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LEGAL AND EDITORIAL DETAILS

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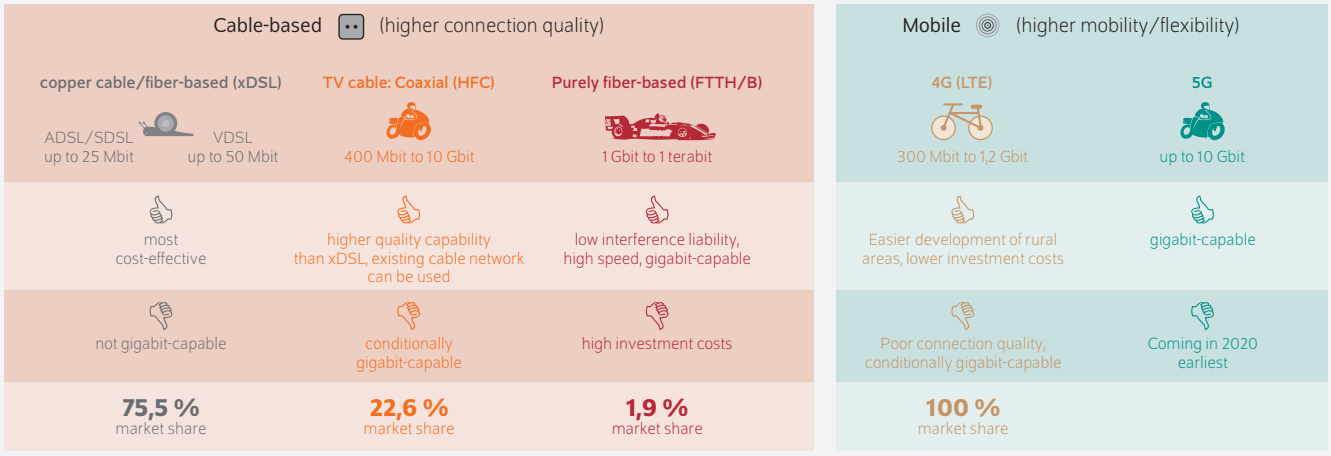
AT A GLANCE

Gigabit access: Germany lags behind in international comparison but demand is low

By Yann Girard, Anselm Mattes, and Claus Michelsen

- Broadband coverage of just under 100 percent for six Mbit/s but low coverage for gigabit-capable connections
- Germany lags behind in international comparison: only two percent of connections are pure fiber-optics (OECD = 21 percent).
- Metropolitan regions in Germany better connected than sparsely populated rural regions, but there are many local gaps within high-density areas
- Current obstacles are lack of willingness to pay and high expansion costs, plus supply and demand trends—however, demand is growing steadily
- Well-balanced combination of expansion driven by the private sector and federal funding policy required

From copper cable to fiber-optic connection: Broadband technologies and their quality capability



Source: Authors' own depiction.

FROM THE AUTHORS

"The private sector will most likely not invest into a nationwide, full-coverage gigabit network expansion. In order to achieve nationwide gigabit network access, public funding for blank spots will be necessary."

— Yann Girard, survey author —

Gigabit access: Germany lags behind in international comparison but demand is low

By Yann Girard, Anselm Mattes, and Claus Michelsen

ABSTRACT

Broadband internet expansion is a topic of widespread discussion in Germany right now. But the country still has not met its own targets. Almost 100 percent of households are supplied with broadband connections with up to six megabits per second, yet Germany has lots of room to catch up when it comes to gigabit-capable connections—particularly in sparsely populated regions. On the demand side, copper cable connections are the technology with the largest market share. At between one and two percent, pure fiber-optic connections only play a minor role. In international comparison, Germany's need to get up to speed becomes very obvious. The OECD average for fiber-optic connection demand is 21 percent of the overall broadband market. Currently, a relatively low willingness to pay and high investment costs are slowing down the momentum of both demand and supply in Germany. But demand is on a constant growth course. In order to develop a full-coverage gigabit infrastructure by 2025, the government should aim for a well-balanced combination of regulatory incentives for private sector investments and effective subsidies to cover "blank spots".

Digitization will be a key motor of technological progress in the 21st century. Data and new business models are fueling the digital transformation and gigabit networks represent the means of transport it requires.[1] According to estimates by the Federal Ministry for Economic Affairs and Energy (*Bundesministerium für Wirtschaft und Energie*, BMWi), GDP in Germany could rise by an additional 82 billion euros by 2020 if digital technologies and the capability of German companies to use them were systematically enhanced. In its *Digital Strategy 2025*, the federal government presented a declaration of intent to this effect in 2016.[2]

A prerequesite for tapping this potential is the full-coverage availability of gigabit-capable broadband connections. But in international comparison, Germany is currently lagging behind. A look at the network deployment status and use of the fiber-optic network clearly illustrates this.

Digitization and digital infrastructure also play a key role in the current coalition agreement. The goal of the governing parties is to grow Germany "into a strong digital country in all respects."[3] To achieve this, the new government is aiming for a nationwide deployment of gigabit networks by 2025. A combination of public funding and private sector regulations support this plan, which relies on competition via open networks and investment incentives through ex-post competition monitoring by the Federal Network Agency (*Bundesnetzagentur*).[4] Moreover, public subsidies for grid expansion are supposed to switch from open-technology

1 Applications such as home office VPN, cloud computing, gaming, and progressive TV (4K, Ultra HD) will have download and upload rates in the three-digit Mbit/s range. Broadband demand will be reinforced by the parallel use of multiple applications (see Christian Wernick et al., "Gigabitnetze für Deutschland," *WIK study*, (2016): 21.

2 See Federal Ministry for Economic Affairs and Energy, *Digital Strategy 2025*, (2016): 6 (available online, accessed June 5, 2018; this applies to all other online sources in this report unless stated otherwise).

3 See. CDU/CSU/SPD, Ein neuer Aufbruch für Europa – Eine neue Dynamik für Deutschland – Ein neuer Zusammenhalt für unser Land; Koalitionsvertrag zwischen CDU, CSU und SPD zur 19. Legislaturperiode, (2018): 37.

4 To simplify the development of fiber-optic networks, a detailed ex-ante regulation such as the one adopted for the copper network should be deemed unnecessary, and policy makers should rely instead on an open access model and development partnerships. The Federal Network Agency should ensure competition via ex-post monitoring of disputed cases.

to fiber-optic-specific support.[5] The public sector's funding volume should amount to ten to 12 billion euros by 2021.

The alternatives: cable-based and mobile technologies

Broadband transmission can be divided into cable-based (fixed) and wireless (mobile) transmission technologies. In Germany, there is discussion about the extent to which these alternatives are complements or substitutes. Currently, the cable-based alternatives are pure fiber-optic connections (fiber to the building/home, FTTB/H), TV cable (hybrid fiber coax, HFC), and copper cable (digital subscriber line, xDSL). The mobile technologies include long-term evolution (LTE, 4G) and the mobile telephony standard of the future: 5G.

Cable-based broadband transmission technologies

The various copper cable variants are combined under the term "**xDSL**," in which the x is a placeholder for different letters depending on whether it refers to a symmetrical (s) or asymmetrical (a) upstream and downstream transmission or a "very high speed" (v)DSL connection.

With a/sDSL connections, download speeds of up to 25 megabit per second (Mbit/s) are possible. Faster download transmission speeds of up to 50 Mbit/s are possible with vDSL.[6] However, to actually achieve these speeds the underlying copper infrastructure must be partially upgraded with fiber-optic cables to the serving area interface (SAI). Once this vectoring technology is in place, download speeds of up to 100 Mbit/s and upload speeds of 40 Mbit/s will be possible. However, the longer the cable, the lower the broadband speed.

Today's **TV cable network** consists of a combination of fiber-optic and coaxial cables. Based on the current DOCSIS 3.0 transmission standard, downstream broadbands of up to 400 Mbit/s can be provided. In addition, the future DOCSIS 3.1 standard will enable downstream speeds of up to ten gigabit per second (Gbit/s).[7]

The abbreviation **FTTH/B** stands for pure fiber-optic connections up to the home or building. It is already possible to realize stable transmission speeds of over one gigabit per second well into the terabit range. In addition to high transmission speeds, this technology offers the benefit of immunity to interference from external influences. The data transmission rate also sustains itself at a high level over long ranges. However, relative to other access technologies, FTTH/B requires a high level of investment.[8]

Mobile broadband transmission technologies

Internet access via mobile communication technology has existed since the middle of the 1990s. This technology is based on automatically switching from cell site to cell site, which first made mobile use possible. With LTE (4G), download rates of up to 300 Mbit/s and upload rates of 75 Mbit/s are feasible. With LTE Advanced or LTE Advanced Pro, download rates of up to 1.2 Gbit/s and 3 Gbit/s respectively will likely be viable in the future.[9] The average actual download rates of German providers are much lower than these values, which can only be achieved under laboratory conditions.

