Roaming in the Mobile Internet: when coverage sharing agreements call for regulation*

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Abstract

We examine competition in Mobile Internet services, when operators bargain over the coverage sharing and their reciprocal roaming charge. Results show that in equilibrium operators cover the overall territory entirely and no-duplication is chosen, no matter how their bargaining power is distributed: operators have aligned incentives to enjoy roaming revenues extra-rents. Only their relative stand-alone coverage and, therefore, their appropriation of these rents, can be affected by how bargaining power is distributed. We finally discuss the scope for regulatory intervention to reduce these rents in the forms of minimum coverage requirements, or control over the level of reciprocal roaming charges.

Keywords: **coverage, sharing agreements, roaming charge, no-duplication, minimum coverage requirement, regulation**

JEL Classification: D4, L5, L86

1 Introduction

Most of the literature on telecommunications has focused on the role of interconnection charges in determining the possible outcomes of competition between interconnected networks and, consequently, the type of regulation that they may call for. For a general understanding of the *standard interconnection issues* see, for example, Laffont-Tirole (2000), or Armstrong (2002). Focussing on *interconnected* - and, therefore, *bilateral* - services, most of these studies neglect another interesting aspect characterizing in particular the Internet Industries: users value the *access per se to unilateral flow of information services* more than the *interconnection to other users* when making use of these services.

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When focusing the attention on unilateral services such as the downloading, or the uploading of flow of information and/or applications, different issues may arise that involve the pure access to these services. In this direction, the seminal paper of Laffont-Marcus-Rey-Tirole (2003) - hereafter LMRT - represents one of the first attempts to explicitly consider unilateral services even though in the wired Internet environment. In LMRT a model of competition between interconnected Internet Service Providers (ISPs) is considered. When a subscriber to an ISP wants to access a web page that only the other ISP can give access to - because the creators of this web page have asked to appear on that platform instead of another - there may be scope for fixing an interconnection charge between rival ISPs to access each other's web pages. This gives rise to what it is labeled as a *hot-potatoes behavior:* ISPs may otherwise (i.e. in the absence of an appropriate interconnection charge to be paid in exchange) have incentives to benefit from rival networks serving their own subscribers as the demand for access may come from one network and be served by the other.[1] If this model gives interesting insights in terms of how to price interconnection processes in order to account for this type of behavior, it still cannot explain other types of behavior which are typically related to unilateral services provided through the wireless Internet instead. As a result, for example questions related to the decisions over the *extent of the coverage* to be offered to subscribers, the level of the roaming charge for allowing for the cross-access, and the subsequent pricing for services to users are left unexplored.

Our work focuses on these alternative questions that arise when considering another type of network services, namely the *wireless Internet, as opposed to the wired Internet,* ones. Wireless Internet services present special features as compared to the wired Internet ones. Even though the wireless Internet services have in common with the wired Internet ones the possibility to give access to unilateral flows of contents (for downloading of contents from the content providers to the users via the network operator connecting them; or from the users to the content providers for uploading of contents, via the connection given to them by the network operators), and they share among them the issue of possible *compatibility*[2] between networks

[1] In LMRT an elaborate example is made to justify the argument. To restate it, suppose that consumers being connected in a European country want to access a Chinese web page. Unless a multi-homing is chosen by this Chinese web page, what happens in reality is that their demand is somehow transferred to the Chinese ISP which hosts the required web page and the downloading cost is incurred by this ISP instead of by the one from where the demand itself originated. Then the European ISP only pays the cost associated with originating the demand, and the rest is faced by the Chinese ISP. Actually, in LMRT the ISPs have to be intended as backbones, being connected through each other all over the world. In their work, this *hot-potatoes behavior* may lead to the application of an *off-net cost pricing principle* in order to fix the level of the possible interconnection to be paid between rival ISPs.

