Business models and resource management for shared wireless networks

Johan Hultell, Klas Johansson, and Jan Markendahl
Wireless@KTH, The Royal Institute of Technology
Electrum 418, S-164 40 Kista, Sweden
E-mail: {johan.hultell, klasj, jan.markendahl}@radio.kth.se

Abstract— **In this paper we analyze main use cases for sharing wireless access networks between multiple operators and service providers. Network sharing has been proposed as a method to lower roll-out costs for 3G operators in Europe, and is widely used in WLAN systems where local access providers offer wireless access to service providers. A similar structure also exist in cellular networks where Mobile Virtual Network Operators (MVNO) provide mobile services without having a mobile network of their own. The development points at a further fragmentation of wireless access networks into specialized service providers that connect to local service and access providers, possibly via an inter-connection provider serving with core network functionality. In this context, we propose a framework for how radio resources could be managed using Service Level Agreements (SLA) and analyze key differences between the SLA for different types of service and network providers.**

I. Introduction

Future mobile service providers will rely on heterogeneous radio access networks provided by multiple operators. The objective of this paper is to identify key requirements for how radio resources should be managed in such multi-operator, multi-access, wireless networks. Recent economical research shows that industry structure depends on technology, modularization and available interfaces. That is, the success of a specific business model does not only rely on end-user demand and competition, but also on the network architecture. Which layers and interfaces that will be standardized for next generation networks, however, depend on the current market development.

The mobile industry is currently shifting focus towards content based services, and this development is enforced by national regulators whose primary aim is to increase competition for mobile services. It is therefore plausible that the fragmentation of the mobile operator market will continue. Hence, to support a continuing growth of the mobile industry the architecture of fourth generation mobile networks needs to facilitate new business models that better match the evolving industry structure.

Previous work on network sharing has mainly been motivated by the potential cost savings during the roll-out phase of 3G networks; see [11] and [23]. Benefits for long-term sharing have also been identified and analyzed in, for example, [3] and [4]. Moreover, sharing of radio resources between multiple operators was studied in [14] and possible network sharing architectures for mobile networks were described in [15]. An improved solution for sharing 3G networks has recently been developed by 3GPP [20]. By connecting the core networks directly to a shared radio access network, less information has to be exchanged between operators and the networks can be managed more independently. Also in the integrated EU project Ambient Networks [1] access to common network resources and management of those is a main objective. In the visions of [1], the best available radio access network is selected based on cost and user preferences. Mobility management over business domains and multiple radio access technologies is thus part of this concept, which sometimes is called Always Best Connected (ABC) [10].

However, the multi-operator solutions proposed by 3GPP and Ambient Networks are essentially based on Common Radio Resource Management (CRRM), which requires information of network availability and load to be exchanged (in real-time) [8][22]. Unfortunately it implies that business critical information on load measurements and network performance is signaled between network providers. This could perhaps be acceptable in the current sharing cases, which mainly considers rural areas (see further Section II), but certainly not in general since it will harm the competition.

Instead we propose a service provider centric approach, where the key market relation is between the user and the service provider. Furthermore we anticipate a horizontal market for wireless access, where local and wide area radio access networks are offered to service providers on a more or less competitive market. When separating the role of the service and access provisioning, Service Level Agreement (SLA) management is important to assure application level performance and capacity. A framework for SLA management in communication networks has previously been proposed in, e.g., [5], [16] and [19]. However, the way SLAs are defined and radio resources actually are managed depends on the business models.

This topic will be treated further in the sequel of this paper which is organized as follows. In Section II the potential of long term network sharing between mobile network operators (MNO) is analyzed. A fragmented market for wireless services and access networks is discussed in Section III and different actors are thoroughly described. Finally, Section IV presents a framework for managing radio resources using SLAs in shared radio access networks. The paper is concluded in Section V.

