ADVERSE SELECTION IN FOURTH GENERATION NETWORKS: QUALITY OF SERVICE FOR ENTERTAINMENT

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ABSTRACT

The mobile communications market is evolving rapidly. Existing communications markets, fixed and mobile, will be integrated in the Fourth Generation environment. This environment is expected to enable the provision of seamless network service that will permit the development of new value added services. Many new such services (e.g. entertainment) have specific network service quality requirements, which make the interconnection of the various access networks a critical factor. Internet experience shows that it is difficult to provide end-to-end service quality. An important reason is information asymmetry. This paper aims to address the problem of information asymmetry in the form of adverse selection and show that simple incentive mechanisms can improve market efficiency.

Keywords: Adverse Selection, Quality of Service, Fourth Generation Networks, Entertainment Services

1. INTRODUCTION

Fourth Generation (4G) technologies enable the provision of seamless service to the end-user through the interconnection of various access networks [14]. Competition on the provision of access service in the 4G market is expected to intensify and profit margins to shrink. Access service may become a commodity. Access providers will have to enter into new market segments in order to sustain profitability. Assuming that regulation policies will not be introduced, economic mechanisms to sustain market stability and improve efficiency are required.

According to the current market trends, access service providers introduce innovative value added services to differentiate their business scope from communication services. Assuming that powerful new end user devices (with adequate processing, communication and storage capacity) will allow full exploitation of 4G technological advances, we focus on network service quality, required from several applications and services, such as entertainment. In the network level, such services are considered "bursty flows" [5], as they have unpredictable traffic patterns, and thus require specific network service quality (i.e. performance guarantees on delay, packet loss rate, jitter etc.). The Internet experience showed that end-to-end service quality could not be provided easily, especially when more than two networks were needed to interoperate [9], which is the case in the 4G market.

This paper aims to address the problem of sustaining high quality services in 4G networks by the introduction of incentive mechanisms to the business interactions between key market players. Such economic mechanisms may alleviate uncertainty in network characteristics (e.g. traffic patterns) that affect service quality provision, by inducing the involved parties to reveal hidden information. This will enable stability and efficiency in the network service market, and allow full commercial exploitation of 4G technological advances.

Serving this objective the paper is structured as follows: Section 2 presents the motivation for research on network service quality provision by focusing on entertainment services, section 3 introduces key players in the 4G market and discusses their strategic objectives towards the provision of value-added services; section 4 presents and identifies adverse selection in the 4G network services market; section 5 sketches a simple analytical model and discusses the impact of incentive pricing schemes. Finally, in section 6 conclusions and further research issues are briefly presented.

2. SERVICE QUALITY IN 4G NETWORKS FOR ENTERTAINMENT

The market of 4G networks is expected to be an integrated environment for all the existing communication markets. In particular, the mobile communications, the Internet, the broadcasting and the traditional fixed-telephony markets will become parts of an integrated market that will provide seamless communication service to end-users. Existing access networks will be interconnected through the IP network, enabling any type of communication (fixed/wired, mobile, broadcasting).

Seamless service involves more than communication. It is the new means that enable value added services provision to end-users through any device, at any time, and in any place. However, value added services have various requirements from network performance. In particular, real time services cannot tolerate high delay rates, high packet loss rates or jitter. In addition their traffic pattern might be bursty. Such requirements generate a cost for the network service provider, especially during periods of high internal traffic as the available network resources are limited. If the network service provider is not compensated for the cost incurred, he has no incentive to provide service quality. In the Internet market, service providers usually offer "best effort" services. The customer's incoming traffic is treated according to the network conditions, without any priority. "Best effort" services may have detrimental effects on the value of a service with specific requirements, and may not be delivered to the end user as expected (e.g. bad quality of video transmission). In such a case end-users might not be willing to pay for the service. It is worth mentioning, that "sensitive" services need specific performance rates during packet transmission. The service provider needs to offer priority classes and continuously monitor the provision of specific performance guarantees.

