Why the Digital Dividend will not close the Digital Divide

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Abstract - The changeover from analogue to digital terrestrial TV made a wide range of frequency spectrum available for redistribution. This fact is known as the "Digital Dividend". Many options on how to make best use of these frequencies are being discussed and have to be evaluated. Spectrum redistribution is further complicated by the need to provide adequate protection or alternative solutions for incumbent users affected by changing spectrum allocation. Moreover, many stakeholders are engaged in the Digital Dividend discussion, with quite contrary positions. Broadcasters see new opportunities for terrestrial broadcasting and would like to offer new services such as HDTV, which requires much more bandwidth. Mobile network operators argue that these frequencies are desperately needed to satisfy the rising demand of mobile data services. Many additional interest groups, like wireless microphone manufacturers, WiMAX deploying companies and others are claiming their rights on these frequencies as well. A major political goal, which is driving the Digital Dividend discussion particularly in Germany, the USA and Australia, is the “Digital Divide”. The term “Digital Divide” refers to the absence of high performance broadband connections in remote rural areas. It is envisioned especially by politicians to use the spectrum made available by the Digital Dividend to close this divide and deliver high-performance internet access by wireless broadband deployment in rural areas. This approach is apparently advantageous, as it seems to solve an urgent socioeconomic problem. However, it suffers from a major issue, inherent to wireless communications: a physically shared medium. The nature of the shared medium and the trade-off between reach and speed significantly limit scalability of the network. Given current growth rates of transmission demands, a wireless broadband access network covering large areas will be likely outdated before being deployed. A case study analysis of a pilot project in Germany backs the finding that the Digital Dividend cannot adequately solve the Digital Divide problem. From a policy viewpoint these issues should be treated separately. The Digital Dividend can improve mobile access to the internet but will not be able to scale with the development of wired networks – the Digital Divide will remain. An alternative approach of using the Digital Dividend for partially a) basic mobile online access (which will as proven not be broadband under any current or future definition) and b) for short range communication under a general authorization is introduced. Due to the specific physics of electromagnetic wave propagation this has the potential to significantly improve the "last mile" problem of network access.

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1. Introduction

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 needed, a “Digital Dividend” – the freed spectrum – is to be distributed. The discussion about who should claim these new spectrum opportunities is at its peak. 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.

This paper focuses on the ability of the Digital Dividend to close the Digital Divide with special regard to those rural areas.

1.1. Research Question and Approach

The intended use of the Digital Dividend dominates political and economical discourses. For many politicians it is quite clear that the free spectrum has to be used specifically to deploy broadband to rural areas in order to integrate the entire nation into the information society[1]. For others, these frequencies should be given to the mobile network operators (MNOs) in order to increase bandwidth and hence capacity of the network[2]. Next to these opinions, many stakeholders are concerned about their legacy rights or want to gain access rights to the frequencies to improve existing or offer new services. As use of electromagnetic spectrum for specific services can be exclusive and has effects on other wireless services, the decision about the Digital Dividend influences public and private interests and even overall welfare. The main question of this paper is the following:

Can the Digital Dividend close the Digital Divide?

In order to contribute to the question of how the Digital Dividend should be used economically efficiently, two sub questions shall be answered within this paper:

1. *How much capacity does the Digital Dividend offer for broadband Internet access?*
2. *Does an economically superior use for the Digital Dividend exist instead?*

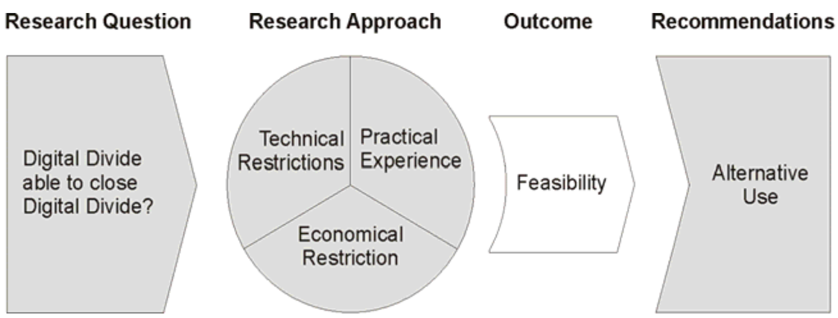

Figure 1: Research Approach

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1 See e.g. Picot (2009b), p. 4

2 See e.g. Bach (2009)

The first question sheds light onto the political believe that the Digital Dividend does contain enough capacity to serve people in rural areas with comparable speed and quality as offered in urban areas. The second question provides recommendations for the future intended use of the free frequency range[3]. The overall research approach is depicted in Figure 1.

To answer the main research question, a threefold approach is required. First, a theoretical analysis identifies the politico-economical necessity to close the Digital Divide. Second, a technical feasibility analysis evaluates the capacity of the Digital Dividend to provide broadband Internet access. Third, a pilot project is analyzed. The findings support the hypothesis that the Digital Dividend is not sufficient for the provisioning of rural broadband, unable to offer city comparable broadband services[4].

1.2. Related Research

With respect to the Digital Dividend, existing research focuses on the rearrangement of frequencies and assigned services, as well as legal and financial applicability to rural areas. Börnsen (2008) and Neumann (2008) come to the conclusion that a wireless network operation in rural areas is economically and legally feasible with the Digital Dividend frequencies. However, the paper at hand takes a contrary position to this existing research.

Regarding the Digital Divide research, e.g., by Torero/von Braun (2006), Warschauer (2004) or Prahalad and Hammond (2002) identifies the necessity to offer broadband in rural areas, especially in developing countries. Recently this has become an issue for industrialized countries, too.

Gilder (1994) suggests not to give exclusive rights to spectrum usage to anyone for the benefit of innovation. Based on Gilder, McGartey and Medard (1994) come to the conclusion that a steady review is required for new technologies, which potentially leads to a better spectrum usage by reallocation[5]. However, we are not already technologically that far, that we can entirely follow Gilder, avoiding any-kind of individual allocation[6].

1.3. Structure

Research question and approach were outlined in this Section. Section 2 describes the Digital Divide phenomenon and the relevance of broadband for economy and society. After introducing the Digital Dividend and major options for spectrum reuse currently in discussion in Section 3, the use of the Digital Dividend for wireless broadband Internet access is analyzed from a technological viewpoint in Section 4. Capacity estimations of the Digital Dividend are contrasted within a case study with current and expected future bandwidth demands. Based on these results, an alternative use of the Digital Dividend is presented in Section 5. Finally, a conclusion is given in Section 6.

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3 See e.g. D21 (2008)

4 See DBCDE (2009)

5 See McGartey/Medard (1994), p. 23

6 See Gilder (1994), p. 112 and McGartey/Medard (1994), p. 29

2. Digital Divide

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 and lead to the creation of the information society[7]. Daily news, entertainment, networking, product information and ordering as well as public transport schedules or holiday planning and booking – just to give some examples – are common information services the majority of citizens of industrialized nations consumes via the Internet[8]. Some of these services are entirely and only available online. In consequence, being offline means being excluded from the information society. This phenomenon is referred to as *Digital Divide*. Its economic and social effects are described in the following.

2.1. Definition

The Digital Divide phenomenon was identified more than 10 years ago. Since then, there has been broad consent that this effect intensifies existing social imbalances and creates new unfairness within and for the society. According to Hoffman/Novak (1998) the term Digital Divide was coined by Lloyd Morrisett, former president of the Markle Foundation[9], who used it to describe a gap "between information 'haves' and 'have-nots'."[10] Welling (2000) refers to the *Digital Divide* as the difference in Internet usage between various groups of the population with identical socio-demographic attributes (e.g. gender, income, education). Consequently, some specific population groups, compared to the entire population, are accessing the Internet significantly less than others[11]. Recently, the term Digital Divide is used in a broader sense by Jackson et al. (2008) to describe the gap in intensity and nature of Internet usage.

In this paper, Digital Divide refers to the gap between the population with access, respective skills and usage patterns of the Internet and those without.

Internet usage correlates – positively or negatively - with income and education, but also gender and age[12]. In the case of Germany, the Internet usage of women in 2007 was 13.3 per cent below men. Age above 60, unemployment, and a net income below 1000 € per month are significant risk factors for being offline[13].By far the biggest influence factor for Internet usage, however, is the availability of broadband Internet access itself.

