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Mobile Network Sharing

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Mobile Network Sharing

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1 Introduction

The sharing of passive network elements is a common phenomenon in mobile markets. Some regulatory authorities also support active sharing of the radio access network. More far reaching sharing concepts like the virtualisation of network functions up to network slicing are currently being developed or are going to be developed soon. Given the need for a significant increase in the number of base stations and sites in a 5 G environment it has to be anticipated that the need for sharing network elements between mobile operators will increase significantly over the next few years.

In Article 59 (3) of the proposed new Code for Electronic Communications the European Commission intends to empower NRAs to impose obligations in relation to the sharing of passive or active infrastructure, obligations to close localised roaming access agreements, or the joint roll-out of infrastructures. We regard this provision as an upcoming greater openness of regulators towards the need for network sharing in a 5G environment.

Before this background the paper analyses how regulatory authorities can make the relevant balance between economically desirable cost savings, reduction of the impacts on the population and the environment on the one hand side, and competition implications of network cooperation on the other hand side which could be unfavourable, in order to decide on individual forms of operator co-operation and its intensity.

The paper is intended to be a comprehensive survey of the relevant strategic reasons which drive mobile operators to share certain network elements and of the criteria and dimensions according to which regulators decide on those types of competitors' cooperation. Sharing of network elements impacts a variety of relevant economic issues including infrastructure competition, innovation of services and efficient investment in networks. The paper will show that overall the experience with mobile network sharing seems to be welfare enhancing. Given the challenge of huge investment needs for 5G and limited incremental revenue potential, a higher degree of network sharing becomes a relevant strategic option for operators and regulators for keeping a competitive market structure.

The paper starts from a broad definition of network sharing (Section 2). The classic forms of mobile network sharing relate to the joint use of passive and/or active network elements. This applies in particular to the joint use of access network infrastructures. Joint use of network infrastructure may, but does not have to include shared use of frequencies. Although in the case of roaming only the (respective) elements of one network are used, this form of co-operation is in the end equivalent to network sharing. Since the network is defined less by the physical hardware, sharing may also refer to software-determined network functions. The most extensive use of a third party network is in the form of an MVNO relationship.

In the third section of the paper we will describe the major market and regulatory trends towards sharing in a comprehensive form. Section 4 provides our economic assessment of the major conflicting economic implications of network sharing, materialising major cost savings through sharing against impairment of competition or the intensity of competition. In this context we will present some specific cost modelling results which we have conducted for different sharing scenarios. We conclude the paper with summarizing some results and recommendations for upcoming regulatory and regulatory policy decisions in Section 5.

2 Forms of network sharing

In this section we describe the various forms which network sharing might take. Besides network usage by MVNOs they are all relevant strategic options for MNOs. Depending on their relative market position and their time of market entry certain forms of sharing may be more relevant to certain MNOs than to others.

2.1 The organizational dimension of network sharing

From a competition law perspective network sharing is a cooperation of independent companies in the area of network infrastructure. The dominant organizational form for sharing is a contractual agreement. Sharing may also be materialized by a joint venture of the parties involved. Outsourcing and the provision of certain network assets and / or functions by third party service providers becomes another major form of network sharing. Outsourcing becomes functional network sharing if the corresponding service provider provides infrastructure services for several MNOs. Tower companies represent a major example for such type of cooperation. The outsourcing model avoids the potential competition problem of sharing that MNOs might have, namely the strategic interest to deny access to their sites and masts for other MNOs.

2.2 Passive sharing

Passive sharing means the joint use of passive network elements. This includes the elements sites, masts, ducts, power provisions and air conditioning, cabinets, cables and combiners. It may include site-related services, like security services. Passive sharing is the mostly used and accepted form of cooperation among MNOs. It requires no active coordination of operators and can be applied in a decentralized matter. Networks basically remain competitively independent from each other. In some countries this form of cooperation even is requested by law or regulation.

Site and/or mast sharing can be mediated by specialized entities like tower companies which provide access to sites and/or masts as a service to several or all MNOs in a

market. Such market solutions for sharing are much less vulnerable to attempts for discrimination and denying access.

2.3 Active sharing

Active sharing means the sharing of active network elements like antennas, nodes or radio network controllers. Active sharing can be focused (and limited) to the radio access network (RAN) or it may also include elements of the core network. RAN sharing can entail all elements of the access network including the backhaul equipment. In its most intense form two operators just own and operate one RAN. RAN sharing may or may not include the sharing of spectrum. Despite sharing the whole RAN network operators can still operate logically separated network and have full control over that network. Furthermore, the operation and maintenance center can be separately operated. Sometimes regulators make that an request, to keep sufficient network independence and control for sharing partners. The logical separation of RANs also requires that the cooperating MNOs furthermore use their frequencies exclusively.