We focus on entertainment service provision, as in many cases service quality is critical. Entertainment services use multimedia applications (i.e. audio and video). They have specific network service quality requirements especially in the case of real time video or high quality audio streaming. Entertainment services are segmented into two broad categories [1]:

- **Pure entertainment**, which mainly includes high bandwidth demanding services with specific network performance requirements, such as online games, gambling, short videos and movies.
- **Entertaining services**, which includes low bandwidth demanding services, such as ring tones, language courses, movie trailers, instant photo and photo exchange and information services.

Such services may become the driving force for commercial exploitation of the 4G networks market. Several market researches support that entertainment services will be the key revenue source for mobile operators and newcomers [7], [15]. Entertainment services will be critical in unlocking revenue opportunities in the business to consumer (B2C) market.

Turning to the mobile segment, despite the current technological constraints, mobile entertainment services are very promising due to various benefits that they can offer compared to Internet entertainment. Some of these benefits are ubiquity, accessibility, reachability, localization and personalization [1]. Mobile entertainment services in Europe are expected to generate 15.4 billion Euro by 2005 [7]. Games are expected to be the most important revenue source by contributing 8.08 billion in 2005 (over 50 percent of all entertainment services) [7].

Recent research work [1], also offers related arguments. In particular, the analysis of Japanese iMode showed that its success was mainly accredited to the emphasis on the entertainment services (compared to WAP, which targeted business use).

In addition, another recent international survey [13] highlights the potential of the upcoming mobile Multimedia Messaging Service (MMS). Multimedia messaging is another possible form of entertainment. The study revealed that over half of the current messaging population is interested in visual enhancements, such as the ability to send photographs, videos or music clips.

Currently, the entertainment services market segment is expanding. However, in the near future, the pure entertainment segment, which will generate high revenues, is expected to increase substantially.

3. THE 4G MARKET PLAYERS AND THEIR STRATEGIC OBJECTIVES

We identify the key players, coming from the existing markets, in order to describe their business interactions on the 4G market. Those are:

- **Mobile Operators** [4] are communications service providers that own wireless network infrastructure and have large customer bases of mobile subscribers. They created the critical mass of customers in the mobile market. Communication services remain their primary revenue source. They are currently developing wireless IP network infrastructures (e.g. GPRS, UMTS). However, they face the challenge of developing new strategies towards provision of value-added services, content and applications, in order to sustain their profit levels. Entertainment is a promising source in order to exploit the opportunities of IP networks.
- **Internet Service Providers** (ISPs) [4] are connectivity and sometimes information providers that have IP network infrastructure and Internet know-how. They have large customer bases of Internet users. They are currently managing their own IP networks, locally. They provide connectivity services and Internet access, through packet switched networks of limited capacity. Many ISPs also provide information services to both individuals and corporate customers. National markets have numerous ISPs that either provide competitive network services or focus on niche markets. In order to sustain profitability and increase revenues from their customers, new value added services should be offered. In addition, by providing connectivity services to mobile operators and other newcomers, extra revenue can be generated. With respect to entertainment they offer such services to end-users and actively exploit this business opportunity (e.g. AOL-Time Warner merger).
- **Internet Backbone Providers** [4] are also connectivity providers that own high-speed backbone networks, which will be integrated as the core network of the 4G market. Their role will be critical, as they will offer global network infrastructure, IP based, for seamless 4G services. They are currently managing their own networks, internationally in an oligopolistic market where entry costs are very high. They may increase revenue by entering to entertainment segment and provide high quality network services to business customers and newcomers.
- **Digital Broadcasters** [16] have broadcasting (or distribution) systems such as Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB), High Altitude Platforms (HAP) and satellite systems that have global coverage and support large cells, full mobility, as well as global access. Their technology can be used as a broadband downlink channel to provide fast transfer of entertainment content in combination with other access systems, which may be used as return channels for data requests and acknowledgement signalling in highly asymmetric services.

