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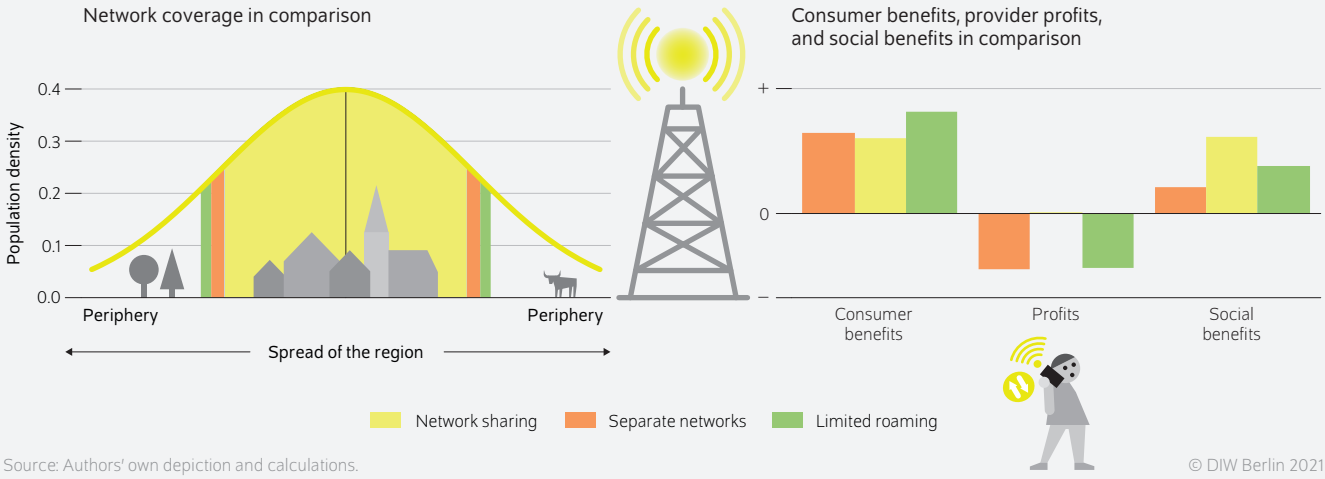
AT A GLANCE

Mobile phone network expansion in sparsely populated regions in Germany: roaming benefits consumers

By Pio Baake and Kay Mitusch

- Model compares network coverage in sparsely population regions with separate networks, comprehensive network sharing, and roaming
- If service providers share networks, only the minimum required coverage will be reached
- Largest network coverage is achieved with roaming: coverage increases by 13 percent compared to network sharing
- Roaming has additional benefits for consumers; they can use their devices outside of the area of their provider
- Consumers benefit from territorial agreements between mobile operators when it comes to network coverage

Largest network coverage, most benefits for consumers: roaming offers advantages in rural areas when expanding networks



Source: Authors' own depiction and calculations.

FROM THE AUTHORS

"If nationwide mobile network coverage is to succeed even in sparsely populated regions, policymakers must adapt regulation to the providers' cooperation models. Roaming could be one way to combine provider and consumer interests."

— Pio Baake —

MEDIA

Audio Interview with Pio Baake (in German)
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Mobile phone network expansion in sparsely populated regions in Germany: roaming benefits consumers

By Pio Baake and Kay Mitusch

ABSTRACT

As part of the 2019 frequency allocation process for mobile communications, the Federal Network Agency required network providers to achieve a certain level of mobile network coverage for the population. Cooperation between different network providers was also permitted for the first time, although it was not specified what forms of cooperation are permitted. Using a model, this report shows that providers can save money by sharing network infrastructure. However, this causes the overall network coverage to decrease unless the regulatory guidelines are modified. One way to increase network coverage while simultaneously benefiting consumers would be to implement international roaming regulations nationally: Network providers may use other networks to transmit data and calls, but may not use them as a basis for contracting with consumers. Overall, given minimum coverage obligations, both consumers and network providers can benefit from cooperation between providers. This also holds true for territorial agreements between providers as long as it is ensured that the required level of coverage is achieved.[1]

1 This Weekly Report is based on the German-language DIW *Wochenbericht* 17/2021, "Mobilfunk-Netzausbau in dünn besiedelten Regionen: KonsumentInnen profitieren von Roaming", published April 28, 2021.