Figure 1 shows schematically which network elements are jointly used in the various forms of active and passive sharing and which are still operated exclusively by the operators.

Figure 1: Forms of sharing and jointly used network elements



Source: Adapted from Nokia Siemens Network (NSN)

RAN sharing is driven by the motive to save network cost. A further reason is to jointly develop network coverage for rural and remote areas with low customer density. This allows to extend network coverage at lower cost.

Network cooperation becomes more far reaching if operators also share elements of the core networks like transport, switching and routing, customer data bases (HLR, VLR), the billing platform and others more. If operators also jointly use their core networks, networks usually are no longer separable and distinguishable and can no longer be operated independent of each other. Furthermore, it becomes highly questionable whether operators are still competitively independent of each other in such a case. Usually, sharing concepts for the core network also include the sharing of the RAN. It becomes highly questionable to what extent operators are then still able to define and to distinguish their products and services from each other. Thus, competition becomes constrained.

If operators also share the logical elements of the core network they lose their ability of an independent service creation. Platform sharing is less relevant between MNOs but it is often characterizing the relationship between MNOs and MVNOs. MVNOs typically use the platforms of their wholesale partner MNO.

2.4 National roaming

Although only the elements of one network are used in case of roaming, this form of cooperation can nevertheless be classified as a form of sharing. In the case of roaming the traffic of a customer of operator A is transported and routed over the network of operator B. Formally, roaming does not require joint network elements, it can just be handled contractually. National roaming can occur symmetrically between MNOs or it can be provided asymmetrically from one to the other operator. In both cases the operator demanding roaming has to deploy its network with a lower degree of coverage.

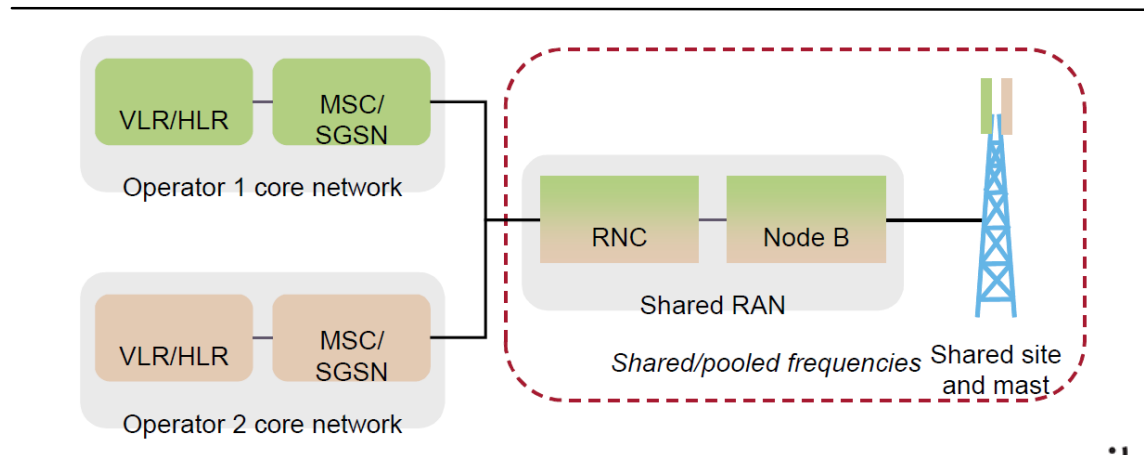
In case of roaming the operators involved still compete at the service level. The ability of the roaming demanding operator to differentiate its services are, however, limited. Roaming is mostly used in asymmetric market scenarios, in particular in case of asymmetric market entry.

2.5 Frequency sharing

The joint use of frequencies, also called as frequency pooling, means the simultaneous use of the spectrum which has been allocated exclusively to each operator in a particular region. Users get access to a larger spectrum in a particular radio cell and the capacity of this cell increases correspondingly. Spectrum sharing can be organized unilaterally or bilaterally. In the first case operator A has access to spectrum of operator B, but not vice versa. In the second case spectrum use is organized symmetrically. RAN sharing in connection with frequency pooling is also called as Multi-Operator Core Network (MOCN). For 3G such a solution is specified in 3G PP Release 6. Figure 2 shows a typical network configuration in case of MOCN. MOCN is of particular interest for operators if there is not sufficient spectrum available or if services with a high

bandwidth requirement are to be provided. The joint use of frequencies can be handled nationwide, or limited to a particular region or location.

