New Organisational Framework For Customised Communication Services in Heterogeneous Infrastructures with Asymmetrical Interdependencies

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Abstract:

The exclusive control over their homogeneous network infrastructure facilitated radio network operators to exploit the value chain far beyond the provision of data transport services. Recently deployed broadband radio access networks such as WiFi or WiMax introduce heterogeneity in terms of technology and also in terms of infrastructure ownership. At the same time, customers became aware of and interested in the set of available technologies and the demand to be "always best connected" appeared. In order to provide customised end-to-end services in a heterogeneous infrastructure, network operators would benefit from using third party network segments to meet the always best connected demand. This may result in mutual dependencies where incumbent operators have to rely on owners of local radio infrastructure to provide access for their customers and where local area infrastructure owners in turn depend on the customer base of incumbents to exploit networking effects. The contributions of this paper are threefold: First, an appropriate ownership independent allocation mechanism for available infrastructure resources is described and analysed. Second, the development of a contractual relationship model is discussed, which also considers asymmetrical dependencies. Finally, we present a view on how the resource allocation mechanism and the contract relation model would be integrated in an end-to-end service provisioning approach.

Keywords: Heterogeneous Infrastructure, Asymmetrical Dependencies, Service Level Agreements, Resource Allocation

JEL: L96, L22, D44

1. Introduction

Although technology for mobile communication underwent significant enhancements in the past decade, the portfolio of mobile communication services remained almost unchanged. As a consequence, the changes in the mobile communications market were mostly related to increased competition to attract customers and maintain and increase the market share. Recently the deployment, user acceptance and utilisation of new broadband radio access networks introduced a new component into the mobile communications market. And the evolution trends pointed out by the current research activities in that field may have the potential the seriously impact future market conditions. Firstly, a large set of alternative radio access networks, an increasing technology awareness of customers as well as a service variety similar to the offers of wired Internet networks may change the user behaviour significantly. For example, the relatively long lasting customer-provider contracts, as commonly found in today's mobile networks, can be expected to be rather an exception than the rule, since customers may select services and connectivity more flexibly in order to optimally match their demands. Secondly, radio access network heterogeneity may aggravate the exploitation of networking effects. In second generation mobile networks , which are frequently denoted as 2G networks, only one radio access network was available, which implied the need to subscribe to a radio network provider in order to access the system. Such a "monopoly" radio technology implied a large accessible customer base and thus inherent exploitation of networking effects. With a number of different radio access networks, which may not be interconnected, the customer base would be subdivided into groups using different radio access systems and thus the exploitable networking effects would be reduced. Thirdly, the enhancements of radio access capacities and terminal capabilities probably make the service specific infrastructure components commonly deployed in today's networks for services like Short/Multimedia Messaging Services obsolete.

In contrast, an increasing number of technically different but commonly usable radio access technologies may also introduce new business opportunities. In particular, the demand for an optimal end-to-end data transport service configuration in a heterogeneous and possibly non-cooperative setting may open opportunities for specialised service providers, which use resources of all available infrastructure owners to provide customised services in an always best connected fashion. An independent and fair resource trading platform, comparable to wholesale markets for any other commodity, could be deployed in order to use network resources owned by other network operators

Additionally, an appropriate resource trading concept would not only facilitate optimal end-to-end service configuration, also asymmetrical provider-provider dependencies would be resolved, which would usually lead to limited competition among all providers. Asymmetrical dependencies refer to situations where, for example, a local radio access network provider collaborates with a large scale network provider.

This paper addresses three major issues of an organizational framework for resource trading within a future heterogeneous infrastructure-service provider scheme: First, an appropriate allocation mechanism for available infrastructure resources is described and analysed. Second, the development of a contractual relationship model for incumbent network operators and alternative carriers is discussed, which considers asymmetrical dependencies. Finally, a view on how the resource allocation mechanism and the contract relation model would be integrated in an end-to-end service provisioning approach is presented.

In particular, the paper is structured as follows. In section 2 we present a possible vision of the evolution of the mobile communications market where today's incumbent network operators loose a significant share of the exploitation of the entire mobile communications value chain. Additionally we identify the problem of end-to-end service provision, which is discussed in detail in section 3. The problem of dynamic end-to-end data transport service creation provides the motivation to consider the establishment of a new framework for network resource trading which facilitates the provision of customised services in a heterogeneous network environment. The contractual models required for resource trading and end-to-end service creation are discussed in section 4 and a multi-layered provider structure to implement end-to-end services is presented in section 5. After a detailed discussion of economic incentives for participation at multi-layered wholesale network resource trading we finally conclude our paper in section 6.

2. Evolution of the Mobile Communications Market

Second generation mobile radio networks can be considered homogeneous to a large extent, i.e. the deployed type of radio network is technically homogeneous and owned by a single business instance. The homogeneity of the radio network is one of the most important features of existing 2G networks, as the pertaining networking effects can be considered the key attraction for all customers.

The deployment of standardised radio technology simplified on one hand the establishment of a homogeneous radio network open to all customers. But on the other hand it facilitated also competition in terms of an oligopoly of operators deploying identical standardised technology. While the interconnection of the competitors' networks clearly increased the networking effects, new mechanisms had to be introduced to achieve market segmentation in face of continuously decreasing prices for the initial voice service provided by 2G networks. This led to operators' policies, where not only network infrastructure services in terms of voice and data transport are provided, but also customised services and content delivery are included in the operators' portfolio. Due to technical limitations of 2G networks in terms of available data rates, terminal capabilities, battery power, etc, the creation and adaptation of services in such networks most commonly required the installation of service supporting infrastructure in operators' networks, e.g. for *Short Message Services*, *Multimedia Message Services*, and for terminal adapted internet access. This inevitable connection between service provision and infrastructure management led to the situation, where incumbent mobile network operators almost exclusively exploit the entire value chain. With the introduction of GPRS mainly to enhance the data transport capabilities of GSM networks[1], mobile users were able to access any type of Internet content, however at comparably low data rates and high cost. 3G networks are supposed to further enhance so called *bit pipe* services for Internet access, thus the exploitation of the content delivery part of the mobile radio network value chain by the incumbent operator may further decrease. However, the inherent multimedia control framework of UMTS called *Integrated Multimedia Subsystem* (IMS) is supposed to compensate this decrease by means of a growing share in the service provision part.

The increasing popularity of WiFi broadband radio technology was initially expected to initiate a new era of public radio communication, both in technical and business terms. WiFi networks provide radio access at comparably high data rates within a geographical limited region using license-exempt radio spectrum. Recent advances in terms of terminal capabilities[2] facilitated the exploitation of such high data rates and as a consequence the content and the services usually provided over wired Internet connections became available and were used by mobile customers. The business expectation was that increasing competition in the market for mobile Internet access would lead to decreasing access prices. Instead, the need to connect distributed WiFi segments to the Internet and insurmountable problems in charging customers for network access and service delivery in a convenient way led to a situation, where mainly incumbent network operators establish WiFi infrastructures as complement to their 2G and 3G networks, where already existing customer-provider contracts and billing mechanisms are re-used. As a result, operators sacrificed the homogeneity of their radio networks in order to satisfy their customer demands. Currently, the customer loyalty is maintained by means of convenient service management and billing, however under the restriction of meeting the customer demand of “always being best connected”. Additionally, the need to install service specific infrastructure in the provider’s network is diminishing in case of high data rate Internet access for high performance terminals. The currently rapidly increasing popularity of Internet-based multimedia services, such as VoIP and VoIP over WiFi, may even jeopardize an economically reasonable deployment of the UMTS IMS, as such services could be provided by third party Internet providers.

The currently observable evolution of broadband radio access may further pave the path for a competitive mobile radio network market with access to network independent but customized services using heterogeneous infrastructures.
To mention only a few examples: In addition to WiFi technology WiMax according to IEEE802.16 is intended to serve as *Metropolitan Area Network* by extending both, the WiFi data rates and the communication range. One application of WiMax may be to serve as backbone network to

[1] GSM networks are the most popular implementation of 2G networks, GPRS as enhancement of GSM is often denoted as 2G+ or 2.5G network.
[2] Multi-mode radio support, high resolution color displays, processing capabilities.

interconnect WiFi segments within a particular region. But additionally also the deployment as retail customer system is foreseen, e.g. as substitute of DSL last mile access. Furthermore, also mobility management of terminals is included in WiMax such that it may at least provide non-seamless broadband access to mobile users. WiMax is supposed to use licensed as well as license-exempt spectrum.