- **Incumbent Telecom Operators** [4] are the traditional telecommunication service providers that use their network to provide fixed telephony services. They have invested on physical network infrastructure including the last mile, which is also used for Internet service provision through modems, ISDN and now xDSL. As they have access infrastructure in place, they can easily enter in the market of entertainment services (i.e. collaborate with content providers).

In addition, several emerging players or newcomers that can make use of 4G technological advances may appear. Indicative examples are:

- **Private Companies** that have communication infrastructure and mainly provide information/content services in existing markets (i.e. banks, chain-shops). Such companies may lease or own communication infrastructure for specific business objectives. They may enter into the 4G market and integrate their communication infrastructure to the core network. However, if their business activity is not in the entertainment sector it is unlikely that they will enter this segment in the near future.
- **Wireless LAN Providers** are newcomers that have developed wireless LAN infrastructure. Their objective is to provide access and Internet connectivity to end-users in specific places "hotspots"(e.g. building, airport). Their network has small coverage. In the near future they are not expected to enter the market of value added services. However, they need service quality in order to serve their customers.

By focusing on the entertainment services' opportunities and presenting the key players as well as their strategic objectives, it is clear that service quality is a catalyst for the successful business exploitation of the 4G market's dynamics. In the remaining part we identify asymmetric information problems in the network services market and propose the introduction of incentive pricing schemes that will enable provision of service quality and improve market efficiency.

4. THE ADVERSE SELECTION PROBLEM IN THE 4G NETWORK SERVICES MARKET

4.1. The Adverse selection problem

Information asymmetry in network service quality provision may lead to inefficient outcomes. In particular, incomplete information on the characteristics of a network (i.e. available capacity, network management policy, type and number of users) may affect efficiency and stability of the market where such a network participates. These characteristics, are known to the network service provider before entering into an interconnectivity agreement with another provider, but will not be revealed. Yet, they may affect the network performance of the interconnected partner [3]. Such characteristics are not revealed because they concern core competences of the business involved. This situation involves ex-ante, or the so-called pre-contractual, information asymmetry, and is described as adverse selection in the context of economics of information [12].

There is no simple direct way to reveal the private information without providing monetary incentives. If there is a mutual benefit when the privately informed party reveals information, then incentives to convey in a credible way such information are needed. In many cases, the uninformed party attempts to infer the private information from observable actions. This leads to two classes of strategies [14]:

- *Signalling*, where the privately informed party takes the lead in adopting behaviour that if properly interpreted reveals information;
- *Screening*, where the uninformed party undertakes activities in order to separate the different types of informed parties along some dimension. This is often done by offering a variety of alternatives, each intended for one of the various types of informed parties, whose choice then effectively reveals their private information.

The formal analysis of adverse selection problems is based on the Principal-Agent model [14], where the principal has the bargaining power to offer a contract, a take-it-or-leave-it offer, and the agent if he accepts, will provide some effort/action, which has a cost, in order to achieve the expected outcome. For the agent to participate, the offer should be better than existing alternatives, the so-called participation constraint. For the principal to maximize his profits, the offer should induce the agent to provide expected effort, at the lowest possible cost, the so-called incentive compatibility constraint. There are several cases that can be modelled in this context; in this paper we sketch a static model.

The implications from information asymmetry in telecommunications market have been studied recently by Laffont and Tirole [11]. They analysed a different class of problems, regarding the information asymmetry that the regulator comes across when dealing with an incumbent telecommunications operator. Their results provide insight to our work, with respect to the applicability of incentive mechanisms in the telecommunications context. In particular, they examined adverse selection implications that the regulator may encounter when trying to introduce price caps to a telecommunication company that operates in a monopoly. Adverse selection appears as the company has hidden characteristics that affect its performance and cost of service delivery, which it is not willing to reveal. They emphasized the danger of providing wrong incentives and they stated that the optimal menu of contracts involved self-selection mechanisms.