The next mobile communication generation (5G) is being developed right now. It will enable transmission rates of up to ten Gbit/s and offer much higher quality. 5G will be rolled out in Germany in 2020 at the earliest but is already the subject of hot debate in the market and on the political level.[10]

Cable-based and mobile services only partially interchangeable

Both mobile and cable-based communication enable language and data transmission, which leads to the question of the relationship between the two services. The evidence supporting the theory that they are interchangeable, meaning one can be substituted for the other, is that landline and mobile communication basically provide the same services, though the latter offers a high level of mobility. Accordingly, mobile communication is likely to replace its cable-based counterpart in the long term. That cable-based services currently provide higher connection quality speaks in favor of a complementary relationship between the technologies. Consequently, cable-based and mobile services should be used in parallel in the medium term. And it is also conceivable that the two technologies will converge to create hybrid models in the future.

Until now it has been impossible to say which relationship will predominate.[11] The data on internet use in Germany do not show that mobile communication is (completely) interchangeable with landlines. For language transmission, the majority of households combine a landline with mobile telephone connections, and the statistics point to only a slight decrease in the number of landline-only households.[12] And data transmission also shows a complementary relationship. The number of both mobile and cable-based connections is increasing. As of 2014, the latter did not appear to be dying out.[13]

5 CDU/CSU/SPD. "Ein neuer Aufbruch," 38.

6 See Monopolies Commission, "Telekommunikation 2017 – Auf Wettbewerb bauen!," *Sondergutachten 78*, (2017): 49 (available online).

7 See Wernick et al., "Gigabitnetze für Deutschland," 25.

8 The investment costs for a nationwide fiber-optic expansion are estimated at around 30 billion euros. See Torsten Gerpott, "Breitbandsubventionen des Bundes 2015 bis 2017 – eine Analyse der Förderzusagen," *ifo Schnelldienst*, 20 (2017): 21. Other sources yield higher values of 45 billion euros. See Wissenschaftliches Institut für Infrastruktur und Kommunikationsdienste (WIK), *Newsletter 95*, (2014): 2.

9 See Rolf Schwab, "LTE in Germany: An analysis of the current market environment and its outlook," *WIK Discussion Papers*, no. 394 (2015): 10.

10 Broadband reception is also offered nationwide via satellite. But due to its high latency and costs, it is considered a substitute technology and we will not include it in the following discussion.

11 See Federal Network Agency, Tätigkeitsbericht – Telekommunikation 2014/2015, (2015): 7 et seq (available online).

12 Statistics for 2014. See Eurobarometer, Special Eurobarometer 414: E-communications household survey and Telecom Single Market survey, (2014): 28. See Federal Network Agency, "Tätigkeitsbericht – Telekommunikation," 47 et seq.

13 Federal Network Agency, "Tätigkeitsbericht – Telekommunikation," 48.

Both connection technologies are evolving. Applications such as video streaming used to be possible only via cable-based connection, but due to improvements in mobile communication technology, such as LTE, wireless use is possible today. At the same time, modern fiber-optic networks are superior to mobile connections in terms of speed and reliability.

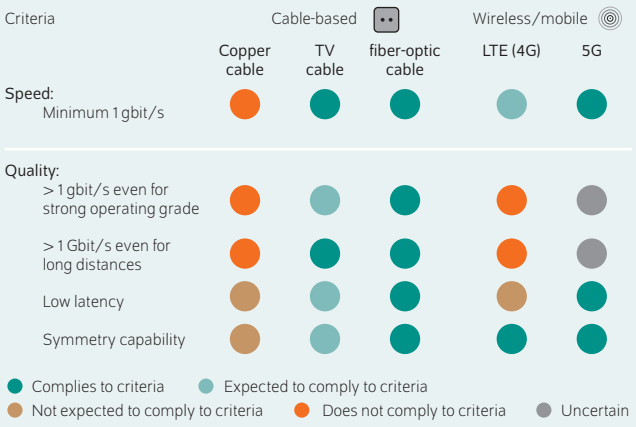
And only a minimum level of substitution by mobile communication would be enough to influence the market for cable-based technologies, because it would create direct competition between the two variants among a portion of subscribers. Good mobile communication availability continues to reduce the extent of cable-based infrastructure expansion in some regions.[14] Today, LTE (4G) connections supply some rural areas lacking satisfactory coverage with cable-based transmission. Therefore, whether or not mobile technology supplements the modernization of the cable-based infrastructure or supplants it entirely will depend on technological developments and future network preferences.

Transmission technologies and their gigabit capability

As a rule, gigabit networks have the following qualities:[15] high bitrate bandwidths (>1 Gbit/s), symmetry capability, low latencies, and low package loss rates. Comparing the gigabit-capability of the various access technologies shows that today's pure fiber-optic connections (FTTH/B) already satisfy these criteria. Most likely, TV cable networks upgraded to the DOCSIS 3.1 transmission standard (HFC)[16] will also satisfy the quality criteria.[17] And the 5G transmission technology will also most likely be gigabit-capable (Figure 1). However, the 5G network requires a high-performance fiber-optic infrastructure to link the individual cell sites. This is why 5G cannot replace the fiber optic infrastructure but can instead take advantage of the synergies it offers.[18]

Figure 1

Access technologies and their gigabit quality capability



Sources: WIK study commissioned by the Federal Ministry of Economics; authors' own depiction.

Most likely only pure fiber-optic connections and the 5G mobile technology will remain sustainable in the future.

Availability and demand

Germany lags behind in international comparison

Comparison of the available broadband speeds in Europe shows that in most countries, at least 60 percent of private households can be supplied with broadband speeds of 30 Mbit/s or more. With an availability of at least 30 Mbit/s in 81 percent of households and 100 Mbit/s in 65 percent, Germany is slightly above the EU28 average of 75 and 51 percent respectively, but has by no means taken the lead (Figure 2).

When it comes to broadband subscriptions, Germany also lags behind in international comparison. This applies for cable-based and mobile broadband connections and for gigabit-capable fiber-optic connections as well. The proportion of fiber-optic connections in the broadband markets of the OECD countries was 21 percent on average, and in South Korea and Japan it is over 70 percent. In Germany only around two percent of broadband connections are "genuine" fiber-optic connections (Figure 3).

Germany also had a below-average level of demand for broadband speed in 2017, as shown in OECD comparison. While countries such as South Korea, Norway, and Sweden attain considerably higher average speeds of over 20 Mbit/s, Germany's average was only 15.3 Mbit/s. Since the statistics reflect broadband connections with subscribers, the question remains as to whether the lower average speed is a consequence of the lack of available high bitrate broadband connection or the demand for higher bandwidths is relatively low in Germany.

Looking at mobile communication, Germany has a data volume demand level of 1.21 Gigabytes (GB) per mobile broadband connection. This is significantly below the OECD average of 2.3 GB (Figure 4). With a data volume of 10.95 GB, Finland is the leader.

Broadband availability depends on the profitability of fiber-optic network expansion and thus, crucially, on the demand for broadband connections. In turn, this can be derived from

14 See Plum Consulting, "Fostering investment and competition in the broadband access markets of Europe," *ETNO* repor,t (2016): 47.

15 See Wernick et al., "Gigabitnetze für Deutschland," 23 et seq.

16 According to the Fraunhofer Institute, typical data rates via HFC networks (coaxial cable) are: DOCSIS 3.0 up to 400/20 Mbit/s; DOCSIS 3.1 up to 1,000/100 Mbit/s, and still undergoing development and laboratory testing, DOCSIS 3.1+ with 10 Gbit/s symmetrical (full duplex). See Fraunhofer FOKUS, Netzinfrastrukturen für die Gigabitgesellschaft, (2016) (available online).

17 See Fraunhofer FOKUS, "Netzinfrastrukturen."

18 Konvergente Netze als Infrastruktur für die Gigabit-Gesellschaft project group, "Impulse Paper," (2017); and Aufbruch in die Gigabit-Gesellschaft focus group, conference of the Digitale Netze und Mobilität platform (2018).

Figure 2

Broadband availability and average demanded broadband speed
Availability (independent of technology) as a percentage of households in 2016 and speed in megabits per second

Sources: European Commission (2017) (available online); Akamai (2017) (available online).

Based on an international comparison Germany does not hold a leading position.

consumers' willingness to pay, which is positively influenced by the benefits of the quality provided. Due to relatively long amortization periods in addition to current willingness to pay, expectations regarding the future growth pattern of consumers' willingness to pay will be key to investment decisions that target fiber-optic network expansion.