[2] For a review on compatibility and standardization issues see Church-Gandal (2004), or Farrell-Klemperer (2004).

through the compatibility/standardization of several contents to be accessible to subscribers of either network for example, they do differ in the *mobility* of their respective usage. Mobility offers wireless Internet networks an option to decide over other elements which cannot be present when dealing with standard interconnection or with wired Internet: *coverage of the territory* and its possible *sharing through agreements* which may also concern then the *roaming charges* operators may have to pay to each other to let their respective subscribers access services in a territory covered by the rival**.** The accessibility in different territories of services and their associated roaming access possibilities make the difference between these two environments and create an interest to study further the implications of possible sharing agreements between network operators, of their impact in terms of social welfare, and, therefore, of whether this may constitute a scope for regulatory intervention, and, if so, of which nature. Roaming agreements exist and are already in place, for example in the wireless telephony. However, in this case the roaming allows one user to interconnect to another one, by accessing a rival network to the one this user has initially subscribed to, any time a call needs to be initiated on a territory not covered by his fellow network. In this paper, we instead study the private incentives to agree over a possible *sharing of the coverage* and the *level of the reciprocal roaming charges* for network operators when having to provide access to services which are at once *mobile* and *unilateral* by nature. This way, we expect to be able to draw conclusions upon which is going to be the *degree of coverage of the territory*, which form *roaming agreements* may take and which role they may play, which *final tariffs* are going to prevail for end users, and whether there exists *scope for regulation*. In other terms: which is the operators' interest? Can we rely on a 'cooperation' between competitors, i.e. should infrastructure sharing be refused, accepted, or even encouraged? These questions have been and are still heavily debated in particular in the context of the third generation of mobile communications, in connections with the high prices of the licenses in some countries and the higher than expected cost of this technology, which have led operators to contemplate more eagerly sharing possibilities - not to mention the environmental concerns triggered by the multiplicity of antennas that may be brought about by the implementation of this new technology.

To this purpose, a model is developed where competing networks have to decide whether to agree on providing cross-access, and at which cost to do so (i.e. which level of the roaming charge will be fixed), thanks to the adoption of, for example, UMTS technology, or Wi-Fi hotspots[3], that allows them to serve subscribers of either networks as long as they are present in the territory users may move to. We do so in what we label as an *open system*, as opposed to the *closed system* we analyze in a companion paper, Fabrizi-Wertlen (2003). Open system stands for the possibility of providing access to the mentioned unilateral services to a user by letting him connect to either networks depending on which territory he wants to use the service, either in the territory covered by his chosen network or the one of the rival network. In our companion paper, a closed system is envisaged instead where users can only access the services offered by their chosen network, but not those of the other one. In this environment, network operators have to decide whether to continue offering a lower quality service (e.g. the 2G, second generation, Mobile Internet one) or to upgrade their services (e.g. offering the 3G, third generation, Mobile Internet ones). In a model of horizontal and vertical differentiation where users may be heterogeneous with respect to their taste for upgraded services we are able to characterize the type of equilibria that may arise in the adoption of Mobile Internet technologies. In that model, the users' subscription choice determines whether they will be able to access *low or high quality* services depending on whether their chosen network provides either the first or the second type of services. However, if quality issues matter in that paper they are going to be irrelevant in this new *open system* context considered in the present work. Given that here each user can access any content either way, and that we assume that networks cannot distort the quality of the access depending on whether it is required by a network's fellow or not, the perceived quality of this access by users is not going to depend on the degree of coverage chosen by the network they belong to, as opposed to that of the other one. Users only care about the extent of the overall coverage of the market to which they may have access to instead. This is a reasonable assumption to be made as long as roaming agreements are feasible by technology. If users can access contents, or applications, which do not have a format that is network-specific, meaning that they have a portable format accessible through either network, there is no reason to assume that users perceive a different quality of the Mobile Internet services depending on whether they get them accessing their chosen network or the rival one. If instead the content to be accessed would be network-specific and,

[3]Wi-Fi, or Wireless Fidelity, allows connection to the Internet using a wireless technology. Wi-Fi enabled computers can send and receive data indoors and outdoors; anywhere within the range of a base station.

This technology, which exploits a particular radio mobile frequency different from the UMTS one, therefore may enable an alternative wireless connection to the Internet or the Intranet in urban areas.

eventually, network-adaptable at an additional cost, then we would have to consider some type of quality issues that could arise as a consequence. In that case a modeling of the cost of adaptability and also of the role of content providers/developers would be needed to complement the analysis. As we will discuss in the conclusion to this work, these considerations are left for further research.[4] In the present work, we rule out quality issues. Doing so, we implicitly assume to be in a mature phase of adaptability or standardization of the Mobile Internet services that makes them be accessible from different devices/networks that are sharing a common protocol for data transfer. For this reason we assume that the real cost of providing access is the same no matter whether this access is required by a fellow or a non-fellow user.