The slow progress in broadband expansion has been a never-ending matter in Germany; one particular issue is providing fast Internet to sparsely populated regions. As supplying individual households with fiber-optic takes a long time and is also disproportionately expensive in many cases, fast mobile systems (3G to 5G standards) offer an alternative. Moreover, due to regular spectrum auctions, there are opportunities in the mobile telecommunications sector for requiring licensed mobile phone companies to further expand their networks.

For example, when auctioning frequency bands in 2019, the Federal Network Agency required the companies that acquired licenses to provide at least 98 percent of households in each federal state with at least 100 megabits per second by the end of 2022.[2] In addition, at least 500 (cellular) base stations[3] with this capability must be put into operation in previously defined "white spots," areas without coverage. Highways and the Intercity Express train routes must be provided with service as well.[4] The network coverage policy will be supplemented by the new, federally-owned *Mobilfunkinfrastrukturgesellschaft* (MIG), which will use spectrum auction revenues to drive network expansion in the remaining white spots from 2021 onward, thus almost completely eliminating them.[5] The Federal Network Agency has already announced that further expansion obligations will likely be formulated as a part of future frequency allocations from 2025 and 2030.[6] These obligations will likely relate to higher performance capabilities and transmission capacities in sparsely populated regions.

However, the network coverage requirements must be proportionate. Complete coverage by each individual mobile

2 Transmission rates of up to 42 megabits per second can be achieved with the UMTS standard.

3 A base station is defined as a stationary radio mast connected to other radio masts either via cables or a radio relay system.

4 Decision of the Presidential Chamber of the Federal Network Agency for Electricity, Gas, Telecommunications, Post, and Railways from November 26, 2018 (File number: BK1-17/001) (2018) (in German; available online; accessed on April 20, 2021. This applies to all other online sources in this report unless stated otherwise).

5 Bundesministerium für Verkehr und digitale Infrastruktur, *5 Punkte Plan zur Mobilfunkstrategie* (2019) (in German; available online).

6 Decision of the Presidential Chamber of the Federal Network Agency, 3 (in German).

DOI: https://doi.org/10.18723/diw_dwr:2021-19-1

service provider would entail high costs and makes little sense even from a social point of view. In sparsely populated areas, mobile telephony becomes a natural monopoly in which competitive infrastructure expansion with separate networks would be inefficient. Therefore, network sharing agreements (NSAs) have been established in mobile communications worldwide in recent decades (Box 1). Regulatory authorities frequently tolerate NSAs and sometimes they even encourage and support them (Box 2).

In a 2010 decision, the Federal Network Agency approved passive network sharing, allowing companies to share locations for the construction of base stations or masts and other supporting constructions.[7] The 2019 spectrum auction also allowed network providers in sparsely populated regions to enter into cooperative agreements that go beyond passive sharing for the first time. This applies to the 500 base stations in the previously defined white areas and to highway and high-speed train route coverage.

This represents an exception from the principle of infrastructure competition, which characterizes mobile communications regulation. However, the exact type of cooperation allowed was not specified. All cases of cooperation must be reported, and the Federal Network Agency and the Federal Cartel Office reserve the right to intervene on a case-by-case basis and devise additional conditions.[8]

In sparsely populated regions, regulatory concerns about NSAs take a back seat

The political discussion on network sharing centers around three topics:

1. Facilitating coverage of sparsely populated areas with 4G technology

2. Network densification in metropolitan areas as a prerequisite for implementing 5G technology

3. New competitors' access to the existing providers' networks

In the context of the first two topics, an NSA is a voluntary, cooperative agreement on equal terms in which companies grant mutual access to their network infrastructures or jointly invest, often in the form of joint ventures. However, there are concerns that this could decrease competitive intensity between the participating companies and limit their incentives for future innovations. The third topic, the network access of newcomers, in contrast, is one-sided in nature and referred to as roaming. There are hopes that the obligation to provide network access, as is currently being discussed in the amendment of the German telecommunications law, will result in more competition at the service level, but there is also the concern that the investment incentives of established network providers could decrease.

