Implications of 3G Licensing to Mobile Telecommunications Market Dynamics

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Abstract— **In this paper, the implications of 3G licensing to the telecommunication business roles involved in the 3G market chain are exposed. The traditional licensing models are described and compared, while the outcome of their adoption over the world is presented. An innovative licensing scheme is proposed, which aims to present the advantages of all existing methods used for the assignment of the 3G licences. This scheme claims to have the adaptability potential for any objective that the regulatory authorities may have. It is assessed via a simulation example based on the 3G licensing procedure of the United Kingdom, the candidates and results.**

Keywords- 3G licensing; Auctions; Beauty Contests; comparative and financial criteria; leverage factors.

I. INTRODUCTION

In the 1990s, mobile communications in Europe were a tremendous success story in terms of both technical and economic developments. Prices declined and penetration rates grew surprisingly. Additionally, the Internet traffic was booming and 3G Systems were seen as the bridge between the wireless world and Internet services, enabling seamless service provision to the users. Mobile Network Operators (*MNOs*) and Mobile Equipment Vendors (*MEVs*) lived at that time in prosperity conditions, while rather new business roles like the Application Service Providers (*ASPs*) and Content Providers (*CPs*) were evolving in order to address issues concerning the introduction of advanced mobile services and applications. Thus, a huge machine was operating at a full speed around the vision of 3G systems.

Spectrum is a scarce resource under the governance of the nations' authorities and its allocation is a very important element for the development as well as the enhancement of the competition in mobile Telecommunication Market Sector (TMS). Specification of the terms and conditions dominating the licensing procedure goes far beyond the spectrum allocation method adopted. The licensing framework and award schemes substantially varied across countries all over the world. Up to now two main licence awarding schemes have been adopted by the majority of the countries worldwide: Auctions and Beauty Contests (BCs). A number of authorities adopted BC schemes rather than auctions, as they believed BCs are the best way to develop the TMS and deliver better and lower priced services to the customer. On the other hand, countries that in general opted for competition stipulation and enhancement preferred auction mechanisms, due to their inherent transparency and fairness.

The outcome of the overall licensing mechanisms presented a high diversity degree worldwide, which can be attributed to the design of the licence awarding processes and the great variations in the conditions and expectations in the TMS. In any case, the 3G great market expectations and prosperity conditions TMS was experiencing at the end of 1999 lead to several unforeseen implications. Fig. 1 illustrates in a timely manner the conditions before and the impact after the 3G licensing processes had taken place. The implications of the selected 3G licensing schemes were significant all over the world, creating financial problems to several business roles of the 3G market chain, introducing also delays to the 3G network rollout.

The aim of this paper is twofold. First, the present as well as the future implications caused by the 3G licensing processes will be presented with respect to all entities involved in the TMS. Second, a novel licensing scheme will be introduced, which reflects the social, financial and market related policies of the authorities, while at the same time potential drawbacks and unpleasant consequences experienced after applying current licensing methods are avoided.

The rest of this paper is structured as follows: in Section II the Licensing Framework of the 3G Services is presented, based on three focal issues. In Section III the 3G licensing award policies are assessed with regards to their impact on TMS. In Section IV an enhanced licensing model demonstrating the advantages of the existent schemes is proposed and evaluated via a simulation experiment based on real data considering the UK auction. Finally, in Section VI conclusions are drawn and future plans are exposed.

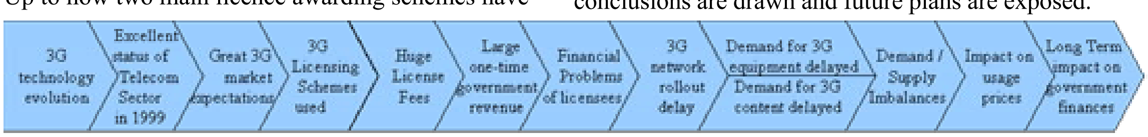


Figure 1. Conditions before and impact after the 3G licensing process

II. 3G Licensing Policies

In subsection II.A, the focal points of the licensing framework are briefly presented. In subsection II.B the two major licensing schemes for the spectrum allocation are briefly described, while in parallel their advantages and disadvantages are highlighted. Subsection II.C presents a brief comparison of the main 3G licensing policies.

