This allows deriving conclusions for the feasibility of a nationwide rollout in rural areas.

From the consumers' perspective, E-Plus Mobilfunk GmbH & Co. KG reported usage figures effective from April 2009[22]. The majority of the test users are online daily, some with several sessions per day. A maximum of 20 active users per day was measured. A total of 60 GB data of traffic were generated, which equals an average of 1.4 GB

18 See Destatis (2006), Grabowhöfe. http://www.destatis.de/jetspeed/portal/cms/Sites/destatis/Internet/ DE/Content/Statistiken/Regionales/Gemeindeverzeichnis/NamensGrenzAenderung/Aktuell/2005,property=file.xls. 10th March 2010 and Amt Seenlandschaft Waren (2009), Gemeinde Grabowhöfe. http://www.amt-seenlandschaft-waren.de/gemgrabo.html. 10th March 2010.

19 According to expert interviews, Bach, C. (2009), Nutzung von Frequenzen aus der Digitalen Dividende zur ländlichen Breitbandversorgung. Speech at eco Forum. 11th May 2009 and Krämer (2009), ibidem.

20 According to expert interviews, Bach (2009), ibidem, and Krämer (2009), ibidem.

21 See Bach (2009), ibidem.

22 See Krämer (2009), ibidem.

Table 2: Maximum parallel Service Use in Grabowhöfe, own calculation

Service	Maximum parallel # users (%)	Restriction
Email	15 (4%)	Upstream
Electronic payment processing	120 (34%)	Upstream
Updates	7 (2%)	Downstream
File exchange	1-2 (1%)	Upstream
WWW	72 (20%)	Downstream
VoIP	120 (34%)	Upstream
Videoconferencing	15 (4%)	Upstream
Telework/home office	1-15 (1-4%)	Upstream/downstream
Other:		
Online video (YouTube) ***See Youtube (2009) Systemvorau-setzungen, http://help.youtube.com/support/youtube/bin/answer.py?hl=de&answer=78358. Accessed 10th March 2010.***	45 (10%)	Downstream
HDTV ***See Tandberg (2007), TANDBERG lowers bit rate for IPTV content delivery. http://broadcastengineering.com/infrastructure/tandberg-lowers-bit-rate-iptv-content/. Accessed 10th March 2010, delivering 720p at below 6MBps in MPEG-4.***	10 (3%)	Downstream

per user within the first three weeks. Regarding connection speeds, the majority is below 3 Mbps, only some can get data connections with more than 3 Mbps.

Matching Theory and Reality: Shortcomings from Grabowhöfe

The first results from Grabowhöfe sound impressive. Unfortunately, there are compelling reasons why using the Digital Dividend to close the Digital Divide is merely a drop in a bucket.

First, the user behavior of the pilot project in Grabowhöfe does not represent average user behavior at all. The traffic generated per user added up to approximately 1.9 GB per month[23]. Compared to a city based broadband user, who generates approx. 9.2 GB[24] on traffic per month, this equals less than one fifth. The distortion might be caused by two major factors: lack of knowledge and time lag effects. Further research including traffic protocols would be required in order to prove these hypotheses.

Second, the capacity restrictions probably already have a negative effect on user behavior. These effects might not have been observed during the period under survey. From an entirely economical point of view, the pilot project is not even able to provide the services defined and qualified by the Ministry of Economy, Labor and Tourism of Mecklenburg-Western Pomerania to all participants of the pilot project. According to their predefined requirements, e.g. only two services - electronic payment and VoIP with a capacity of 128 kBps - require a connection with less bandwidth than 1 Mbps[25]. Comparing these figures to the project setup, major shortcomings can be identified. To show this, the theoretical maximal data rate of the area is calculated and matched with the parallel use of exemplary services in the following.

To extend broadband services from a technological perspective, to the entire population of Grabowhöfe, the service will be calculated at a user base of the 1065 inhabitants. Each of the three antennas is providing 7.2 Mbps in downstream and 1.5 Mbps in upstream direction to 10 users maximum in parallel. Assuming an equal distribution of the population in Grabowhöfe, one antenna is hence assigned to one third of the population under perfect conditions. This results in a maximum total throughput for 355 users of 72 Mbps downstream and 15 Mbps upstream, respectively.