4.2. Adverse Selection cases in the 4G network services market

We concentrate on the business relationships for interconnectivity service, which is essential for seamless network services provision in 4G. This market exhibits information asymmetry problems, which may have negative effects on the entertainment services provision in 4G networks by deteriorating service quality. In particular, we focus on the players that can offer IP network services and interconnectivity in the 4G market and discuss the impact of adverse selection on their profitability if they continue to use current types of interconnection agreements, namely peering and transit. Peering agreements involve the exchange of traffic and routing information between two networks at no interconnection charge. Peering partners only exchange traffic that originates from the customer of one partner and terminates to the customer of the other partner. The alternative to peering is transit agreement. There are two main differences between peering and transit. In transit agreements, one partner pays another partner for interconnection and therefore becomes its customer. The partner selling transit services will route traffic from the transit customer to its own peering partners as well as to its other customers, thus providing wider connectivity than in peering [2].

In the 4G network services market, there are two types of information components that may lead to adverse selection. Hidden information components that are in *direct control* of a network service provider and involve the roaming or interconnection agreements made, the available capacity of his network and the resource allocation policy used. Information components that are *not in direct control* of a network service provider are the types of his customers (i.e. heavy versus light users) and the traffic load. Hidden information may affect both the quality of the service delivered and the cost of providing it. Thus, there is a need to introduce incentive schemes that will reveal such information and fairly compensate the network service provider.

The players that can provide IP interconnectivity are ISPs and backbone providers. Because of their different network size, they might be approached by different customers in the 4G market. In the new seamless network environment, the various access providers will become customers of ISPs and backbone providers in order to get global connectivity through the IP networks.

ISPs may offer IP access and interconnectivity on local or national level. In 4G network service market their new customers might be mobile operators, WLAN providers and other private companies that provide communication services to end users. As discussed (section 2) the ISP network capacity is limited. In addition each ISP has its own customer base (individuals-business users) that utilize its network resources. The ISP objectives involve retaining its customers and expanding its business to the newcomers by exploiting emerging business opportunities. Assume that the ISP does not want to invest in increasing its network capacity because of high costs and uncertainty. New customers may have negative effect on the ISP business, if not charged according to the cost they generate. When resources are scarce and should be distributed among customers without knowing who is valuing them the most, inefficient allocation is possible [11]. Furthermore, there is high opportunity cost for the ISP. The ISP, due to incomplete information, may allocate his resources inefficiently and loose a high value customer over a low value one, thus loose profits. The existing ISP's customer base might have predictable traffic pattern. However, new customers may not have such pattern. For example, a WLAN provider might not know the actual number of users that are connected to its network. A mobile operator are not able to estimate subscribers' demand for IP network services.

There exist various ways that an ISP may apply in order to deal with adverse selection because of new customers' hidden characteristics. However, they are not flexible or efficient and they can generate negative effects. To one extreme, the ISP can allocate specific network capacity (i.e. 2Mbps) and avoid any risk of congestion in its network. Yet, such policy is not efficient [9]. End users' demand is very volatile and such policy may restrict the value adding business activities of a customer (e.g. mobile operator) when delivering services with specific requirements on network performance. The ISP might use current interconnection agreements, and treat newcomers as partners. Obviously, peering, the free exchange of traffic, would not serve in this case. Both mobile operators and WLAN providers have no parity to ISPs with respect to any measurable dimension (i.e. network infrastructure, capacity, coverage, customer base) and thus will not offer them any benefit. On the other hand a transit agreement based on a flat fee rate and specific network capacity would restrict market potential as already discussed. With respect to telecommunication interconnection agreements, the market shows that they do not work for IP networks for several reasons [10], [6], [8]. The most important reason is the high cost of measuring traffic (in contrast to circuit switched networks).