While the Internet was largely text based in its first decades, today's´ Internet is an integrated multimedia information service with pictures, audio and video information. For communication and collaboration, a broadband access is a prerequisite. Major institutions have updated their broadband definitions from several hundred kBit/s to 2 Mbit/s[14] and higher. This might currently suffice for most services, but will not hold for the near future. As history showed, bandwidth demand was always positively related to bandwidth supply and will continue to grow with the availability of new and innovative services. Recent developments in the field of social communities and collaboration systems additionally show the need for a significant amount of upload capacities, increasing demand for a symmetrical broadband access[15]. Today, low data rate internet access is equal to having no access at all.

Quite oddly, the problem of lacking broadband access exists not only in developing countries. Looking at industrialized nations, in areas of high population density – and hence high customer density – broadband Internet access is typically available and affordable for all social classes. In sparsely popu-

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7 See Picot/Reichwald/Wigand (2008), p. 132

8 See Picot (2009a)

9 See Markle (2009)

10 Hoffman/Novak (1998), p. 2

11 See Welling (2000), p. 1

12 See Jackson et al. (2008), p. 437 and Gerhards/Mende (2008)

13 See Gerhards/Mende (2008)

14 The ITU (2003) defines broadband as 1.5 – 2.0 MBit/s, the OECD (2009) as 256 kBit/s, and the FCC as 768 kBit/s to 1.5 MBit/s, according to Martin (2008)

15 See Picot (2009a)

lated areas, however, such broadband connections are not readily available[16]. This lack of broadband access is the major cause of why the level of "offliners" has not reduced faster in recent years and persists at a high level[17].

The absence of communication infrastructure has massive negative effects on the economy and the society as a whole. These effects can be observed even better in developing countries, where communications infrastructure penetration levels are far behind industrialized nations. In the end, the same time lag effects, developing countries have in the overall penetration in access to communication technologies can be compared to the gap between the people in industrialized nations with broadband access, and those, living in rural areas without. Torero and von Braun did prove that the willingness to pay for communication services in rural areas in developing countries is even higher than the normal price levels within cities[18]. Results can be transferred to rural areas in industrialized nations.

2.2. Economic and social Impact

Information and communication technologies are essential in the process of economic growth, social interaction and enhancing the standard of living[19].

The OECD identified a positive correlation between the availability of broadband and growth in GDP[20]. In consequence, broadband was regarded to be a "General Purpose Technology"[21] already in 2007. Specific case studies from, e.g., Lehr et al (2006) show substantial positive effects by the availability of broadband to growth in employment, growth in rents and even a significant positive effect on the number of new business establishments in the United States. These results are drawn from a regression model based on the data of the FCC for the United States between 1998 and 2002[22].

It has to be stated that broadband by itself does not lever an economy. It acts as a complementary technology to other information technologies[23]. For example, a broadband access does require a personal computer system and proper skills to use the combination of product and service. This is also the reason, why the availability of e.g. ICT (Information and Communication Technologies) equipment and content are important levers for the broadband penetration and vice versa. That is why network effects play an important role in the Digital Divide phenomenon, too[24].

Greenstein/McDevitt (2009) observed 29 billion USD in total revenues for Internet access in 2006, creating another 8.3 to 10.6 billion US$ in new GDP as direct effect of the availability of broadband. But furthermore, they show that another 4.8 to 6.7 billion USD in consumer surplus was created, which is not directly quantifiable by regular GDP calculation[25].

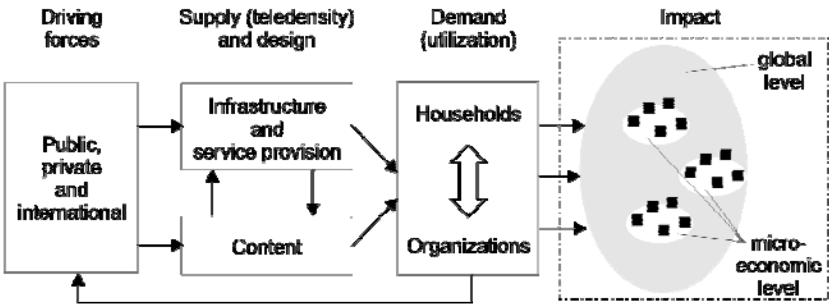

Figure 2: Framework for Broadband Demand, Supply and Impact[26]

[16] See e.g. BMWi (2008), or ACMA (2008), p. 8
[17] See Gerhards/Mende (2008)
[18] See Torero/von Braun (2006)
[19] See e.g. Pohjola (2001)
[20] See OECD (2008),
[21] See OECD (2007), p. 9
[22] See Lehr et al. (2006), p. 12 - 15
[23] See Lehr et al. (2006), p. 4
[24] See Picot/Reichwald/Wigand (2008)
[25] See Greenstein/McDevitt (2009)
[26] According to Torero/von Braun (2006), p. 22

Torero and von Braun (2006) describe the effects of information and telecommunication technologies on a global level as indicated in Figure 2. The figure tries to value the indirect effects of the availability of broadband, which is even harder to measure. Despite the direct impact of broadband on the GDP, the driving forces of infrastructure and service provision as well as content can be either of public or private origin, generated on national or international level. In a next stage, the availability of broadband and/or the content have a direct effect on the demand on business and private consumers. In consequence, both impacts of being online have two effects, one on the household/organization itself, and the other created by network effects on global level. Additionally, the household impact has a positive effect on global level and, again, vice versa. These impacts include positive effects on employment, wealth, education, skills and quality of labor force, community participation and quality of life[27].

The latter facts focus on the social perspective of broadband. E-Mail, instant messaging and social communities already have the same relevance as the telephone. For sure, especially these indirect effects are hard to measure, however, the presence of ICT infrastructure in developing countries is positively correlated to Foreign Direct Investment (FDI), education and access to education. In industrialized nations, the younger generation of today is already planning and organizing their private live with "web 2.0" applications[28]. Leaving the ongoing discussion about the meaningfulness of these social communities aside, it's a matter of fact, that, e.g., *facebook* is used by more than 100 million users per day actively[29]. One could imagine a school class, where the pupils organize their spare time activities online. One child lives in a rural place, where broadband Internet access is not available yet and in consequence, she is not able to communicate online via a social online community. Being excluded from a broadband connection to access a social community platform leads sooner or later to social exclusion.

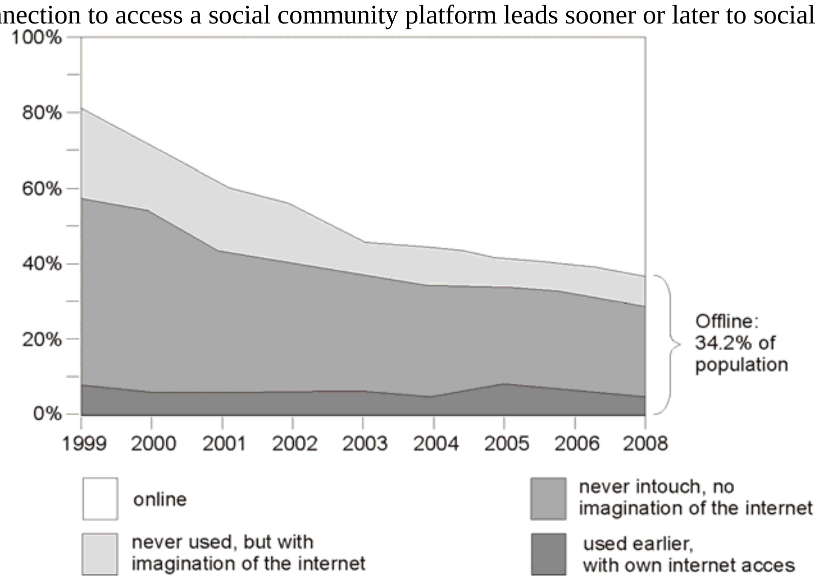

Figure 3: Digital Divide in Germany[30]

Major disadvantages for those without online activities were described recently in the *Handelsblatt*, heading an entire page *"Virtuell überfordert, real im Abseits"* (transl. "Out of the virtual world, out of the real world")[31]. Beside the communication services described above, browser based software[32] or services like e-learning, e-home or e-health bring additional comfort into home and live. Moreover, financially it does not pay off to be offline. For example, airlines charge additional fees for offline bookings and the Deutsche Bahn AG started an approach of introducing offline service fees in 2008[33].