Many concerns about network sharing take a back seat in regard to network coverage in sparsely populated regions. For example, the fact that active sharing could limit the possibilities and incentives for future innovations plays a less important role in sparsely populated regions because there, ensuring coverage by the established standard technologies is more important than innovative technologies. Competition between mobile service providers can be influenced in the periphery at best, and not in the core areas of the nationwide market. So far, it is hardly observable that mobile prices in sparsely populated regions differ from those in metropolitan areas, which suggests that the prices in the periphery are determined by competition in the metropolitan areas. NSAs, which are limited to sparsely populated regions, can therefore be quite long term and in-depth. They can include not

Box 1

Network sharing and roaming

A basic distinction is made between passive and active sharing: passive network sharing refers to the shared use of network elements that do not process or convert telecommunications signals and therefore are not specifically meant for transmitting signals. Examples include co-locations, locations for base station construction that are shared and towers or other supporting structures that are used jointly.

In active network sharing, technical elements that can create, process, strengthen, and direct signals are used jointly. RAN (radio access networks) sharing focuses on sharing network access equipment, including the active elements of base stations and possibly antennas. MORAN (multi-operator radio access network) sharing involves sharing all active elements of a radio network, but not the spectrum. Finally, in MOCN (Multi Operator Core Network) sharing, frequencies are also shared, at least partially. Thus, the users can access all frequencies using the services of their respective mobile service provider.

The differences between the types of active network sharing lie in the capabilities of the network operators to determine the services they offer independently, for example in regards to transmission quality.

National/local roaming is a form of cooperation in which one operator uses the equipment of another operator in the same country in order to offer its users network access and services. Thus, fundamentally, roaming is a one-sided network access agreement. If companies invest in different areas, they can grant each other reciprocal access there, as is the case in the international context.

7 Federal Network Agency, *Gemeinsame Nutzung von Funknetzinfrastruktur und Funksressourcen* (2010) (in German; available online).

8 "Infrastructure sharing and roaming can contribute to improving mobile network coverage. Frequency assignment holders may enter into cooperative arrangements for joint economic network expansion in compliance with competition and antitrust laws ("burden sharing")." Federal Network Agency, 4.

Box 2

Network Sharing Agreements in Europe

All through Europe, mobile service providers cooperate using so-called Network Sharing Agreements (NSAs). NSAs may vary in the ways networks are shared and in terms of the used technology (Table).

Table

Selected European NSAs

Country and year	Type of sharing, technology	Participating companies
Sweden, 2001	RAN sharing for UMTS (3G)	Telia and Tele2 founded the joint venture Svenska UMTS Nät AB (SUNAB) for operating their shared 3G network infrastructure. Similarly, Telenor and Tre founded the joint venture 3GIS for operating their shared 3G network infrastructure outside major cities.
Sweden, 2009	RAN sharing for LTE (2G to 5G)	Telenor and Tele2 founded the Joint Venture Net4Mobility to operate their joint network infrastructure.
France, 2011	National roaming for UMTS (3G)	Free Mobile uses the Orange network (France Telecom).
Austria, 2012	National roaming for GSM (2G) and UMTS (3G)	Drei uses T-Mobile's 2G network and T-Mobile uses Drei's 3G network.
France, 2014	RAN sharing for 2G, 3G, and 4G	SFR and Boygues Telecom
Spain, 2017	National roaming for GSM (2G), UMTS (3G), and LTE (4G)	Yoigo possesses its own 2G/3G/4G licenses but has its own infrastructure only in metropolitan areas. Outside of its own service areas, a "national roaming" agreement exists with Orange (France Telecom).
Italy, 2017	National roaming for GSM (2G), UMTS (3G), and LTE (4G)	Iliad, as a new market entrant, has been given both the opportunity to acquire sites that had to be surrendered after the merger of Wind and Tre to form WindTre, and a 'national roaming' agreement with the united network for five years.
Germany, 2019	Passive sharing (transmission towers) for all technologies	Agreement cover up white spots between Deutsche Telekom, Vodafone, and Telefonica/O2.
Great Britain, 2021	Mast sharing for 4G	O2, Three, and Vodafone built and share 222 4G transmission towers in rural areas, such as in Scotland, as a part of the Shared Rural Network (SRN).