A. Terms and Conditions

The following issues may be incorporated in the 3G licensing framework [1]. First, the number of licences to be awarded, the licence duration and reservation value as well as the licence fee payment modality should be considered. The aforementioned aspects are of outmost importance, since they influence the number of potential candidates, stimulating therefore competition among interested parties. For the determination of the parameters, the current TMS status should be taken into account in conjunction with a forecast of the future demand for 3G services, as well as technical issues, such as the size of each licence [2]. Second, special treatment for new entrants. Different techniques have been considered by the authorities in order to attract new entrants to the 3G market and thus enhance market competitiveness. Such include i.e. awarding more licences than current 2G incumbent operators, giving additional spectrum to new entrants, reserving explicitly a number of licences for new players in conjunction with relaxed obligations imposed and 2G-3G roaming conditions. Third, rights and obligations of the potential licensees. This issue may comprise coverage (geographical and/or population) obligations in conjunction with minimum QoS service requirements imposed to potential licensees, roaming rights and obligations, (i.e. 3G-3G and 3G-2G roaming), universal service, number portability, open network provision, MVNO/SPs access, network infrastructure sharing possibility ([3]). Finally, technology neutral licences awarding [4] and environmental issues may be included in the general principles of the licensing procedure.

B. Award Schemes

Two major licence award schemes may be adopted for the allocation of spectrum. The first scheme is the Beauty Contest. The second scheme is the auction method that has become quite popular lately, as means of scarce resource allocation and licensing around the world. Apart from these two dominant licence assignment policies, there is also a hybrid approach that combines features of the two, while rarely lottery schemes have been applied. In some cases the licences have been awarded directly, without any kind of contest. In the following subsections, the two basic methods are briefly described, while their advantages and disadvantages are highlighted.

1) Comparative Bidding (Beauty Contest)

In comparative bidding, also known as Beauty Contest (BC) ([5][6]) the authorities set a number of criteria, possibly with different weighting factors, denoting the relative importance of each criterion to the final result. These criteria may include general qualification information such as financial robustness, technical feasibility, telecommunications market expertise and experience, reliability, competitiveness, social behaviour, as well as more specific data (i.e. speed of the network roll out, geographic/population coverage, QoS, technology, pricing, customer care). The interested parties announce their strategic plans for the usage of the licence. These plans are evaluated on the basis of the aforementioned criteria and the candidate with the best offer is awarded the licence.

One of the main advantages of BCs is that they include a range of criteria that cover several objectives of the authorities. However, this is also one of their crucial failings. First, a wide range of criteria constitute BCs very complicated, time consuming and resource intensive processes from the perspectives of both the authorities and the applicants. Second, the licensee selection process is constituted quite impartial, subject to political strengths and the influence of pressure groups, especially when the when there is no transparency in how each factor is weighted in the final decision or how certain parameters are objectively measured. Additionally, the tendency of the authorities to favor incumbents, questions the credibility of BCs even more. Even when the BC is objective and fair, it may lack efficiency, in the sense that the ability of the regulator to successfully identify the best proposals is limited. Additionally, authorities are not efficiently qualified to determine the value of the licence, while potential candidates may present opportunistic behaviour [7].

2) Auctions

Auctions are quite popular means of allocating spectrum and telecommunications licences in an international level, thanks to their inherent fairness and transparency [8]. They are market-based mechanisms that work efficiently in a competitive setting. They employ a price criterion to allocate spectrum and are generally coupled with increased efficiency and revenue maximization. General pre-qualification criteria, comprising financial capability, technical feasibility, expertise and experience could be applied, in order to set out the basis on which companies can take part in the auction. Thus, it is ensured that only appropriate companies, which comply with specified threshold capabilities, bid for the licences. In this way, distortion possibility of the auction process due to financial risky bidders may be reduced.

Auctions aim to allocate the spectrum to the candidates with the highest valuation of it. The fact that resources are directed to those that value them the most, highlights the efficiency of auctions and makes bidders to generally welcome properly designed auctions. It also encourages services and technologies to be made available sooner as the spectrum is assigned at a cost that is based on the expected return for its use. Another important feature is that the auction scheme is simpler, thus avoids the delay associated with BCs. On the other hand, auctions have created many concerns due to the fact that prices could be raised greatly, as opposed to other allocation policies. This may lead to adverse impact on consumer prices, even though economists argue that the prices subscribers will be charged with will not change [9]. However, the huge upfront payments may affect and raise the risk of this network investment and erode the finances of operators, leading licensees to cash flow shortage, requiring them to assume debts, reducing their credit rating, causing delays in the original plans and in some cases even their bankruptcy.

In general, auction is considered to be an efficient method only when the number of licences to be given exceeds the number of the current incumbent 2G operators. Otherwise, there would be no interest on behalf of new potential players in the market, thus reduced competitiveness will be inevitable. Moreover, the potential licensees could either explicitly enter into agreements regarding their bid strategy during the auction or implicitly forecast the behaviour of the rest candidates with respect to their bidding strategies and thus lead to tacit collusive behaviour [10].