Furthermore, recent activities in research are developing a new generation of radio systems, called *Ultra Wide Band* (UWB) systems, which are supposed to exploit a wide range of available spectrum in coexistence with primary users of licensed frequency bands. In short words, such UWB systems transmit in a frequency band, which may include bands that have been licensed for use by other systems, but at power levels that imply minimum interference, i.e. primary systems perceive such UWB transmissions as noise. The regulation for use of UWB systems still has to be settled in Europe, but generally the permission of a license-exempt mode can be expected.

Alternatively, *Cognitive Radio* combined with *Software Radio* approaches may be used to further exploit the available spectrum in a license-exempt mode. This means, that a system continuously monitors the use of some part of radio spectrum by primary users and re-uses this spectrum at times, when primary users are inactive.

In summary, the already existing broadband radio technologies as well as those being currently under development further expand the capabilities of mobile radio access in terms of available data rates and/or communication range while facilitating operation in a license-exempt mode. Provided that appropriate multi-mode terminals are available these technologies can be supposed to further contribute to infrastructure heterogeneity, both in terms of technology and ownership.

The previous discussion of a possible evolution of the mobile communications market is illustrated in Figure 1, which depicts the development of the market shares of incumbent mobile network operators in the business segments “Content Provision”, “Communication Services”, and “Infrastructure Services”. These business segments are seen from the perspective of a mobile network operator, i.e. the content provision segment refers to business relationships with independent content providers in order to adapt their content specifically to be delivered via the own mobile radio network. This includes, for example, the *Wireless Application Protocol* adaptation and specific Internet content provision, e.g. *I-Mode*. The communication services segment represents all communication services including voice as major part but also Short/Multimedia Message Services. Infrastructure services refer to all data transport services, regardless whether the data transport supports own or third party services. Please note that all communication and content provision services require such infrastructure services. The illustrated development of market shares does not indicate the share of the total market, the aim of Figure 1 is rather to present a qualitative development and the market shares at the time where the GPRS data service has been introduced are used as reference.

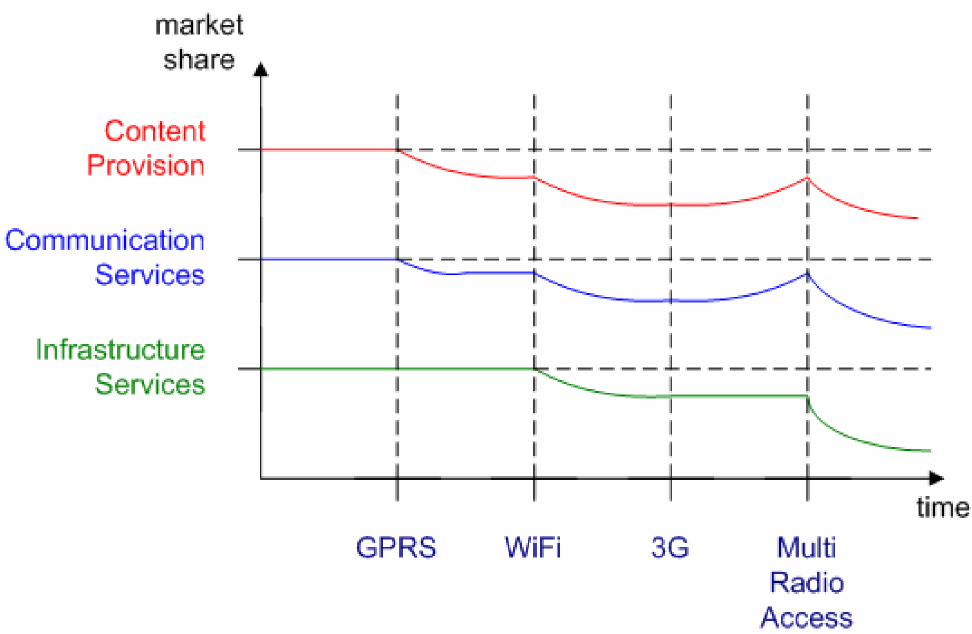

Figure 1: Development of Market Shares of Incumbent Operators

After the introduction of GPRS mobile Internet access became feasible[3], however at high prices. The major applications using this mobile packet data service were email, VPN and HTTP. The generic HTTP support facilitated access to non-adapted Internet content, which led to a decrease in the content provision activity of the network operator. VPN and email services are transparent for the operator's network, thus these services take a small share of the communication services segment. But the overall third party business share originating from GPRS data services can be supposed to be rather small. With the deployment of WiFi networks HTTP is in principle supported at much higher data rates and at significantly lower prices. We assume proper dimensioning of WiFi segments such that high data rate Internet access is provided and conclude that this would lead to a loss in the content provision segment. Similarly, email and even VoIP over WiFi cause a decrease of the communication services share. The radio access provided by WiFi network segments causes of course also some reduction of the infrastructure services share, where complementary WiFi infrastructure deployed by the pertaining 2G network operator is accounted to belong to the incumbent's mobile network and therefore attenuates this reduction. Due to this accounting and the geographically limited deployment of WiFi access segments, we only have to consider marginal losses. The subsequent deployment of third generation UMTS networks (3G networks) not only extends the data rates of GPRS for mobile users, it also includes the flexible and powerful multimedia delivery and management system IMS. The multimedia streaming services, where content may be adapted to 3G network and terminal characteristics, may in the best case increase the content delivery share. Also multimedia communication such as video conferencing, is often assumed to be a typical application supported by 3G networks, therefore we optimistically assume that also the communication services share may increase. As 3G networks are supposed to substitute

2G networks in the medium to long term, we assume constant infrastructure share development. The extent of share increases clearly depends on the technology and service acceptance of customers, the increase depicted in Figure 1 is again only a qualitative increase. The last stage of the considered development - the extensive deployment of multiple broadband radio access networks by various independent business entities - can be expected to have an intensified “WiFi”-effect. We introduce the term *Broadband Radio Access Provider* (BRAP) to denote the business entity owning and operating a local broadband radio access network.

These BRAPs offer higher data rates at even more competitive prices and this may lead to wired network-like usage of HTTP and all Internet services. One consequence would be a decreased content delivery and communication services shares. Furthermore, the increasing number of BRAPs generally reduces the market share of incumbent network operators. It is of course debatable how severe the loss of market shares in each segment is, however we claim that the depicted qualitative development is not too visionary.

An exact prediction of the extent of market share losses due to deployment of current or future local broadband access radio networks can only hardly be done. However, one important question arising from the above described potential market evolution is whether incumbent network operators and BRAPs can coexist and benefit from each other.

A commonly found assumption is that probably no suitable business model for BRAPs exists and that a BRAP network only serves as a complement to other businesses, e.g. radio access in hotels, restaurants, shopping malls, etc. But regardless whether the incumbent operators or new business instances own local broadband access networks, the customer demand for broadband access can be expected to impact the market evolution.

The ultimate consequence from such an evolution would be a complete separation of content and infrastructure, i.e. network operators provide infrastructure services for data transport and communication services and content delivery are applications using available infrastructure services.

Up to now one important technical aspect has been disregarded: The configuration of end-to-end services to meet customer demands. In 2G and 3G systems the network operator does not only adapt content and controls multimedia streaming. Equally important for proper service delivery is an appropriate configuration and dimensioning of the infrastructure carrying all data. When a network is becoming more heterogeneous, especially in terms of ownership, then the full control over the entire end-to-end infrastructure gets lost. *Service Level Agreements* (SLAs) among all involved parties would be required to ensure proper end-to-end service delivery. The often deployed long term inter-provider contracts probably prevent flexible service creation and rapid adaptation to

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[3] We disregard the GSM 9.6 kbps data service here.

varying customer densities and demands. Apart from technical obstacles also economic barriers have to be overcome. The asymmetrical dependencies, where a local radio access provider is assumed to depend more on the service contract with a large network operator than vice-versa, may hinder an economically reasonable and independent growth of BRAPs. In the following sections we first discuss the technical obstacles related to end-to-end service creation and management and subsequently introduce a market approach to facilitate our approach to solve the technical as well as economic problems.

3. End-To-end Infrastructure Services

The most basic and also most essential form of end-to-end service provision in data networks is to guarantee connectivity to all other connected network nodes. The problem of end-to-end service provision was first raised when the global Internet infrastructure was installed. The Internet is comprised of a set of individual *Internet Service Providers* (ISPs), which are interconnected to achieve connectivity to all global destinations. Initially peering agreements between ISPs facilitated the required interconnectivity, where ISPs mutually granted transport of traffic induced by the customers of the peering ISPs free of charge[4]. But as soon as smaller ISPs with rather small numbers of customers developed, peering agreements in order to achieve global connectivity would have imposed unacceptable diseconomies for large scale ISPs. Consequently, also bi-directional and asymmetric customer-provider relationships evolved between ISPs.