In addition to growth in demand, the regulatory framework affects investment decisions. If a regulation places an upper limit on network operators' pricing freedom, for example, this will generally have a negative effect on investment profitability.[19] However, retail customers (who are already subscribers) would benefit from the lower subscriber price resulting from higher competitive and price-related pressure. To generate sufficiently high incentives to invest, the regulatory framework needs to achieve a suitable balance in combination with public subsidies for grid expansion.

Broadband availability in Germany

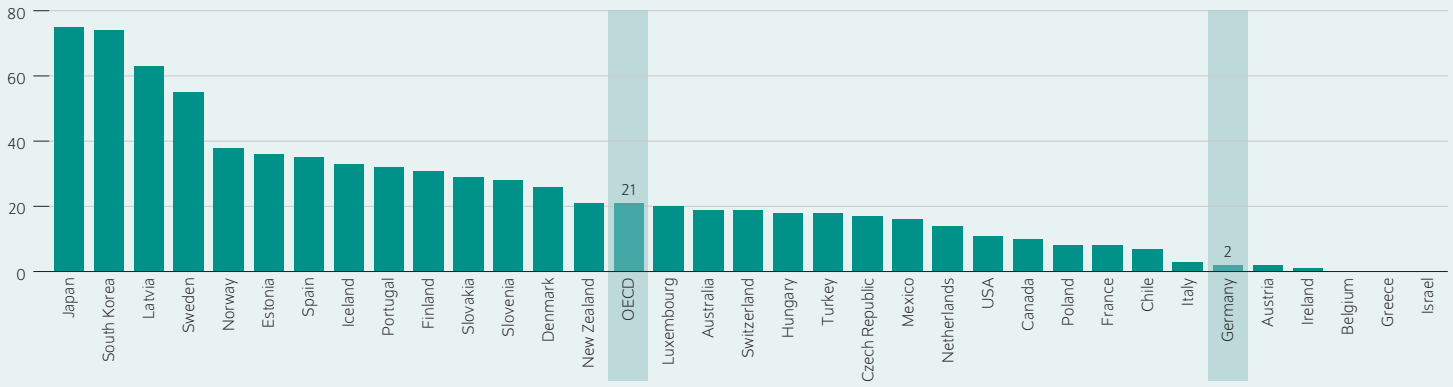
Broadband availability in Germany has constantly improved in recent years for both cable-based and mobile communication. Currently, the majority of private demand is adequately met (Figure 5).

Broadband speed has significantly increased in the past seven years. In 2010, almost 100 percent of households had access to a connection with at least one Mbit/s and 81.7 percent with at least six Mbit/s, but only 39.5 percent had 50 Mbit/s or more. In 2017, almost 100 percent of households had bandwidths of at least six Mbit/s and just under 77 percent had 50 Mbit/s or more.

19 Moreover, long-term commitment to a regulatory regime or the risk of regulation also play an important role in any investment decisions.

Figure 3

Demand for fiber-optic connections
Share of FTTH/B connections in 2016 in the OECD in percent

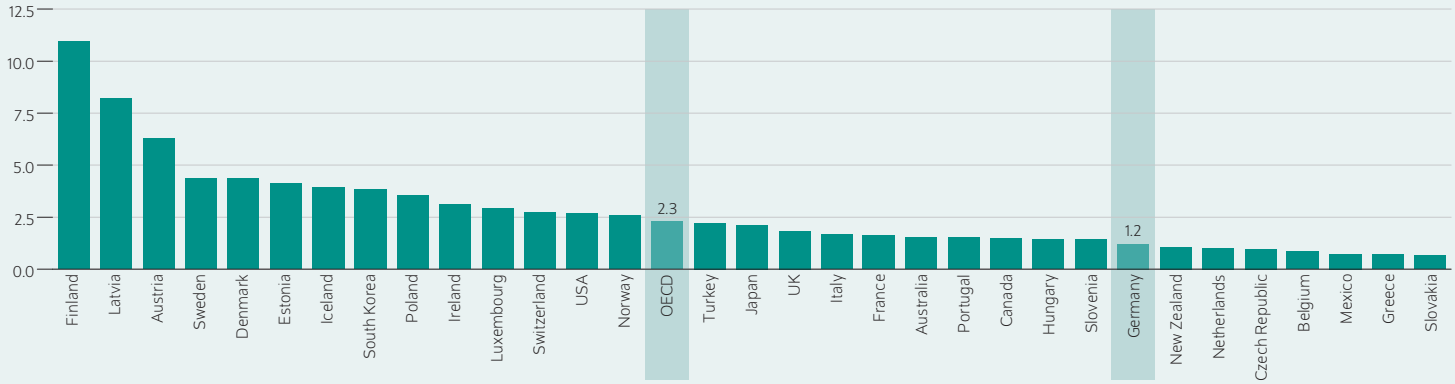


Source: OECD Broadband Database (2017).

Germany lags far behind in fiber-optic connections.

Figure 4

Data volume per mobile broadband connection
In gigabytes



Source: OECD Broadband Database (2016).

The data volume demand in Germany is only half as high as in the OECD average.

Breaking the statistics down into cable-based and mobile technologies shows that nationwide supply with low broadband speeds exists with both mobile and cable-based technologies. Over 90 percent of German households can use a mobile connection with one or more Mbit/s and around 97 percent have the opportunity to subscribe to a cable-based copper cable connection of at least one Mbit/s. However, higher broadband speeds of more than 16 Mbit/s are primarily provided through cable-based technologies (Figure 6). Only 6.6 percent of households have mobile access with more than 16 Mbit/s. In contrast, around 49 percent of all households have access to a copper cable connection with over 50 Mbit/s (Figure 7).[20]

TV cable networks cover around 64 percent of households. They are primarily in urban or suburban regions. Unlike

20 See TÜV Rheinland, Bericht zum Breitbandatlas, (2017) (available online).

copper cable connections, the performance of TV cable connection hardly varies, and all households connected to the network can take advantage of a connection with over 50 Mbit/s. With just under seven percent availability, fiber-optic connections still play a minor role in the provision of broadband access.

Broadband demand in Germany

On the demand side, copper cable connections are the technology with the largest market share. With a share of between one and two percent only, fiber optic technology plays a minor role. However, the Federal Network Agency documented that the number of fiber optic connections with subscribers rose from 200,000 to 600,000 between 2013 and 2016.[21] TV cable connections were able to expand their market share from 15 percent in 2012 to 22.5 percent in 2016 (Figure 8).

Measured by the number of SIM cards used, the number of mobile communication subscribers hit a plateau between 2010 and 2015. Currently, more than 130 million SIM cards are actively used in Germany. In contrast, the data volume used has grown constantly. Between 2010 and 2017, the data volume increased 22-fold. It broke the one million gigabyte-barrier in 2017 for the first time. And the monthly data volume used per SIM card rose from 0.05 GB in 2010 to 0.93 GB in 2017.[22] A comparable rise in data volume was also apparent in cable-based broadband connections (Figure 9).

No longer full of blank spots, but many local gaps in cities

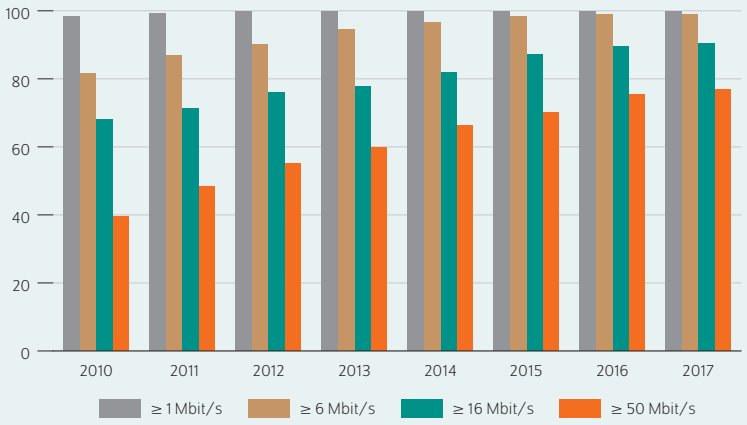
The availability of fast internet varies strongly by region. Looking at the supply to private households with bandwidths of over 50 Mbit/s, an east-west disparity becomes apparent. In most regions of eastern Germany, only three-quarters of households have been supplied with the relevant bandwidth. In western Germany, the majority of regions up to 95 percent have it (Figure 10).

However, this picture ignores the fact that connection to fast data transmission technology is highly variable within each region. For example, areas of high population density are connected extremely well in most cases, while in sparsely settled surrounding areas less than half of all households are connected with more than 16 Mbit/s (Figure 10). And in cities, parallel blocks may have access to very different bandwidths.