Figure 2: MOCN sharing configuration



Source: BIPT (2012)

2.6 Virtualization of network functions

Virtualization of network functions is a new trend for telecommunications networks. Certain control functions of the network nodes are separated and located into central servers within a cloud. This approach enables the re-use of these functions also in other network elements. Furthermore, it enables the adoption of new features or requirements. Such Software Defined Networking (SDN) or Network Function Virtualization (NFV) allows a faster and more flexible definition of services. NFV is conceptually available today and it is going to be standardized in the 5G context.

NFV allows vendors or software operators to provide the same network functions for different MNOs. If these IT providers offer virtual network functions to different operators, this becomes a form of sharing of network elements.

A more far reaching step of virtualization combines virtual network functions such that dedicated VPN for certain applications occur. Such VPN are called network slices in the context of 5G standardization. A network slice may be a video surveillance network for an industrial area or a network for monitoring traffic flows in a city.

2.7 Network usage by MVNOs

The business models of MVNOs reach from a pure reseller to a full MVNO, which comes close to an MNO. These business models differ according to the type and number of network elements which the MVNOs own and control themselves and those

where they use the MNO's network. While a reseller only runs its own billing and customer care platform, full MVNOs have their own HLR and can rely on their own core network.

3 Market and regulatory trends in network sharing

In the study upon which this paper is based upon¹ we have conducted a variety of case studies on how regulators dealt with mobile network sharing issues and which forms of sharing have been successful in the market reality. In addition we show how the European Commission as competition authority dealt with mobile network sharing in several merger cases. For important details we refer to this study. For the purpose of this paper we first of all shortly summarize our findings on international experience. Secondly, we present selected individual examples of remarkable highlights.

1. Passive network sharing is an almost universal reality in the market. This form of network sharing is welcomed without any reservation, promoted and sometimes even requested by regulatory authorities.
2. Most regulatory authorities also support active sharing of the Radio Access Network and have established appropriate supporting regulations.
3. However, in the market reality there are only a few examples of comprehensive RAN sharing. These are typically implemented in firmly structured joint ventures of the operators involved.
4. From this we conclude that multifaceted and restrictive conditions are not conducive to RAN sharing. Regulatory authorities committed to opening up this option for operators and thereby enabling to realise the associated cost savings, must take a liberal approach regarding the conditions and restrictions of RAN sharing.
5. Core network sharing does not occur in the market. Regulatory authorities also regard this form of sharing with considerable scepticism and reluctance. In this case they no longer see sufficient options for competitive service differentiation. This also corresponds to our assessment.
6. Most regulatory authorities reject the joint use of frequencies or only permit this option to stringent conditions at the "edges" of the network. However, frequency pooling is a market reality in Denmark and Sweden.

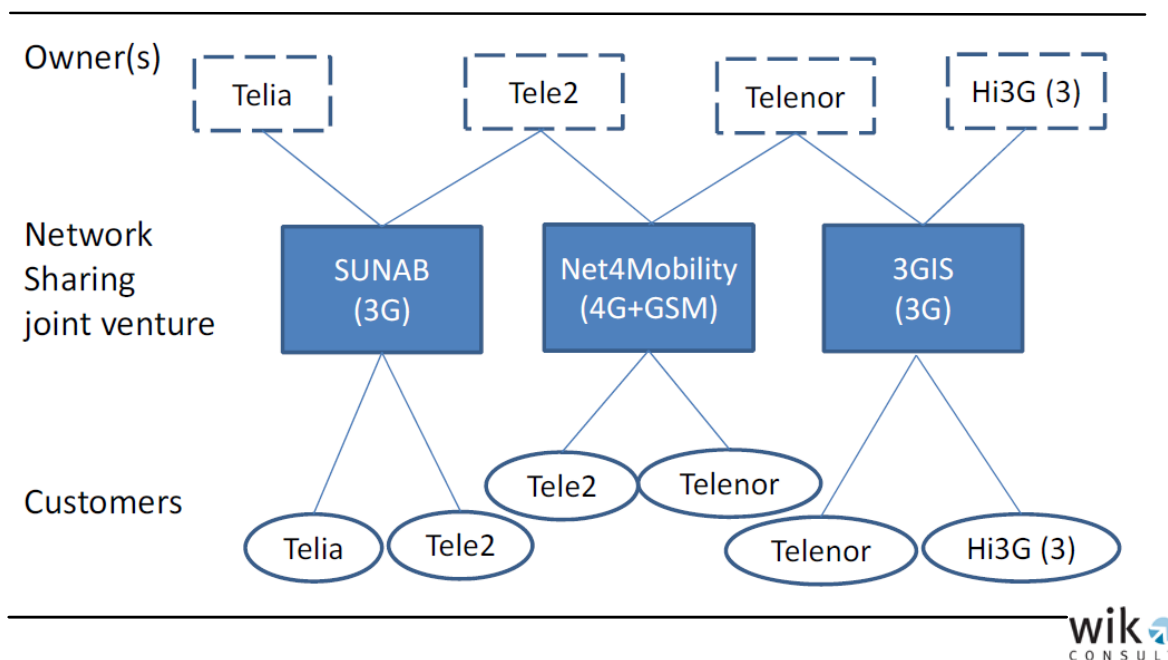
¹ See Neumann et al. (2016).