For Germany, the ARD/ZDF Offliner Studie 2008 shows 34.2 per cent of the population without any access to the Internet, thereof 22.4 per cent which have never been in touch with the Internet at all[34]. A detailed overview of so called "offliners" is shown in Figure 3.

27 See Torero/von Braun (2006) and Lehr et al (2006), p. 6
28 See Pick/Azari (2008), p. 112 or More at al. (2002)
29 See Facebook (2009)
30 Data from Gerhards/Mende (2008)
31 See Hofer (2009), p. 11
32 See Buxmann/Hess/Lehamnn (2008), 500ff.
33 See Deutsche Bahn AG (2008)
34 Data from Gerhards/Mende (2008)

Taking these data into account with the lacking availability of broadband or even Internet access at all in rural areas, a linkage can be established as follows: 72 per cent of the German population live in cities, 28 per cent live in rural areas[35]. A coincidence with the matching figure of 22.4 per cent above cannot generally be ruled out.

In Germany, rural areas suffer already from the migration of young workers to cities, leading to a rural exodus. This rural exodus, or so called devastation is principally caused by incorrect political decisions regarding the provision of modern and future-proof communal patterns and infrastructure[36]. This effect is intensified by the fact that high performance communication infrastructure is regarded today as a matter of course, when it comes to location and investment decisions of firms and workers[37]. If broadband infrastructure is not available, this results in a location disadvantage which cannot be compensated by other factors[38]. Even more so, it is important to spread broadband to rural schools, libraries and other public institutions in order to comply with the demands on the job market[39]. Recently, Jackson et al (2008) could prove that the time using computers and the Internet is a positive predictor of academic performance[40]. Furthermore, the presence of broadband drives innovation. And that is why lagging behind when it comes to broadband internet access can develop into a vicious circle for a certain region which is even harder to break for developing countries[41]. Access to broadband will improve especially the economic plight of developing countries[42]. This is not only why, especially for rural areas, the availability of broadband access is of major importance in order to compensate for existing disadvantages.

Consequences of a widening Digital Divide as shown 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's why there is broad consent on 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 the society[43].

Summing up, the biggest lever to get rid of the Digital Divide gap will be the availability of a broadband connection in general. "Leaving regions out of the digital economy is not an option."[44] Being online means being part of the community, of communications, of education and many more; in the end being online means participating at the knowledge economy. And being offline leads to exclusion.

"Rather than spending considerable amounts of money on governmental or other "high level" conferences simply to talk about the digital divide, and repeatedly study the phenomenon, one would be better advised to create conditions for these efforts to concretize, and provide the necessary support for the networks to take off and grow."[45]Therefore the problem of access has to be solved first. Additional measures can be taken afterwards, like education, usability or reduction of technology adversity.

2.3. Countermeasures

The rural availability of broadband, adequate personal abilities and demand for using Internet services can be compared to the old "chicken and egg" problem. The one group of experts argues according to Gilder that supply will drive demand for broadband[46]. The other group is in favor of establishing appropriate skills and knowledge about the Internet, which will result in an increased demand for broadband access[47].

Regarding skills and competence for using Internet services, the German Government started in May 2009 the initiative "Internet erfahren", in order to help people getting in touch with the Internet

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35 See Destatis (2009): 59 million people live in 2065 cities with more than 1.000 inhabitants.
36 See Klüter (2005)
37 See Büllingen/Stamm (2008)
38 See Holznagel/Deckers (2009)
39 EP (2000) and BMWi (2009), p. 7
40 See Jackson et al (2008), p. 440
41 See James (2008), p. 59
42 See Fink/Kenny (2003), p. 15
43 See Kubicek/Welling (2001), p. 497
44 Reeding (2007), p. 2
45 Menou (2001), p. 6
46 See Gilder (1997), p. 12
47 See BMWi (2009)

and to overcome inhibition thresholds, which are seen as an initial cause for not being online[48]. Other projects are targeting the supply side in order to provide broadband access in areas, where it is not available yet. An example is the *Breitbandinitiative Bayern*, which encourages bringing broadband access to small villages and towns with a funding of 19 million EUR[49].

For this analysis, the authors follow the assumption that availability drives demand. In general, this hypothesis is supported by Gilder's law, which proves that bandwidth demand is driven by bandwidth supply[50]. The theory is confirmed by looking at site decisions for companies but also for private households. Companies are not settling in commercial areas without Internet access, they even more require high bandwidth capacity networks for the connection to their WAN services. Even for private households, there is a difference in rent prices for flats with and without broadband Internet.[51].

Several initiatives started recently to cover the white spots in rural areas and provide the people there with an adequate access to the Internet[52]. Whereas a minority focuses on wireline connections, the major share has started to argue in favor of wireless Internet access. Major reasons brought up in the discussions pledge for wireless deployments for the sake of speed, cost and simplicity of implementation.

Technically speaking, areas without DSL, Digital Subscriber Line, availability on the local loop phone line are to be covered with a wireless broadband network. People then can access the Internet via wireless devices like a notebook card or a router consisting a wireless-to-wireline element, which then connects the home network. Specific technologies like WLAN, WiMax, or UMTS for wireless broadband access are introduced in the following section.

Especially for developing countries, wireless broadband access seems to be a good solution. But for industrialized nations some question are still open and will be looked in detail in the following.

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[48] See BMWi (2009)

[49] See STMWIVT (2009)

[50] See Picot/Reichwald/Wigand (2008), p. 147

[51] See Cisco Systems (2009)

[52] Examples are the Breitbandinitiative D21, Breitbandinitiative Bayern, Breitbandinitiative Rheinland-Pfalz

3. Digital Dividend

Compared to analog transmission, digital terrestrial broadcasting allows transmitting television signals with higher spectral efficiency, i.e., for the same number of broadcast television programs, only a fraction – about one third to one sixths depending on the level of compression and standard – of the spectrum is needed[53]. This fact is known as the "Digital Dividend": for the same number of television channels less spectrum is needed and the respective frequencies can be made available for other uses. Figure 4 shows the current frequency assignment – after switchover to digital television – in Germany.

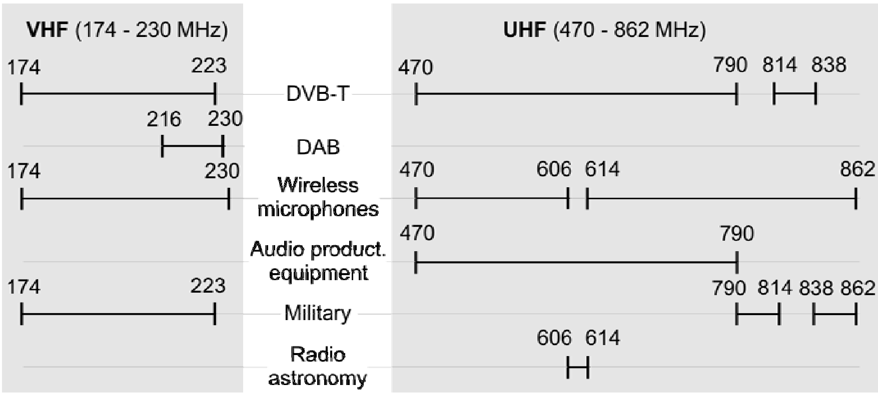

Figure 4: Spectrum utilization in the VHF and UHF bands in Germany[54]

While the switchover from analog to digital terrestrial transmission is underway in most countries of the world, the actual size of the Digital Dividend depends on national choices. Only a small part of the Digital Dividend, namely the spectrum between 790 MHz and 862 MHz, has been identified by the ITU for co-primary IMT applications in the medium term[55]. Depending on the number of terrestrial television stations and frequency planning in a given country, this leaves a major part of the Digital Dividend to national choice. Before evaluating the possible options for reassignment, some principal remarks about spectrum regulation are in order.

3.1. Spectrum Regulation: Spectrum as an economic Good

The state limits and controls private economic actions through regulation. In contrast to other laws, regulation has a limited scope and concerns only a specific part of the economy; it is sector specific. The telecommunication sector is subject to market and technical regulation[56]. As part of this technically regulation, spectrum regulation is regulation of the right to access to the electromagnetic spectrum[57]. Spectrum regulation controls directly or indirectly, who, at a given location and point in time, is allowed to emit electromagnetic waves of a certain frequency and power. Spectrum regulation hence consists of purely technological rules, whose objective is governed by political, social and economic considerations.