Backbone providers have large IP infrastructures and can provide connectivity and access services in a global scale. Their customer base includes mainly ISPs and large multinational companies. In 4G networks new customers could be mobile operators with trans-national coverage, broadcasters and incumbent telecom operators. Backbone providers have high capacity networks that can serve high traffic loads. However, the problem appears in their interconnection points, the main bottleneck in the current Internet market. Adverse selection due to unpredictable volume of traffic may lead to frequent congestion problems at these points that could deteriorate the seamless network. In addition, the opportunity cost is very high since backbones mainly serve ISPs, so congestion in a specific interconnection point will not only lower quality for individual customers connected, but also for customers served by the connected ISPs. In such a case secondary effects may be severe and can generate negative network externalities.

Existing policies to alleviate the problem of the customer's unknown traffic pattern involve traffic measurement and frequent upgrades of interconnection points' capacity, which may be costly. Limited capacity allocation will not generate profits and can be proved inefficient. In addition, interconnection agreements with broadcasters involve high traffic load that is unpredictable, as it derives from end-user demand and may intensify congestion problems.

Pricing policies with incentive mechanisms may facilitate the ISP's and the backbone provider's resource management without incurring extra cost. Such policies may alleviate the adverse selection problem and allow the ISP and backbone provider to generate profits. Incentive schemes will enable them to have better knowledge of the various types of their customers and allocate more efficiently their resources. In addition, customers will pay fairly the cost incurred in the network because of their traffic.

5. INCENTIVE SCHEMES IN A SIMPLE ADVERSE SELECTION MODEL

We sketch a simple model in order to show the implications from adverse selection in the 4G network services market. We use the Principal-Agent model. We show that simple screening contracts can improve market efficiency.

Consider an ISP with national coverage (the Principal) that provides interconnectivity to mobile operators. The ISP tries to determine the traffic level that mobile operators will submit. For simplicity assume that there are two types of operators: high traffic and low traffic. If the ISP could observe the type of mobile operator, then it could tailor the contract exactly to extract all the benefits from it. In practice however, the traffic profile of a mobile operator is private information. The contract agreed between them should take into account this information asymmetry: the ISP should set the terms of the contract to distinguish between high and low-traffic mobile operators. This sorting effect will allow the ISP to maximize its profits.

From the network perspective suppose that the benefit gained by the mobile operator is given by the function *u (x,h)*, where *x* is the average rate of packets submitted and *h* is the peak rate offered to the operator by the interconnectivity contract (*h > x)*. A standard assumption is that *u* is a continuously differentiable and increasing function. The two types of mobile operators are distinguished by their average packet rates: the high-traffic operator has an average rate x_H and the low-traffic operator an average rate $x_L < x_H$. Mobile operators can estimate their average rate, and control their peak rates but the ISP cannot. According to the single-crossing property assumption, which is required for the application of incentive schemes in case of adverse selection [14], the marginal value of the peak rate is greater for the high-traffic operator:

$$\frac{\vartheta u(x_H,h)}{\vartheta h} > \frac{\vartheta u(x_L,h)}{\vartheta h}$$

The cost structure of the ISP also depends on the values of peak rates chosen by the mobile operators. One possible cost measure is the effective bandwidth of an on-off fluid with average rate *x* and peak *h*. The formula of the effective bandwidth expresses the fact that allowing higher *h* results in more bursty traffic in the ISP [5]. Bursty traffic may be very costly for the ISP and in case of high internal traffic can lead to congestion and serious degradation of service quality.

Instead of working with the full detail of the benefit function, we use a simplified version. Let the benefit that a mobile operator *i* receives from submitting an amount of traffic *t* while paying a charge *T* be

$$\phi_i u(t) - T \tag{1}$$

u(t) is a continuously differentiable, increasing, strictly concave function.

There are two types of mobile operators: $i \in \{L,H\}$, with $\varphi_L < \varphi_H$. The mobile operator with parameter φ_L has a lower marginal benefit from submitting traffic, for all traffic levels and for a given charge. The L-type will be referred to as the "low-traffic customer", and the H-type as the "high-traffic customer". We assume there is a unit mass of mobile operators; of which a fraction μ are low traffic, the remaining $1-\mu$ are high traffic.