C. Comparison

In this subsection, a brief comparison of the main 3G licensing schemes (auction, beauty contest, lottery, no-contest) is given, as far as the licensing procedure and the potential results are concerned. Table 1 presents their pros and cons considering eleven main comparison criteria.

The degree of satisfaction of the selected criteria with respect to each licensing policy, is identified by the following four distinct levels: significant advantage denoted by ++, partial advantage denoted by +, partial disadvantage denoted by –, and finally, significant disadvantage denoted by --.

TABLE I. COMPARISON OF THE MAIN 3G LICENSING SCHEMES

	High efficiency of licensees	Licensees that valuate the licence higher	Transparency & fairness	Low administrative costs	Low licennsing procedure duration	High government revenues	Reasonable licence fee guarantee	High compentitiveness incentives	Low collusion possibilities	Low credit risk taken by government	Reasonable end-user 3G prices
Auction	–	++	++	+	++	++	– –	–	+	++	– –
BC	++	–	–	– –	– –	–	++	+	–	–	++
Lottery	– –	– –	++	++	++	– –	++	++	++	+	+
No-contest	+	–	– –	+	++	–	++	– –	–	++	+

III. ASSESSMENT OF THE 3G LICENSING POLICIES REGARDING THE TELECOMMUNICATION MARKET SECTOR

In the following subsections, the design issues and the current as well as the potential future implications of the 3G licensing award schemes will be elaborated in a more detailed manner.

A. Phase I: Facts and Design

Licensing conditions, terms and award schemes substantially differed across countries worldwide, due to the regulatory framework flexibility. Different requirements, obligations and terms influenced the potential licensees' business case, the competitiveness degree introduced and, thus, the outcome of the licensing procedure.

As depicted in Fig. 2, the two major licence award processes were adopted by approximately 83% of the countries, while the no contest technique was adopted by approximately 10% percentage of countries (e.g., Isle of Man). Additionally, 7% of the countries that had originally adopted BC or auction, issued the licences following a no contest technique (i.e., Singapore and Hong-Kong). Countries that in general opted for competition stipulation and enhancement preferred auction mechanisms (e.g., UK, Germany, Canada), as in auctions the candidates with the highest valuation of licences are in most cases the winners. In this respect, the financial power and potential strength of the candidates plays a substantial role in the final result. Countries that accounted more for the market sector development and prosperity adopted in most cases the beauty contest technique (i.e., France, Sweden, Japan, Korea). This method focuses on qualitative aspects of the development, such as coverage as well as to service provisioning quality and price issues.

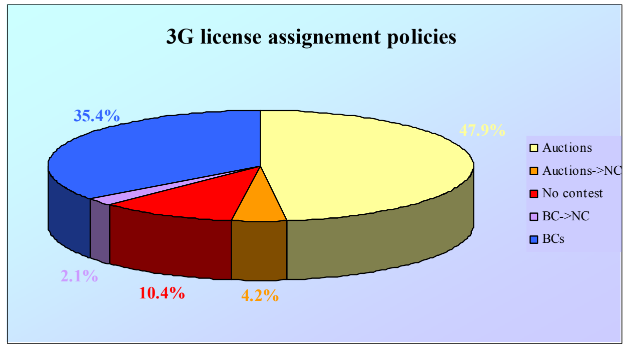


Figure 2. Percentage of each licensing method

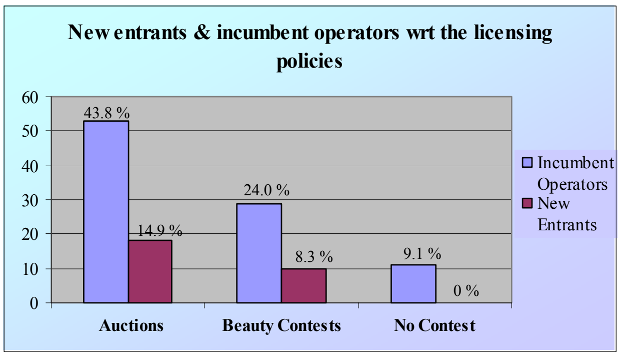
Regarding the number of licences, issuance of 4 to 6 licences per country seems to be the general case. For the determination of this parameter, technical considerations as well as enhancement of market competition has been taken into account. Concerning the licence duration 15-20 years have been considered adequate by most of the authorities. New entrants in most cases were only implicitly attracted (only UK reserved explicitly a licence for new entrants). In case of auction based allocation mechanisms, authorities imposed to the licensees a minimum degree of coverage obligations and quality characteristics for the 3G services, while more strict constraints were imposed in case BC technique has been adopted [4]. Additionally, in case of auctions, payment of the licences' fee were usually up-front so as to bind the licensees to their commitments, while in case of BCs a more conservative paying method was adopted (i.e., installments or royalties), in order to minimise the financial burden on the operators. Considering licensees' rights and obligations regarding network infrastructure sharing, MVNO access and open network provisioning, in most cases the authorities did not exclude those options, whilst they considered their emergence on a commercial and not on a mandatory basis. Some exceptions were observed. Specifically, Italy inhibited MVNO access, while Hong Kong mandated the open network provision.