The right to access spectrum, or loosely speaking the "right to spectrum" itself, is an economic good as it can be used to communicate wirelessly. Depending on regulation, spectrum can be viewed as a common good, usable by everyone; a club good, usable by a limited number of users; or an individual good[58].

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

54 See Bundesnetzagentur (2008), Frequenznutzungsplan and TKG §54

55 See ITU Radio Regulations

56 See TKG (2008) and Picot (2008), p. 2

57 See BMWi (2008), EMVT § 13

58 See Picot (2008), p. 15

There is a fundamental rivalry in spectrum access: a certain swath of spectrum can only be used by a specific user at a certain location and time. Simultaneous use leads to interference between systems, which might or might not have adverse effects, depending on the respective system design. The rivalry in access has technological and physical reasons. To find sensible technological rules to regulate spectrum, the fundamental physical and technological facts have to be taken into consideration, as spectrum ranges vastly differ with respect to their technological, and hence economic, usability. The physics of electromagnetic wave propagation for example determine which frequency ranges are most adequate for mobile radio communication, stationary directional radio links or close range radio communications[59]. This together with the receiver design, and hence the technological state of the art, determines the playing field of spectrum regulation. Both aspects cannot be neglected when evaluating and discussing the different interests of spectrum users, in other words when regulating spectrum.

Spectrum regulation is a particular case, as, due to the vast amount of technological degrees of freedom, ex ante uncertainties about the effects of a regulatory decision will always remain. The technological complexity, the long development cycles of wireless communication standards as well as the multitude of national and international stakeholders lead to long decision making processes and very sluggish regulation[60]. Having this in mind, it is especially important to anticipate technological development and in time evaluate these developments with respect to possible consequences for spectrum access rights.

3.2. Spectrum scarcity

Almost all technologically useful spectrum has already been assigned to a certain purpose and to specific users. This leads to a situation where spectrum is scarce due to the regulation imposed on it. If spectrum is subject to reassignment, demand usually exceeds supply[61]. Spectrum access rights are then redistributed according to a reward procedure, e.g., an auction, lead by the respective regulatory body[62]. The time scale of such spectrum auctions and reassignment for new purposes spans from months to years.

3.3. A closer look at the Digital Dividend in Germany

The Digital Dividend discussion in Germany concerns, up until now, the spectrum from 790 MHz to 862 MHz only. Figure 5 shows the current assignment in Germany.

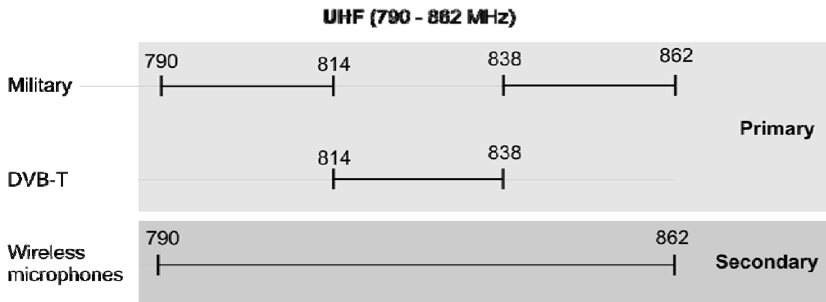

Figure 5: Spectrum utilization in Digital Dividend Frequencies[63]

59 See e.g. Tanenbaum (2003), p. 105

60 For e.g. UMTS, the process began in 1991, and lead to the definition of the core band in 1997, see 3GPP (2009)

61 See Bundesnetzagentur (2009a), p. 8f.

62 Finding ways to accelerate spectrum assignment for certain applications (Dynamic Spectrum Access) is currently a very active research field. On-demand assignment of spectrum resources will change spectrum assignment for certain applications such as mobile communication in the long run. See e.g. Klöck (2006) and references therein.

63 See Bundesnetzagentur (2008), Frequenznutzungsplan and TKG §54

As can be seen in the figure, the spectrum is currently assigned to a number of users in concurrent use. In practice, the frequencies are predominantly used for TV broadcasting and wireless microphones. If terrestrial broadcasting and military as the main users vacate these bands as planned during switch-over to digital transmission, spectrum reassignment is a reasonable step to assure efficient use of spectrum. For the reassignment the impact on all spectrum users has to be evaluated. A reassignment of this spectrum will concern existing rights of use of market participants, but will furthermore allow potential new market entrants to provide innovative products and services.

3.4. Options for Reassignment

Spectrum assignment is based on the *ITU Radio Regulations*, which the respective national regulatory bodies put into national law. The ITU Radio Regulations are revised approximately every 4 years during the *World Radio Conference* (WRC) and principally identify certain frequency ranges for radio services. 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[64].

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)[65]. These options can be associated with existing or new services and affect each of the market participants; some options are mutually exclusive.

For the digital dividend, the following market participants and services are under consideration:

- **Mobile cellular communication**
  The frequencies of the Digital Dividend would allow cellular operators to decrease infrastructure costs in sparsely populated areas and at the same time provide enhanced bandwidth for the next generation of mobile communications based on third generation standards such as UMTS or, in the near future, advanced standards such as LTE[66]. At same transmission power, enhanced indoor coverage is possible within these frequency ranges. The market participants in favor of this solution are Mobile Network Operators (MNOs) and equipment manufacturers.

- **Other broadband services**: IEEE 802.16 (Worldwide Interoperability for Microwave Access, WiMAX) is a notable set of technologies capable of providing broadband Internet access. It is not part of the ITU's IMT-2000 definition and can operate apart from cellular wireless networks. The market participants favoring this solution are local Internet access providers and WiMAX equipment manufacturers.

- **Terrestrial broadcast services**
  As the digital broadcasting standards are more spectrum efficient, they can provide better quality using the same bandwidth. Terrestrial broadcasting with enhanced TV resolution (HDTV) and on-demand services are possible. Market participants favoring this solution are private and public broadcasters.

- **Wireless media equipment (wireless audio/video)**
  Wireless media production equipment is based on short range radio transmission with comparatively low power. Market participants in favor are equipment manufacturers, media productions and theaters[67].

- **Consumer equipment communication and wireless local area networks**
  Consumer Equipment Communication and wireless local area networks (WLANs) were a major technological driver with high market impact in recent years. CEC and WLAN provide local high speed data connections. Assignment of Digital Dividend frequencies would allow significantly better penetration of building walls and better coverage than with current spectrum assignments, in the range of 2.4 and 5 GHz. This option is favored by the respective equipment manufacturers.

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[64] See ITU Radio Regulations
[65] See Bundesnetzagentur (2008), Frequenznutzungsplan and TKG §54
[66] See UMTS and LTE standards published by 3GPP
[67] See e.g. APWPT (2009)

	Cellular Wireless Communication	Other broadband service	Terrestrial broadcasting	Wireless Media Equipment	Consumer Equipment / WLANs
Licensing	Individual allocation, country-wide	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	< 30 km	< 30 km	50 – 100 km	< 5 km	< 1 km

Table 1: Comparison of Reassignment Options[68]

Table 1 gives an overview of the reassignment options and corresponding regulatory approaches, which are briefly discussed in the following.

3.4.1. Individual Allocation

A prime example for individual allocation of frequencies is spectrum allocation for mobile communications in the GSM or UMTS bands[69]. Individual allocation is usually justified by a business model which depends on high reliability and requires investment into infrastructure, as it is the case for cellular communication systems.

3.4.2. General Authorization

A general authorization allows anyone to access spectrum under certain technological constraints. Examples of general authorizations are the Industrial, Scientific and Medial (ISM) bands, carrying such diverse applications as wireless local area networks (WLANs), wireless personal area networks (WPANs), garage openers or microwave ovens[70]. Due to the uncoordinated spectrum access and heterogeneous technologies, performance cannot be guaranteed but depends on the number of spectrum users present. This is why general authorizations are usually limited by regulation to low transmission power and hence near range applications.