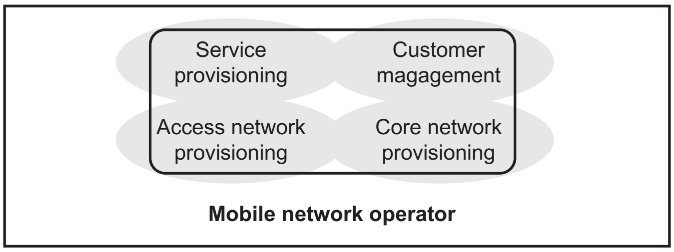

Fig. 1. The mobile network operator offers a complete customer offer.

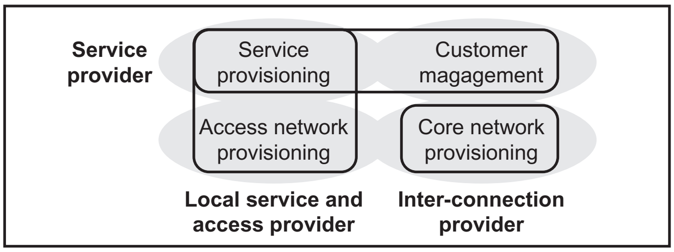

Fig. 2. Value constellations for different actors on a fragmented market.

II. Network sharing between mobile network operators

Even though a large number of operators have evaluated potential solutions and partners for network sharing only a few sharing agreements have been implemented so far [17]. Instead, 3G license holders have delayed or stopped their roll-out to reduce the risk involved with large investments. The question is then, when does the cost savings motivate sharing infrastructure with a competitor?

A. Cost savings in relation to risks

The cost savings achieved by sharing networks has been estimated to be in the order of 10-15 percent, calculated over a time period of 6-10 years [7][18]. These savings stem from reduced capital and operational expenditures related to the network, which constitute 40 percent of the total costs. The remaining 60 percent correspond to marketing, billing, administration, and licences [13].

Considering the substantial risk of entering a network sharing agreement those modest cost reductions imply that network sharing is beneficial in specific cases only. For example, in regions with a very low population density. This would also partly explain why only a few cases of network sharing have been implemented in practice. More specifically the problems are related to:

- *Trust* related to traffic monitoring and network management of the shared network.
- *Compatibility* between the shared network and the sharing partners own 2G or 3G networks.
- *Competition* between operators with significantly different market shares.

Note also that regulatory requirements and policies have a strong impact on network sharing of this kind, both in terms of when it is applicable and how it is implemented.

B. Drivers for network sharing in the long run

In the long-run, network sharing between MNOs could only be motivated by substantial savings in operational expenditures. Particularly in rural areas with a low network utilization level (and consequently high overhead costs), exiting the sharing agreement clearly implies a higher incremental cost as compared to continued sharing. One example of this is when sharing partners build geographically separated networks during the roll-out phase and share them via national roaming to offer full coverage.

The network in each region is thus initially owned and managed by a single MNO, and each operator can expand the coverage of its own network gradually. The benefit with this strategy is twofold. Firstly, the workload of network planning and deployment is distributed over time and, secondly, it is an efficient method to reduce time to market. However, this type of geographical sharing is still associated with considerable risks [17].

Sharing a network could also lead to capacity gains due to efficient pooling of resources. E.g., if two or more license holders cooperate and have a large number of carriers available they could afford to provide higher data rates with wide-area coverage. But this is a secondary effect and only motivates why two operators already involved in a sharing agreement could choose not to exit although demand increases.

III. Business models and key issues for a fragmented wireless access and service market

The complete customer offer for mobile services can be divided into: (i) services, (ii) customer management and billing, (iii) access network provisioning and (iv) transport network provisioning. Traditionally, MNOs have incorporated all of these parts into their offering, see Figure 1, and this has enabled high profit margins. Currently there is a clear trend towards horizontal markets where companies focus on specific areas of the customer offering. This development has mainly been driven by cost and organizational efficiency, but also by national regulations. Figure 2 presents the envisaged actors in a fragmented market and comparing them with the MNOs reveal some fundamental differences.

For example, the MNO will mainly offer services for a mass-market whereas the service providers (SP) is specialized in services aimed towards well-defined market segments. The local service and access provider (LSAP), on the other hand, will instead exploit local presence to offer high speed access in combination with content based services. Finally, the inter-connection provider (ICP) connects SPs to different LSAPs so that users can be offered more coverage. A consequence of unbundling the mobile industry is that services offered to the users becomes decoupled from the radio access provisioning. In the following, each of the market players will be described in detail.