By allowing for cross-access, we also allow for operators to agree on whether to share the associated cost of creating this access (e.g. the cost of putting additional antennas on the territory for data transmission which uses a larger bandwidth capacity).[5] Therefore, the cost of access may be interpreted as per-access cost of building the necessary infrastructure for transmitting data, which can be calculated as the value of the *long-run-incremental-cost*[6] associated with the infrastructure needed to provide access to this type of services in a given area. Mobile Internet services are carried out using the Internet Protocol (data transmission) whose cost only depends on installed capacity (large bandwidth) and no longer on the real time of connection and transfer of data per se. Because of these characteristics, we abandon the standard *usage-based pricing* and focus instead on an *access fee* subscribers pay to their chosen network that is *usage-independent*. The consequence is that, if users of say *network* 1 need to access services when moving in an area where only *network* 2 is present, *network* 2 will receive from *network* 1 a *roaming charge* for the provision of this access, but each network charges a subscription fee to its fellow users for their potential access to services using either networks. Therefore, if networks agree over the sharing of the coverage and upon their reciprocal roaming charges, the cost associated with a particular user's access may be met either by the network this consumer belongs to, or by the rival one, depending on which one of the two is present in an area where the user asks for this access. Once this special feature has been recognized, it becomes clear that letting the rival operator be present alone in an area means letting the rival alone pay for the access it provides while having

[4] For an analysis of quality issues in the wireless telephony environment see, for example, Cambini-Valletti (2005).

[5] In our companion paper, we have interpreted this cost as linked to the constant cost that *application service providers (ASPs)* incur to transmit the services to the operators. It could also have been interpreted as the cost of providing access itself.

[6] These costs are the ones that correspond to the configuration of the network itself, its maintainance, and also the ones associated with innovations that may improve the provision of services themselves.

to repay him the roaming charge for the access (eventually) provided to users subscribed to the network not present in that area. This feature is somehow similar to the hot-potatoes behavior described above: in the presence of an agreement over the roaming charge to be paid for that access, networks may prefer to let the other one serve their own subscribers to the situation where both of them would be present instead. This is so, as we will see, as long as there exists a scope for the appropriation of rents that may come from roaming agreements.

Results of the model will show how Mobile Internet networks always agree to cover the entire territory and not to overlap each other's territory, when they are free to bargain over the degree of coverage of the territory and their reciprocal roaming charge. No matter how the bargaining power is distributed between them, operators have aligned incentives to enjoy extra-rents coming from the roaming revenues. Only their relative stand-alone coverage and, therefore, their degree of appropriation of these rents, will be affected by the distribution of the bargaining power. Therefore, the no-duplication behavior is a way of guaranteeing them to exploit these rents, which would vanish if overlaps of the covered territory were to be observed. The scope for rents come from the fact that operators are aligned in their desire to inflate their reciprocal roaming charge in order to extract the mentioned rents from users willing to use their proposed services in either territory, whether they would provide them access directly or not. Inflated roaming charges as compared to their real associated costs, as well as inflated subscription fees, will be the consequence of this behavior: final users bear the cost of the operators' choices of no-duplication of coverage of the territory and, therefore, of inflated roaming charges. The work suggests for regulatory interventions in order to reduce the scope for the appropriation of these extra-rents. One possibility that will be discussed consists in fixing a *minimum coverage requirement* for each Mobile Internet operator in order to induce a potential overlap that would not be observed in equilibrium otherwise if operators were free to bargain upon both their respective coverage and their reciprocal roaming charge. Alternatively, a *control over the setting of the roaming charge* and/or its level may help mitigate the need to intervene without the inconvenience of inducing undesirable duplication of infrastructure over the territory (e.g. in order to reduce the presence of multiple antennas in a given territory). Depending on which are the objectives pursued by the regulator, one or the other practice, or a combination of both, may be recommendable.

The work is organized as follows. Section 2 describes the model, the users' subscription decisions, the determination of the subscription fees by operators, and the sharing agreement between network operators in terms of coverage and roaming charge. Section 3 discusses the impact on social welfare of this unregulated environment for the coverage of the territory and the level of the roaming charge and suggests for possible solutions and regulatory intervention. Finally, section 4 concludes the work and suggests further possible extensions.

2 The model

2.1 Some notation

In this section, we provide a description of the links that cross-access makes possible as well as provide an initial explanation of how access and roaming may be introduced into a formal model. Doing so, we also introduce the notation used throughout the paper.

Fig. 1 represents the type of links and access that are feasible when cross-access is made possible.