3.4.3. Spectrum Sharing: primary and secondary use of spectrum

The same spectrum can also be assigned individually and generally for different users and uses. This results in *spectrum sharing,* the coexistence of heterogeneous technologies in a certain spectrum range. Looking at the current spectrum assignment in Figure 5, professional wireless microphone systems (PWMS) are secondary users between 790 MHz and 862 MHz. Another prominent example are the 5 GHz bands, which are assigned to military radar and wireless local area networks alike[71].

The technological rules, given by e.g. frequency masks or maximum transmission power, assuring coexistence with only minor interference between devices depends on a multitude of technological factors. These rules are today determined by coexistence studies, whose time scale is also measured in months to years[72].

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68 See power allocations in “Frequenznutzungsplan“. Power and range are approximate estimates, based on current mobile communications standards. See e.g. 3GPP (2009) and IEEE (2009a).

69 See Bundesnetzagentur (2008), Frequenznutzungsplan

70 See Bundesnetzagentur (2008), Frequenznutzungsplan

71 See Bundesnetzagentur (2008), Frequenznutzungsplan

72 A famous example is Ultra Wideband Regulation (UWB), which – due to prolonged coexistence studies – came into being only in Germany 2006, with a 4 year time lag with respect to US FCC regulation, see Eisenacher (2006).

4. Using the Digital Dividend to mitigate the Digital Divide

The Digital Dividend was quickly and with broad consent identified by political stakeholders 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. The major reasons brought forward to support this approach are rollout speed, convenience, and significantly reduced infrastructure cost.

This section analyzes technical and economical aspects of wireless broadband provisioning. A feasibility analysis shows that wireless access only is not an option to integrate the population of rural areas into the information society. At first, the technical model of wireless broadband access for rural areas is described in detail, followed by an analysis of its limitations. Physical restrictions of electromagnetic waves lead to a trade-off between reach and speed, which has an additional negative economic impact. Based on a case study from a pilot project in Germany, these theoretical aspects are put in contrast with the reality, thus deriving implications for the use of the Digital Dividend.

4.1. The Concept of rural wireless Broadband Internet Access

Rural areas are lacking of high performance wired communication infrastructure[73]. This is, as seen in Section 2, not only the case in developing countries but also in industrialized nations. Wireless access using the Digital Dividend frequencies shall serve as a wireless alternative to overcome the last mile(s) problem[74].

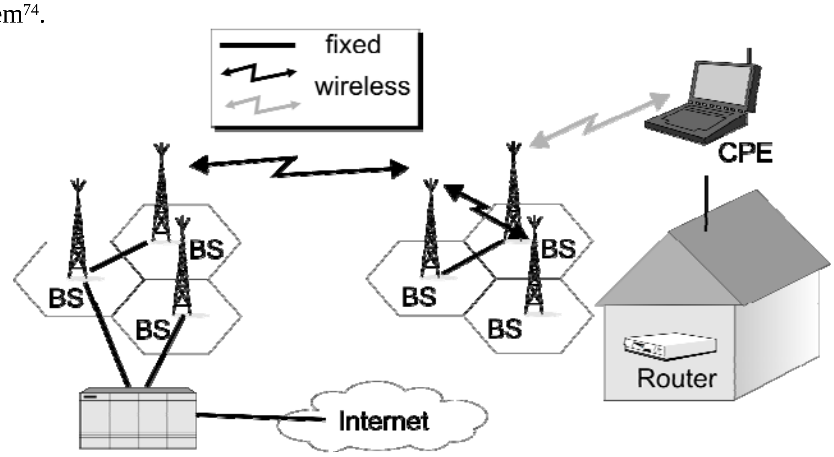

Figure 6: Wireless Broadband Access Architecture

Today's wireless systems have a site-based (cellular) hierarchical structure. A base station, which is connected to the backbone network, covers a certain geographical region wirelessly. Mobile terminals then directly communicate with the base station[75]. In the frequency range between 30 MHz and 3000 MHz currently used for medium distance high data rate communications, propagation of electromagnetic waves extends to the radio horizon. The radio horizon is roughly equivalent to the optical horizon: to cover a large area, base stations are installed on elevated antenna sites. Depending on the technology and transmission power, cell sizes have a radius of one to several dozen kilometers. Outdoor coverage – reception with a roof antenna – is easier to achieve than indoor coverage.

This setup is shown in Figure 6. The concept consists of a base station, which is either connected by a fixed line or wireless via microwave access to a backbone network. The end user devices are connected directly via a CPE or via a wireless router, which redistributes the connection into the in-house network[76].

73 See Picot/Grove (forthcoming)
74 See e.g. D21 (2008)
75 See e.g. Leon-Garcia/Widjaja (2006)
76 See e.g. Tanenbaum (2003), p. 103f., Börnsen (2008) or Tisal (2001)

To install a base station, a network operator has to setup a new antenna site or reuse, where available, existing GSM or UMTS sites. Introducing broadband wireless on the Digital Dividend frequencies means introducing a new technology. For existing MNOs, this means updating the existing infrastructure; new market entrants would need to construct their own infrastructure.

For a fast roll-out, handing over the Digital Dividend to current MNOs, is advantageous due to their existing infrastructure base and related resources, which are already in place. In addition, MNOs have an existing customer base and a broad access to the market. This is likely to have a positive impact on consumer awareness and therefore facilitates penetration. Moreover, the high acceptance of combined product bundles (e.g. fixed line and Internet; fixed line; internet and mobile) has shown, that customers prefer to buy communication services out of one hand[77].

The second option, giving the spectrum to entirely new market players, requires them to build a new infrastructure: the barrier to market entry is high. Increased costs make servicing of areas with low population density particularly unattractive. Furthermore, in contrast to the MNOs, new market entrants have to build up consumer attention and the required infrastructure for sales and service operations. Especially in Germany, where the main broadband access technology is DSL based, people perceive DSL as being equivalent to broadband internet access. For broadband access providers using alternative technologies it is already very hard to find customers, even if prices are lower than those of DSL competitors[78].

Furthermore, the second option is far more complex in terms of spectrum allocation, which is discussed together with limitations of wireless broadband technologies in the next section.

4.2. The Relationship between Reach, Speed, Frequency and Transmission Power

As a first approximation, the theoretically achievable data rate in a network setup ultimately depends on the available signal strength at the receiver and the available transmission bandwidth. These two parameters define the channel capacity, which physically limits the speed at which information can be exchanged[79]. The available signal strength at the 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. This immediately shows that – assuming constant transmission power – high data rates are possible close to the transmitter, while the achievable rate declines with distance. The channel capacity defines an upper bound. A given transmission standard such as defined by, e.g., WiMAX now offers a certain data rate for a fixed bandwidth and fixed signal strength. Depending on the wireless standard, this effective data rate might be well below the channel capacity or approach it. 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[80]. 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 is 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[81]. Hence, for large cells low 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.

[77] Recently, all major European communication providers turned towards double or triple play offerings, which decrease churn, see e.g. Di Feliciantonio (2008)

[78] See e.g. Bundesnetzagentur (2009c), p. 69, showing about 92 per cent connected via DSL technology in Germany

[79] See Shannon (1949)

[80] See Geng/Wiesbeck (1998)

[81] See Geng/Wiesbeck

Figure 7 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[82]. These cells are, however, able to support 12 times more users. From MNOs viewpoint, the Digital Dividend frequencies are hence especially suited for large cell sizes and at comparatively low user density.