7. National roaming is a form of network sharing which is well established in the market. The agreements are usually closed through commercial negotiations. Particularly in situations of market asymmetries, primarily in terms of market entry, regulatory authorities assess national roaming positively. In many cases roaming is also imposed by regulators. However, with regard to roaming, regulatory authorities generally provide restrictions in terms of time and/or extent of roaming.
8. In some countries national roaming is also seen as an opportunity to assure communication in the event of individual operators' network failures. We regard this as an option worthy of consideration.
9. Currently, the virtualisation of network functions up to network slicing is yet to become a reality in the market. However, conceptual design and standardisation are progressing at such a pace that regulatory authorities must expect that these concepts will become a market reality with the advent of 5G networks at the latest. All concerns relating to competition policy applying to network sharing are also relevant here. Regulatory authorities must ensure, even in case that non-network operators take over the control of certain network functions, that regulatory control options are retained, e.g. by amending the definition of an operator.
10. In so far as MVNOs enjoy sufficient competitive freedom, they can promote and intensify competition in (heavily) concentrated mobile markets. By analogy with the merger case, in cases of comprehensive network co-operation, regulatory authorities can and should impose an MVNO obligation as a condition for the co-operating network partners.

As a more detailed example for a comprehensive sharing model we want to refer to the Swedish case. Sweden seems to be the EU country with the most intense degree of mobile network sharing. Sharing between all four MNOs is a sustainable and dominant element of the market structure. Sharing got a boost in 2000 when the incumbent operator Telia representing a 50% market share at that time did not receive an UMTS licence.² The result of the award process was a shock to Telia and led to a merger with the Finnish operator Sonera to TeliaSonera. Furthermore, Telia arranged for a sharing agreement with Tele2 to get access to the 3G market in Sweden. The licence conditions allowed sharing of up to 70% of the radio infrastructure. Tele2 and TeliaSonera built a joint radio network on the basis of the Tele2 licence and frequencies and the existing infrastructure of Telia. Network planning and deployment is conducted by the Joint Venture SUNAB. Sharing is related to the whole RAN, backhaul and the frequencies, and of course the passive infrastructure. Each operator, however, owns and operates its own Network Operation Center for monitoring and controlling its network.

² See OECD (2014).

Figure 3: Market structure, cooperation and network sharing in Sweden



Source: Markendahl et al. (2013)

Also the other two MNOs formed a network cooperation in form of the Joint Venture 3GIS.³ Different to Telia/Tele2 these venture partners had to build their own radio network for (at least) 30% of population. The partners of the SUNAB venture on the other hand, only (have to) rely on one network infrastructure.

In 2009 the sharing structure was further intensified when Tele2 and Telenor formed a new 4G related venture besides the already existing network cooperations. Figure 3 shows the resulting complex network cooperation structure in Sweden. The Net4Mobility cooperation is rather intense as the venture even owns the joint spectrum. Furthermore, existing 900, 1800 and 2600 MHz spectrum has been transposed into the venture.

Different to other network cooperations, those in Sweden are not limited in time but planned for the foreseeable future. The mutual dependencies of MNOs are significant. Although the ventures could be terminated, a separation would be very costly and therefore more or less prohibitive. The intensity of network cooperation which is unique in Europe questions the competitive independence of the MNOs in Sweden. Extensive network sharing in Sweden does, however, not seem to be an obstacle to intensive competition in the market. The OECD⁴ reports an impressive performance of the Swedish market: Network coverage amounts to nearly 100% for 3G and 99,2% for LTE already in October 2013. This is in particular impressive in front of the low population

³ The fifth operator Orange was originally part of that venture before it left the market.