B. Phase II : Impact on the TMS

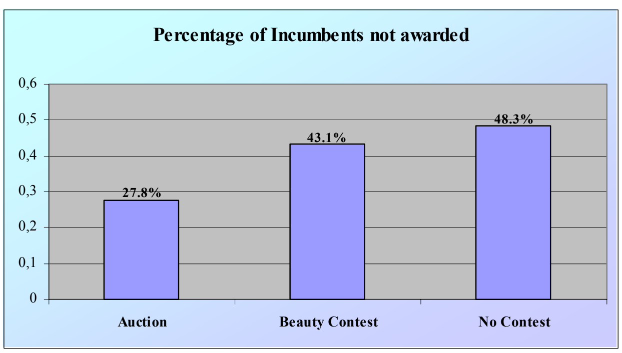
MNOs have already spent almost $107 billions for spectrum in the race to offer next-generation mobile services, hoping that 3G will be a revolution toward strong growth and market stability. This signifies the removal of substantial value from the mobile sector, both directly through high licence fees and indirectly through deflating stock prices and worsening debt ratings, to which 3G substantially contributed. The above chain has led to significant funding problems for several

MNOs, and in a number of cases it has already resulted in 3G network rollout delays.

The results of the 3G licensing procedures indicated that incumbents were generally not ready to share their market positions, mostly in the main European markets. The charts of Fig. 3 depict the number of incumbent operators and new entrants, as well as the percentage of incumbent MNOs that did not finally acquire a 3G licence, with regards to the licensing scheme adopted. Based on these diagrams, it is interesting to note that only 23% of the 3G licences that have been awarded up to January 2003, have been sold to non incumbent operators. As expected, the lower percentage (27.8%) of "blocked out" incumbents corresponds to the auction countries, as most of them have awarded at least that many licences as the national/local 2G MNOs.



(a)



(b)

Figure 3. (a) Percentage of licences awarded to incumbent operators and new entrants (b) percentage of incumbents not awarded with a 3G licence

An interesting issue is the level of the 3G licence prices. In case the licence fee is higher than its average valuation, dire consequences for the 3G seamless integration worldwide may emerge. In Fig. 4, the average cost per capita is illustrated, with regards to the awarding policy. It is quite interesting that licensees in auction countries have paid over eleven times more for the right to deploy 3G networks. Making spectrum available for industry as economically as possible is contradictory to the governments' target to maximize the incoming revenues. The allocation of 3G licences challenges governments to mediate between divergent public interest objectives: cashing in on their role as arbiters of radio spectrum, versus promoting competition. On the surface, the auction model seems to be a profitable way for governments to hand out temporary monopolies on radio frequency, leaving the market potential to determine the licence fee. But the disadvantage and the overall impact on the auction-awarded licensees and the 3G rollout plans are not counterbalanced by the revenues of state treasuries.