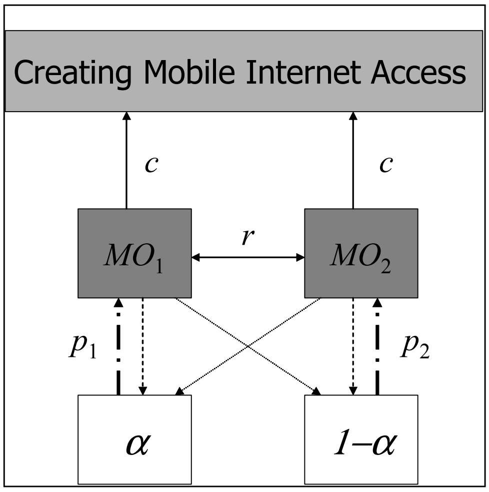

Figure 1: Open system

Users are uniformly distributed along a unit line and choose which Mobile Internet operator to be subscribed to. There are two horizontally differentiated Mobile Internet operators labeled MO_i, with $i = 1, 2$. Operators charge a subscription fee p_i to their subscribers for accessing Mobile Internet services. Creating this access is associated with a cost, c, which is assumed to be equal for both operators. Operators 1 and 2 have respectively a share α and $1 - \alpha$ of subscribers. As discussed in the introduction, opposite to the situation in Fabrizi-Wertlen (2003), when sharing agreements are possible, subscribers of network i can not only access their own network, but also the other one any time they are asking for access in an area not covered by their chosen network. For this access, a reciprocal roaming charge, r, has to be paid between the network the subscriber belongs to and the network that actually gives access to these subscribers.

We denote the *overall available territory* by T and we normalize it to one. Each MO_i will choose which part to cover within this available territory, so that the *chosen territory* by each operator, T_i, will satisfy $T_i \leq T \equiv 1$. Depending on which part of the territory has been chosen by each operator, there may exist an *overlap* between territories, β, which represents the part of the territory that would be served by both operators at once. This part of territory will not let any cross-payment for roaming arise, since by default each operator would provide access directly to his own subscribers. The roaming charge will have to be paid only in the event that a subscriber of, say, MO_i uses the access of MO_j, with $i \neq j$. Therefore, this can only happen for what we label as *stand-alone coverage* of MO_j, denoted $\gamma_j = T_j - \beta$, which corresponds to the part of the chosen territory where operator j is alone. Having normalized the maximum available territory to one, we can interpret the overall extent of territory and the stand-alone coverage chosen by each operator as its relative portions. The need to virtually distinguish between *overall chosen territory* to be covered by each (T_i) and stand-alone coverage (γ_i) depends on the need to separate the part of the coverage that would create possible subscription revenues alone, from the one that will give rise to roaming net revenues also. The overall available territory fixes an implicit constraint on the choices networks might make, i.e. $\gamma_1 + \gamma_2 + \beta \leq T$, which tells us that the sum of each stand-alone coverage, and possible overlap, can never exceed the total available territory.

2.2 Timing

The steps of the game are as follows:

1. Mobile operators bargain over their coverage sharing, T_i and, therefore, γ_i, and their reciprocal roaming access charge, r;

2. subscription fees[7], p_i, are set;

[7] Remember that as in our companion paper, Fabrizi-Wertlen (2003), we concentrate here on usage-independent pricing. This is because we are considering here as well asymmetric services that can be provided through the Internet Protocol (data transmission) whose cost may only depend on installed capacity (large bandwidth) which does not depend then on the usage of the services.

3. users decide which network to be subscribed to;

4. Mobile Internet operators provide access and profits are realized.

Given this timing, in the following subsections, we will solve the model backwards.

2.3 Users' subscription decision

Users have mass one, they are uniformly distributed along the unit line and they only value the availability of access to the services. Their utility, which we define as θ[8], is usage-independent and it is the same regardless of which network users are actually connected to when requiring the access. This is possible because, once subscribed to any of the two networks, users can have access to the required services either through their own network or the rival one thanks to the roaming agreements operators may sign between them. However, we assume that MOs are perceived as being horizontally differentiated à la Hotelling. MOs are located at the extremes of the unit line and users have to decide to which network to be subscribed to knowing that each time they choose a network that does not correspond to their ideal one, they incur a psychological cost, t, that is proportional to how distant this network is from their ideal one.[9]

By equalizing the utility users may get when subscribing either to MO_1 or MO_2, we get the following condition that determines the way users are split between the two networks:

$$\theta - p_1 - t\alpha = \theta - p_2 - t(1-\alpha). \tag{1}$$

This condition yields market share, w.l.o.g, for operator 1 equal to:

$$\alpha = \frac{1}{2} - \sigma(p_1 - p_2) \equiv \frac{1}{2} - \sigma \triangle p, \tag{2}$$

where $\sigma \equiv 1/2t$ and $\triangle p = p_1 - p_2$.