The ISP offers volume pricing schemes. In particular, two sets of prices (α_L,p_L) and (α_H,p_H) are offered, where α_i is an access charge and p_i is a charge per unit of traffic level t_i to be submitted. In this case, the profit of the ISP is

$$\mu(a_L + p_L t_L) + (1-\mu)(a_H + p_H t_H) - c(\mu t_L + (1-\mu) t_H) \tag{2}$$

where t_i is the traffic level chosen by the i-type mobile operator when paying the variable price p_i, $i \in \{L,H\}$.

The ISP is constrained when maximizing profit by mobile operators' behaviour. In particular, when choosing the terms of the interconnection contract, the ISP must take into account two facts: the mobile operators must wish to (i) participate in the agreement (the participation constraints); and (ii) choose the interconnection terms designed for them, not for the other type; (incentive compatibility constraints). These constraints can be written as:

$$\max_t \, [\phi_L u(t) - a_L - p_L t] \geq \underline{u}\,, \tag{3}$$

$$\max_t \, [\phi_H u(t) - a_H - p_H t] \geq \underline{u}\,, \tag{4}$$

$$\max_t [\phi_L u(t) - a_L - p_L t] \geq \max_t [\phi_L u(t) - a_H - p_H t]\,, \tag{5}$$

$$\max_t [\phi_H u(t) - a_H - p_H t] \geq \max_t [\phi_H u(t) - a_L - p_L t]\,, \tag{6}$$

In these equations, $\underline{u}$ is the 'reservation utility' of the mobile operator: the smallest amount of benefit from the interconnectivity contract that they are willing to accept. The reservation utility is treated as a parameter in this analysis, although there is dependence on the profit-maximizing solutions. In practice, $\underline{u}$ is determined by a variety of factors, including the outside options of the mobile operators. Thus, the better are the alternatives available to the mobile operators, the higher is the $\underline{u}$. We can interpret an increase in $\underline{u}$ as an increase in the market size.

At the profit-maximizing solution only two of the constraints will be binding [14]: the participation constraint of the low-traffic (more generally, low valuation) mobile operator, and the incentive compatibility constraint of the high-traffic operator. This means that the profit-maximization problem of the ISP can be simplified considerably. We derive the marginal benefit of each type of mobile operator from (1) and substitute t, respectively, in the binding constraints (3), (6) that give:

$$a_L = \phi_L u\left(u'^{-1}\left(\frac{p_L}{\phi_L}\right)\right) - p_L u'^{-1}\left(\frac{p_L}{\phi_L}\right) - \underline{u}\,, \tag{7}$$

$$a_H = \phi_H u\left(u'^{-1}\left(\frac{p_H}{\phi_H}\right)\right) - p_H u'^{-1}\left(\frac{p_H}{\phi_H}\right) - \phi_H u\left(u'^{-1}\left(\frac{p_L}{\phi_H}\right)\right)$$
$$+ \phi_H u\left(u'^{-1}\left(\frac{p_L}{\phi_L}\right)\right) + p_L\left(u'^{-1}\left(\frac{p_L}{\phi_H}\right) - u'^{-1}\left(\frac{p_L}{\phi_L}\right)\right) - \underline{u} \tag{8}$$

By incorporating (7) and (8) into (2) we get the ISP's profit-maximization problem. The ISP seeks p_H and p_L that will generate the maximum profit by sorting efficiently the two types of mobile operators. We avoid presenting the analytical description of the solution and we concentrate on the results.