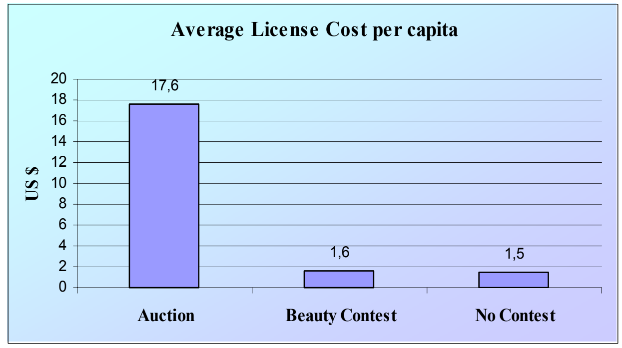


Figure 4. Average cost of 3G licence per capita per country

At this point it should be noted that a lot of divergence in the licence prices has incurred all over the world. After the early maxima in the 3G licence fees (case of UK and Germany), the licence costs dropped and eventually settled in relatively low levels. While to some this "course" may appear suspiciously similar to the volatility of recent TMS conditions, to others it is rationalised as deliberate and proportional to the target market opportunities of the respective nations [11]. Naturally, MNOs that did pay practically nothing for obtaining the 3G licence, are in a pretty enviable position and can defer capital that would otherwise end up in the government's treasury, and invest in equipment, network-building and fast service deployment. The wide divergence in the results of licence allocation methods becomes more and more prominent as time goes by. Up to now 6 licensees have withdrawn from the 3G mobile market and returned their licences. The impact of these diverging licensing methods on the 3G marketplace is still incomplete. However, from a geographical perspective, Europe is the continent that has the highest 3G market disadvantages, as the licensing schemes and expectations of operators lead to unreasonable prices. The Asian experience with spectrum allocation has been less problematic, as governments have learnt from Europe experiences and have been modest in their proposals for licence fees. In turn to the far less expensive 3G licences, operators have been cautious about network construction costs and time scales.

Regarding the up-to-now impact of 3G licensing on the business roles involved in the 3G market chain, we may say that the MNOs are the ones that have "suffered" the most, while the 3G users remain almost intact. The licensees that have paid high 3G licence fees, are currently in a difficult financial situation, as most of them are heavily indebted, while their hope to break even seems to fade away as network rollouts are delayed. Further more, 3G licensing substantially increased the 3G cost of supply compared to 2G, as the number of MNOs and corresponding networks was potentially increased by almost 30% [4], while most licensees committed to high network coverage ratios. Thus, in several countries, a substantial imbalance arose between the 3G cost of supply and the expected demand and potential revenues. This has led MNOs and governments to seriously consider industry consolidation solutions, mostly in Europe [3], where the worst funding problems exist.

In the 3G business chain the only parties involved that enjoyed some positive impact were the governments that managed to raise significant revenues by 3G spectrum auctions. But then, for those governments that held stakes in the incumbent MNOs (e.g., Germany, Netherlands, France, Greece), the one-time proceeds for the 3G licences are, at least partially, indirectly offset by the deterioration of the stock market position and the debt ratings of their respective incumbent MNOs. In other cases, governments were able to capture a lot of value through 3G licensing with no or a very limited stake in the incumbents (e.g., UK, Spain, Italy).

Finally, another business sector that has also suffered by the 3G licensing implications, is the one of 3G MEVs. MEVs invested large amounts in R&D to develop new 3G products and launch them as fast as possible, pushing for early adoption of standards. But because of the downturn in the telecom sector in the new millenium, MNOs reduced their level of equipment purchases in both fixed line and wireless networks [4]. Additionally, the 3G networks rollout delays, forces other players –apart from the MNOs– to share part of the rollout costs and even leads the MNOs to pull out from markets less attractive to them. To relax their short term financing problems, some operators have also entered into prefinancing agreements with MEVs, which has sometimes been a decisive selection criterion. These agreements risk to further increase the debt ratio of the vendors. As a consequence, many MEVs find themselves in a difficult financial situation, while they have already lowered their high 3G expectations due to delays and reduced orders.

C. Phase III: Potential Future Implications on the TMS

The future implications of the 3G licensing policies will go on affecting all the business roles involved in the 3G market chain. The 3G network rollout delays and the financial problems burdening mostly MNOs, will have a serious impact to governments, 3G MEVs, CPs and SPs, MVNOs and 3G customers. The MNOs are still expected to face the heaviest consequences of their 3G expensive bet.

Perhaps the most determinative potential future impact of the high licence fees will be introduced by the prices that 3G subscribers will have to pay. If present implications on the TMS, lead to more expensive 3G services, the rate and speed of diffusion of these services may be slowed down. In this case a chain reaction of further negative results will take place, affecting all the suppliers of complementary 3G products, such as equipment, content and applications. There may also be global distributional consequences. Companies mostly involved in BCs countries, may gain at the expense of those that are more dependent on the outcome of auctions, which have resulted in 90% higher licence fees. Despite these potential negative impacts, the possible positive effects of state expenditure of the revenues raised by the auction, should by no means be ignored. As for the answer on how the high licence fees will affect the end user service prices, there appears to be a fundamental disagreement between academic economists and MNOs.