[8] This notation is used in order to create a parallel with that proposed in our companion paper, Fabrizi-Wertlen (2003), where this parameter represented the quality level of services consumers may have access to when subscribing to a particular network. In that work different types of service quality were proposed depending on whether operators chose standard Mobile Internet services or more technologically sophisticated ones. In the present work, instead, the utility of having potential access to the services, as already discussed in the introduction, is taken as being the same all over the two networks thanks to the *open system* environment that allows the users to access services using either of the two networks available. Keeping a similar notation between the two works will help us compare results obtained here with the ones obtained under the *closed system* environment.

[9] We assume competition à la Hotelling in order to account for users to choose (subscribe to) either one or the other network; in addition, Hotelling differentiation creates a parallel in this analysis to the one provided in Fabrizi-Wertlen (2003) where results are expressed as function of the transportation costs as well. However, in the rest of the analysis it will become clear that the differentiation of operators is not the responsible for the main results we will obtain in this paper. We could fix the transportation cost, t, to $t = 0$ and results, as well as policy recommendations, would remain the same.

As already discussed, the users' subscription decision is unaffected by the relative degree of sharing of the territory by operators. All matters for them is the access to services using either one or the other network and, therefore, the corresponding subscription fees to be paid for their potential access. This is guaranteed to be the case as long as the roaming agreement is enforced in equilibrium. As it will be the shown in the subsection devoted to the sharing agreement and the setting of the roaming charge, operators do prefer to give access to each other's subscribers by paying a roaming charge in exchange, so that roaming agreements are going to be enforced in equilibrium.

2.4 Setting of each Mobile Internet operators' subscription fee

MOs have to determine the level of the *subscription fee,* p_i, their subscribers will have to pay, the *extent of coverage over the territory* (which will induce the level of possible overlaps and, therefore, of the extent of the final stand-alone coverage), $T_i \leq T = 1$ with $i = 1, 2$, and the *roaming charge,* r, associated with the potential cross-access.

Given this, we can write, w.l.o.g., the profit of operator 1 as follows:

$$\pi_1 = \alpha\left(\gamma_1 + \beta\right)\left(p_1 - c\right) + \alpha\gamma_2(p_1 - r) + \left(1 - \alpha\right)\gamma_1\left(r - c\right). \tag{3}$$

This profit consists of three different parts: the first is the one that derives from serving its own subscribers within its own covered area $T_1 = \gamma_1 + \beta$; the second one is the difference between subscription revenue it gets by its subscribers and the roaming charge it has to pay for letting them access the rival network any time they move into the area γ_2 served by the rival operator alone; finally, the last is the net revenue of giving access to the rival's subscribers whenever they move into an area γ_1 that operator 1 serves alone.

Within the context of the Hotelling model we consider, it should be noted that in equilibrium the entire market will necessarily be covered - each operator has an incentive to cover any part of it that is left uncovered by the rival. In other terms, condition $\gamma_1 + \gamma_2 + \beta = 1$ always hold in equilibrium. Moreover, the opportunity cost of attracting an additional subscriber is the same for both networks (even if they have asymmetric coverage) and is equal to $c + \left(\gamma_1 + \gamma_2\right)\left(r - c\right)$. This comes from the fact that stealing a user away from the rival: (i) generates more access, the cost of which is $c + \gamma_2\left(r - c\right)$; and (ii) reduces the access revenue by $\gamma_1\left(r - c\right)$. It can also be seen from the expression of the profit above, which can be rewritten as

$$\pi_1 = \alpha\left[p_1 - \left(c + \left(\gamma_1 + \gamma_2\right)\left(r - c\right)\right)\right] + \gamma_1\left(r - c\right), \tag{4}$$

where the second term is not affected by the pricing decisions.