Global connectivity is now most commonly achieved by means of nested bi-lateral connectivity agreements, i.e. a small scale ISP has only one connectivity agreement (as a customer) with one adjacent backbone provider, which in turn maintains a set of agreements with other ISPs (as a customer) to provide connectivity to all other adjacent domains and so forth[5]. Figure 2 depicts an exemplary scenario with a set of small ISPs connected to a large backbone ISP *B*[6]. ISP *A* has a service agreement with ISP *B*, who in turn has service agreements with all other ISPs, such that traffic sent from ISP *A* can be forwarded to any destination ISP.

[4] R. Gibbens, R. Mason, and R. Steinberg. Internet service classes under competition, IEEE Journal on Selected Areas of Communications, December 2000

[5] N. Semret, et al. Pricing, provisioning and peering: Dynamic markets for differentiated Internet services and implications for network interconnections

[6] Please disregard the tables in Figure 2 for the moment.

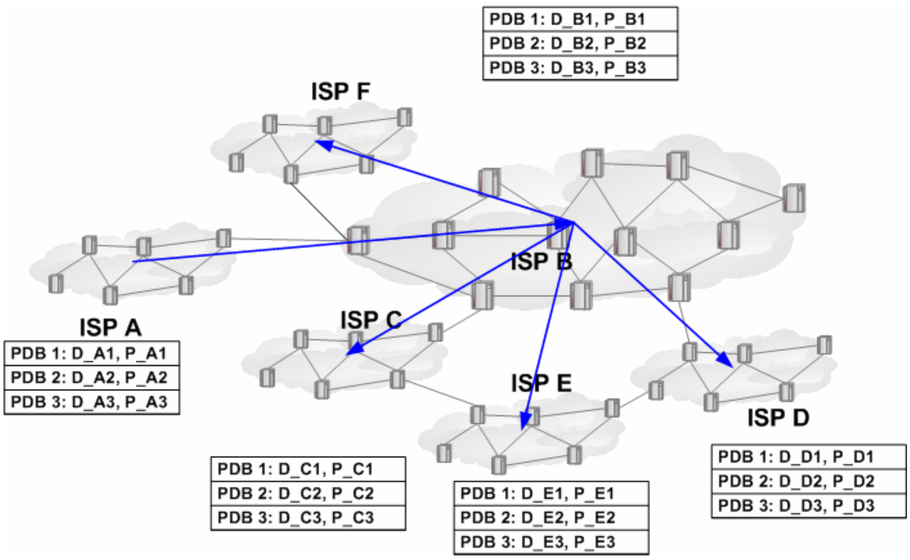

Figure 2: Nested Bi-lateral Service Agreements

In context of a heterogeneous radio network infrastructure the same principle applies. Radio access networks need to be interconnected and connected to the wired Internet network. BRAPs would need to subscribe to at least one ISP in order to offer network connectivity and Internet access, i.e. ISP *A* may represent a BRAP in a mobile communications context. Incumbent 2G or 3G radio network operators maintain SLAs with backbone network operators and Internet ISPs to achieve end-to-end connectivity between their radio networks and to the Internet. The major difference to small scale local radio network operators is the absence or reversed direction of asymmetry of the interdependency between 2G/3G operators and ISPs. Assuming that all radio access segments are interconnected by one ISP, the network traffic offer of one incumbent to the ISP's network is comparably large, which results in increased economies of scale for the ISP. Therefore the attractiveness of SLAs with 2G/3G operators for ISPs can be considered comparably high, which may eventually lead to a situation where the ISP depends on the increased economies of scale contributed by the radio network operator. This is in contrast to a BRAP, which clearly depends on the exploitation of networking effects offered by the ISP who offers global Internet connectivity.

Instead of relying on a single ISP for global connectivity a set of bi-lateral service agreements with a selected set of ISPs could be stipulated. Figure 3 illustrates a scenario where ISP *A* wants to achieve full connectivity to ISP *E* and therefore maintains SLAs with all intermediate ISPs. A dependency related to a single path between ISP *A* and ISP *E* can be lessened by stipulating SLAs with ISPs along alternative paths. But maintaining multiple redundant SLAs puts an additional economic burden onto a single ISP due to the associated contractual commitments. Apart from that, the dependency on some ISPs may be impossible to be resolved due to absence of alternative paths, e.g. ISP *B* cannot be substituted in the example of Figure 3.

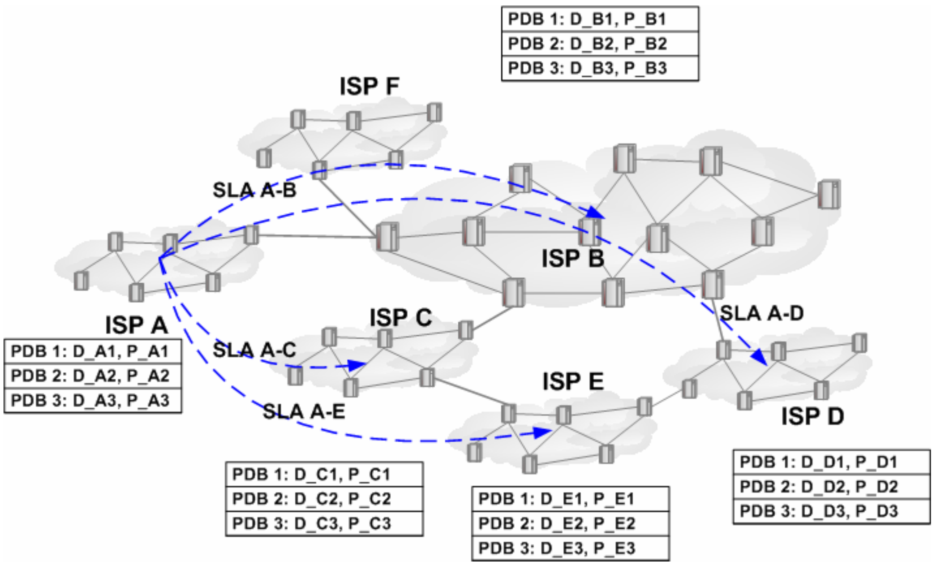

Figure 3: Direct Bi-lateral Service Agreements

But already in 3G networks the provision of connectivity among all radio access segments and to the Internet is considered insufficient to support all foreseen applications of such networks. The class of so-called real-time applications, like voice and video conversation, typically requires a certain level of quality of the underlying transport service. Additionally, also customers using non real-time applications, like HTTP and email, would become dissatisfied if the data transport performance falls below a certain minimum threshold. In context of communication networks the term *Quality of Service* (QoS) denotes the characteristics of the delivered services in terms of availability, reliability and performance. But most commonly the term QoS is deployed to refer to the service performance and for consistency reasons the term QoS is used synonymously with service performance throughout this article. We generally distinguish user-centric QoS and network-centric QoS. The former is selected by the customer demanding a network transport service, either from a set of a-priori stipulated QoS classes or arbitrarily defined, and can be denoted as time invariant for the duration of the connection. The latter shall depend on the current network state and thus may vary over time. In other words, user-centric QoS denotes services with quantitative performance guarantees, while network-centric QoS refers to services with qualitative performance differences. As the focus of our work is on customised services we deal only with user-centric services.

Providing multiple types of QoS clearly imposes additional complexity. Apart from technical mechanisms to ensure proper QoS delivery by the network also the SLAs among ISPs and radio network operators are affected. One approach to provide different levels of QoS is to follow a class-based approach, where one QoS class is defined by a set of upper or lower bounds on particular performance metrics[7]. In order to achieve end-to-end connectivity for all QoS classes provided by a particular ISP a set of bi-lateral SLAs for each class with all ISPs, whose domains are traversed between source and destination, needs to be maintained. ISPs can arbitrarily define user-centric service classes which are implemented by appropriate link sharing directives. Thus, the composition of the various QoS classes defined differently by each ISP would theoretically lead to a huge number of services. We exemplarily discuss network transport service composition from source ISP *A* to destination ISP *E* in Figure 3. The services offered by each domain are defined as *Per Domain Behaviors* (PDBs). A PDB is defined by a set of performance thresholds, for example thresholds for the domain[8] internal delay (D) and loss probability (P). ISP *A* can compose an end-to-end service to ISP *E* as arbitrary permutation of the user centric PDBs of the traversed domains. For a path between ISP *A* and ISP *E* traversing ISP *B* and ISP *C* we already have 3^4 different combinations with different performance guarantees for each combination. The number of possible combinations by also exploiting different routes between source and destination ISP is $2x3^4$, which is already a large number in this rather small-scale example. Therefore even a coarse qualitative granularity of provided end-to-end service classes results in a non-negligible set of SLAs with various ISPs. The stipulation and maintenance of these SLAs by small scale radio access network providers can be considered a fundamental market entry barrier.