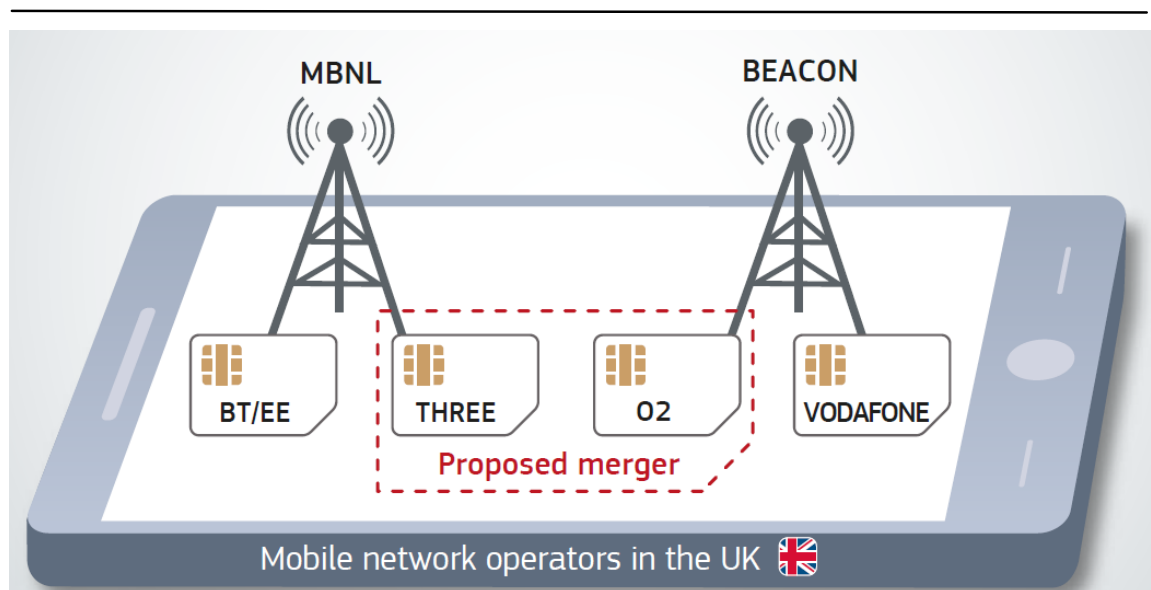
⁴ See OECD (2014), pp. 45 ff.

density in Sweden. Sweden also benefits from a relative low price level. Also the market structure has become more competitive over time. The HHI index decreased from 3914 in 2000 to 2750 in 2008 and 2535 in 2013. TeliaSonera no longer exhibits market dominance. Its market share has reduced from 51% in 2000 to 34% in 2013.

Compared to markets with much lower levels of network cooperation like Germany or Switzerland in particular, the indicators of market performance look higher in Sweden than in those countries.

Network sharing played a major role in the rejection of the intended merger between O2 Telefónica UK and Hutchinson in the British mobile market. In some similarity to network cooperation in Sweden the four British MNOs cooperated within two network joint ventures (see Figure 4). De facto the 4 MNOs owned and operated two RANs. The MNOs benefit from significant cost savings but competed at the same time at the service level intensively.

Figure 4: Network cooperation and operator merger in UK



Source: EU (2016)

Although DG Competition had the usual reservations against the reduction of the number of MNOs by the merger in the first place, the major arguments against the intended merger followed from the resulting implications on network cooperation. These arguments were specific to the British market and the proposed merger. The new merged entity would have become partner of both existing network joint ventures. The entity would have had full access to the network deployment plans of the remaining competitors Vodafone and EE. This structure would – according to the Commission – significantly restrict the deployment of 5G and would have significantly reduced

competition on the wholesale market. Proposed remedies of the companies did not solve the structural problem of the network cooperations. Therefore the Commission did not approve the merger in the end.

4 Assessment of network sharing

4.1 Reasons for sharing

Why do MNOs engage in sharing agreements and give up parts of their planning decision independence? Literature and our analysis have provided seven major reasons for MNOs to conclude sharing agreements:

1. Cost savings

The realization of cost savings seems to be the main motive for network sharing and the joint use of network elements. Savings, may occur in capital expenditure and in operating expenditures. The extend of potential savings depends on whether sharing occurs in a brownfield or in a greenfield environment. In a greenfield environment the maximum amount of savings is achievable. The partners are able to coordinate site locations in an optimal manner and are not only able to jointly use existing site locations. The number of sites can be reduced significantly. In a brownfield environment site savings are only achievable for new sites and for sites which are already in use. To make use of longer term savings stranded costs have to be materialized in a brownfield environment. In Section 4.3 we will present our own cost model based calculations on achievable cost savings.

2. Better use of capital and resources

Sharing of network elements leads to a better use of capital and other resources. This is obvious in the case of site sharing. It is also mainly relevant in the case of national roaming when coverage driven radio cells become better utilized. A more efficient use of resources becomes in particular relevant in case of asymmetric entry. Second movers can partially compensate against competitive disadvantages of a later market entry by getting access to already existing network resources of competitors.

3. Time to market

Network sharing enables faster market entry in case of asymmetric as well as in case of symmetric entry.