The lack of availability of higher speed bandwidths for commercial customers is viewed as an obstacle to a region's economic growth.[23] In this area as well, a mixed picture is

Figure 5

Development of broadband availability in Germany
As a percentage of covered households (all technologies)

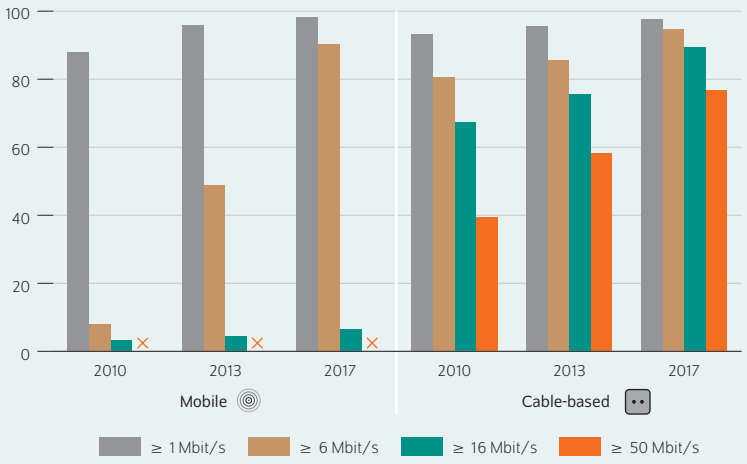


Source: Breitbandatlas (2017).

The broadband availability of up to six Mbit/s is now close to 100 percent.

Figure 6

Development of broadband availability for wired and mobile technologies
As a percentage of all households in Germany



Source: Breitbandatlas (2017).

Mobile technologies cannot compete with high bandwidths.

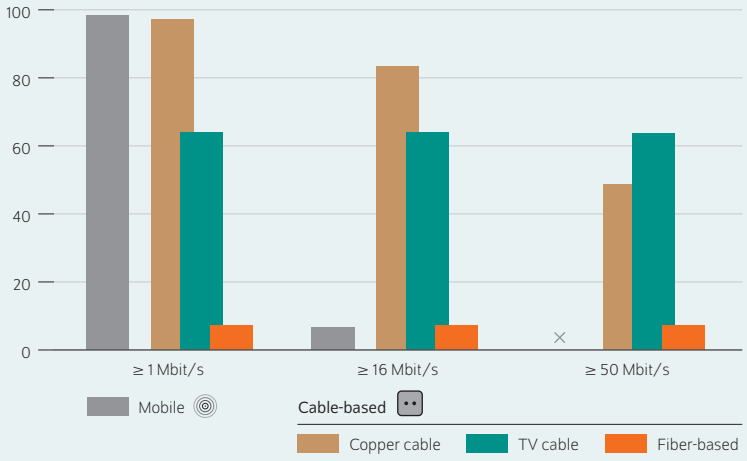
21 In 2017, Dialog Consult documented around 2.4 million available fiber optic connections and 747,000 fiber optic connections with subscribers for Germany. See DialogConsult/VATM. 19. TK-Marktanalyse Deutschland 2017, (2017): 20.

22 See Federal Network Agency, Tätigkeitsbericht – Telekommunikation, 23, 28.

23 For Germany, see the Association of German Chambers of Commerce and Industry, Umfrage Netzwerk Industrie 2017, (2017); and in academic circles, see for example George S. Ford and Thomas M. Koutsky, "Broadband and economic development: A municipal case study from Florida" *Review of Urban & Regional Development Studies*, 17.3 (2005): 216–229.

Figure 7

Broadband availability for selected technologies
Percentage of households in Germany, 2017

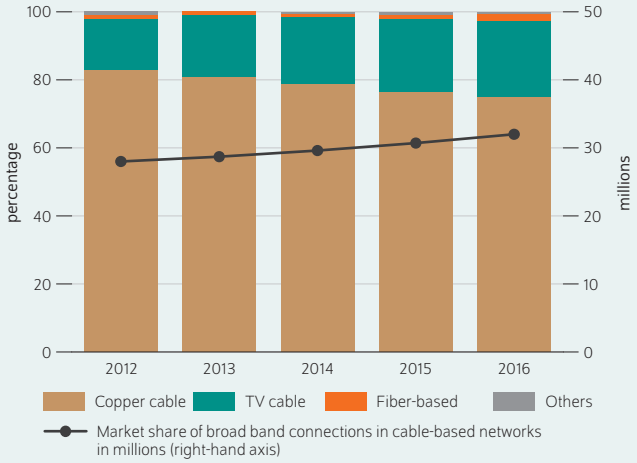


Source: Breitbandatlas (2017).

At 50 Mbit/s, TV cable availability is the highest.

Figure 8

Wired technologies in the German broadband market
Market share in percent (left-hand axis); number of marketed broadband connections in millions (right-hand axis)



Source: Bundesnetzagentur (2015, 2017).

The market share of copper cable connections drops in favor of the gigabit-capable connections.

emerging: metropolitan areas typically have excellent access but supply diminishes sharply in rural regions, where locations with bandwidths of 50 Mbit/s and higher are few and far between. Full coverage of all locations—as written into the new coalition agreement—seems to be a highly ambitious undertaking, given the current supply situation in Germany.

In view of the repeatedly expressed assumption that demand is significant, it is remarkable that of the approximately 2.4 million fiber -optic connections available in 2017, only 747,000 had subscribers. This cannot be a consequence of the lack of potential in fiber optic technology; fiber-optic expansion is a key investment in the future. Instead, the insufficient level of paying customers and high costs of expansion are slowing down growth in both supply and demand. However, WIK, a think tank for infrastructure and communication services, has forecast that by 2025 around 85 percent of German households will demand broadband speeds of more than 150 Mbit/s and 30 percent will want more than one Gbit/s.[24] There was not only a significant increase in available fiber-optic connections and those with subscribers between 2012 and 2017, but the ratio of subscribed to available connections (the take-up rate) also rose slightly in this period (Figure 11).

Players in the gigabit expansion

Deutsche Telekom is providing around one-third of the available fiber optic connections. Its competitors are mostly city utilities in regions of higher population density such as Netcologne (Cologne), M-Net (Munich), and WilhelmTel (Norderstedt/Hamburg). They had an almost 90-percent share of the market for connections with subscribers in 2017.[25] At 230,000 subscribing households, Netcologne's fiber optic network subscribers exceeded Deutsche Telekom's last year for the first time.[26] And recently, private operators such as the Deutsche Glasfaser Group have reinforced the expansion in rural areas, since they are using micro trenching[27] and other procedures to make it more cost efficient to install fiber-optic networks.[28]

The investment costs for nationwide fiber-optic expansion are estimated at around 30 billion euros.[29] Due to the high level of investment required, efforts to forge expansion

24 Federal Network Agency, "Tätigkeitsbericht – Telekommunikation," 52.

25 Mobile communication exhibits similar market segmentation. Deutsche Telekom, Telefónica, and Vodafone have an equal (one-third) share of the market for this technology, which consisted of 132 million active SIM cards in 2017.

26 Achim Sawall, "Wer in Deutschland die meisten Glasfaseranschlüsse verlegt," (2017) (available online).

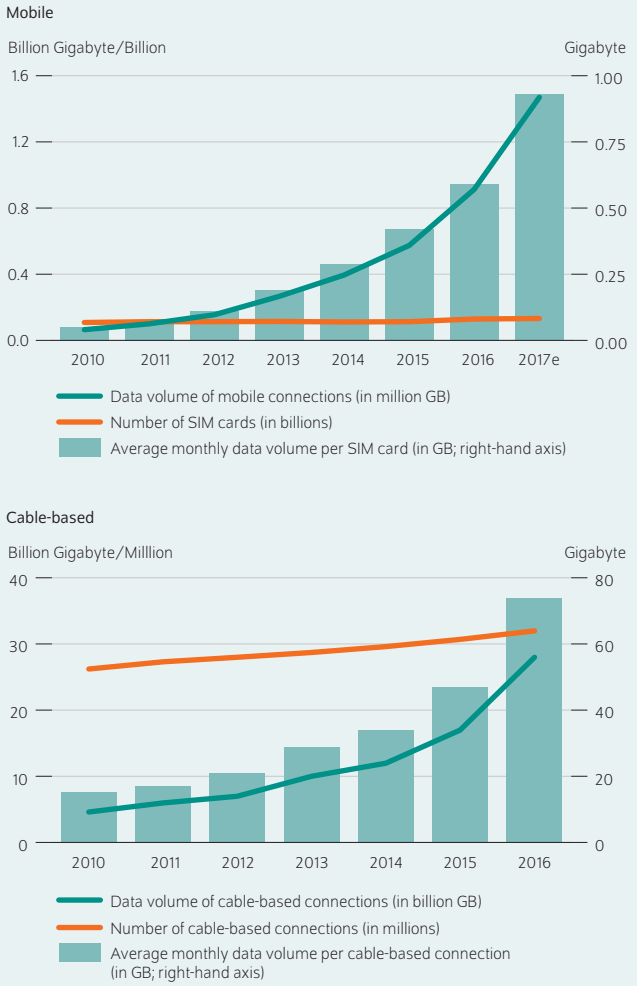
27 Trenching is a method of laying the pipes for fiber optic lines by milling narrow grooves and slots in the ground or asphalt. The method enables pipe and fiber optic lines to be laid quickly. Micro, mini, and macro trenching are used to differentiate among trenches of various depths and widths and the milling technique used.