Economists support that the price MNOs paid for 3G licences is a fixed (sunk) cost, which cannot be recouped from customers, as fixed amounts do not affect the position of the maximum profit point [12][13]. In this perspective, MNOs will have no option, but to ignore this licence fee cost in their decisions on providing and selling 3G services. On the other hand most MNOs disagree. They believe that extreme licence fees impose high barriers to licensees and will inevitably result to higher prices as the added cost will be passed on to the consumers [14]. Additionally, higher licence fees force MNOs (mostly the small ones) to borrow more. Greater borrowing increases gearing ratios, which in essence cause an increase of the "perceived risk" of lending. This leads to lower credit ratings that increases the coupon payments that MNOs have to make to investors holding bonds. Thus, their borrowings fall, while there may also be sale of other assets by MNOs in an attempt to improve their credit ratings. These sales, however, may negatively impact on the MNOs' returns from economies of scale and scope. The above chain, that has been verified up to now by the TMS events, introduces an increase in the marginal cost of the mobile services. This relocates the maximum profit point of each 3G MNO towards lower quantity and higher price levels [12]. Thus, the result will be higher prices for 3G services, while there is a proven increase in MNOs' bankruptcy risk, mostly in smaller companies.

Regarding 3G network roll-out, it should be noted that the average delays are more than three times higher for "BC 3G operators" than for "auction 3G operators" [1]. This delay phenomenon, where auction market companies perform better in terms of rollout, was more or less expected. The reason is that in addition to the pressures of competition, MNOs in these countries face extra pressure to repay their high borrowings with the revenues brought in from selling 3G services ([1][4][15][16]). One thing is certain: end-users will have to be more patient for the full range of new mobile data services and applications to enter the markets.

It is estimated that the 3G licensing policies will create significant transition problems in mobile markets, which have already made their appearance. The demand-supply imbalances that will evidently follow may require restructuring in the mobile operator market chain in several countries, a trend that can already be detected at present. It is expected that 3G will have a catalyzing effect on the industry consolidation and dynamics, leading several MNOs to further delay rollouts, reform their business structure or even withdraw from certain mobile markets. In order to take advantage of economies of scale, to attract new customers by offering seamless global roaming and to obtain superiority in technology and operational skills, MNOs are likely to resort to further consolidation. But as the managerial complexity will then increase greatly, the achievability of wide consolidation among operators is questionable, if every single step towards this direction is not combined with great attention and detailed planning.

MEVs and CPs will also have to deal with the adverse impact of 3G licensing, as 3G high licence fees extracted significant financial value from the industry, shifting money from content and application development to infrastructure investments. Thus, MEVs will inevitably experience a further delay and significant reduction in the demand for 3G equipment, as MNOs reduce their capital expenditures. As for the CPs and ASPs, 3G licensing is also estimated to bring some problems. These companies have already started serious restructuring and setting of new priorities, after the telecom and Internet "bubbles" burst in the dawn of the new millennium. As their current financial situation is quite dangerous, they are expected to follow the MNOs call for short-term profit generation via attractive content applications. The content demand will initially focus on applications for the current 2G/2.5G infrastructures of MNOs, as the latter will start launching mobile services via the available 2.5G technologies before 3G is deployed. It is only for data applications requiring higher bit rates, such as extensive e-mails, video conferencing and interactive gaming, that 3G bandwidth will be definitely necessary.

In any case, governments will have to face the consequences of the financial problems in the TMS chain. Specifically, they have to deal with their telecom shares value dropping, while the potential for fiscal income is reduced, due to the financial downturn of many telecom companies. On the other hand an increase in unemployment may follow as many people work in the IT and TMS, and several telecom operators have proceeded with contract terminations.

IV. Proposed Enhancements For 3G Licensing Methods

Judging by the previous assessment and market results, we come to the conclusion that several unpleasant results could have been avoided, if the licensing scheme had been designed more properly. In this section we aim to present a licensing mechanism, that combines the advantages of both main 3G licensing schemes, while it avoids most of their disadvantages. Our initial goal is to design a spectrum licences awarding model that demonstrates the following features: (i) high transparency and fairness by establishing concrete evaluation criteria and measurement techniques, (ii) efficiency so that the potential licensees are the most qualified candidates, as well as the ones that valuate the licence higher, (iii) it encourages and enhances competition in the market, allowing new players and minor operators to enter the scene, (iv) avoids unreasonable high prices, (v)it is not prone to legal challenge, (vi) it prevents abuse of market power, (vii)protects consumer rights by ensuring reasonable 3G service pricing as well as minimal roll out network delays, and (viii) it reduces possibility of collusion and opportunistic behaviour of the candidates. Some issues that mostly concern regulatory authorities, such as small process duration and low administrative costs, are considered to be second priority issues, as they are far counterbalanced by the achievement of the aforementioned objectives.