Sources: Internet research (see below).

only passive but also active infrastructure elements, such as network access devices or antennas.

Different NSA regulations and minimum coverage obligations in sparsely populated areas

Different types of regulation (referred to as variants) were analyzed in a simple model (Box 3) to evaluate the effects of NSAs in sparsely populated regions. It is assumed that two network providers in a sparsely populated region must build up new networks.[9] The most important regulatory instrument for the sparsely populated regions is the minimum coverage obligation. Such obligations are paired with different variants of complementary regulation in the following analyses: the "separate networks" variant, in which no cooperation is permitted; the "network sharing" variant, in which mobile service providers may use other providers' network infrastructure;[10] and the "limited national roaming" variant, which adheres to reciprocal international roaming regulations and allows a provider's customers to use the networks of other providers for data transmission and calls.[11] As a further dimension of regulation, for each of these variants (insofar as it is sensible) it is examined whether territorial agreements should be permitted or forbidden. In regards to consumer prices, it is assumed that they are fixed and given from a broader, national environment.

Separate networks lead to areas with competition and to areas with only one provider

In the separate networks variant, customers of a mobile service provider only have network access where their provider has established its own network. Each individual network must fulfill the minimum coverage obligation.

A numerical specification (Box 3) was used to calculate the separate network coverage that the two mobile operators would choose under this regulation, assuming a required network coverage of two-thirds of the population (Figure 1).[12] Initially, it is assumed that no territorial agreements may be concluded. The providers select a considerable overlap area, but there are also exclusive areas in the periphery so that the total network coverage exceeds the required coverage of two-thirds by each provider.

The large overlap area can be explained by the concentration of the population in the center of the region. Nevertheless, the networks are not completely identical because companies have an incentive to become monopoly providers in some areas and thus achieve higher demand. These exclusive areas ("gray spots") are relatively small, however, at only 14 percent of overall coverage, as population density decreases in the outlying areas. Thus, larger investments would be necessary to increase the exclusive area and still fulfill the minimum coverage obligation.

If territorial agreements are permitted, networks are pushed out further so that overlap areas become smaller and exclusive areas become larger. Overall, this increases network coverage by about one percent, as the providers must expand their coverage areas to fulfill the minimum coverage obligation for the entire population. As a result, territorial agreements do not only increase the profits of mobile service providers but benefit consumers as well: More consumers receive access to at least one network and can use their mobile devices in a larger area. Together, these effects outweigh the

9 Alternatively, the model can refer to providers who must upgrade existing networks for new transmission standards or must expand their transmission capacities.

10 For example, Deutsche Telekom and Telefonica/o2 are planning passive and active sharing in sparsely populated regions. See Telekom's press release from January 19, 2021: Telekom und Telefónica teilen Netzinfrastruktur für weiter verbesserte Netzversorgung (in German; available online).

11 Unlike national roaming, limited national roaming does not allow providers to also offer contracts or connections in regions without coverage by their own network.

12 This requirement is lower than the 98 percent required in Germany as a whole. However, given the high population figures in metropolitan areas, which are generally covered 100 percent, the requirements for sparsely populated regions are reduced.

Box 3

Model

In a representative sparsely populated region new networks must be built or existing networks must be upgraded to meet new transmissions standards. Two competing mobile service companies $i = 1,2$ have the task of fulfilling minimum coverage obligations. The cost of network expansion increases quadratically in the size of the region R_i covered by the grid i:

$$cost = \frac{c}{2} R_i^2$$

wherein c is a cost parameter. The population in the region is located on a line symmetrical around a central point (normal distribution with variance 1).

Both providers offer flatrate contracts with identical prices p_i determined nationally. The consumers' demand decisions follow a nested logit model for a two-step decision process: Should a mobile phone contract be concluded at all? And if yes, with which provider?