28 Bernd Beckert, "Ausbaustrategien für Breitbandnetze in Europa," (2017): 27.

29 See Gerpott, "Breitbandsubventionen."

Figure 9

Development of the number of users and the volume of data in the German mobile and cable-based network
In billions of gigabytes (left-hand axis); number in billions/millions (left-hand axis); Gigabyte (right-hand axis)



Source: Bundesnetzagentur (2016/2017).

The growth of data volume in mobile and cable-based networks continues.

partnerships can be observed between telecommunication companies and between telecommunication companies and energy and water utility operators (typically public utility companies). These could range from joint expansion and operation of the infrastructure to separate construction and granting preferred access. The presumed advantages are sharing the costs of expansion and spreading the risk that arises from uncertain demand development and long amortization periods.

However, partnerships like these are problematic when they restrict competition. The Bundeskartellamt, Germany's federal competition authority, views expansion partnerships in the regions that the market inefficiently supplies (blank spots) as acceptable.[30] State funding programs ranging from the EU to the state level focus on regions like these. By 2017, federal funding programs provided around four billion euros for co-financed expansion projects for broadband speeds of at least 50 Mbit/s. As a rule, the federal funding portion is 50 percent, but it can be up to 70 percent in structurally weak regions.[31] At 823 million euros, Mecklenburg-Western Pomerania has taken the lead in tapping these subsidies. Bavaria and Baden-Württemberg apply for relatively little funding, probably relying on their own well-funded programs.[32]

Federal funding typically takes one of two forms. The coverage gap model permits municipalities to commission national telecommunication companies for broadband expansion by closing "profitability gaps" with federal funds. In contrast, the operator model funds expansion in municipalities autonomously. Accordingly, the models differ in the way they spread risk: the operator model situates it squarely in the municipality. However, it also strongly supports fiber optic expansion since communities take the overall economic interests of their region into consideration with an eye to the future.[33]

We must note that the prevailing bureaucratic procedures and high level of heterogeneity in funding programs on the state level make it more difficult to tap the federal funding available. As a result, around 667 million euros remained in the pot in 2017.[34] These issues should be considered if there are plans for a major increase in the funding for broadband expansion.[35]

Conclusion: balancing act between funding and regulation

In summary, we can state that gigabit network deployment in Germany lags significantly behind the targets set in the most recent coalition agreement. In international comparison, the infrastructure is underdeveloped. This applies regardless of the technology considered. In order to develop a full-coverage gigabit infrastructure by 2025, a well-balanced combination of private sector-driven grid expansion and effective public subsidization policy is necessary.

The regulatory conditions will decide whether or not private sector telecommunication companies continue to invest in expansion. A balance between two extremes must be found here. On the one hand, access regulations for network

30 See Monopolies Commission, "Telekommunikation 2017."

31 See Monopolies Commission, "Telekommunikation 2017," 65.

32 See Monopolies Commission, "Telekommunikation 2017," 66.

33 Bernd Beckert, "Ausbaustrategien," 27; and Monopolies Commission, "Telekommunikation 2017," 71 et seq.

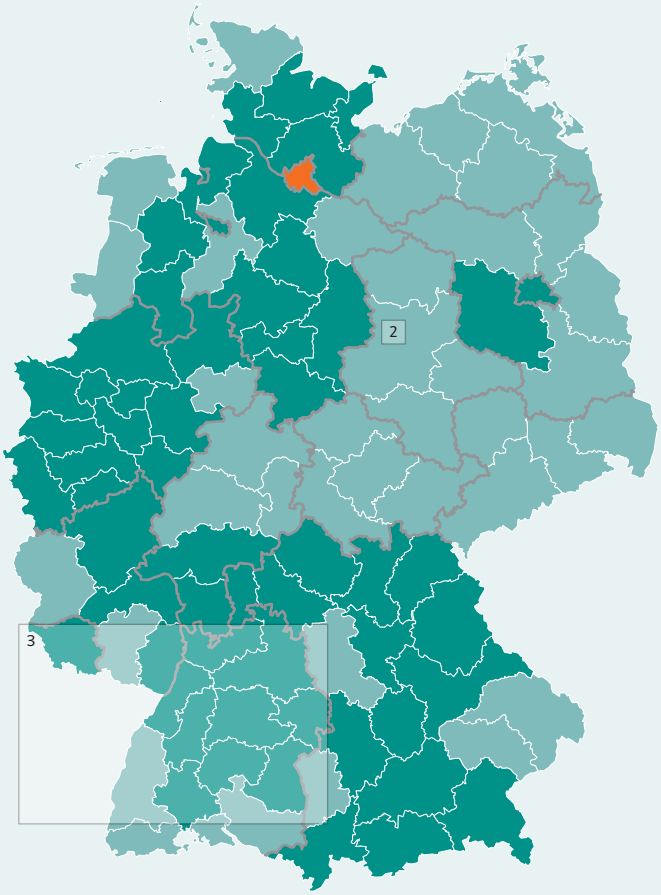
34 Monopolies Commission, "Telekommunikation 2017," 74; and Federal Ministry of Finance; Schriftliche Anfrage, (available online).

35 In this context, a 2018 study by Tomaso Duso, Mattia Nardotto, and Jo Seldeslachts analyzed the effect of broadband funding programs in Germany in Lower Saxony and Bavaria between 2008 and 2013. See Tomaso Duso, Mattia Nardotto, and Jo Seldeslachts, "Ausbau der deutschen Grundbreitbandversorgung: Erfahrungen aus der Vergangenheit mahnen zur Besonnenheit", *DIW Wochenbericht* 25 (2018), 543.

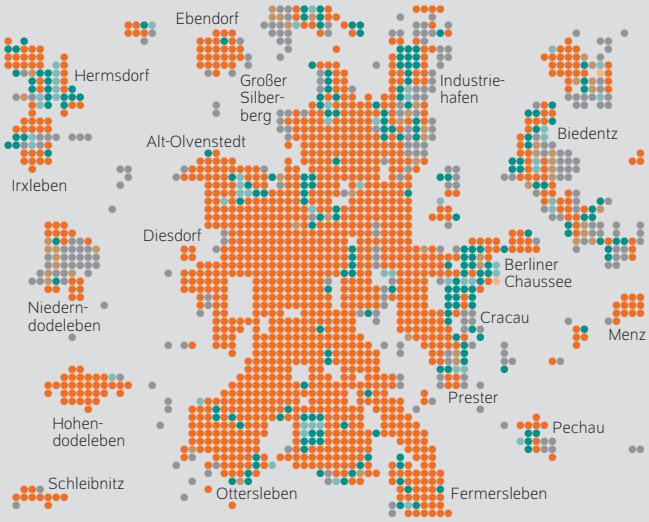
Figure 10

Private broadband availability by region of more than 50 Mbit per second
As a percentage of households (wired and mobile)

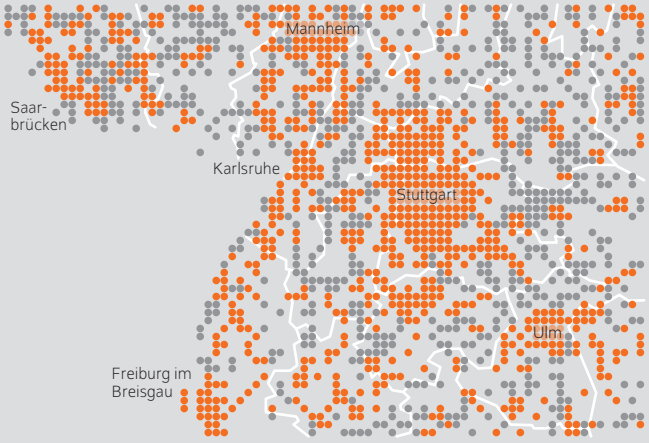
1. Private households in Germany (planning regions)



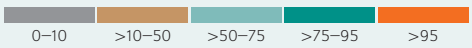
2. Private households in Magdeburg region



3. South western Germany in industry locations



Broadband availability as a percentage of households:



Quelle: Breitbandatlas (2017) (available online).

Relatively homogeneous broadband availability in Germany, but large differences within the regions.

operators must not be too restrictive, so that the private sector has incentives to invest into grid expansion. On the other hand, a sufficient level of regulation must be maintained to secure competition among telecommunication providers.