To simplify the notation we define $u'^{-1}(\cdot) \equiv z(\cdot)$. According to the properties of $u(\cdot)$, $z(\cdot)$ is a strictly decreasing function. The ISP's profit function is concave in p_H and p_L so the first-order conditions are necessary and sufficient to determine the solution:

$$\left(1-\mu\right)\phi_{H}u'\left(z\left(\frac{p_{H}^{*}}{\phi_{H}}\right)\right)=c'\left(\mu z\left(\frac{p_{L}^{*}}{\phi_{L}}\right)+\left(1-\mu\right)z\left(\frac{p_{H}^{*}}{\phi_{H}}\right)\right) \tag{9}$$

$$\mu\phi_{L}u'\left(z\left(\frac{p_{L}^{*}}{\phi_{L}}\right)\right)-\left(1-\mu\right)\left[\phi_{H}u'\left(z\left(\frac{p_{L}^{*}}{\phi_{H}}\right)\right)+u'z\left(\frac{p_{L}^{*}}{\phi_{L}}\right)-p_{L}\left(z\left(\frac{p_{L}^{*}}{\phi_{H}}\right)-z\left(\frac{p_{L}^{*}}{\phi_{L}}\right)\right)\right]$$
$$=c'\left(\mu z\left(\frac{p_{L}^{*}}{\phi_{L}}\right)+\left(1-\mu\right)z\left(\frac{p_{H}^{*}}{\phi_{H}}\right)\right) \tag{10}$$

According to (9), the high-traffic mobile operator is offered (other things being equal) an efficient price per unit (i.e., that equates the marginal benefit to the marginal cost). According to (10) the low-traffic mobile operator is offered an inefficient price per unit (i.e. does not equate marginal benefit to marginal cost): the price per unit is distorted upward in order to ensure that the high-traffic operator chooses the pair (α_H, p_H), and not the pair intended for the low-traffic operator. This distorting term is zero if mobile operators are identical, so that $\varphi_L = \varphi_H$, or if there is only one type of network, so that $\mu = 1$. Having determined the profit-maximizing p_L^* and p_H^* ,it is straightforward to compute the profit-maximizing choices of α_L^* and α_H^* by equations (7) and (8). Note that the profit-maximizing traffic levels do not depend on the reservation utility level $\underline{u}$, but the access prices do in a very direct way: on a one-to-one basis, the higher is the $\underline{u}$, the lower are α_L^* and α_H^*. This shows clearly how the ISP's profit from interconnection is decreased when the outside option of its customers increases in value.

This model showed that the introduction of a simple incentive scheme might alleviate implications from the adverse selection problem for the ISP. Obviously, when dealing with adverse selection, the equilibrium achieved is not the first best (i.e. in full-information mobile operators will pay the exact price per unit that will make them willing to participate). There is always a cost for the uniformed ISP to reveal information. In this case the ISP loses profit because of information asymmetry: surplus must be yielded to the high-traffic customer in order to satisfy its incentive compatibility constraint. Without this 'informational rent', the high-traffic customer would choose the same interconnection terms as its low-traffic counterpart. The ISP would gain lower profit than if he were able to distinguish without using incentive schemes (i.e. full information available) the high-traffic customer and take advantage of its intrinsically higher valuation.

6. CONCLUSIONS AND FURTHER RESEARCH

In this paper we focused on the adverse selection problems and their implications on service quality provision in the 4G seamless networks. By presenting a static model of adverse selection, we showed that simple screening mechanisms can be applied and alleviate asymmetric information problems. However, adverse selection has a cost, as the most efficient solution cannot be achieved. Analysis of adverse selection in dynamic models will provide further insight on incentive schemes qualitative properties (i.e. form of contract).

Another class of asymmetric information cases deals with problems that may appear after an interconnection agreement is made and lead to opportunistic behaviour because of the unobservable action of the contracted network service provider and the uncertainty for network conditions (moral hazard). Furthermore, we explicitly avoided discussion on competition among the various access service providers that offer substitute network services, and may intensify asymmetric information problems. When networks are competing for access to end users, strategic behaviour may lead to free riding and opportunism and deteriorate market competition and decrease social efficiency. Obviously much more research work is needed before we end up designing incentive schemes for the 4G networks market.

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