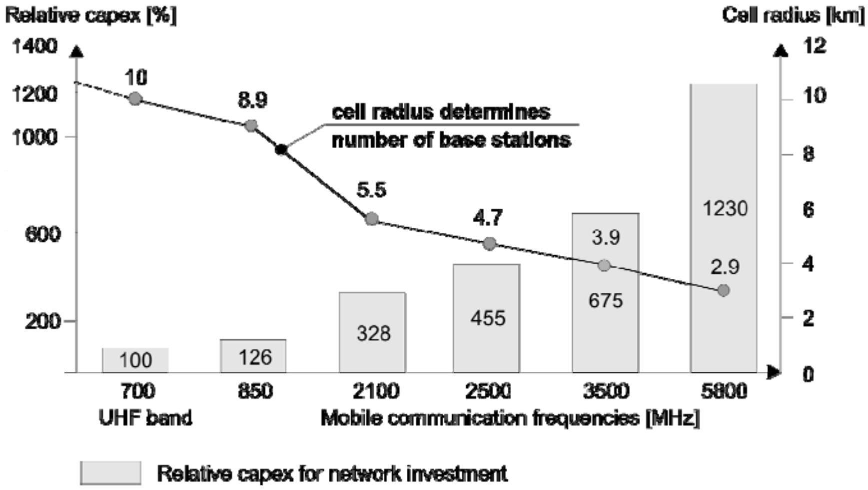

Figure 7: Relative capital expenditure (capex) and number of required base stations[83]

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 cellular networks, the cell size increases. A frequency cannot be reused within the same area twice. If transmission power now is allowed to be higher on a specific frequency range, this increases the operating range. But on the other hand, the maximum reuse of this frequency in other areas decreases. A comparison of nationwide TV broadcasting and mobile phone telephony might serve as a good illustration. For TV broadcasting, a very high transmission power (up to 100 kW[84]) is used for covering wide areas with the same high bandwidth signal. This frequency cannot be reused within the coverage area again for other communication, as it is blocked by this strong signal within the entire area. In a cellular mobile phone network, each cell base station uses a single frequency. All users communicate with the nearest base station, so there is no need to distribute the signal over e.g. an entire nation. A mobile phone has a maximum transmission power allowance of 2 watts and the base station antenna array for e.g. UMTS has a maximum transmission power allowance of 20 Watt per antenna[85]. This is only 2 per cent of the maximum allowance for DVB-T. The major advantage of this approach is that this frequency can be reused again in a next cell several kilometers away.

To sum 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 the far away households with internet access. The price to be paid for the high level of coverage is the bandwidth individually available. As explained above, the bandwidth available per user will be low, as a reuse of frequencies is not possible in wide areas.

When using low transmission power, the bandwidth available per user will increase massively. Here, the price will be a much smaller maximum distance between the antenna and the user, leading also to a much worse indoor coverage. Thus the network density of base stations or access points has to be increased massively.

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82 See Forge/Blackman/Bohlin (2007), p. 8f.

83 According to Krämer (2009) and Forge/Blackman/Bohlin (2007), p. 9

84 See Bundesnetzagentur (2008), Frequenznutzungsplan and TKG §54

85 See 3GPP (2009)

4.3. Limitations of wireless broadband technologies

Compared to wired technologies, wireless broadband technologies are inherently less reliable due to the physical nature of the free space propagation of electromagnetic waves. Transmission speeds have historically been slower by orders of magnitude.

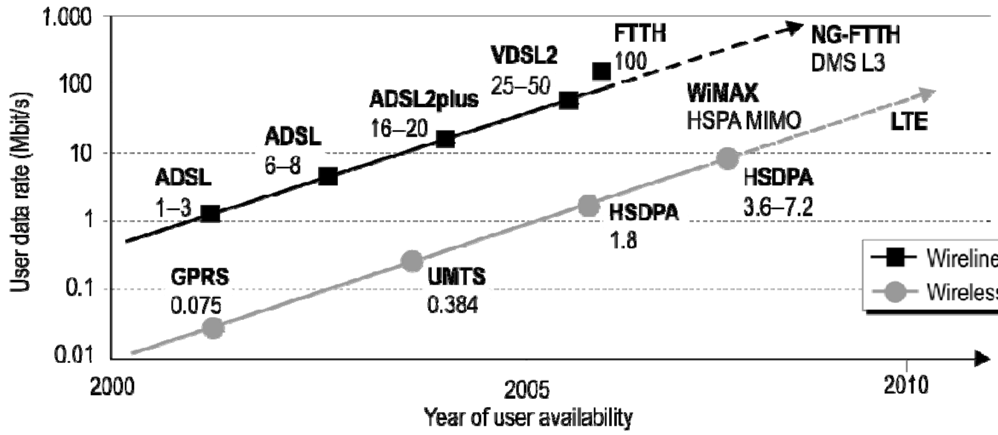

Figure 8: Development of wireline and wireless date rates in access technologies[86]

On short range, wireless transmission with comparatively high data rates - several hundred MBit/s to several GBit/s – will be possible in the near future with technologies based on the IEEE 802.11 (WLAN) and IEEE 802.15 family of standards[87]. It is, however, much harder to attain data rates in the order of 100 Mbps and faster in omnidirectional cell-based communication access networks. This is why wireless broadband will be and already is a 'last mile and meters' access technology to the wired network. Figure 8 shows the development of wireline and wireless broadband access technologies. In absolute figures, the gap between wireless and wired technologies is widening at a fast pace.

4.4. 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..

Demographic Characteristics

Grabowhöfe is a small town located in eastern Germany. It consists of 1065 inhabitants living on 31.12 km^2[88]. Broadband wired access is not available there yet, due to two major reasons. On the one hand, the Deutsche Telekom AG deployed dark fiber in the eastern parts of Germany after the reunion, not compatible with the actual network architecture. Fiber can thus not be used to connect the households. On the other hand, rural areas in Germany are not served by DSL or alternative broadband offerings due to entirely financial reasons. According to the Deutsche Telekom AG, 86 % of the 845.000 households are capable at least of DSL light, a product offering a data rate of up to 128 kBit/s[89]. Additionally, the federal state of Mecklenburg-Western Pomerania is suffering from migration to other parts of the country. This leads to a reduced customer potential and increasing rollout costs per person and additionally limits the incentives of private telecommunication companies to invest in TAL or coax cable upgrades.

In numbers, in 1971 590.079 people were living in of Mecklenburg-Western Pomerania, which reduced to 489.432 inhabitants in 1990 with extremely negative effects for the local population[90]. And this negative trend has not stopped from there on. Especially rural areas have suffered from a loss of more than

86 Based on BMWi (2008), p. 20
87 See IEEE 802.15 WG
88 See Destatis (2006)and Amt Seenlandschaft Waren (2009)
89 See MWAT (2009a)
90 See Klüter (2005), p. 2f.

12 per cent of their population, compared to 10 per cent population decrease in cities[91]. These effects are certainly caused by multiple reasons, but one important influence factor is the level of education and unequal living conditions compared to cities. The area is additionally suffering from a low business density, going along with higher unemployment and lower average income than in the rest of Germany[92]. These facts describe the initially quoted “chicken and egg” problem quite well. The area is suffering from an undersupply of communication services and a lower level of living conditions. Which factor contributed to which one cannot be solved initially, but for sure, an immediate provision of standard broadband communication infrastructure is required in order to reduce at least the disadvantage of not being part of the information society. Therefore, a pilot project to deliver broadband access based on the Digital Dividend spectrum was introduced.

Project Realization[93]

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. The target of the project is to answer the question whether wireless technologies are capable of serving rural areas in Mecklenburg-Western Pomerania with broadband internet access. According to the State Secretary of the Ministry, Dr. Stefan Rudolph, achieving this goal would result in an important location factor, not only for businesses but also for the local population[94]. 50 test users in Grabowhöfe were selected in order to test the wireless broadband access in a testing period until the end of 2009. The service and the equipment required for usage are provided free of charge to the participants.

In consequence, the pilot project is also providing insights about the demand side, which can be matched with the data of wireline broadband access technologies.

Technical Specification[95]

The infrastructure consists of three antenna arrays, located on one existing E-Plus Mobilfunk GmbH & Co KG owned radio mast. 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[96]. A schematic view of the setup is shown in Figure 9.

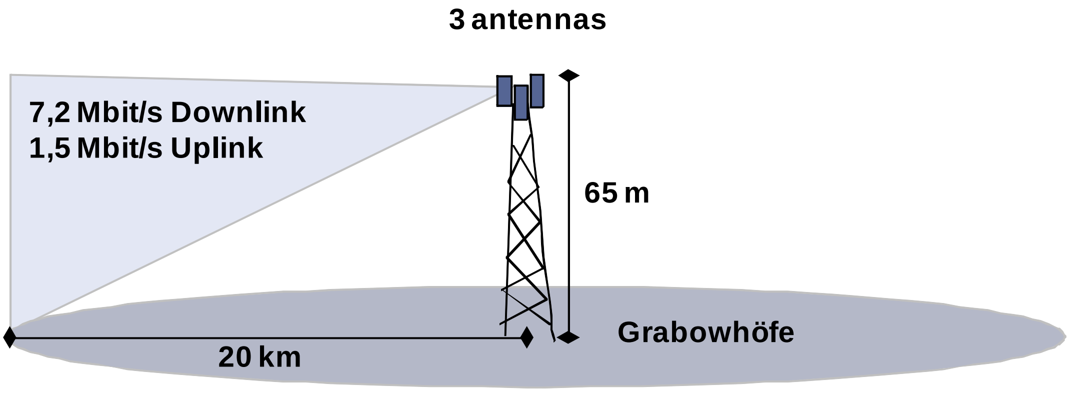

Figure 9: Wireless Broadband Pilot Setup in Grabowhöfe

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 MBit/s uplink and 1,5 MBit/s downlink per user are realized. For using the service, the 50 test users received a USB card for PCs or notebooks or WLAN routers with HSDPA functionally in order to connect their home network infrastructure.