The size of a provider's network area is a significant factor when consumers are evaluating providers. In the case of separate networks, this size corresponds to the individually developed area R_i. With network sharing and limited roaming, the size is equal to the jointly developed area $(R_1 \cup R_2)$.

In the cases of separate networks and limited roaming, the minimum coverage obligation is expressed by the restrictions that the population share in each area R_i must be at least equal to the value $\overline{F}$ required by the regulator, with $0{,}5 < \overline{F} < 1$. However, in network sharing, it is only required for the jointly developed area $(R_1 \cup R_2)$ to satisfy this condition.

For the numerical specification of demand in the nested logit model, the following values are assumed: $\mu = 0{,}25$, $p_1 = p_2 = 0{,}5$, $c = 0{,}25$, $\overline{F} = 2/3$ with μ reflecting the differentiation of the two providers, and the deterministic part of the logit utility function is given by $(R_i - p_i)/\mu$. The utility of "no contract" is normalized to zero.

negative effect that a smaller share of consumers can choose between two providers.

But even if territorial agreements are allowed, this limited form of cooperation does not overcome one fundamental issue of separate networks: When customers of one provider enter the exclusive territory of the other, they have no network access. This is reflected negatively in customers' network connection ratings and thus decreases the networks' demand and profitability.

Comprehensive network sharing: cost savings, but lower network coverage

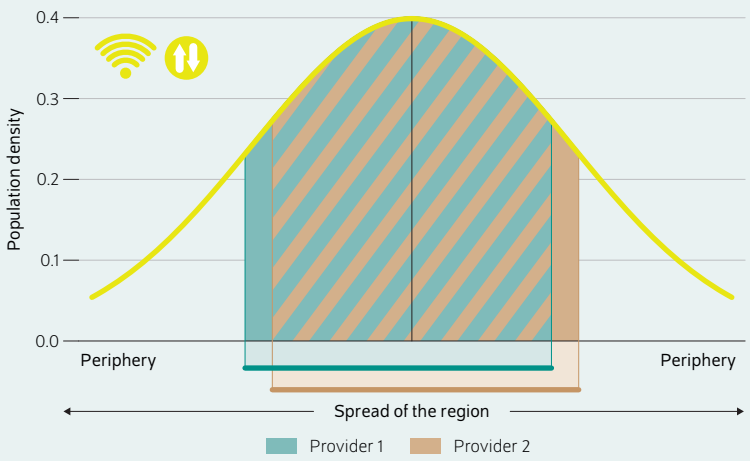
The second variant entails an extensive form of active network sharing in sparsely populated regions in which every mobile service provider may use the network of the other, if necessary, for offering network access, services, and its own contracts. Thus, the minimum coverage obligation applies to both networks *together* and it is inevitable that providers would coordinate via territorial agreements.

Due to the territorial agreements and shared network usage, providers will attempt to minimize the overall required investment costs. Each provider invests in an area that extends from the center in only one direction at a time; the networks do not overlap (Figure 2). As a result, the overall network coverage meets the minimum coverage obligation of two-thirds of the population exactly.

Compared to the separate networks variant, providers lose demand but benefit from the lower costs of network investment. Consumers have a choice between the two providers

Figure 1

Network coverage with separate networks, no territorial agreements



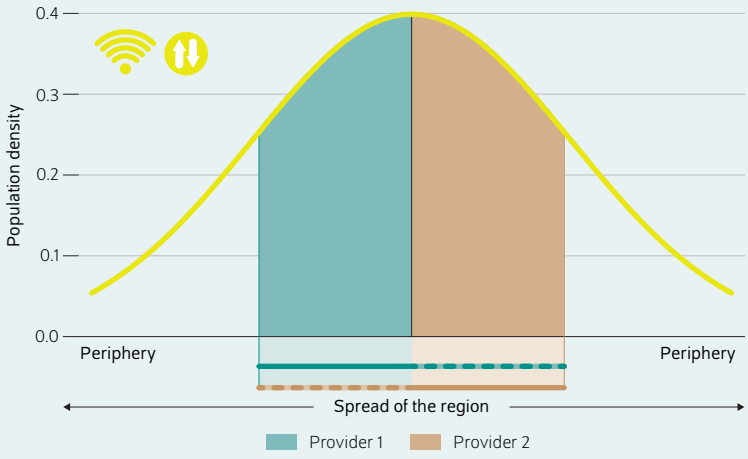
Notes: The area below the curve represents the share of the population that a network provider reaches with its infrastructure. Dark green represents the first provider, ocher the second.