4. Resilience

National roaming can be a model to maintain service active in case of breakdown of a network or parts of a network. In case of disaster or network outages the traffic of one network can be (partially) handed over to the network of a competing operator.

5. Extension of network coverage

Network sharing improves the network coverage for users if the footprints of cooperating networks is not identical. At the margin any user might get access to the maximum coverage provided by all networks. The relative importance of improving network coverage by sharing becomes more relevant in the roll-out phase of a network but remains relevant also in a mature stage of network deployment.

6. Environmental and administrative approval advantages

Getting site approvals and authorizations becomes a major bottleneck of network expansion in many countries. Site sharing and the use of existing sites can overcome this bottleneck to some degree. In many countries authorities make the joint use of sites a requirement for providing approvals.

7. Coordination and decreasing the intensity of competition.

Similar to mergers network sharing agreements may also be motivated by the intention to reduce competition intensity. Depending on the degree of sharing the competition factor network coverage becomes less relevant or might even become neutralized. Furthermore, sharing leads to information exchange of strategically relevant information (e.g. upgrading to a new radio technology) which enables or makes coordination of behaviour easier.

We have presented the reasons for network sharing from the firms' perspective which engage in such agreements. All reasons mentioned here – besides the potential impairment of competition – also support overall economic objectives and lead to more efficiency.

4.2 Regulatory assessment dimensions

Regulatory and/or competition authorities, which have to deal with specific network cooperation agreements or have to establish guidelines for the approval of such agreements, have a variety of concerns and criteria for testing the acceptance of such agreements. Their main concern is whether there are (significant) impairments of competition. We will discuss here different potential impairments. On the other hand, there is a variety of positive regulatory policy implications of sharing. Thus, regulatory authorities face trade-offs between policy objectives upon which they have to decide.

All mobile markets are characterized by tight oligopolistic market structures. The currently observable tendency towards more horizontal concentration makes the markets even tighter. The tighter the market structure the more important the independence of MNOs becomes for maintaining effective competition. Network cooperation in a tight market structure makes it even tighter. On the other hand, network cooperation can be an alternative to a merger between two MNOs which enables them to internalize most of the relevant cost savings without destroying the competitive relationship between the two MNOs involved. If a merger would e.g. reduce the number of independent MNOs from 4 to 3, a network cooperation might only reduce it to 3,7 or 3,5 independent operators. From that perspective sharing can be the preferred option from a competition policy point of view. From the standpoint of the operators involved, sharing might be an alternative to a merger which would not be admissible. In case of sharing it is even more probable that the cost benefits of the cooperation will be transferred to customers compared to a merger.⁵

Network sharing might make collusive behavior easier or might even support it. This holds in particular if cooperation is negotiated before the network roll-out starts. Active RAN sharing might even be structured such that basic parameters like network coverage, cell capacity, data rates and other service features can no longer be defined or changed independently. Such type of differentiation is, however, essential for infrastructure competition. If it no longer prevails through to the sharing model, competition reduces from infrastructure to service competition. For that reason, regulators do not allow specific forms of sharing or impose regulatory remedies which decrease the level of constraints in service creation.

The dominant competition model in the mobile market rests on infrastructure competition. To work effectively, this model needs strong investment incentives to build and operate independent networks. There is the presumption in the literature, that network sharing generally reduces the incentives to invest in mobile networks. Theoretical economic analysis, however, does not provide final and conclusive results on this hypothesis.

Fabrizi and Wertlen (2008) show in a model on optimal market coverage at (unconstrained) allowed roaming agreements that MNOs try to avoid network duplication to maximize rents from roaming. Valetti's (2003) model results show that only colluding operators have an incentive to conduct roaming agreements. Stühmeier's (2012) modelling results generate a decision dilemma for regulators: While MNOs increase their investment at roaming rates below cost, they lower roaming quality. At roaming rates above costs the opposite holds: MNOs reduce their investment, but they increase roaming quality. In his modelling the effect of roaming rates on coverage remains ambiguous and depends on the relative size of retail and roaming markets.

⁵ See OECD (2014), p. 70.

We do not share the view as often addressed in the literature that sharing reduces investment incentives in general. The impact of sharing on network investment needs a careful analysis of the market scenario in which sharing occurs. There are market situations or scenarios in which sharing even generates investment incentives. Furthermore, proper regulatory remedies regarding the shaping of the sharing model can transpose potentially negative investment incentives into positive incentives. Roaming provides the best prove for this hypothesis. In case of asymmetric market entry roaming enables a second mover to provide a relative nationwide service offering although its network is not fully developed correspondingly. The improved competitive position through roaming furthermore enables the operator to generate a higher cash flow compared to a scenario where the operator does not have access to roaming. This chain of effects generates a higher self-financing leeway for own network investment and therefore generates positive investment incentives. This can be further incentivized by a regulatory remedy which limits the availability of roaming timely. Capacity-based wholesale prices for roaming further incentivize own investments.