Given this, the equilibrium prices are necessarily the same and the market shares are thus equal to 1/2; together with the previous "full coverage" remark, it follows that the prices (subscription fees) are given by the condition

$$p_1 = p_2 = c + \left(\gamma_1 + \gamma_2\right)\left(r - c\right) + \frac{1}{2\sigma}, \tag{5}$$

so that each operator's profit takes the form

$$\pi_i = \frac{1}{4\sigma} + \gamma_i \frac{r - c}{2}. \tag{6}$$

Proposition 1 *When sharing agreements are feasible, in equilibrium Mobile Internet operators have an interest not to leave any part of the available territory uncovered so that condition* $\gamma_1 + \gamma_2 + \beta = 1$ *is always fulfilled, i.e. an endogenous full coverage is always guaranteed.*

2.5 Sharing agreement and setting of the reciprocal roaming charge

From equation (6) it can be noted that the profit each operator can enjoy becomes, in the presence of a possible roaming agreement, an increasing function of both the stand-alone coverage and the roaming charge to be paid for providing access to non-fellow users needing it.

This tells us that each of these two operators would want to cover as much as possible of the available territory alone, and to fix the highest as possible roaming charge compatible with users to subscribe to either one or the other network.

However, in the absence of an agreement between operators, none of them can guarantee that the final outcome of an uncoordinated decision on the degree of coverage by each would not correspond to a final possible overlap. This would not be strictly preferred by any of the two operators as any expansion of a territory by one operator above the level that was guaranteeing no overlap will not increase the profit of the operator that chooses to do so, but instead decrease the profit of the other one. For an illustration of the argument see figure 2.

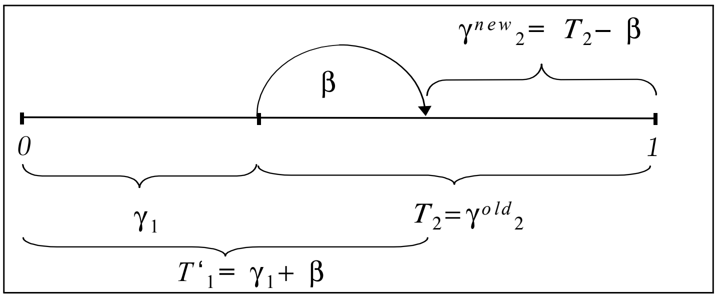

Figure 2: Effects of expanding the territory beyond γ_1

To avoid such an indeterminacy of the final outcome, operators may be pushed to agree on their respective coverage ex-ante, i.e. at the same time as they agree to give access to each other networks thanks to the setting of their reciprocal roaming charge. Different scenarios can be envisaged about the way they may reach such an agreement. However, one natural way to think about how the agreement can be reached is to assume operators meet and bargain over their respective stand-alone coverage, while fixing their reciprocal roaming charge. Depending on the distribution of their respective bargaining power, a more or less symmetric split of the overall territory can be therefore observed, but in any case the agreement is preferred to the no-agreement situation. In that case, the profit of each operator would correspond to the value each operator can obtain if the system was closed[10]:

$$\pi_i = \frac{1}{4\sigma}. \tag{7}$$

This lower bound for the possible profits to be obtained by each operator represents the threat point within a Nash bargaining that operators may undertake when deciding upon their respective stand-alone coverage.

This means that even in the limit case, for which one of the two operators by not covering the territory at all, would leave the other free to cover it entirely, this operator would not be worse off if compared with the case in which it would have refused any potential agreement over the sharing of access.

Once it has been noted that each of the operators is at least as well off when accepting the sharing agreement as if he was to refuse it, the distribution of the bargaining power will lead to a territory sharing, which implies a specific way the overall industry's profits are shared between these two operators.

[10] In our companion paper, Fabrizi-Wertlen (2003), operators facing a closed system were able to enjoy a profit that corresponds to the degenerate value of the profits that can be enjoyed when the system is open instead, i.e. the one for which $\gamma_i = 0$.

Proposition 2 *The sharing agreement is always stable: (i) the no-agreement outcome is never strictly preferred by any of the Mobile Internet operators no matter the extent of his stand-alone coverage; (ii) the division of the territory between the Mobile Internet operators corresponds to their relative bargaining power; (iii) none of the Mobile Internet operators is strictly better off by deviating from this agreed division.*

A scope for rent extraction exists only as long as the roaming charge is fixed at a level above its associated cost. Therefore, the decision to be taken, once we have discussed the scope for agreeing on sharing the coverage, is the one concerning the setting of the level of the reciprocal roaming charge.

Operators are aligned in their interest to fix the highest possible roaming charge, compatible with maintaining the participation from the users' side in their consumption of the Mobile Internet services. Therefore, each operator solves for:

$$\begin{cases} \max_r \left(\pi_i^*\right)_{T^*=1,\beta^*=0} = \frac{1}{4\sigma} + \gamma_i\left(r-c\right) \\ s.t. \quad \theta - \left(p^*\right)_{T^*=1,\beta^*=0} - t\frac{1}{2} = 0, \end{cases} \tag{8}$$

where the maximization of the profit has to be made under the users' participation constraint.