In case of nested SLAs as illustrated in Figure 2, the role of backbone ISPs generally becomes more dominant, since the set of end-to-end service classes that can be offered by all attached ISPs clearly depends on the set of classes provided by the backbone ISP. The tables depicted in Figure 2 describe the set of service classes with guaranteed performance bounds to the respective destination ISPs to which ISP *B* maintains SLAs.

As a result, a competition of local ISPs attached to the same dominating backbone cannot include a differentiation of the number and characteristics of the offered services. For example, ISP *B* offers data transport services to any host of ISP F only with the three indicated PDBs[9]. Consequently, ISP *A* to *D* have to offer identical data transport services to ISP *F* and thus a differentiation among them is reduced to different competitive prices. This results in a lack of incentives for service providers to put efforts in the creation of specific and customized service classes. Instead, if in competition with other service providers pricing is dominant, operational costs need to be minimized which may motivate service providers also to minimize the number of provided service classes[10].

Summarizing, long-term bi-lateral SLAs as found today may impose a non-negligible market entry barrier especially for small locally operating ISPs, while nested SLAs may result in a possible lack of incentives for service providers to put significant effort in service differentiation due to the “de-facto” standard set by the adjacent backbone ISP. Furthermore the asymmetrical dependency of

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[7] S. Blake, et al. An architecture for differentiated services, RFC2475, December 1998

[8] A domain denoted the set of network elements and connections owned and controlled by one ISP.

[9] The term PDB in this context is not accurately used, as, for example, an end-to-end service from ISP A to ISP F involves PDBs of all traversed ISP. Thus it is a composed PDB.

[10] Katz, R.L.: Irrational Exuberance or the Seeds of Volatility, The New Telecommunications Industry and Financial Markets: From Utility to Volatility, CITI Conference, April 2002, New York

small and large scale ISPs, where BRAPs correspond to small scale ISPs, put tight boundary conditions on the business models of all involved entities.

In face of the inevitable need to establish cooperation agreements among all data network providers in order to facilitate end-to-end services traversing the network of independent operators, one reasonable approach is to minimize the technical and economic burdens induced by these cooperation agreements. A straight forward approach would be to deploy short-term service agreements among arbitrary fixed and radio network operators. Such short-term contracts would significantly reduce monetary and other contractual commitments which are typical for long-term SLAs. In order to facilitate short-term SLAs we propose the establishment of an open wholesale market for network resources, where ISPs and radio network operators can buy and sell resources depending on their traffic offer and network load. The following section describes different contractual models for SLAs stipulated on wholesale markets and points out how wholesale network resource trading reduces the risk of asymmetrical dependencies and fosters the development of individual ISPs and BRAPs providing customised services.

4. Contractual relationship model

For the introduction of a contractual relationship model a proper discussion of the mobile communications value chain is probably overdue. A value chain is a string of companies or activities working together to satisfy market demands. The value chain typically consists of one or a few primary value (product or service) suppliers and many other suppliers that add on to the value that is ultimately presented to the buying public.
In this context, vertical integration means the extent to which successive stages in production and distribution are placed under the control of a single firm. A firm that participates in more than one successive stage of the production or distribution of goods and services is vertically integrated. Horizontal integration is the absorption of several firms into a single firm involved in the same level of production and sharing resources at that level. Therefore horizontal integration is the central organization of all units at the same stage of production.

Today the telecommunications market is to large extent vertical integrated. Vertical integration is driven, as mentioned above, due to the existing technical conditions, i.e. the homogeneous infrastructure of 2G networks. But the mobile telecommunications market is also characterised by considerable horizontal integration as for homogenous infrastructure the oligopoly is the market outcome mainly due to high sunk costs, network effects and economies of scale.
However, with the introduction of heterogeneous infrastructures, i.e. the existence of different broadband radio access technologies, the value chain structures can be expected to change.

Concentration strategies on core competencies by BRAPs will lead to the disintegration of the value chain. Moreover, the introduction of an open wholesale market for mobile access infrastructure capacity will reduce at least one benefit of integration: the economics of internal control and coordination. Furthermore, heterogeneous infrastructure also imposes several strategic costs of integration[11]. These are for example a) the increased operating leverage, b) the reduced flexibility to change partners, c) the high overall exit barriers and d) the capital investment requirements. We anticipate the existence of sophisticated networks owned by independent market players as probably no single mobile operator is able to finance next generation full coverage mobile telecommunication systems.

The major advantage of an emerging wholesale market is that dependencies of small scale infrastructure providers from incumbent operators probably diminish. The reason is that in order to establish an end-to-end service in an always best connected approach, small scale BRAPs or ISPs are recognised as a pure technical part of the whole network to be traversed, instead of a rather small business (competitor) with minor market power. There are still asymmetrical dependencies between small BRAPs/ISPs and incumbent operators. But those asymmetrical dependencies now add up to a value added service for the customers. BRAPs offer sophisticated mobile access technologies, ISPs the access to the Internet (HTTP-services) and incumbent operators provide the customer base and respective network effects.

From the above presented discussion we hypothesise that traditional incumbent mobile operators, ISPs as well as BRAPs have strong economic interests to participate at an open communications infrastructure wholesale market. Within this section, we present a proposition on how the contractual relationship between these different types of infrastructure providers may be evolving. We focus the discussion on two aspects: the type or time duration of the contract and the pricing-scheme.

In order to differentiate between types or time durations of a contract we distinguish between a) spontaneous and b) advanced contracts. Spontaneous contracts are real-time agreements on a call-by-call basis. The major advantage lies in the flexible and short-term option to match supply and demand of infrastructure resources. Fluctuations in demand or supply can be flattened for example by the application of pricing strategies, i.e. accounting for congestion in the network. The disadvantages are increased coordination and administrative costs. Advanced contracts focus more on customer-requested services with user-centric QoS to be delivered at a particular time in the near future and may have time durations that exceed real time agreements. Advanced contracts may be established on a basis of hours, days, weeks or months. But even those contracts react on market changes and differ from (long-term) nested SLAs as described above.

[11] G. Nickel, S. Recker, M. Pohler, *Enhanced Cost Accounting for Quality of Service in Data Networks*, Telecoms in the 21st Century, ITS 15th Biennial Conference, September 5th - 7th 2004, Berlin, Germany

The pricing scheme for offering network resources at the open wholesale market probably depends on the type or duration of the contract. Before going into more detail, we would like to state, that from a network and economic perspective a preferred pricing scheme approach should favour that network resources are used most efficiently. Network efficiency is the utilisation level of a network; economic efficiency is given, if the set of admitted users receiving a certain level of QoS value their services higher than users who have been denied service by the network for the same service level[12]. However, network providers face difficulties to assess the value that a user places on different services. The monetary value of a data packet is therefore difficult to appraise. Although one can make some assumptions on such utility functions depending on the type of application, the uncertainty in the calculation off the utility function is far too high to lead to accurate values, on which pricing decisions can be based.

The question is how exactly can the price be determined as the network internal cost of the provided infrastructure can be supposed to be a complex function. The costs are influenced by several parameters associated with network related investments, operations and maintenance, capacity, QoS types, topology, network configurability, traffic load- and user behaviour models. Furthermore, parameters describing the competitive environment have to be considered in pricing. These mentioned price affecting elements can be split into internal and external parameters, where the competitive environment, user behaviour and the topology of neighbouring BRAPs can be clearly defined as external parameters. Consequently we can state that a price function consists of two parts: Internal parameters which are assessable and controllable by the BRAP itself and an external part, which is mainly driven by the outside world.

It would be inevitable to include service parameters in the pricing scheme of BRAPs, ISPs and incumbents in order to account for the differences of services and their pertaining resource consumption properly. Service parameters for example include edge-to-edge delay, jitter or loss probability. Service providers with a high price/ high quality strategy would focus on the supply of, for example, low delay services for which premium prices are enforceable.