The usual presumption in the literature is that network sharing might have benefits regarding certain policy objectives but that is at the detriment of competition. This presumption, however, does not hold in general. There can be market situations where the generation of network sharing agreements among MNOs may intensify competition and do not decrease it. This holds in particular in case of asymmetric market structures. There may be two reasons for such market structures. Firstly, early market entrants usually have first mover advantages which can often only very difficultly or even not all be compensated by second movers in the infrastructural competition process. This effect is documented and confirmed in a variety of empirical studies. The opportunity for a late mover to use network elements of first movers in the market may not fully compensate the competitive advantages of the first mover(s). It may, however, increase the speed of effective competition. By using (parts of) the passive infrastructure of the first mover the second mover benefits from an earlier and more cost effective network availability. This makes the second mover a relevant and effective competitor earlier. More effective and faster can be the option of national roaming. By using this option the second mover can provide a full network coverage much more cost effective.

Secondly, network sharing can intensify competition in case of incumbency advantages even when market entry occurs symmetrically. A dominant fixed network operator may have much better access to sites than a new mobile-only entrant. The same holds for the availability of core network infrastructure and the connection of base stations via fibre. Such incumbency advantages may – at least partially – be compensated by passive sharing of those network elements. Also in the case of persistent and sustainable market asymmetries sharing between the smaller operator(s) and the large operator may foster competition and can make market structures more symmetric and more competitive.

The impact of sharing on competition can depend on the sharing partner and the constellation in which they cooperate. If, for instance, a market dominant MNO closes a network sharing agreement with the second largest operator, this cooperation is to the detriment of the third MNO (if there are only three operators in the market). Overall, network sharing in the market constellation mentioned above therefore weakens competition and should not be accepted by regulatory or competition authorities.

Insofar as network sharing improves network coverage for a larger group of customers and saves environmental resources this supports usual regulatory policy objectives. Lower costs for operators due to network sharing benefits customers if lower costs result in lower end-user prices and increased service quality. Whether or not that will occur depends on the degree of competition in the respective market.

4.3 Modelling cost savings through network sharing

The main economic driver for network sharing is realising cost savings in network construction and operation. These savings are not only beneficial in terms of business economics, but also concerning the national economy. Regulatory authorities therefore require a clear picture of the extent of the cost savings which can be realised through network sharing.

With the aid of a generic analytical bottom-up LRIC costing model which has been adapted to the conditions in Switzerland we have analysed different scales of approaches to sharing in terms of their essential effect on costs.

For this purpose, we have parameterised a model which takes into account not only 2G and 3G, but also LTE technology up to Release 10 with the characteristic traffic behaviour of central Europe and the population distribution in Switzerland. The model takes into account the frequency spectrum which is currently assigned to the Swiss mobile operators. With its network planning tool the model in a first step determines the systems a network operator requires for the intended network coverage meeting the demand. This includes all components of a mobile network, starting with the antenna sites and their radio equipment, through the backhaul and core network locations, to their functions for user and service management, the IMS and the gateways to other networks. After determining the necessary network elements in terms of number and capacity, in a second step the production costs of such a network are calculated using current market data. The costs per year of operation are determined, among other things, by writing off the necessary investment and by determining the operating costs of the network.

For Switzerland, typical market shares have been used for the size of the networks; for the simulation of different sharing options these market shares were then also combined and the costs of joint operations were determined.

In accordance with the bottom-up modelling approach, the model results of co-operation are always subject from the outset to the construction of a joint network (the "greenfield" sharing view). In the case of existing networks, the calculated savings of co-operation would therefore only apply in the long term, i.e. to the extent that the network structures can be adapted and the old elements which are no longer required are excluded from the amortisation and the associated costs.

The model results indicate that site sharing demonstrates the largest relative saving effect, followed by RAN sharing, whilst the additional contribution from full roaming (or core network sharing) turns out to be relatively low. Depending on the scenario, site sharing savings can account for up to 45% of the summated stand-alone costs of the cooperating operators for sites, RAN sharing up to 40% of the RAN costs and sharing including the core network can save up to 33% of total mobile network costs.

The amount of cost savings depends on the relative size of market share of operators which cooperate. The larger the combined market share of the cooperating MNOs the larger the relative cost savings.

The savings in the case of roaming become even more pronounced in sparsely populated areas. In this case, the additional traffic for the roaming provider only generates a (small) fraction of the costs which the operator demanding roaming saves by not deploying its own network infrastructure there. The smaller the roaming proportion of traffic, the greater this relative cost saving is for the roaming operator.