Project Analysis

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.

[91] See Klüter (2005), p. 3f.
[92] See Destatis (2006)
[93] According to expert interviews, Bach (2009) and Krämer (2009)
[94] See MWAT (2009b)
[95] According to expert interviews, Bach (2009) and Krämer (2009)
[96] See Bach (2009)

From the consumers' perspective, E-Plus Mobilfunk GmbH & Co. KG reported usage figures effective from April 2009[97]. 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 per user within the first three weeks. Regarding connection speeds, the majority is below 3 MBit/s, only some can get data connections with more than 3 MBit/s.

4.5. Matching Theory and Reality: Shortcomings from Grabowhöfe

The first results from Grabowhöfe sound impressive. The story from zero access at all to daily connectivity and impressive data traffic on a mobile network seems to show that wireless connectivity is capable of shifting the offliners right into the information society. This might lead to the assumption, that the Digital Divide is closed in Grabowhöfe and the concept will solve the same problem in the rest of the rural areas. 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[98]. Compared to a city based broadband user, who generates approx. 9.2 GB[99] 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. Due to the fact that the citizens have been excluded from a broadband access before, many people do not know about the existence of standard bandwidth intense services like e.g. automatic update, downloads, file sharing, Internet radio, online gaming, streaming video or VoIP. In consequence, they do not have an "online life", which is characterized by communication over the Internet. However, through continued contact and use, they will adapt to these services with a time lag. Correlated with the knowledge about the services, their user behavior will change, when it comes to, e.g., online shopping or information research. Additionally, after a time of exposure, network effects kick in and connect these former offliners with other internet users. Further research including traffic protocols would be required in order to proof these hypotheses. It is reasonable to assume that, in the end, the same usage pattern appears as of other fixed broadband users, if the physical capacity restrictions were absent.

Anwendung	Bandbreite Downstream	Bandbreite Upstream	Latenzzeit	symmetrisch/ asymmetrisch
E-Mail	1 MBit/s	1 MBit/s	zweitrangig	symmetrisch
elektr. Zahlungsverkehr	128 kBit/s	128 kBit/s	zweitrangig	symmetrisch
Updates	10 MBit/s	128 kBit/s	zweitrangig	asymmetrisch
Austausch von Dateien	10 MBit/s	10 MBit/s	zweitrangig	symmetrisch
WWW	1 MBit/s	128 kBit/s	wichtig, <= 1 s	asymmetrisch
VoIP	128 kBit/s	128 kBit/s	essentiell, <=150 ms	symmetrisch
Video-Konferenzen	1 MBit/s	1 MBit/s	essentiell, <=150 ms	symmetrisch
Telearbeit/Home-Office	1 MBit/s-10 MBit/s	1 MBit/s-10 MBit/s	wichtig, <= 1 s	symmetrisch

Table 2: Minimum requirements for Internet Services according to Ministry of Economy, Labour and Tourism of Mecklenburg-Western Pomerania[100]

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. The restrictions can be characterized from an economical and a technological perspective:

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. These services are shown in Table 1.

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97 See Krämer (2009)

98 Linearly interpolated from 1.4 GB in 3 weeks.

99 See Gerpott (2008)

100 See Tavangarian et al. (2008), p. 6

According to Table 1, only two services - electronic payment and VoIP with a capacity of 128 kBit/s - require a connection with less bandwidth than 1 Mbit/s. However, for VoIP latency is essential to be low and as latency and bandwidth are correlated positively, this leaves just electronic payment services for data rates below 1 Mbit/s[101]. Moreover, six out of eight internet services require a symmetrical service, whereas the current deployment is delivering an asymmetrical service with a higher download than upload capacity. Comparing these figures to the project setup, major short comings 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 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 proving 7.2 MBit/s in downstream and 1.5 MBit/s 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 MBit/s downstream and 15 Mbit/s upstream, respectively.

According to the minimum requirements provided by the Ministry, this allows maximum parallel service use according to Table 3. For sure, not all inhabitants will probably watch IP-based HDTV at the same time. But it does not even need the world cup 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 (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 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 Mbit/s per user in upload for more than one user.

Service	Maximum parallel # sers (%)	Restriction
E-Mail	15 (4%)	Upstream
Electronic Payment Processing	120 (34%)	Upstream
Updates	7 (2%)	Downstream
File Exchange	–1-2 (1%)	Upstream
World Wide Web	72 (20 %)	Downstream
VoIP	120 (34%)	Upstream
Video Conferencing	15 (4%)	Upstream
Telework/Homeoffice	1-15 (1-4%)	Upstream/Downstream
Other:		
Online Video (youtube)[102]	45 (13%)	Downstream
HDTV[103]	10 (3%)	Downstream

Table 3: Maximum parallel Service Use in Grabowhöfe, own calculation

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. To avoid this, telecommunication provider normally cap the long term data rate under a “fair use” policy to an amount much lower (and not broadband) than the instantaneous data rate[104].

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 at all. A capacity calculation which takes into account all Digital Dividend frequencies can further support to these assumptions:

As mentioned, in the current setup, the maximum downlink data rate of 7.2 MBit/s is served in three different cells, formed by an ensemble of three sectorized antennas. A cell can serve the maximum data rate to 10 users simultaneously. The channel bandwidth of UMTS is 5 MHz, so that in total 15 MHz are in use at the site. Extrapolating linearly to 72 MHz, all Digital Dividend frequencies could support the maximum data rate for 144 users at once, equivalent to a total data rate of roughly 432 Mbit/s (3 MBit/s per user) to 1036 Mbit/s (7.2 MBit/s per user). This would indeed be – and at the expense of

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101 See Picot/Grove (2009)

102 See Youtube (2009)

103 See Tandberg (2007), delivering 720p at below 6MBit/s in MPEG-4

104 Mobile operators limit maximum data traffic per month, including flat rate tariffs, see e.g. T-Mobile (2009)

significantly higher infrastructure costs than currently installed at Grabowhöfe – a satisfactory broadband access by today's, but not tomorrows, standards. If however – what is certain to be the case – the frequencies are integrated into a cellular structure, not all bandwidth in the Digital Dividend can be used. If the best case reuse factor of 4 is assumed[105], the supportable maximum drops to 36 users. And even this assumes equal distribution across all cells, so the actual number will be lower.

At third, the wireless broadband coverage via HSDPA does not qualify to be future proof. On the one hand, actual HSDPA connections offer up to 7.2 MBit/s. In Asia, first connections are installed with 21 MBit/s download rate[106]. Future predictions for LTE include predictions for LTE, offering 170 MBit/s downstream per cell by the end of 2013[107]. Again, these 100 MBit/s are shared among the users connected to the base station. In contrast, DSL offers in cities already 16 MBit/s individually per connection, whereas fibre based connections in cities provide at least 100 MBit/s individually guaranteed per household[108]. In addition, fibre based connections can easily be upgraded to several GBit/s. On the other hand, lock in effects in existing technology on consumer and service provider site exist. Both, CPE and base station, would have to be exchanged for technological leaps offering bandwidth upgrades. These lock in effects will prolong upgrade cycles as the entire equipment has to be exchanged at once on both consumer and provider. Moreover, there are no incentives for the provider to upgrade technology, as the completion on Local Loop (LL) level is not existent, acting as a classical monopolist. Evermore, the willingness to pay of the customer base is limited if it is required upgrading to newer Customer Premises Equipment (CPE) evices in order to gain marginal additional broadband speed.