Regardless of the specific design of the regulation, the private sector will most likely not invest into a nationwide, full-coverage gigabit network expansion, because there will still be regions in which the cost of expansion will be too high and users' expected willingness to pay too low. In order to achieve nationwide gigabit network access, public funding for blank spots will be necessary.

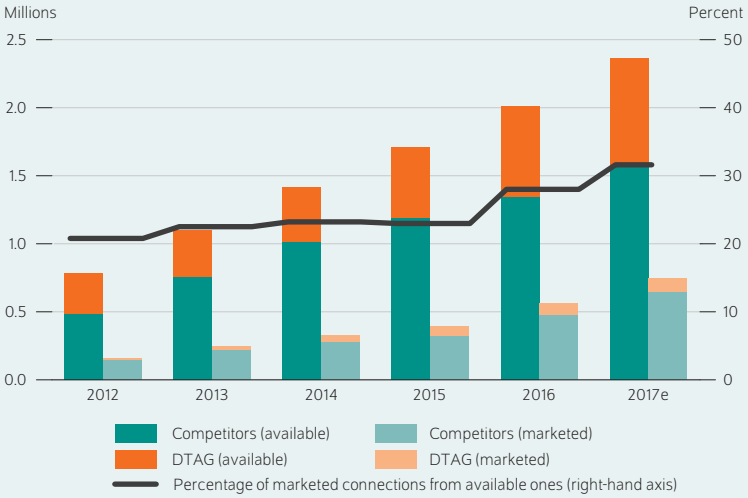
Previous experience with public funding of gigabit infrastructure expansion shows that it can actually be effective and lead to greater expansion. However, the extent to which this expansion will be efficient when subject to cost-benefit considerations is unclear.[36] To obtain the optimal expansion strategy, the mix of measures selected must be based on empirical analysis in the sense of evidence-based economic policy. This applies to future-oriented impact assessments,

36 See Tomaso Duso, Mattia Nardotto, and Jo Seldeslachts, "Expansion of Germany's broadband supply" (2018).

such as those that are the rule for similar regulatory measures on the EU level and retrospective ex-post evaluations that assess the actual efficacy of measures. In particular, a binding, systematic impact assessment procedure based on the model of the European Commission should be implemented for regulatory measures: the Federal Network Agency should commission independent audits.

Figure 11

Available and marketed fiber-optic connections in Germany
In millions; Share of marketed to the available FTTH/B connections in percent



Source: Dialog Consult/VATM (2017).

The market share of available connections is increasing in the last two years.

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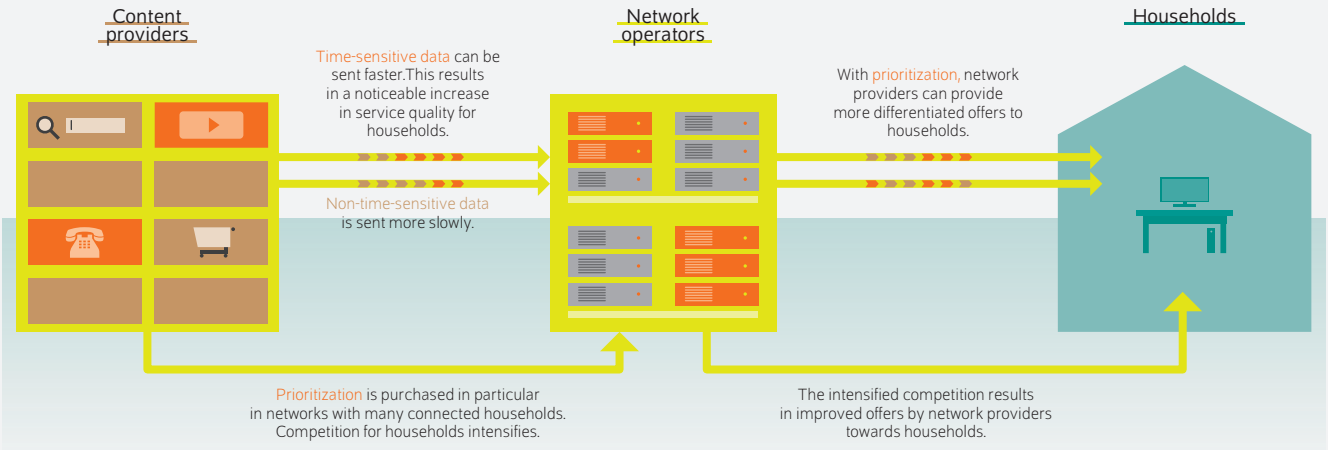
AT A GLANCE

Net neutrality: prioritization is beneficial from an economic perspective

By Pio Baake and Slobodan Sudaric

- The general possibility to prioritize data packets is beneficial from an economic perspective and can lead to a more efficient use of existing network capacity
- Competition among network operators would intensify and they could differentiate their offers more finely—private households would be the primary beneficiary
- Access to prioritization must be transparent and free from discrimination
- Modifications in the spirit of net neutrality must go hand in hand with a clear commitment to competition law and its enforcement
- The best-effort principle for data transmission was designed for non-time sensitive applications and cannot live up to the requirements of real-time applications

How households can economically profit from the introduction of data prioritization



Quelle: Eigene Darstellung.

FROM THE AUTHORS

"Prioritization would enable network operators to use their existing infrastructure more efficiently. However, freedom from discrimination and fair competition would have to be ensured, whether through explicit regulation or the consistent enforcement of existing competition laws – especially when it comes to companies of significant market power."

— Pio Baake, survey author —

Net neutrality: prioritization is beneficial from an economic perspective

By Pio Baake and Slobodan Sudaric

ABSTRACT

The principle of net neutrality was adopted by the European Union as a regulation promoting equality among all data packets in the Internet. Considering net neutrality from a purely economic viewpoint, however, the general possibility to prioritize data packets would likely lead to a more efficient use of existing network capacity. This is particularly applicable given the growth in data traffic and time-sensitive applications such as live streaming. Competition among network operators could intensify if they had the possibility to differentiate their offers more finely—and private households would be the primary beneficiary. However, modifications in the spirit of net neutrality must go hand in hand with a clear commitment to competition law and its enforcement. Access to prioritization of individual data packets must be transparent and equally available to all network participants. Network operators which also act as content providers as well as market participants with strong market positions in particular must not have the possibility to discriminate content providers.

The term "net neutrality" refers to the principle of treating all data traffic on the Internet the same, and without discrimination with respect to application or service.[1] Historically, it is based on the "best-effort principle," which means that all data packets are treated equally when they are transmitted from provider to provider in the Internet (Box 1). Neither the sender, recipient, packet content nor purpose of the data transmission plays a role. For a long time, this principle was considered fundamental but has been under debate in the last few years. In the U.S., the debate on net neutrality has led to fluctuation in development: regulations that are tight at some points in time are loosened at others.[2]

In the EU, the debate was stilled for the time being by Regulation (EU) 2015/2120 and the complementary Body of European Regulators for Electronic Communications (BEREC) guidelines on its implementation.[3] In effect, the EU has provided for the principle of net neutrality in order to ensure that end users can access content and information and choose among services and applications freely, while safeguarding the Internet ecosystem as a driver of innovation.[4] Exceptions are permitted for traffic management measures—for example in case of a temporary network overload—and services with special quality requirements. Those include applications within telemedicine and machine controls which rely on fast, reliable data transmission.

The EU regulations are supplemented by specifications promoting network operator transparency and the duty to inform. For example, they must provide information on how their traffic management process affects the quality of the Internet access offered and how possible volume restrictions could influence the use of applications and services. The national regulatory authorities are responsible for monitoring compliance. In Germany, the Federal Network

1 See Tim Wu, "Network neutrality, broadband discrimination," *Journal of Telecommunications and High Technology Law*, 2:141 (2003).

2 Insight into the development in the U.S. is provided in an overview by Yvonne Chan (available online, accessed June 5, 2018; this applies to all other online sources in this report unless stated otherwise).

3 Body of European Regulators for Electronic Communications (BEREC), BEREC Guidelines on the Implementation by National Regulators of European Net Neutrality Rules, 2016 (available online).

4 The European Parliament and the Council of the European Union, Regulation (EU) 2015/2120, points (1) and (3) (2015) (available online).

Box 1

Best-effort principle

This principle refers to network operators agreeing to transmit all data packets as quickly and with as high a quality as possible within the framework of their transmission capacity. The principle does not guarantee complete, perfect transmission. Instead, it reflects the network operators' general intention. Originally designed for non-time sensitive applications, the principle cannot live up to the quality requirements of real-time applications.