BRAPs can also adjust prices according to the requested bandwidth, taking into account both economies of scale in infrastructure costs and users (or incumbent operator's) willingness to pay for mobile broadband access.

We exemplarily discuss a price function of the provided bandwidth in Figure 4. In this example, costs for supplying higher bandwidth do not increase linearly, thus higher bandwidth can be provided at a lower price per unit. However, extremely high bandwidth data rate services[13] may be

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[12] M.Pohler, S. Recker, Virtual Domains in Multi-Layered Structures to Foster Competition and Service Diversity in Future Communication Networks, The Stockholm Mobility Roundtable 2003, May 22nd-23rd , Sweden

[13] In this context bandwidth and data rate are used synonymously.

products, which only technology intensive BRAPs can offer, and as a result such providers may not face extensive competition and may be able to charge a high fee for such services. In this case the price can actually rise exponentially.

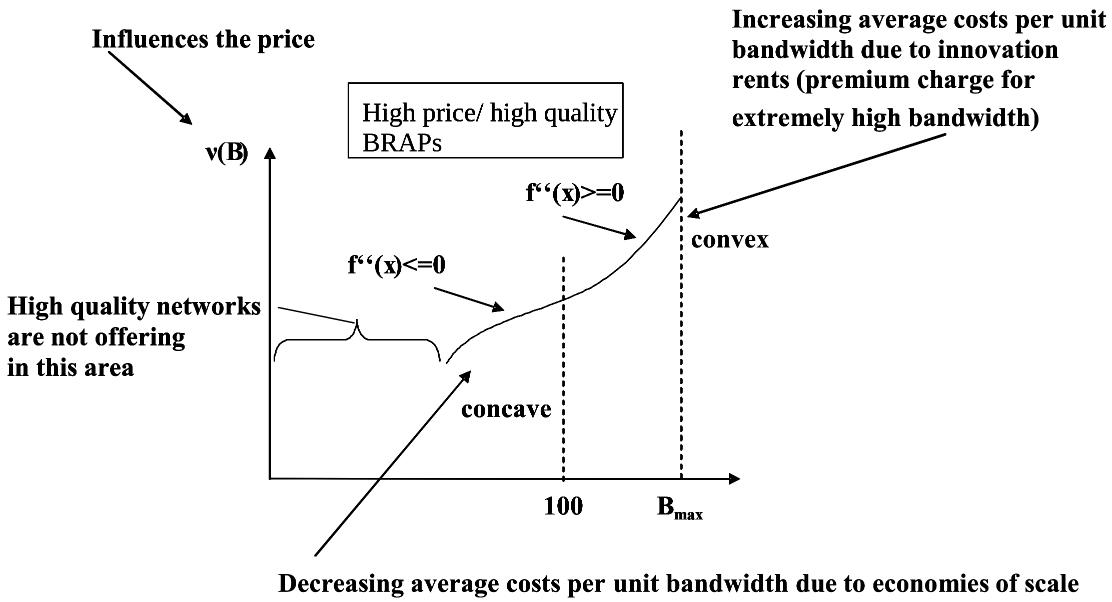

Figure 4: Price Function of a High Quality BRAP

Despite existing pricing schemes based on bandwidth and other service parameters, we conclude that spontaneous contracts will lead to price structures comparable to spot markets, whereas for advanced contracts the pricing structure is intimately related to the real cost unit rate of the offered service. One basic approach in order to find a well accepted pricing mechanism within the contractual relationship model between two business instances participating at the wholesale market may look like as follows (see Figure 5):

We discuss a contract between BRAP and an incumbent mobile network operator with bandwidth as relevant service parameter. Within an advanced contract, the incumbent operator specifies a bandwidth B_{res} that he wants to have guaranteed from the BRAP and for which a volume charge for the allocated resources has to be paid (allocation charge). But the in fact used bandwidth may temporarily exceed the allocated bandwidth. Such excess bandwidth may not have a service guarantee and is charged according to actual usage (usage-based charge). A service offer of the BRAP issued on the wholesale market place would include the price p together with his offered B_{res} and possibly information about the excess service conditions.

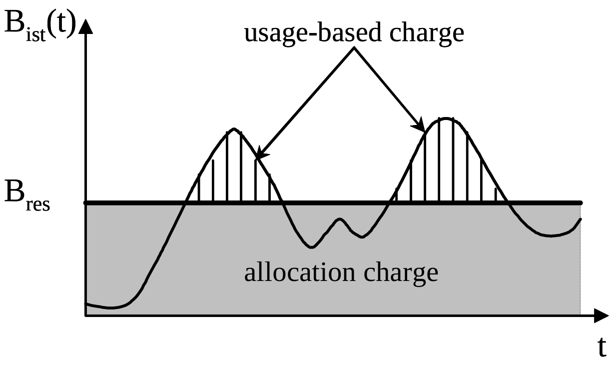

Figure 5: Pricing Scheme in Dependence of Reserved Bandwidth and Usage

The market outcome of an open wholesale market is characterized by individually negotiated contracts, and consequently BRAPs are forced to calculate prices not only according to their cost basis, but also in accordance to the market. Advanced contracts may facilitate a stable calculation basis for BRAPs and therefore reduces the risk of business failure. Spontaneous contracts on a call by call basis offer the possibility to sell excess capacity. As we believe that the growth of heterogeneous broadband mobile infrastructure will reduce the power of incumbent operators in the context of customer retention or ownership, spontaneous contracts offered by BRAPs will be an essential part of their business model, as in the future mobile customers wish to be "always best connected".

Assuming that a wholesale market for network resources exists, we discuss in the following section how end-to-end service provision can be implemented based on network resource trading with the above discussed contractual models.

5. Multi-layered service provider structure using network resource markets for customised end-to-end service provision

In order to combine heterogeneous network infrastructure owned by different parties in order to enable an end-to-end service which meets the approach of "always best connected", we introduced the open wholesale market. Such a market will facilitate short-term SLAs between incumbent operators, ISPs and BRAPs in such a way, that these parties are able to buy and sell network resources depending on a) the traffic demanded by customers as well as b) on their own network load.

The almost infinite variety of customer demands in terms of individual service performance parameters and the effort required to buy resource for service provision on basis of spontaneous or advanced contracts suggests that there will be probably no single instance aiming at covering the entire service spectrum. Instead, particular service and possibly also content providers may focus on the provision of a well selected set of services with appropriate service parameters. We also generally consider the case, where service providers focus on a business of providing particular services for other service and content providers, i.e. such intermediary providers buy resources from other providers on the wholesale market such that they are able to provide an end-to-end service of a certain quality between particular network locations. Such providers act like specialised wholesale traders and the resulting market structure can be expected to have a multi-layered structure.

The idea is that individual service requests are processed on the uppermost layer on the timescale of call durations and that with descending layer the duration of SLAs increases as well as the dimension of the assigned network resources. Each resulting layer is characterized by *1)* the respective time scale of their SLAs, *2)* by the granularity of the provided QoS classes and *3)* by geographical dimensions and density of service coverage.
Thus by means of partitioning of resources with ascending layer the number of service requests to be processed by one domain or ISP is aggregated with descending layer. This partitioning and aggregation effects lead to scenario for provision of a multitude of user-centric services that is scalable in terms domain operation. Such a scheme is facilitated by the existence of a wholesale market with the possibility of short-term SLAs.

Figure 6 depicts a possible differentiation of service provider layers in terms of time scales of resource assignments and the degree of flow aggregation. The squares and rectangles shall represent infrastructure and data services layers. On the infrastructure layer exemplarily a composition of one backbone with intermediate regional and small BRAPs or ISPs is depicted. The first data services layer is comprised of a number of specialised intermediary providers, which book resources from a subset of the existing infrastructure provider. The SLAs between these providers have been mediated by the respective instance of the open wholesale market.

The larger dimensions of domains have to be interpreted as larger geographical domain dimensions with sparser coverage, as selected end-to-end links from the lower service layer are composed to basically one domain. The process of segmentation of acquired resources and specification on particular performance delivery is continued on each subsequent hierarchical layer.