Our calculations on cost savings seem to be a bit lower than calculations made by others. BEREC (2011) is reporting cost savings calculations conducted by Vodafone which range from 10% to 40% depending on the degree and level of sharing. AT Kearney (2009) reports site cost savings of 69%. The basis of these calculations, however, is less clear and therefore not directly comparable to our own calculations.

4.4 Assessment of various forms of sharing

Passive sharing has a long tradition in mobile markets and is the most widespread form of sharing. The reason for its common use is that passive sharing supports a variety of policy objectives without impairing competition or other policy objectives. In particular the competitive independence of operators remains valid. Cost savings are significant. They can amount to up to 45% of the corresponding stand-alone cost. For these reasons regulatory authorities not only have a positive attitude towards passive sharing. They often even request it and/or make site approvals depending on sharing among MNOs.

In case of RAN sharing the cooperation partners in essence run a uniform radio network. Depending on the shape of the sharing model the competitive independence of operators can be affected. Regulatory remedies on area agreements for network

planning, a separate control of active network elements, the possibility of a separate network independent of the cooperation partners and on independent service creation and quality definition can be and are being used by regulators to maintain competition. Some regulators do not impose such remedies and even allow the joint use of frequencies. Given the market reality only strong interaction between the MNOs in the form of a joint venture seems to incentivize the emergence of active RAN sharing. The additional savings due to core network sharing are limited. Regulators are generally sceptical towards this form of sharing.

Roaming mainly occurs in asymmetric market scenarios. Here it intensifies competition. By imposing constraints on the duration or the areas for roaming regulators can keep investment incentives and infrastructure competition.

Frequency pooling in the case of RAN sharing becomes relevant if there is not sufficient spectrum available and if services with high bandwidth requirements are to be offered. Most regulators do not allow frequency sharing because they assume that independent service provision no longer is possible in such a scenario. In any case frequency pooling only makes sense beyond the individual coverage obligations which are related to the allocation of frequencies.

The virtualization of network functions will become highly relevant in a 5G network environment. It will generate business models and might intensify competition. To keep regulatory control regulators have to develop concepts how to potentially regulate those who provide network functions without being MNOs to cope with potential impediments to competition. One possibility is to adopt the operator definition accordingly.

Given the tight market structure in mobile markets, MVNOs can contribute to intensify competition. MNOs might regard network sharing as an alternative to a merger. Regulatory and competition authorities should constrain the competition risks of sharing agreements by imposing an MVNO obligation. Similar to merger remedies regulators oblige sharing partners to provide network capacity to at least one full MVNO to further stimulate competition.

5 Conclusions and recommendations

The need for a significant denser mobile radio access network structure in a 5G environment will challenge the still prevailing paradigm of infrastructure competition in mobile markets. It is hard to imagine that the need for a doubled or tripled number of base stations can still support a market structure of three (or even four) independent operators and radio access networks. In a recently published study, the investment bank HSBC (2017) has pointed out that 5G might challenge the infrastructure paradigm in mobile markets fundamentally. Will a (further) concentration in the (national) mobile

markets become the only policy and business option for a viable adoption of the 5G technology environment?

We have shown in this paper that active network sharing can be a helpful and perhaps a decisive policy and business option to keep a network competition model and to deal with the cost challenge of denser mobile networks at the same time. Active network sharing can save more than 40% of the corresponding radio access network cost. At least local frequency sharing can further support the capacity and bandwidth requirements of certain (new) 5G applications.

Active network sharing is compatible with the competitive independence of network operators if certain safeguards are taken care of by regulatory measures. These safeguards have to guarantee that operators can still design major service and quality parameters independent of each other. From a competition policy point of view a market structure of "2,6 operators" is more attractive than a market structure of just two operators.

Passive network sharing has a long tradition in mobile markets. Currently there are, however, only a few countries in which mobile operators share their whole RAN. It seems to be that the regulatory conditions regarding active RAN sharing and frequency pooling are too restrictive in many countries to make that an interesting business option. Regulatory and competition authorities, however, would be better off if operators decide for more intense network sharing instead of merging mobile operators totally. Therefore, regulators should relax too restrictive conditions for active network sharing to make that option more attractive to mobile operators.

Regulatory and competition authorities must also pay greater attention to network co-operation through virtualisation of network functions. Such concepts will become prevalent as 5G develops. We might see new and other players than mobile operators to operate network functions as a business model for themselves or as a service for several MNOs. Regulators may have to adapt the definition of a network operator in this context in order to enforce legitimate regulatory interests.

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