Summing up, the pilot project in Grabowhöfe does not provide city comparable Internet access to its citizens as a matter of fact. For sure, the wireless access is better than nothing. But 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. Therefore, 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. A solution comparable to the pilot project in Grabowhöfe amounts to investing subsidies in a proprietary technological solution, likely to be outdated in the near future. As a matter of fact, this would equal an investment decision into sunk cost. Therefore, it should be calculated, if the provision of real city comparable broadband infrastructure in rural areas would be economically more efficient, than the sunk cost investment in rural wireless broadband.

However, as the frequencies of the Digital Dividend are not optimally used for the wireless only provision of broadband to rural areas, an alternative, economically more efficient use is discussed in the following section.

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105 See Geng/Wiesbeck (1998)

106 See CSL (2009)

107 See Bach (2009) and Bundesnetzagentur (2009b), p. 8

108 See Picot/Grove (forthcoming)

5. So what's the Digital Dividend good for?

The analysis showed major restrictions for the ability of the Digital Dividend to close the Digital Divide in industrialized nations.

In the end, the analysis showed that a mobile network cannot substitute the existence of a non-shared wireline based broadband access. That is why the Digital Dividend spectrum should be used differently than for rural broadband access. Two major options, leading to higher economical efficiency are presented in the following: The allocation of the spectrum to MNOs without restriction and short range communication for home use as a LL alternative.

5.1. Enhancing Mobile Operator's Coverage and Services

The actual concept to give the Digital Dividend to the MNOs includes the restriction to serve rural areas first, in order to make use of these frequencies within population dense areas[109].

From a political perspective, the goal seems reasonable, as this should give the providers an incentive to upgrade and expand mobile broadband coverage in rural areas in order to solve the Digital Divide problem. As the analysis showed, the Digital Dividend will not suffice to integrate the rural areas into the information society. Furthermore, this restriction will decrease MNO's incentives to invest in infrastructure in general. In consequence, overall welfare will be negative, if this obligation is put in force as the following analysis shows up.

For wireless coverage, a simple production function for an MNO is introduced:

$$P(x) = R(x) - C$$

whereas $R(x) = r(x_c) + r(x_r)$ *and* $C = c_c + c_r$

The profit of an MNO is generated by the revenues $R(x)$, depending on the number of customers and their consumption of services. By looking at a one period model, costs C are simplified to occur as fixed only, due to the high one time investments into infrastructure installation and license fees for the frequency spectrum. The revenues can be split up into those in population dense areas in cities $r(x_c)$ and in rural areas $r(x_r)$. Costs are separated respectively into c_c and c_r. As revenues in population light areas are relatively small compared to cities, $r(x_r)$ they can be neglected. The MNO production function can be reduced to:

$$P(x) = r(x_c) - c_c - c_r \cdot$$

If now additional capacity in cities and therefore additional frequencies are required in cities in order to serve more customers and deploy a higher capacity, the MNO will only invest, if the additional revenues will be higher than the additional cost, not only in cities, but also in rural areas.

Therefore, deployment in rural areas therefore will only occur, if:

$$\Delta r(x_c) \geq \Delta c_c + \Delta c_r \cdot$$

Costs are increased by Δc_r compared to the function without the obligation to upgrade rural infrastructure. In consequence further market distortions occur: the MNO will wait for an additional investment into infrastructure in cities to the extent, when additional revenues will not only exceed costs in cities, but also in rural areas. Thus, the MNO will wait much longer with the upgrade of both areas, the city and the rural area than without the obligation. Regarding costs, they include the licensee fees for the spectrum. If they are tied to an upgrade of rural areas an awaited high income from frequency auctions[110] will be quite low in reality.

Summing up, the restriction to upgrade rural infrastructure in order to make use of the same frequency range within cities has to be removed. On the one hand, this will reduce upgrade cycles and thus capacity going along with a reduction in international comparable level of wireless broadband in cities. In addition, the rollout of wireless infrastructure is depending on price levels in cities, which slow competitive pricing schemes for those, which possess an obligation to invest into rural areas, and those, who do not acquire those frequencies. Moreover, integrated telecommunication companies will gain a competitive advantage, as they could move to Fixed Mobile Convergence (FMC) offerings,

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

110 See Krempl (2009)

shifting traffic within cities back to wireline infrastructure. In general, the market showed already, that an upgrade of rural infrastructure will not occur, where the business case is negative. As observations from UMTS /WiMAX/WLL have shown, there has not been any coverage of rural areas yet outside entirely experimental stage. For UMTS and 3G respectively, national coverage is concentrated on population dense areas only. In addition, WiMAX and WLL frequency holder have handed them already partially back[111] to the Bundesnetzagentur in Germany, which was rather surprised about the fact, that no one is investing into rural areas, although companies had paid for the frequencies[112]. Putting an additional obligation on top, will not make a negative the business case positive at all.

In the end, the first option of an economical use of the Digital Dividend is the assignment to MNOs without an obligation. This will expand the provision of mobile wireless services in cities as well as further. In addition, due to the lower frequency band of the Digital Divide, coverage will increase also towards rural areas, as long as the business case for the sites stays positive. From a policy viewpoint, the Digital Divide issue and the Digital Dividend – however similar the words might sound – should be treated separately in industrialized nations.

5.2. Short Range Communication and LL Alternative

The second option allocates 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, 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 in-house connections through several walls without exceeding the compulsory maximum transmission power. 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. A lot of consumer equipment is still wired, thus getting rid of the required physical connections would increase consumer convenience. Even more, in-house future wireless data connections will require much more capacity in order to get NGN wireless into notebooks and handheld devices. Blocking these frequencies for rural areas will reduce the growth potential of bandwidth intense Internet services, as the WLAN connection is or shortly will be bottleneck.

WLAN standards are becoming smarter - dynamic frequency selection and power control reduce frequency collisions and increase interoperability. The dynamic frequency selection mechanism scans the entire frequency range first before starting data transfer in order to minimize disturbances and to make an optimal use of the frequency range for all the participants. Also during transmission, the channel is observed the entire time. If a collision happens, channels can be switched automatically. Power control allows to optimally adapt transmission power to facilitate efficient use of frequencies. These mechanisms are already implemented in the next version of 5 GHz WLAN[113].

Dynamic frequency selection makes a reuse within cities much easier and convenient for the user. By making use of smart power control and allowing different transmission power modes, the short range communication can be extended to a local loop alternative. In the end, this leads to lower transmission power for in-house communication and a higher transmission power for LL alternative connections from the Serving Area Interface (SAI or KVZ) to the home. An advantage of this idea is that the expensive digging of new LL can be postponed until the capacity is required at that specific home. And a high performance wired based infrastructure has to be deployed into rural areas. The rest of a LL can be then be deployed wirelessly. As in cities the availability of alternative infrastructures is very high, more devices will be in use within compulsory lower transmission power, so that they can coexist next to each other. And as the population density in rural areas is lower, transmission power for the LL alternative use can be higher.

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[111] See e.g. heise (2009a)

[112] See heise (2009b)

[113] See IEEE (2009b)

6. Conclusions and Outlook

For rural areas in developing countries, wireless broadband provides access to the information society much faster compared to a wired provision. As, in general, the density of high performance wired broadband infrastructure is relatively low, compared to mobile phone coverage, it will take too much time to concentrate on deploying wired broadband nationwide[114].

However, in industrialized nations, where the density of high performance communications infrastructure is very high, rural wireless broadband does not fulfill city comparable bandwidth requirements. In addition, for developing countries, the wireless provision is actually the only chance for nationwide broadband access, nevertheless shared, in the near future. However, the installment of wireless infrastructure will lead by increasing usage to increasing traffic, which requires in the following an upgrade of the underling wired infrastructure.

Focusing on the industrialized nations again, this looks exactly the opposite way. A nationwide high penetration of high capacity bandwidth LL as well as a high capacity backbone infrastructure is already deployed. The share between high capacity LL connected houses in industrialized nations compared to those without is quite the opposite of developing countries. The today’s deployment of the Digital Dividend for rural broadband would lead to a widening gap between bandwidth capable infrastructure in population dense areas, whereas rural areas would be in the same situation in the future again, as they are today. By installing a bandwidth restricted shared medium today, the necessary funding for the required high performance infrastructure in cities will be sunk today, not available for installment of city comparable broadband access infrastructures. Furthermore, returns from handing over the Digital Dividend to MNOs without any restriction can be used to subsidize wired broadband rollouts in rural areas. The 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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114 See Picot/Grove (forthcoming)

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