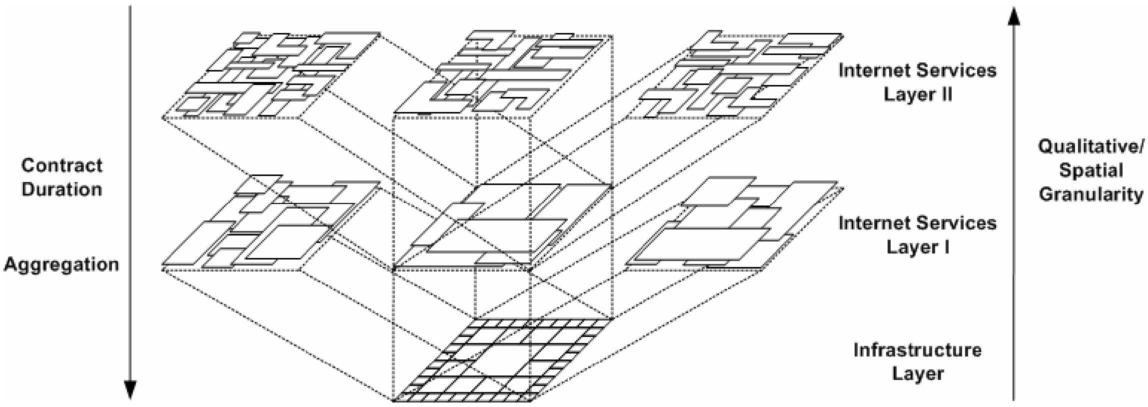

Figure 6: Multi-layered Service Provider Structure

The vital pre-requisite for the described alternative strategy of a multi-layered wholesale market structure is the existence of economic incentives for players on the infrastructure layer and on all Internet services layers. The arbitrage opportunities discussed in the following represent such incentives. Generally unit prices and tariffs must be incentive compatible, cost covering and they must avoid arbitrage[14]. The identified arbitrage opportunities are intended to be exploited in a wholesale scenario such that in the subsequently resulting equilibrium state these arbitrage opportunities do not remain. The exploitation of arbitrage provides the necessary income for business entities taking the role of wholesalers.

We generally distinguish arbitrage opportunities that can be exploited in a single service setting, i.e. data transport services without different performance levels, and arbitrage opportunities that arise after the implementation of different service quality classes.

Arbitrage is defined to be the attempt of exploiting price differences of identical or similar commodities on different markets. In the discussion of arbitrage in single service networks we consider a minimum batch size of the tradable amount of network resources as market separation method. We discuss the arbitrage opportunities of buying and selling different resource sets on such markets.

In particular, we consider a set of homogeneous customers with a known demand profile in equilibrium state, which shall be time invariant over the time frame of interest. The customer demands for (identical) data transport services shall be modelled as Poisson arrival process and each service shall have a negative exponentially distributed duration. Let there be N customers, and let λ and μ be the expectations of the arrival and service rate respectively and assume that the monopoly infrastructure owner has always sufficient capacity to satisfy the customers' demand. Analogous to queuing theory we can denote this model in Kendall's notation as M/M/m/0 - N model with a limited number of sources N and a set of parallel m servers with $m \geq N$.

[14] C. Courcoubetis and R. Weber, Pricing Communication Networks,Economics, Technology and Modelling. John Wiley & Sons Ltd, 2003.

Using the detailed balance equations for the resulting Markov-chain we can determine the probability of being n customers in service:

$$P(n) = \left(\frac{\lambda}{\mu}\right) P(0) \prod_{i=1}^{n} \frac{N-i+1}{i} \tag{4.1}$$

with

$$P(0) = \left(1 + \sum_{j=1}^{N} \left(\frac{\lambda}{\mu}\right) \frac{\prod_{k=1}^{j} N-j+k}{j!}\right)^{-1} \tag{4.2}$$

In a trivial cost covering pricing scheme the unit price could be set depending on the probability of selling n identical data transport services, i.e. assuming we have a total amount of fixed cost C and zero marginal cost[15] we can determine the minimum unit price to cover cost from

$$p = \frac{C}{\sum_{n=0}^{N} nP(n)} \tag{4.3}$$

Now consider the case where the infrastructure owner, in the following denoted simply as ISP, sells blocks of resources to a wholesaler, who in turn resells these resources on the retail market. Let us further assume that the ISP also sells resources on the retail market and that the resource blocks sold to the wholesaler have a size corresponding to the amount of resources consumed by L customers. Assume a competitive retail market where wholesaler and ISP sell at identical prices, i.e. customers equally likely select one or the other. This scenario can be modelled by a two dimensional Markov chain as depicted in Figure 7, where each dimension represents the number of customers being served by the ISP and wholesaler respectively[16]. The equally likely selection of one of the two competitors on the retail market yields a transition probability from state (i, j) to $(i+1, j)$ equalling the transition probability to state $(i, j+1)$ with $i + j < N - 1$.

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[15] Which is a reasonable assumption for network resource commodity pricing.

[16] S. Recker, *Wholesale network resource trading in multi-service networks: Scalable approach for customized QoS and economic necessity to foster service diversity*, IEEE International Conference on Networking, March 1st - 4th , 2004, Le Gosier, Guadeloupe

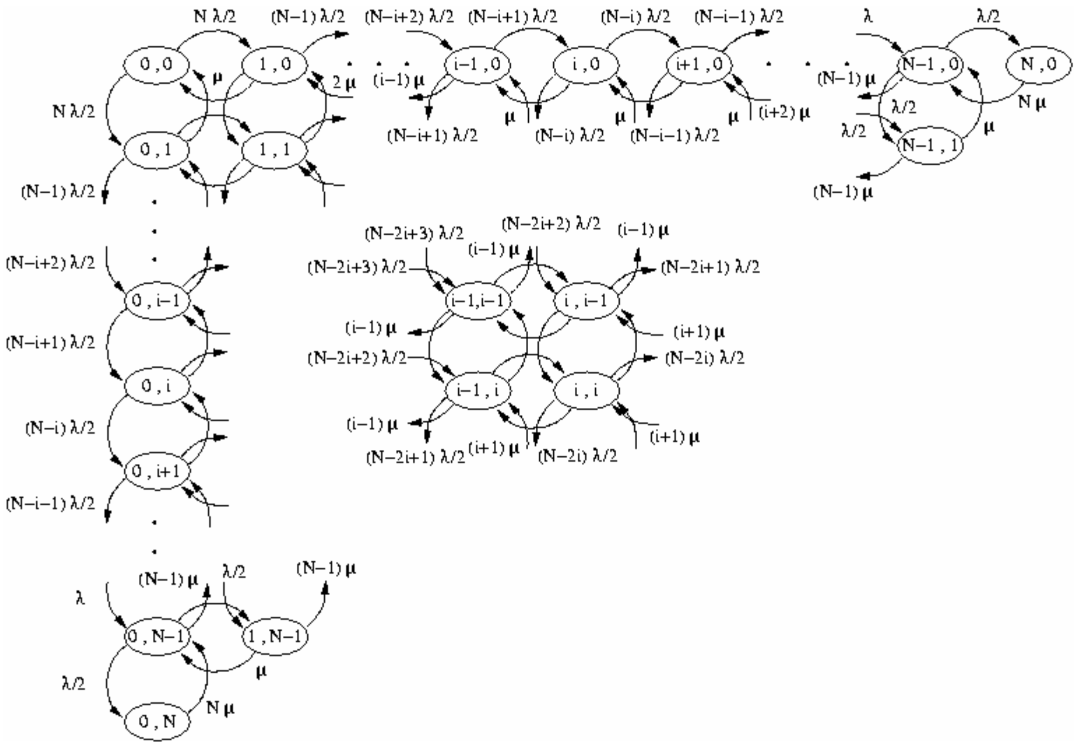

Figure 7: State Transition Diagram for one Wholesaler in Perfect Competition

Each of the three diagrams on the left hand side of Figure 8 depicts some exemplary numerical results for probability distribution of the number of customers in service for the ISP with and without wholesale and for the wholesaler with $N = 100$. The state probabilities without wholesale have been computed by (4.1), the probability of the wholesaler serving n customers is given by the sum $\sum_{j=0}^{N-n} P[n, j]$. The state probabilities of the ISP in case of wholesale is depicted exemplarily for a wholesale batch size $L = 10$. The state refers to the amount of resources sold in units equivalent to resource consumption of one customer. Since the wholesaler always needs at least one resource set of size L, the probability of having sold less than ten "customer resource sets" is zero. This type of forward selling of resources yields in a shift of the probability distribution function to the right, i.e. with wholesale the ISP effectively sells more network resources. The different diagrams refer to different traffic load situations, i.e. high and low traffic load means $\lambda/\mu > 1$ and $\lambda/\mu < 1$ respectively and medium traffic load corresponds to $\lambda/\mu \approx 1$.