The solution to this problem shows that operators will agree on proposing the same level of roaming charge corresponding to

$$r^* = \theta - \frac{3}{4\sigma}. \tag{9}$$

As in Fabrizi-Wertlen (2003), we can determine a threshold for which providing shared access is profitable for both MOs if compared to a situation in which each has to guarantee it on its own. This is valid, as long as users' valuations are high enough, more formally, when $\theta > \frac{3}{4\sigma} + c$[11]. So, if user's valuations for the proposed access to the services were high enough, the roaming charge would be fixed to a level higher than the associated cost of providing access to these services itself.

As a consequence, for $\theta > \frac{3}{4\sigma} + c$, the final subscription fee will be:

$$\left(p^*\right)_{T^*=1,\beta^*=0} = \frac{1}{2\sigma} + \theta - \frac{3}{4\sigma} > \frac{1}{2\sigma} + c = \left(p^*\right)_{closed-system}. \tag{10}$$

[11] This constraint comes from the industry budget constraint that has to be fullfilled as well, in order for each operator not to make negative profits.

The results obtained can be summarized as follows: when operators are allowed to agree over the sharing of the coverage and over their reciprocal roaming charge there exists a scope for extra-rents to be extracted from users and to be shared between operators proportionally to their relative coverage.

Proposition 3 *Within a sharing agreement, Mobile Internet operators always agree on fixing a level of their reciprocal roaming charge which is inflated with respect to its associated cost of providing access: Mobile Internet operators extract extra-rents, coming from roaming revenues, from users via the setting of inflated subscription fees.*

3 Is there scope for regulatory intervention?

Given the results obtained, i.e. that operators would agree on sharing the territory to be covered and on setting an inflated reciprocal roaming charge, and, therefore, an inflated subscription fee, some questions may arise like "*why should a regulator leave operators free* to *decide upon the sharing of the coverage of the territory*", "*why should a regulator leave operators free* to *negotiate their reciprocal roaming charge*", or "*why should the no-duplication of access infrastructure be desirable within this context*"? Knowing that no external intervention may lead to an outcome where users are worse off and MOs are able to capture a bigger share of the possible users' surplus, "*why should a regulator not intervene*"?

In order to address these questions, we should discuss the real objective function of the regulator. If the regulator maximizes the sum of the joint profits of the industry and the users' surplus such that both have equal weights, then an intervention would be irrelevant, as the roaming simply creates a scope for transferring rents from users to MOs. However, if a larger weight is put on the users' surplus within the evaluation of the social welfare, compared to the joint profits of the industry, then imposing ex-ante "*network duplication requirement"* or a *"minimum coverage requirement*" could be valuable rules to be applied by regulator when, for example, releasing licenses to operators to provide Mobile Internet services[12].

If a regulator cared more about users' surplus than industry profits, then imposing ex-ante a rule that requires the "*complete overlapping*", which means "*obligation for each operator to cover the overall territory*",

[12] As an example, consider the case of Czech Republic where a requirement to cover 90% of Prague area by 2007 has been required to operators having gotten the licenses to provide 3G Mobile Internet services. Covering Prague represents something like covering 50% of the potential 3G service users. This type of requirement finds its rationale in the analysis provided in the present work.

or fixing an ex-ante level for the roaming charge to be paid between operators, i.e. having a "*perfect control over the level of the roaming charge",* would be useful in order to let the appropriability of extra-rents coming from roaming vanish. This is because the control over the precise level of the roaming charge itself, whenever it could be implemented perfectly, would be a good tool for the reduction of possible rents operators might obtain otherwise by acting in a completely unregulated environment. Setting $r = c$, for example, using the timing described in our model, at stage 0, when combined with the no-duplication recommendation (letting operators free to agree over the sharing of the coverage), may lead to the same outcome obtained within a *closed system* in terms of final prices and profits, thereby removing the incentives for operators to collude in exploiting roaming rents.