Source: Authors' own depiction based on their own calculations.

When two providers establish their own separate mobile networks, it creates an area in which both providers compete for consumers. Additionally, it creates spots in the outlying areas in which only one provider is active.

Figure 2

Network coverage with network sharing



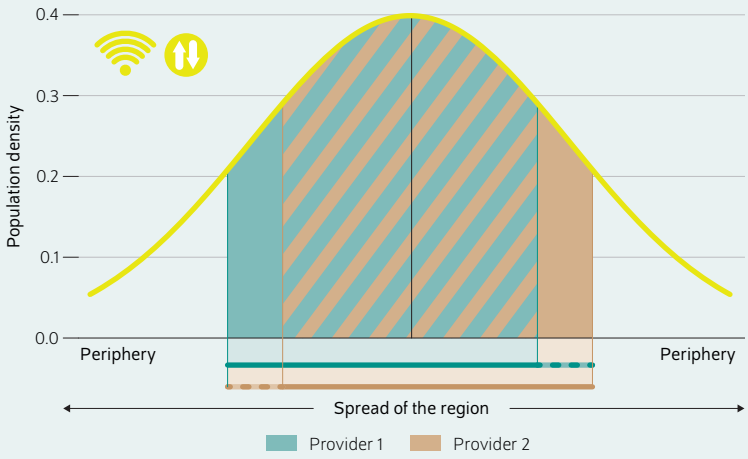
Notes: The area below the curve represents the share of the population that a network provider reaches with its infrastructure. Dark green represents the first provider, ocher the second. In the shaded area of the bars, the providers reach the population using the infrastructure of the other provider.

Source: Authors' own depiction based on their own calculations.

When every service provider can use other providers' networks, providers will avoid overlapping areas to minimize costs; at the same time, overall coverage decreases.

Figure 3

Network coverage with limited national sharing, with territorial agreements



Notes: The area below the curve represents the share of the population that a network provider reaches with its infrastructure. Dark green represents the first provider, ocher the second. In the shaded area of the bars, calls and data are transmitted over the other provider's network.

Source: Authors' own depiction based on their own calculations.

Network coverage is greatest when providers build their own networks, but consumers can also use the other network.

throughout the covered area, but in the end, they have a lower overall network coverage than under the separate networks variant.

Finally, if network providers are allowed to agree on prices for network access from each other, the results do not change. Network access prices lead to payments between providers, but they offset each other and therefore do not affect providers' investment decisions.

Limited national roaming: middle-road variant with advantages for consumers

The third variant involves regulations for international roaming. A distinction is made between "residents" and "visitors" of a place. Residents can only sign contracts with mobile service providers that have built a network in their place of residence. However, as visitors, they may also use their phones in other locations where only another provider's mobile network is available. Customers must be prevented from circumventing this distinction by "permanent roaming," which can be prohibited by regulations such as the EU's regulation on roaming (no. 531/2012). Thus, this variant is called "limited national roaming."[13]

This is a middle-road variant between separate networks and network sharing. As with network sharing, a company's customers have network access everywhere where one of the two companies has invested. However, because contracts can only be offered in areas with a provider's own network, the minimum coverage obligation applies to every individual network, unlike in network sharing.

Qualitatively, similar results are found for providers' investment decisions under restricted national roaming as under separate networks (Figure 3): Providers will build their networks in a way that leads to overlaps as well as exclusive areas. Although consumers' increased usage options raises demand, providers are less able to gain a competitive advantage over rivals by expanding their own networks. Compared to the separate networks variant, network providers have a somewhat lower incentive to move their networks outward. Here, too, territorial agreements lead to higher network coverage, whereas the effect is greater than under separate networks due to the consumers' higher willingness to pay.