Box 2

Examples of Federal Network Agency measures for ensuring net neutrality

Equal access: According to the Federal Network Agency, there have been serious violations of the EU regulation in the form of prohibiting the use of voice over IP (VoIP), messaging services, and/or peer-to-peer applications. The conflicts were settled by adjusting the relevant network operators' general terms and conditions of business. The same applies to measures that fall under network management with unequal treatment of various applications and services. Zero-rating offers, in which the data traffic of selected applications and services are not throttled after they exceed volume restrictions, were also examined. As a result, Deutsche Telekom adjusted its zero-rating offer for Spotify such that data traffic for Spotify would also be throttled, for example.

Transparency: According to the Federal Network Agency, the majority of the complaints it receives deal with deviations between contractually agreed and actual download speeds. With its *Breitbandmessung* application,[1] the Federal Network Agency offers browser- and app-based options to measure the quality of Internet connections. The annual report on broadband measurement for 2016/17, based on trial measurements, showed that across all broadband classes and network operators, 71.6 percent of users received at least half of the contractually agreed maximum data transmission rate for downloads. For mobile broadband connections, the value was 18.6 percent.

1 Federal Network Agency application for measuring data transmission rates (available online).

Agency (*Bundesnetzagentur*) publishes annual reports about the measures applied to safeguard net neutrality (Box 2).[5]

Network requirements became more demanding

The authors will discuss the regulations from a purely economic viewpoint in the following. Other frequently emphasized aspects of the debate on net neutrality, such as safeguarding freedom of opinion, democracy, political control, or the preventions of political misuse, are not included in the analysis.

The economic analysis is based on the assumption that data traffic in both cable-based and mobile communication networks will continue to rise dramatically; it is also based on the observation that new time-sensitive applications, such as live streaming and telemedicine services or machine-machine communication, already add to or will add to the volume of data traffic. Also, developments in the Internet protocol now make it easier to differentiate between data packets and therefore handle their transmission differently.[6] On the other hand, transmission capacity in cable-based (partially copper-based) and mobile transmission networks remains limited.[7] High data traffic adversely affects data transmission and causes quality reductions in the user experience of applications and services.[8]

Internet stakeholders and approaches to prioritization

The key (economic) stakeholders in the Internet can be divided into three groups: households, content and application providers (such as Google, Netflix, Amazon, and news sites), and network operators (ISPs such as Deutsche Telekom and Vodafone in Germany) (Figure 1).[9] The latter provide connections to households and content providers, and therefore access to the Internet. In economic terms, they are the platforms upon which households and content providers interact. Connections between network operators are typically realized via direct interconnection or exchange points such as the Deutsche Commercial Internet Exchange (DE-CIX) in Frankfurt.[10]

Prioritizing the transmission of data packets for specific applications would boost their quality on the one hand. On the other hand, this would lead to potential sacrifices in quality for applications and services whose data packets continue to be transmitted according to the best-effort principle (Figure 2). Technologically, this would be based on reduced

5 Federal Network Agency, Netzneutralität in Deutschland Jahresbericht 2016/2017 (2017) (available online).

6 Examples include models of "differentiated services" where data packets can be divided into different classes and the data flow prioritized accordingly.

7 Yann Girard, Anselm Mattes, and Claus Michelsen, "Gigabit access: Germany lags behind in international comparison, but demand is also low," *DIW Weekly Report*, no. 25/26 (2018): XX (available online).

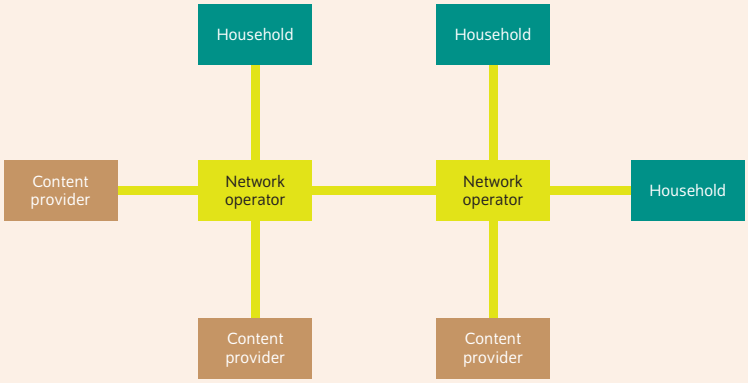
8 Quality reductions can be classified as a) latency or delays in end-to-end transmission, b) latency fluctuation (jitter), and c) the likelihood that individual data packets get lost.

9 On the following, see Pio Baake and Slobodan Sudaric, "Net Neutrality, Prioritization and the Impact of Content Delivery Networks," (computer printout, 2018).

10 In the case of direct interconnections between network operators, we can distinguish between peering and transit agreements. Peering agreements without direct payment between network operators are typically based on symmetrical data traffic. In transit agreements, network operators with high outgoing data traffic volumes pay fees to the transiting network operator.

Figure 1

Schematic representation of the key economic stakeholders in the Internet

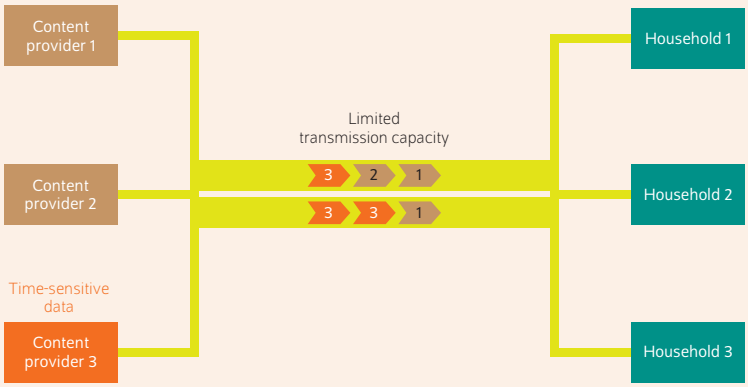


Source: Authors' own depiction.

Network operators provide the infrastructure through which consumers in the households have access to applications and services of the content providers.

Figure 2

Schematic depiction of a transmission of data packets according to the best-effort principle



Source: Authors' own depiction.

The time-sensitive data packet has to wait until transmission capacities are available: Households loose the potential additional benefit of the time-sensitive service.

transmission capacity for non-prioritized offers (Figure 3) or the delayed transmission of data packets through various exchange or connection points in the network (Figure 4).[11]

Prioritization leads to more differentiated offers

Within the framework outlined above, the debate around net neutrality and prioritization can be reduced to one question: should network operators be allowed to offer content providers the possibility of a prioritized data transmission?

From the viewpoint of content providers, prioritized transmission is an alternative to best-effort transmission by network operators. The alternative would be optional. The more the quality of a content provider's offer is influenced by transmission quality (e.g. time-sensitive applications)—and the more households and customers can be reached via the network of the respective network operator, the more valuable the prioritization alternative becomes.

From the perspective of network operators, prioritized transmission becomes an instrument for differentiating among content providers with different time-sensitive applications and services. The basis for differentiation is self-selection: content providers can decide whether or not they will pay to prioritize their data packets. The greater the number of households that are connected to a network, the more profitable prioritization becomes. In other words, the greater the number of households that can be reached, the higher the demand for prioritized transmission.

This creates an incentive for network operators to increase the number of connected households by reducing subscription prices. Without prioritization, this incentive does not exist.

Households would be the beneficiaries of prioritization

It seems obvious that network operators would take advantage of the prioritization option if they were permitted to do so. Which content providers opt for prioritization depends on how time-sensitive their offers are. Since only offers with sufficiently high added quality would be prioritized, indicating a higher willingness to pay for said prioritization, the selection process would be efficient. Households would not only enjoy the benefit of higher quality if offers were prioritized. They could also count on increased competition for their subscription.

The outcome is, however, ambiguous with regard to the consequences for network operators and content providers. Network operators would earn more income as a result of prioritization, but on the other hand they would have less

11 For the new 5G mobile communication standard, a division into logical networks (network slicing) with different quality characteristics is under discussion. Delayed transmission can be mapped by queuing models such as the MM1 model. In these models, prioritization increases the (average) processing or waiting time for non-prioritized data packets, while this effect becomes smaller if the total available capacity is large. Pio Baake and Slobodan Sudaric (see above) used an MM1 model.

income due to more intense competition for household subscriptions driving subscription prices downward. Altogether, the situation could put network operators in a so-called prisoner's dilemma: each operator would benefit from prioritization, but if they all do so their profits decrease.[12]

The effect on content providers is also twofold. The providers that do not prioritize will lose out due to reduced transmission quality, while those whose applications are time-sensitive will benefit.

Investment incentives for network operators could rise

Regardless of the detrimental effect regarding non-prioritized applications, prioritization would increase static efficiency overall. It is in the interest of network operators to make their networks as attractive as possible to households. They can achieve this by adjusting the prioritization price schedule for content providers in a way that increases the average quality of all applications.