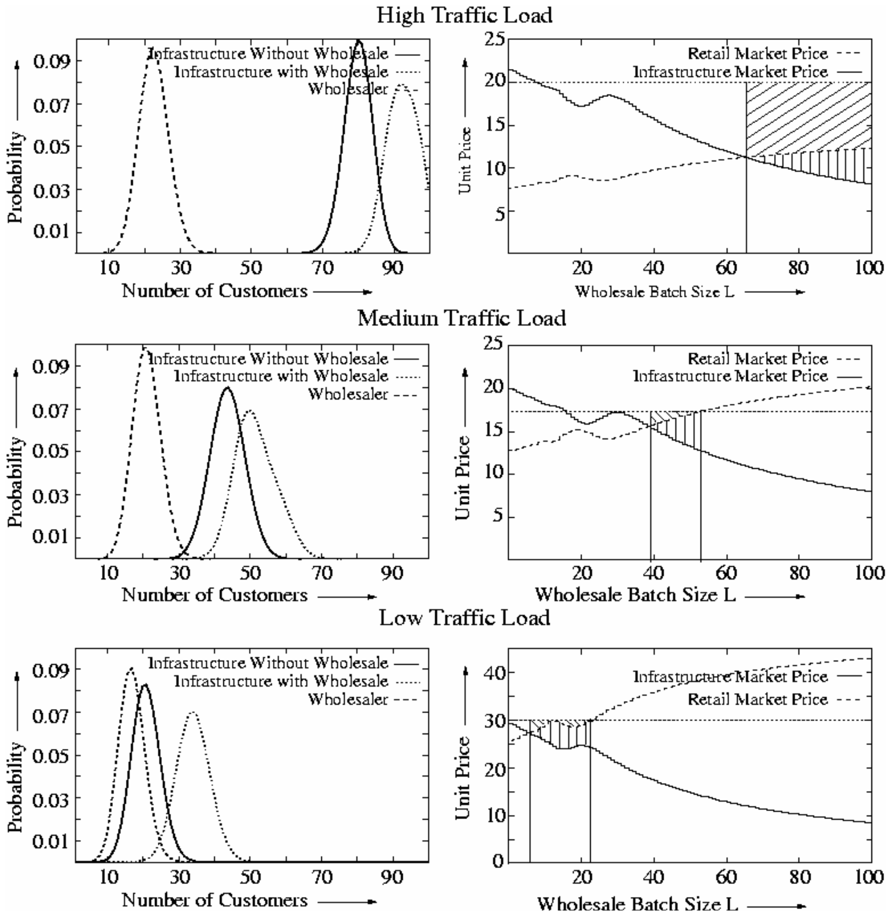

Figure 8: State Probability Distribution and Cost Covering Prices

The three diagrams on the right hand side of Figure 8 depict the cost covering unit prices as function of the batch size L traded on the network resource wholesale market. Prices are given for the wholesale and retail market and as reference the cost covering price charged by the ISP without wholesale. The unit prices have been computed by (4.3) using the state probabilities of the wholesaler and ISP respectively. Arbitrage opportunities only exist where the minimum ISP unit price is less than the minimum retail price to be charged by the wholesaler to cover the cost of buying resource units from the ISP. Otherwise the ISP would not be able to sell directly on the competitive retail market due to the lower price of the wholesaler. Additionally, arbitrage only works when the cost covering unit price of the wholesaler is less than the unit price without wholesale. Then the difference between these prices can be exploited by both, wholesaler and ISP. Figure 8 depicts the intervals of L where arbitrage opportunities exist. Thus by selling resource sets of size L with L being within these intervals an ISP can increase profit while an additional wholesale instance can economically run its business. What is important to note is that the arbitrage opportunities in high traffic load situation are significantly better. But high traffic load in this case refers to the arrival rate being larger than the service rate, i.e. frequently invoked services of short duration. This is in contrast to the expected rather long duration of services requiring user-centric-

QoS[17]. Therefore a careful analysis of the traffic profile to be supported by the wholesaler is inevitable.

The previously discussed market separation by introducing minimum batch sizes for network resources is generally applicable in any type of data network. We now focus on additional arbitrage opportunities arising in networks that provide services with different performance levels.
We discuss the scenario of a network offering data transport services discriminated by a single performance parameter $q \in [q_{min}, q_{max}]$, where the perceived service quality shall increase with q. Let the number of independent supported service classes in $[q_{min}, q_{max}]$ be set to M.
Now the cost to provide a service with quality q shall be a strictly increasing, convex function[18]. This can be intuitively justified by the fact that better deterministic QoS guarantees require over-proportionally more network resources especially in case of bursty traffic characteristics and thus the cost must also increase over-proportionally. The spectrum of the performance parameter q and an example of the associated cost function $C(q)$ is depicted in Figure 9.

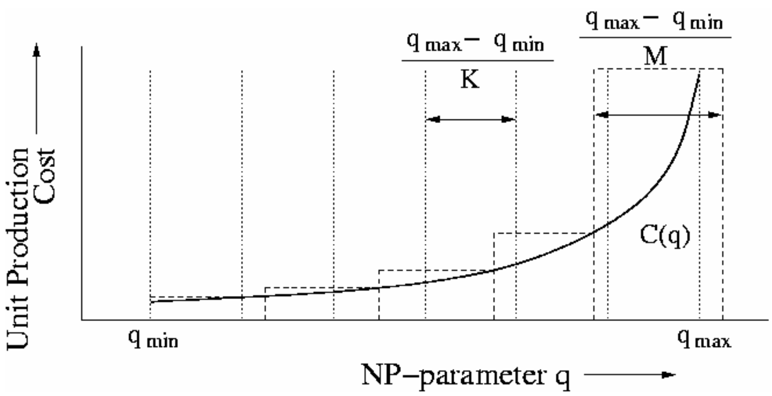

Figure 9: Service Demand Intervals in Service Performance Spectrum

For one particular service class m the guaranteed bound on the performance parameter q must be the upper bound of the pertaining class interval $q_{min} + (q_{max} - q_{min})(m/M)$. Therefore the effective price for each supported service class is constant over the service class interval of q:

$$C_{eff}(q) = C\left(q_{min} + \frac{m}{M}(q_{max} - q_{min})\right) \forall\ q \in q_{min} + \left[\frac{m-1}{M}(q_{max} - q_{min}), \frac{m}{M}(q_{max} - q_{min})\right] \quad (4.4)$$

17 N. Semret, et al. Pricing, provisioning and peering: Dynamic markets for differentiated Internet services and implications for network interconnections

18 S. Recker, *Cost model and optimal allocation of service curves in reservation based networks*, IASTED International Conference on Parallel and Distributed Computing and Networks, February 17th – 19th 2004, Innsbruck, Austria

Now consider a set of customers who have a known demand portfolio consisting of $K > M$ service classes within the valid spectrum of q. Associated with each of these service classes is a utility function $U(\cdot)$. If $U(\cdot)$ is a utility function, then a user prefers option a over option b, i.e. $a \succ b$ iff $U(a) \geq U(b)$. For services with guaranteed performance parameter thresholds the user's utility generally depends on the respective parameters, i.e. the utility is a function of q. It is a common understanding that for customers requesting deterministic bounds on performance parameters the individual utility function is *S-shaped*[19], i.e. below a certain threshold of q a normalized utility is close to zero, while above this threshold it is close to one without significant marginal changes. A set of such utility functions for the demanded services classes is illustrated in Figure 10.