Proposition 4 *There exist ex-ante regulatory interventions that may reduce the appropriation of extra-rents coming from roaming revenues by Mobile Internet operators: (i) fixing a 'minimum coverage requirement' higher than half of the available territory, an overlap of the territories covered by each Mobile Internet operator would be induced; (ii) a control over the level of the reciprocal roaming charge would mitigate or even let vanish the scope for appropriability of rents.*

If the regulator wants instead to encourage the adoption of new technologies and let MOs have larger profits [13], then, probably, "*no intervention"* is the best rule to be followed. Moreover, we may think that no-intervention implies no-duplication of the access infrastructure which in turn translates into '*less antennas'* on the overall territory. This is because, for example, the access to the Mobile Internet may need to be made by the use of signals to be converted and carried out by physical antennas to be put on a given territory or area to be served. For this reason, our cost c could be easily interpreted as the cost of building/putting an antenna in a given territory to allow for potential access by users moving in that area. Given that, no-intervention would most likely translate into 'less antennas', which could be a good reason per se for a regulator to prefer not to intervene, as intervening would induce a possible proliferation of antennas over the territory instead.

Proposition 5 *Imposing ex-ante a 'no-duplication requirement' by regulation induces the appropriation of*

[13] In order, for example, to let them cover extra sunk costs associated to the adoption of this new technology itself – that we did not take into account explicitly in this model, like the cost of getting the necessary licence to provide these services at the first place.

extra-rents coming from roaming revenues by Mobile Internet operators, but helps reducing the proliferation of the infrastructure necessary to provide the Mobile Internet services.

If the regulator would care about both preserving the environment and users' surplus, probably an ex-ante recommendation in terms of "*no-duplication*" could be the mandatory, to be accompanied with an ex-ante control of the level of the *regulated roaming charge*. This combination of the two tools to be implemented whenever possible, seems to be a valid solution in order to meet at once all the mentioned regulatory goals.

4 Conclusion

The present analysis has provided an initial insight into the role coverage sharing agreements and the setting of a reciprocal roaming charge may play in creating the scope for Mobile Internet operators to appropriate extra-rents. Once operators are free to decide upon both how to share the coverage of a given territory and their reciprocal roaming charge, their appropriation of extra-rents cannot be avoided. Our analysis shows that in these circumstances, competing operators would collude and originate in equilibrium situations characterized by comprehensively covered territory, a territory sharing, a higher final subscription fee charged to consumers than would be the case in the absence of sharing access agreements, and higher operators' profits, or profits at worse equal, to those attainable through refusing any roaming agreement.

The observation of this possible phenomenon may create the scope for regulatory intervention depending on the objectives of the regulator, i.e. depending on whether these are concerned with boosting profitability for firms on new segments, maximizing users' surplus, protecting the environment, or any combination of these objectives.

It follows then, that the decision, authorities in different countries have taken, to require a minimum coverage by each operator when allocating the 3G radio mobile spectrum licenses, for example, could have been the result of a precise policy more or less oriented toward the need to avoid operators appropriating roaming extra-rents. However, if a no-duplication recommendation was followed instead, this could be the result of a rational choice as well: it could be used to encourage the adoption of new technologies; or could create the scope for leaving some rents to operators to let them recover the huge costs of obtaining licenses in the first place; or simply it could prevent the undesired proliferation of antennas all over the territory.

It is also important here to address the reasons for considering a constant marginal cost of providing access. The focus on such an assumed cost is quite realistic as, a priori, there are no economies of scale in the provision of access itself linked to the chosen coverage by each operator. However, when explicitly taking into account fixed costs linked to the provision of the access itself, the model should be adapted accordingly in order to characterize the impact that these costs may have on the incentives for operators to induce equilibria similar to those described here. One more consideration on this point may be necessary.

A possible extension of the present work may allow for considering additional costs to the ones envisaged here that are associated with the roaming possibilities we allow for. If roaming, or cross-access is feasible only when contents to be accessed are made adaptable, i.e. somehow compatible and portable under different standards the networks may adopt, then providing/developing a given content, in a given format, following given compatibility rules, may be costly as well. When such a scenario is allowed for, content providers may play an active role in determining the shape the overall coverage agreements may take, as they may change the relative advantage operators have in enjoying roaming revenues as compared to when they can do so without having to incur any extra-costs for that. Remember that in our analysis the real cost of giving access to either fellow users or non-fellow users is the same, and is equal to c. Introducing the cost of content developments and, possibly, of some market power from the application content providers/developers could provide some interesting insights in terms of the sharing agreements to be observed, the networks' choices in terms of compatibility standards and, therefore, the competition to be played among operators adopting differing standards, and, eventually, between contents providers/developers for example. This type of considerations are left for further research.

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