Reciprocal payments between network providers for roaming services provided by the other increase the providers' incentives to expand the areas they serve exclusively: the larger a provider's exclusive territory, the higher the revenue from roaming services. Profit maximizing roaming prices lead to the same network coverage that is achieved with territorial agreements.

13 The limited national roaming considered here is reciprocal in nature and thus differs from unilateral national roaming, which is intended to give new entrants access to the existing providers' networks (and where permanent roaming is a prerequisite for market entry). In the BEREC Report on Infrastructure Sharing from 2018 (page 10, especially footnote 4), *reciprocal* roaming is viewed as a form of intensive "active sharing with joint deployment."

Benefits for consumers greatest under limited national roaming

To compare the economic effects of the different regulatory variants with each other, the following section observes the respective network coverages, the benefits to the consumers, the providers' profits, and the social benefit—the sum of the benefits to the consumers and profits. For the separate networks and limited national roaming variants, it is assumed that territorial agreements may be concluded.

The highest network coverage is achieved under limited national roaming. Both networks overlap less relative to the separate networks variant (Figure 4). Compared with comprehensive network sharing, network coverage is eight percent higher with separate networks and 13 percent higher with limited national roaming.

Accordingly, consumers benefit most from limited national roaming. Compared to comprehensive network sharing, the benefits for the consumers increase by 34 percent. These benefits include the additionally connected consumers, who would not be covered under network sharing, as well as the consumers' ability to use their mobile devices in a larger area. With separate networks, consumer benefits are only seven percent higher than with network sharing. However, the expansion costs for limited national roaming are similarly high as for separate networks and thus significantly higher than for network sharing. According to the social benefit criterion, limited national roaming ranks in the middle between the two other variants. The social benefit is highest in the network sharing variant because the providers save high costs.

Price competition does not change the basic results

If, contrary to common practice, providers decide to choose different consumer prices in different regions, they must consider the intensity of (regional) price competition in their investment decisions: the larger the areas exclusively served by only one provider, the weaker the regional price competition between providers. As a result, providers move their networks outward under the separate networks and limited national roaming variants, achieving more network coverage overall.

In view of the variant comparison, this does not change the qualitative results. Nevertheless, network access and roaming prices can be used to increase consumer prices. If regionally differentiated consumer prices emerge, regulatory interventions may be considered.

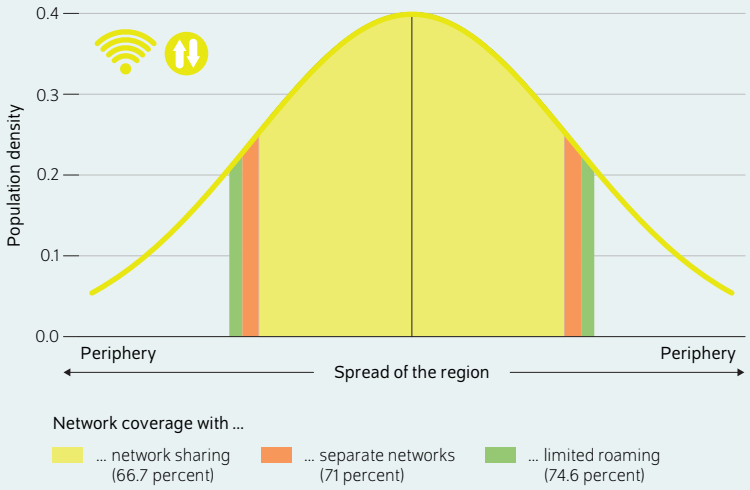
Conclusion: network coverage obligation is essential framework for cooperative agreements