A similar argument applies to the incentive for network operators to invest in their network infrastructure. The frequently voiced presumption that implementing prioritization would reduce incentives to invest[13] proves to be shortsighted, since it overlooks the reciprocal effects between the number of subscribing households and demand for prioritization on the part of content providers. Investing in the network increases transmission capacity and the appeal of the network. If the number of subscribing households increases as a result, this will increase demand for prioritization—a positive effect from the perspective of network operators that is impossible to benefit from under strict net neutrality.[14]

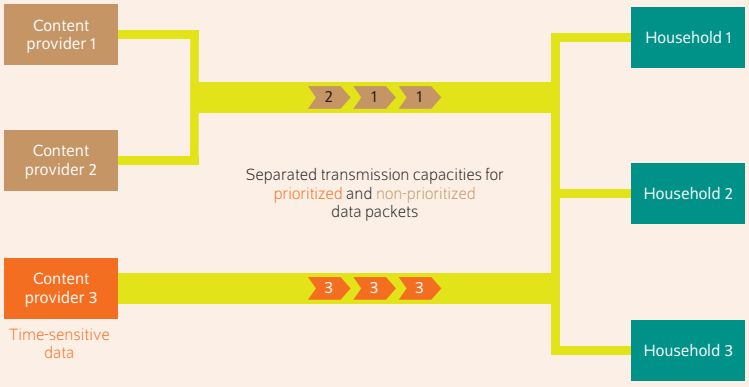
Competition and non-discrimination are essential

Our previous argumentation assumed that prioritization would be offered as an extra option alongside pure best-effort transmission. This implies that the process would be free from discrimination and all content providers would have the same prioritization options for their data traffic. It also assumes that there is competition among network operators for household subscriptions.

The last point depends both on the number of network operators and the quality of information households receive as they decide which network operator to subscribe to. Here, the transparency obligations which are part of the EU regulation play an important role. If households have clear

Figure 3

Schematic depiction of a transmission of data packets with prioritization (separation of transmission capacities)

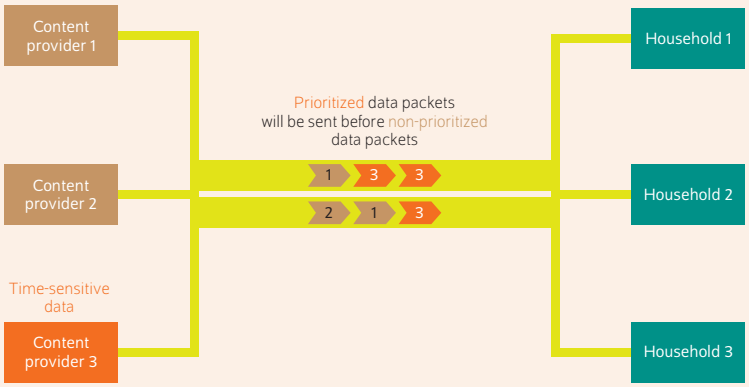


Source: Authors' own depiction.

A part of the available transmission capacity is reserved for time-sensitive data packets: These can now reach households without having to wait for non-prioritized data.

Figure 4

Schematic depiction of a transmission of data packets with prioritized transmission



Source: Authors' own depiction.

Time-sensitive data will be sent before non-prioritized data to ensure a smooth performance of time-sensitive applications. The transmission of non-prioritized data is delayed.

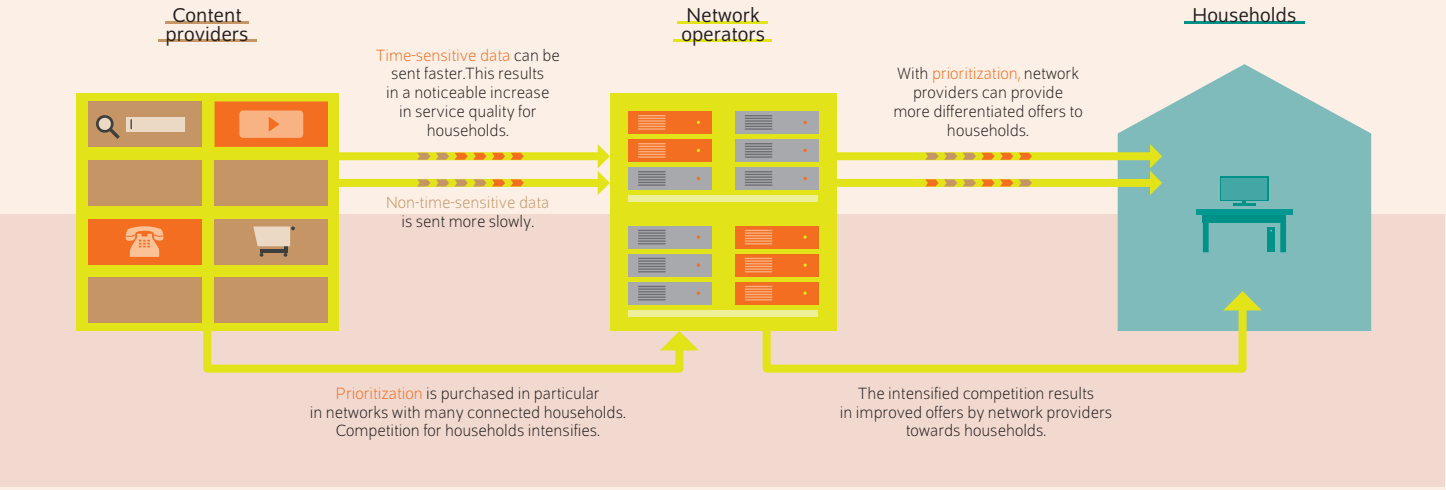
12 For more on this finding, see Marc Bourreau, Frago Kourandi, and Tommaso Valletti, "Net neutrality with competing internet platforms," *The Journal of Industrial Economics*, 63(1) (2015): 30–73.

13 See for example Federation of German Consumer Organisations, Fünf Mythen zur Netzneutralität, (2015) (available online).

14 Other studies arrive at similar results regarding network operators' incentive to invest. See Jan Krämer and Lukas Wiewiorra, "Network neutrality and congestion sensitive content providers: Implications for content variety, broadband investment, and regulation," *Information Systems Research* 23(4) (2012): 1303–1321. Others had inconclusive findings, see Jay Pil Choi and Byung-Cheol Kim, "Net neutrality and investment incentives," *The RAND Journal of Economics*, 41 (3) (2010): 446–471.

Figure 5

Households profit in several ways from the possibility of prioritization



Source: Authors' own depiction.

Better offers by network operators as well as improved time-sensitive applications and services by content providers give additional benefits to households.

information on the transmission quality they will receive, whether or not content providers offer prioritization and the extent to which they actually use it, prioritization will intensify the competition among network operators. The possibility to offer prioritization, allows network operators to further differentiate their offers which are available for all market participants in the same way.

The demand for non-discriminatory prioritization offers can be viewed as a safeguard against misuse. This applies to content providers with strong market positions and vertically integrated network providers, which offer applications and services alongside Internet subscriptions, and thus act as content providers at the same time. The less intense the competition between content providers, the easier it will be to grant exclusive contracts for prioritized data transmission to the disadvantage of competing content providers. The same applies when network operators offer their own content and give their data preferential treatment.

To avoid this risk, regulations must stipulate non-discriminatory offers for prioritization and consistently enforce existing competition laws.

It is difficult to say how prioritization would affect content provider innovation. On the one hand, the increase in transmission quality from prioritization could be the basis for new business models that rely on providing highly time-sensitive applications. Autonomous driving or telemedicine are only two of the applications that could benefit. On the other hand, we must be aware that data traffic prioritization could lead to a decrease in best-effort transmission quality if network capacity remains constant. Content providers that continue to rely on best-effort transmission could be faced with additional challenges as a result.

Conclusion: prioritization is economically beneficial. Effective competition is essential

In view of limited network capacity and constant technological innovation, theoretical considerations show that exemptions from the principle of net neutrality such as prioritization of data traffic could be economically beneficial. Prioritization would enable network operators to use their existing infrastructure more efficiently. At the same time, competition for household subscriptions would become more intense and network operators would have greater incentive to expand and improve their networks. However, freedom from discrimination and fair competition would have to be ensured, whether through explicit regulation or the consistent enforcement of existing competition laws. It is essential to guarantee equal access to the differentiation options for everyone in order to ensure equal opportunity among content providers. Transparency and traceability is also essential for competition to function properly, whether this involves the definition of specialized services, network operators' offers of differentiation options, or providing private Internet connections.

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JEL: L13, L51, L96

Keywords: Net neutrality, efficiency, investment incentives