A. Service providers

The key issue for SPs in future mobile networks will be to effectively identify and respond to shifting customer demand. This requires a service platform [9], suited for their specific service offerings, and a well defined customer segment. Thus, the customer relation is anticipated to be built on content and there is less need to maintain high transition costs for the subscribers (which is the current practice).

B. Mobile network operators

The MNO has at least one cellular network, for example GSM/EDGE, WCDMA or a future 4G radio. Hence, the key asset for MNOs is the license enabling them to offer mobile services with wide area coverage. Considering the huge investments involved they have a strong position, particularly for providing services that are coverage driven (such as personal communications). MNOs are the only actor that alone provides a complete customer offering, see Figure 1. Moreover, we can expect them to focus and have a strong position in providing services suited for a mass-market. In particular those that require wide area coverage. Notice also that MNOs already today in most countries are obliged to offer excess capacity to SPs such as Mobile Virtual Network Operators (MVNO).

C. Local service and access provider

Recently MNOs, public hot spot initiatives [2], and companies have started to offer WLAN access as a complementary service. The most promising of those initiatives are perhaps companies with local presence and existing assets that can be exploited, for example in terms of infrastructure or a customer base [12], and thereby act as LSAPs. As the WLAN hot spot industry matures, they will be more accessible for the LSAPs and their customers. We can thus expect an increasing number of LSAPs in the near future. This would in principle enable a high capacity network with scattered, though cheap, coverage. From an SP perspective, such a network would especially be useful for services that do not require full coverage. However, for the SP to benefit from the access provided by LSAPs a new market actor is needed; the ICP.

D. Inter-connection provider

ICPs offer core network services to SPs, connect them to LSAPs, and act as a clearing house [6]. The inter-connection provider has agreements with many network providers, potentially with overlapping coverage. Hence, the ICP can be viewed as a virtual network provider by the SPs, and as a major SP carrying a significant amount of traffic from the LSAP perspective. Perhaps the main motivation for introducing ICPs is in reducing transaction costs and the profit is obtained by decreasing the systematic risk through a diversified portfolio (similar to the business case of insurance companies).

IV. Radio resource management using service level agreements

Herein we outline key working assumptions for managing radio resources in the fragmented for market for mobile services described in Section III. In particular, we consider service level and capacity assurance (SLA management) and handovers between networks that are managed by different actors (multi-operator CRRM). We will for simplicity focus on the following use cases that capture the main aspects:

1) ICPs connecting multiple SPs to LSAPs, and
2) MNOs hosting multiple SPs.

This is further illustrated in Figure 3. Notice, though, that in practice LSAPs may also provide services via other LSAPs or MNOs networks. MNOs could also lease capacity from LSAPs when the coverage and capacity of their own network is poor.

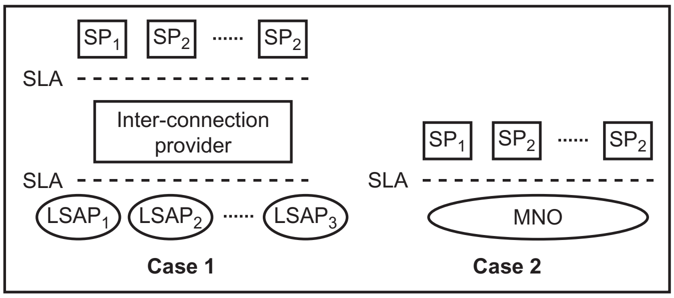

Fig. 3. The figure illustrates two considered cases of network sharing. To the left multiple service providers connect to local service and access providers via an inter-connection provider. The second case is a mobile network operator that offers wireless access to different service providers.

A. Service Level Agreements

We assume that an SLA is signed between companies that provide radio access and services. It specifies what radio access bearer services that are offered, including all necessary parameters related to performance such as throughput, availability and quality of service. In principle the SLA should be independent of the network provider and radio access technology in use. However, a few factors will depend on the applied business model.