Over the course of the 2019 frequency allocation, the Federal Network Agency required mobile service providers to expand their networks, as it had previously done. By the end of 2022, every established mobile service provider should be able to cover at least 98 percent of the population of every federal state in Germany. For the first time, a cooperation in which mobile service providers satisfy the requirements jointly is permitted. However, it was not specified what type of cooperation is permitted; reference was only made to the arbitration role of both the Federal Network Agency and the Federal Cartel Office. Additionally, the Federal Network Agency made it clear that this is only a first step: "For the frequencies available in the medium term from 2025 and from 2033, coverage requirements will have to be redefined in a second and third step."[14]

To evaluate Network Sharing Agreement (NSA) regulations, different regulatory systems were analyzed. Minimum coverage obligations are the most important regulatory instrument for sparsely populated regions. Under this assumption, it can be seen that consumers benefit from territorial agreements between companies, while territorial agreements in other sectors are often at the expense of consumers and therefore prohibited. Comprehensive network sharing beyond this allows providers to save significant costs, as network sharing comes with a common minimum coverage obligation. This increases the social benefit at the expense of consumers, however, since the overall network coverage achieved is lower than that of separate networks. This would need to

Figure 4

Network coverage with separate networks, network sharing, and limited national roaming, each with territorial agreements



Notes: The area below the curve represents the share of the population that a network provider reaches with its infrastructure. Yellow represents network coverage under network sharing, red shows the additional network coverage under separate networks, and light green shows the additional network coverage under limited national roaming.

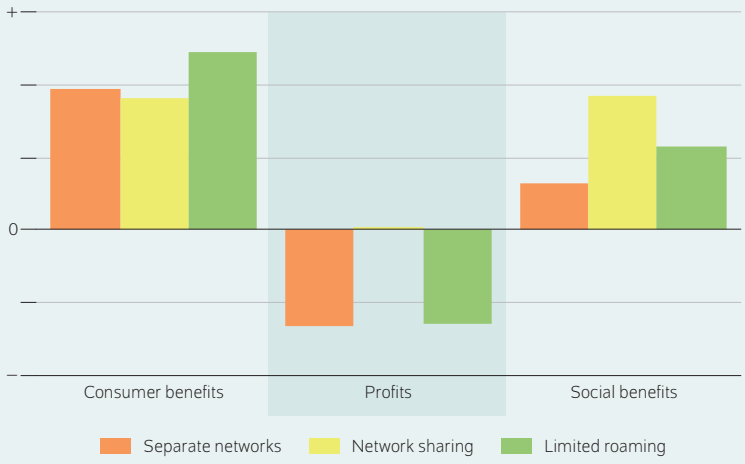
Source: Authors' own depiction based on their own calculations.

The least network coverage is achieved with network sharing. With separate networks, coverage is eight percent higher, and with limited national roaming, 13 percent higher.

14 Decision of the Presidential Chamber of the Federal Network Agency, 3 (in German).

Figure 5

Consumer benefits, provider profits, and social benefits in comparison
In normalized monetary units



Source: Authors' own calculations.

Consumers benefit most from limited national roaming; providers score the greatest profits under network sharing.

be considered in the specific definition of minimum coverage obligations if comprehensive network sharing is to be allowed in sparsely populated regions.

An intermediate solution between completely separate networks and comprehensive network sharing is limited national roaming, a variant that has received little attention in the discussion to date. In reciprocal roaming, mobile service providers grant the customers of their competitors access to their network. However, companies may not offer contracts in areas in which they have not invested. In this context, the *individual* minimum coverage obligation continues to apply so that the overall network coverage increases. However, the companies' expansion costs are higher and thus the profits are lower than under network sharing.

The results also shed light on different long-term effects of the regulatory variants. Comprehensive network sharing implies that companies have an incentive to specialize in larger areas within the sparsely populated regions and to no longer invest in the areas of the cooperation partners. In the long term, this could lead to companies limiting their individual ability to act and develop in the future. In contrast, limited national roaming leads to parallel investment by companies in a considerable area of the sparsely populated regions, thus preserving both companies' long-term development capabilities.

Currently, cooperation in mobile network expansion is developing dynamically along with the regulatory approaches. This analysis shows that for sparsely populated regions, network coverage requirements provide a good framework for cooperation. Within this framework, territorial agreements and limited national roaming should be permitted, although not necessarily every form of network sharing.

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