According to the minimum requirements provided by the Ministry, this allows maximum parallel service use according to Table 2. For sure, not all inhabitants will probably watch IP-based HDTV at the same time. But it does not even need the World Cup on IPTV to bring Grabowhöfe to its capacity limits. Whereas 15 users, equaling 4% of the total population, are still able to use e-mail in parallel, only seven users

23 Linearly interpolated from 1.4 GB in 3 weeks.
24 See Gerpott, T.J. (2008). Zehnte gemeinsame Marktanalyse 2008. Dialog Consult/ VATM.

25 See Tavangarian, D., Krohn, M., Scheil, D., Brozio, L. (2008). Breitbandzugang zum Internet in Mecklenburg-Vorpommern. Study on behalf of the Ministry for Economics, Labour and Tourism Mecklenbourg-Western-Pomerania. 2008, p. 6.

(2%) can start an auto update at the same time. When it comes to HDTV, only ten users (3%) can watch a high definition video stream at the same time. The biggest impact has been on telework, which is seen as one of the major benefits for rural broadband provisioning. However, the pilot project does not even fulfill its bandwidth requirements of 10 Mbps per user in upload for more than one user.

The situation is further exacerbated by the fact that excessive usage by one user has negative external effects on the other users due to the single shared medium described earlier. At this stage, it becomes even more obvious, that if the requirements defined by the government cannot be met, the project does not provide broadband services to the citizens in rural areas.

Looking into future development, the wireless broadband coverage via HSDPA does not qualify to be future proof. The next wireless standard to be deployed is LTE, which promises to offer 170 Mbps downstream per cell by the end of 2013[26]. Again, these 170 Mbps are shared among the users connected to the base station and do not meet at all today's and future demand for bandwidth at all.

Conclusions and Outlook

As the analysis did show, the pilot project in Grabowhöfe does not provide city comparable Internet access to its citizens as a matter of fact. As the calculation has shown, the maximum wireless bandwidth available will not suffice in order to get more than 10 per cent of the citizens of Grabowhöfe online with a connection comparable to a modern, city-like, broadband access connection.

The existing gap between those with access to high performance Internet access and those with only access to a shared medium will not shrink; it will even become wider in the future. It is questionable, if public funding should be used for a service provisioning with a technical solution, which cannot offer at the predefined requirements from the Ministry. Thus, by installing a bandwidth restricted shared medium today, the necessary funding for the required high performance infrastructure in cities will be sunk and not available for the installation of city comparable broadband access infrastructures.

Furthermore, the proposed concept by the German regulatory body to give the Digital Dividend to the MNOs includes the requirement to serve rural areas first, in order to make use of these frequencies within population dense areas[27] has to be put in question. Unfortunately, this restriction decreases MNOs' incentives to invest in infrastructure in general, as the MNO will wait for an additional investment incentives into infrastructure in cities until additional revenues will not only exceed costs in cities, but also in rural areas. This is also a reason why the outcome of the Digital Dividend auction in Germany in May 2010 only resulted in comparably low biddings of a total of Euro 4.4 bn[28].

Another option to be considered is the allocation of the Digital Dividend to short range communications in order to connect inhouse communications equipment and serve as a local loop alternative at the same time. In short range communications, significant frequency assignments for WLANs are currently available only at frequencies in the GHz range. Attenuation in these frequencies is high, and it is difficult to establish inhouse connections through several walls. Therefore, lower band frequencies of the Digital Divide would be more convenient. Examples for short range high performance communications are wireless connections capable of HD video or uncompressed wireless audio and would help to create an entire new market.

Summing up, higher returns from handing over the Digital Dividend to MNOs without any restriction could be used to subsidize wired broadband rollouts in rural areas. A Digital Dividend should either be auctioned to the existing mobile phone operators to make this bandwidth available on mobile networks or be made available under a general authorization to allow operations of WLAN comparable standard for local communication with a two range approach. A use for the primary broadband provision in rural areas has been rejected.

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26 See Bach (2009), ibidem and Bundesnetzagentur (2009b), Eckpunkte über die regulatorischen Rahmenbedin-gungen für die Weiterentwicklung moderner Telekommunikationsnetze und die Schaffung einer leistungsfähigen Breitbandinfrastruktur – Konsultations-entwurf – Stand 13.05.2009. Federal Network Agency of Germany. Bonn., p. 8.

27 See Bundesnetzagentur (2009a), ibidem, p.8 and 39f.

28 See Bundesnetzagentur (2010), Frequenzversteigerung in Mainz beendet, press release of 5th of May 2010.