In some cases the SLA could for example include the traffic volume that a service provider is guaranteed, even at specific places and at certain points in time. Large ICPs and SPs would have a strong impact on the radio network planning and dimensioning. It is therefore necessary for both LSAPs and MNOs to offer long term capacity allocations, probably at a discounted price. A smaller SP or LSAP that directly connect to a network provider is instead typically charged per connection, based on the characteristics of the radio access bearer.

An SLA is divided into Service Level Specifications (SLS), which define each service and the corresponding QoS level that an SP is entitled to. An example of a an SLS is given in Table I.

B. ICPs connecting multiple SPs to LSAPs

Performing CRRM across business boundaries is difficult, since exchange of information between competing network providers must be minimized. For example, CRRM in UMTS is based on service and user priorities for each sub-system.

TABLE I

AN EXAMPLE OF A SERVICE LEVEL SPECIFICATION FOR A SPEECH SERVICE.

Parameter	Maximum level
Blocking probability	2%
Dropping probability	1%
Guaranteed capacity	20Erlang/km^2
Data rate	12.2kbps

Moreover, load information has to be signaled between radio network controllers [8][21] and this would reveal business sensitive information. There are also clear incentives for network providers to maximize their traffic load by, e.g., sending false load information messages. Consequently, multi-access control between LSAPs and MNOs could therefore, without modifications, not use the same distributed CRRM functionality that is specified in 3GPP today.

In fact, if a strict separation of competing LSAPs is desired, not even the reason for handover can be disclosed since it would contribute to the competitor intelligence. For example, related to the coverage and load of neighboring networks. From a business perspective it would therefore be more appropriate to perform service, load and coverage triggered handovers solely based on information available at the ICP. This data could be obtained by

- exchanging information directly with the LSAPs,
- collecting performance statistics from terminals,
- tracking the obtained QoS for different radio access bearer requests,

or a combination thereof. Since there should not be any signaling between LSAPs regarding the reason for terminating or setting up a connection, the actual handover mechanism is by necessity hard (break before make). This naturally puts requirements on the setup time of new connections.

Moreover the reduced efficiency will have to be compensated by over-dimensioning. However, considering the modest costs for increasing capacity of a wireless local area network this is well compensated by the benefits of preserving competition. Yet, some load balancing can be obtained via the ICP as discussed above.

C. MNOs hosting multiple SPs

An MNO that operates multiple radio access technologies would typically hide the complexity of multi-access control for the service providers. The standard functionality for CRRM, as specified by 3GPP, can then be used [21][22].

To complement this, the MNO could also incorporate SLA management in radio network planning, dimensioning, and management. By measuring the relevant parameters for each SLS the MNO could adjust the priority for the specific radio access bearer and SP, at the network level or with finer granularity. Note that this functionality assumes a large network with multiple SLA instances, so that such a statistical approach is useful.

V. CONCLUSION

In this paper, key requirements for radio resource management in multi-operator, multi-access shared wireless networks have been identified. We argue that a necessary requirement for successful resource sharing between competing actors is that their networks is business-wise decoupled.

One promising business models for future shared networks include mobile network operators that offer wide area wireless access to specialized service providers. Another example is local service and access providers providing local area coverage for service providers and mobile network operators (possibly via an inter-connection provider).

Common radio resource management as specified in 3GPP can, without modifications, not be used in such networks since it requires that information is exchanged between network providers. Instead we propose that network selection is performed by either the service provider or the inter-connection provider. Even though this reduces network performance it is most likely the only way to preserve competition.

The service level agreements will depend on the size of the actors involved and large service providers may be offered bulk capacity at a discounted price. Major network providers also have possibilities to maximize the network performance by statistical averaging between different service providers.

ACKNOWLEDGMENT

The authors would like to thank Mr. Perttu Laakso and Dr. Martin Kristensson of Nokia Networks for sharing their views and ideas on multi-operator networks. Also the financial support via the Affordable Wireless Services and Infrastructure (AWSI) program funded by the Swedish Foundation for Strategic Research, and the Novel Access Provisioning (NAP) project sponsored by the Swedish Agency for Innovation Systems is greatly appreciated.

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