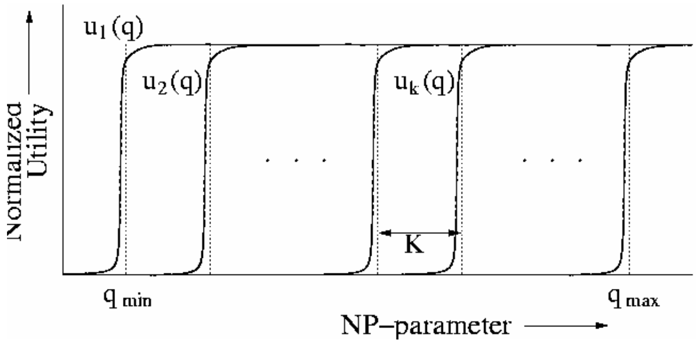

Figure 10: Performance Dependent Customer Utility Functions

From consumer theory we know that the consumer's problem is to maximize the *Customer Surplus* being the difference of normalized utility and price of a service, i.e. a customer with service demand class k always aims at obtaining a service quality

$$q_k = \arg\max_q \left[U_k(q) - C(q) \right] \tag{4.5}$$

Taking into account the shape of the utility function and the cost function $C_{eff}(q)$ being constant over one supported service class interval m the formulation of the customer's optimization problem when requesting service class k yields:

$$q_{k,opt} = q_{\min} + \left\lceil \frac{k}{K} M \right\rceil \frac{q_{\max} - q_{\min}}{M} \tag{4.6}$$

In an unconstrained market the supplier's problem is to maximize profit. The amount of available network resources shall always be sufficient to provide the requested services, i.e. we assume an infinite technology set. In order to compute the revenue of one provider we need to have a function indicating the price-demand elasticity, where we assume the categorized data transport services being independent commodities, i.e. the cross-elasticities $\varepsilon(i, j)$ are set to zero. A reasonable

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19 A. Bouch and M. A. Sasse, "Network quality of service: What do users need?" *Proceedings of the 4th International distributed conference (IDC'99)*, pp. 78–90, 1999

approach is to deploy a strictly decreasing, convex Marshallian demand function[20]. We want to deploy one demand function for all service classes, where we have to account for a price acceptance threshold increasing with the guaranteed QoS, i.e. for better data transport customers are willing to pay more. Therefore we normalize the service price for demand class k by the value of the cost function depicted in Figure 9 for the upper QoS demand $q_{\min} + (q_{\max} - q_{\min})(k/K)$.

By disregarding any basic service fees we set a service price equal to the effective cost of that service given by (4.4) at the performance parameter $q_{k,opt}$ determined from (4.6) and obtain the demand-QoS elasticity function:

$$X(k,M) = X\left(\frac{C\left(q_{\min} + \left\lceil \frac{k}{K} M \right\rceil \frac{q_{\max} - q_{\min}}{M}\right)}{C\left(q_{\min} + \frac{k}{K} \frac{q_{\max} - q_{\min}}{M}\right)}\right) \tag{4.7}$$

Here a price being equal to the production cost implies a maximum demand where the production cost with respect to $C(q)$ are minimal, i.e. maximum demand is achieved for $M = K$ with X_{opt}. In other words, matching customer demands more exactly can be expected to increase demand. Now from the discussion in section 3 we have learned about the difficulties implied by providing a large set of end-to-end user-centric QoS classes services of independent ISPs. These difficulties can be reflected in a strictly increasing, convex function of the cost for providing M service classes $\kappa(M)$. The convex shape can be justified by the fact that the cost over-proportionally increases with the number of offered service classes.

The trade-off of limited service class granularity and thus less revenue for less complex technical and administrative complexity identified in section 3 is manifested in the following provider's discrete optimization problem:

$$\max_M \left\lfloor \sum_{m=1}^{M} R(m) - \kappa(M) \right\rfloor \tag{4.8}$$

with $R(m)$ being the revenue achieved by service class m:

$$R(m) = C\left(q_{\min} + \frac{m}{M}(q_{\max} - q_{\min})\right) \sum_{i=i_{low}}^{i_{high}} X\left(\frac{C\left(q_{\min} + \left\lceil \frac{k}{K} M \right\rceil \frac{q_{\max} - q_{\min}}{M}\right)}{C\left(q_{\min} + \frac{i}{K} \frac{q_{\max} - q_{\min}}{M}\right)}\right) \tag{4.9}$$

with $i_{low} = \max\left[1, \left\lceil \frac{m-1}{M} K \right\rceil\right]$ and $i_{high} = \left\lfloor \frac{m}{M} K \right\rfloor$.

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[20] The Marshallian demand function $\mathrm{x(p, y)}$ is the optimal solution of the utility maximization problem subject to a budget constraint y.

The introduction of appropriate wholesale structures can facilitate the service diversity and class granularity required by users while improving the profit of the infrastructure owner. By sub-dividing the task of providing M service classes into multiple sub-tasks, i.e. N wholesalers each provide M_n service classes with $\sum_{n=1}^{N} M_n = M$, we can decrease the total cost of providing M classes due to the convex shape of $\kappa(M)$ provided that $\kappa(M)$ is the same for the ISP and all wholesalers. In order to achieve this sub-division incentives are needed for all affected parties, i.e. arbitrage opportunities to be exploited by a wholesaler need to be identified.
Let the production profit of the ISP given by (4.8). In case of N wholesalers, where each of these wholesalers is exclusively allocated to one interval of the spectrum of q, the ISP needs to support N service classes and each of the wholesalers $\lceil M/N \rceil$ classes. For any $N < M$ the ISP can increase the production profit by $\kappa(M) - \kappa(N)$, since still customers are provided with at least M service classes and the revenue determined from (4.9) does not change. The minimum unit price on the wholesale market to cover ISP cost is consequently reduced proportionally to the gain $\kappa(M) - \kappa(N)$, while the retail unit price remains on the level of service provision without wholesale. Anticipating equal distribution of the cost gain wholesalers can run their business if

$$\frac{\kappa(M) - \kappa(N)}{N} \geq \kappa\left(\left\lceil \frac{M}{N} \right\rceil\right) \tag{4.10}$$

holds.

In order to motivate incumbent network operators and new Internet business entities to consider their involvement in a multi-layered resource trading scenario two economic incentives have been identified, namely the arbitrage opportunities arising when separating the market for network resources by discriminating minimum batch sizes and the service granularity of the network transport services traded on each market. In both cases the equilibrium state after introducing at least one wholesale instance is Pareto-optimal in so far as neither the infrastructure provider nor the wholesaler or the consumers can improve their situation by following a different strategy, e.g. by not participating in the wholesale scenario.

With regard to the batch size market segmentation, we found that arbitrage opportunities to be exploited by wholesalers depend on the traffic characteristics. The maximum difference of wholesale and retail prices has been observed for frequent short duration services. But typical durations of application traffic requiring user-centric QoS, e.g. reliable virtual leased lines or highly sensitive interactive multi-media applications, are expected to be comparably long lasting. In this context we need to take the simplicity of the deployed model into account. The Poisson arrival and service model may not be accurate enough to represent typical applications. But already in our rather simple model we were able to identify incentives for ISPs and wholesalers to implement at least a 1-tier hierarchy.

Regarding the partitioning of service classes by wholesalers we have provided intuitive reasoning for the existence of economic incentives, which is based on accounting only for cost covering prices. But in fact a variety of aspects needs to be considered when unit prices for network resources are determined. However, our results outline a possible way to promote service diversification by splitting of network resources, which usually service providers try to prevent today by introducing specific tariffs with basic fees.

6. Conclusion

The development of novel broadband radio access networks such as WiFi or WiMax introduce heterogeneity in terms of technology and infrastructure ownership. As the user acceptance and utilisation of new broadband radio access networks rises with the deployment of those networks, the future market conditions in telecommunications will seriously change. We provided a sound discussion of a possible development of the mobile communications market and have shown that incumbents operators may lose market shares in all of their three market segments (infrastructure service, communication service, content provision).

Consequently, we have dealt with the question whether incumbent mobile radio network operators and new broadband radio access providers can mutually benefit from each other and what the obstacles on the path to a joint exploitation of the entire value chain are. We have investigated a resource trading concept based on an open wholesale market that facilitates the establishment of end-to-end services by independent and specialized service providers in an always best connected approach. The possibility of crafting short-term contracts on such wholesale markets either in a spontaneous fashion or for future points of time is the major attraction of this approach. By having reliable access to network resources on basis of such short-term contracts the problems of asymmetrical dependencies and of diminishing cooperation incentives can be resolved. The reason is that small scale broadband radio access providers or ISPs are recognised as an infrastructure component of the whole network to be traversed rather than as a rather small business or competitor with minor market power. By trading network resources on an open wholesale market the involved participants may complement each other: BRAPs offer sophisticated mobile access technologies, ISPs the access to the Internet (HTTP-services) and incumbent operators provide the customer base and respective network effects. Asymmetrical dependencies may not be completely be dissolved, but their impact on the business case of individual market participants can be expected to be minimised.

The prerequisite for the existence of wholesale markets has been investigated in terms of a formal analysis of the economic incentives to participate at wholesale network resource trading, where boundary conditions for reasonable operation of small and large scale fixed and wireless service providers in a multilayered structure have been identified. As exemplary incentives we have shown that arbitrage opportunities exist, which arise when separating the market for network resources by discriminating minimum batch sizes and the service granularity of the network transport services traded on each market. Although an economically reasonable exploitation of such arbitrage would require an in-depth analysis of business models, market conditions, etc. we have proved the theoretical existence of arbitrage opportunities between adjacent multi-layered wholesale markets and outlined a possible way to promote service diversification by splitting of network resource bundles.