A. Mathematical Formulation

In order to design a licensing scheme that demonstrates all the aforementioned features, it is evident that both comparative criteria (like the ones used for BCs), as well as mere financial criteria have to be considered. The following analysis [1] will mostly address the case of 3G licensing needs. The comparative criteria $x_i \in X$, ($i = 1,2,...,n$) are selected by the regulatory authorities and reflect the governmental objectives in each case. The set X of these criteria may comprise the following general requirements:

$X = \{$ *geographic/population coverage, network rollout, network /infrastructure sharing, seamless international roaming, MVNOs access support, SPs access support, technical refarming, retail pricing commitments, relative expertise, range of future services, Quality of Service guarantees (i.e. transmission rate, delay, jitter, SNR, ...), universal service commitments, number portability, efficient use of spectrum, current penetration, financial robustness, soundness and feasibility of business plan* $\}$. However, not all these criteria are valuated the same by all governments. The relative significance of criterion x_i for a specific government will be indicated by its corresponding weight: w_i, ($0 \le w_i \le 1$). The financial criterion is the price of licence. The price that a candidate is willing to pay for the licence will be denoted as: p. The relative significance of the financial criterion will be denoted by weight: w_p, ($0 \le w_p \le 1$). The following equation stands in order to normalize the resulting values: $\sum_{i=1}^{n} w_i + w_p = 1$. It is noted that the cases of auctions or BCs are addressed if $w_i = 0, \ \forall i = 1,...,n$ or if $w_p = 0$, respectively. Each 3G licensee candidate j, ($j = 1,2,..., N$), commits to fulfil the comparative government criteria in a certain degree. The degree that candidate j addresses the comparative criterion i, will be denoted as: $x_{ij}, 0 \le x_{ij} \le 1$. This is the normalised value of x_{ij}^* (real value of the criterion), and is provided by the formula: $x_{ij} = x_{ij}^* / \max_j \{x_{ij}^*\}$. Thus, the case where $x_{ij} = 0$ expresses that candidate j fails to satisfy criterion x_i completely, while the case where $x_{ij} = 1$ implies that candidate j is the one that addresses criterion x_i the most, with regards to all other candidates. The normalised price (i.e. price expressed as a percentage of the highest bid) that candidate j is willing to pay for the 3G licence, will be denoted by p_j. If the actual bid price is denoted by p_j^*, then the following equation holds: $p_j = p_j^* / \max_j \{p_j^*\}$. Thus, it stands that: $0 \le p_j \le 1$. It is noted here that the values of the criteria x_{ij} for all licensee candidates are collected during the first phase of the proposed licensing scheme, where all candidates present their 3G business plans. The second phase of this scheme includes an auction-like procedure, where all licensee candidates announce their bids p_j.

We introduce the comparative criteria evaluation function z_{c_j} that expresses the evaluation of candidate's j offer, with regards to all the comparative criteria, as follows:

$$z_{c_j} = \sum_{i=1}^{n} w_i \cdot x_{ij} \tag{1}$$

Subsequently, we introduce the evaluation financial criterion function z_{p_j} that expresses the evaluation of candidate's j offer, as far as his bidding price is concerned, as follows:

$$z_{p_j} = w_p \cdot p_j \tag{2}$$

A fundamental parameter that also needs to be considered is the nature of the candidate companies. Many problems have been created as the strong companies and the incumbent operators have pushed aside the weak and new entrants that could not afford the high prices. As already stated, in order to reduce this phenomenon, in many cases the governments have offered one licence more than the number of incumbents, leaving place for one new entrant. But this was not proven to be the best solution [4]. In order to encourage a competitive telecom market in our licensing scheme, we classify the potential licensee companies into 4 categories: (i) the strong/big incumbent operators, (ii) the strong/big new entrants, (iii) the weak/small incumbent operators, and (iv) the weak/small new entrants, where strong and weak is determined by the annual turnover and profit that the MNO presents. We introduce another two parameters that depend on the category of the candidate: v_{c_j} ($0 \le v_{c_j} \le 1$), that indicates the "bonus" given to candidate j, as far as its comparative criteria evaluation is concerned, and v_{p_j} ($0 \le v_{p_j} \le 1$), that indicates the "bonus" given to candidate j, with regards to its financial criterion evaluation. These two parameters depend entirely on the category of the candidate. In case the government wishes to give small operators a chance to get a 3G licence, it may assign them $v_{p_j} = 0.30$ (i.e. 30% bonus on their bidding price), while in case it wishes to encourage new entrants, it may assign them $v_{c_j} = 0.10$ (i.e. 10% bonus on their comparative criteria evaluation function). It should be noted that since the governments should valuate higher the technical efficiency and the commitments of the candidates on the comparative criteria, than the raised by the spectrum licences vendue revenue for the state treasury, the maximum "price bonus" v_{c_j}, should be significantly lower than the maximum "comparative evaluation bonus" v_{p_j}. Thus, the following equation should hold:

$$\max_j\{v_{p_j}\} > \max_j\{v_{c_j}\} \tag{3}$$

At this point we may introduce the overall evaluation function z_j that expresses the evaluation of candidate's j offer. The following equations stand:

$$z_j = (1+v_{c_j}) \cdot z_{c_j} + (1+v_{p_j}) \cdot z_{p_j} \overset{(1),(2)}{\Rightarrow} \tag{4}$$

$$z_j = (1+v_{c_j}) \cdot \sum_{i=1}^{n} w_i \cdot x_{ij} + (1+v_{p_j}) \cdot w_p \cdot p_j \tag{5}$$

For notation simplicity, in this paper we restrict to a licensing awarding model in case of one licence – lot that is to be awarded in a single round (sealed-bid auction-like) process. Notation may be extended in order to address the multi licence multi round (English auction like) case [1]. The licensing scheme can be formally stated as follows:

Given: (i) the degree of compliance x_{ij}, of candidate's j offer with each comparative criterion $i = 1,2,...,n$, (ii) the normalised price p_j that candidate j is willing to pay, (iii) the weights w_i of the comparative criteria $i = 1,2,...,n$, (iv) the weight w_p of the financial criterion (bidding price), (v) the leverage factor v_{c_j} of candidate j, on his comparative evaluation, and (vi) the leverage factor v_{p_j} of candidate j, on his bidding price, then the company that is to be awarded with the licence is candidate m, if and only if:

$$z_m = \max_j\{z_j\} \overset{(4)}{\Rightarrow} z_m = \max_j\{(1+v_{c_j}) \cdot z_{c_j} + (1+v_{p_j}) \cdot z_{p_j}\} \overset{(5)}{\Rightarrow}$$

$$z_m = \max_j\{(1+v_{c_j}) \cdot \sum_{i=1}^{n} w_i \cdot x_{ij} + (1+v_{p_j}) \cdot w_p \cdot p_j\} \tag{6}$$

It should be noted here, that in order to preserve the licence scheme's transparency and fairness, all weights (w_i, w_p) for the specified criteria and the leverage factors (v_{c_j}, v_{p_j}) for each category of candidates, are announced before the candidates show their interest for the 3G licence, long enough for them to work on a sound, efficient and feasible business plan.

B. *Results*

In this subsection, we will present results indicative of the effectiveness of the proposed licensing scheme. The multi licence multi round licensing model was used in order to simulate the United Kingdom 3G spectrum auction [1]. The criteria used for the comparative evaluation function z_{c_j} are the following: (i) population coverage commitment in 5 years, (ii) speed of network rollout, (iii) network/ service quality provisioning, (iv) financial robustness, (v) network sharing/MVNO access provision commitment, (vi) technical expertise, and (vii) current penetration (subscribers on 31-3-2000). The financial criterion is the price that the candidate operator was willing to pay for any of the five 3G licences. The maximum 3G licence valuation for the eight candidates that were not awarded with any licence, is identical to their last offer in the UK 3G auction. As for the five licensees, it is assumed that the maximum price they would be willing to pay (i.e. the last bid after which they would withdraw from the auction) is $a\%$ above their maximum bids. The leverage factors $v_{c_{jl}}$, $v_{p_{jl}}$ of candidate j, on its comparative evaluation and bidding price for 3G licence l, are selected so as to promote new entrants to the 3 smaller licences (C, D, E), thus enhancing the competition in the TMS, while for one of the larger licences (B) all leverage factors are set to zero. The last licence (A) was reserved for the new players. It should be noted that the same leverage factors have been applied for all non incumbents.

The simulation performed produced quite interesting results [1]. These results may be summarized in the following points. First, the licence assignment is different from the one determined by the UK auction, depending on the leverage factors selected. The experiments performed have used v_c varying from 0% to 20% and v_p up to 60%. In most cases, at least one more new entrant is introduced in the UK TMS, increasing the competitiveness of this business sector of UK. It is observed that for any pairs of leverage factors, there are some low values of $a \leq 9\%$, where another new entrant (i.e. NTL Mobile), wins licence A over the new entrant that was actually awarded with A (i.e. TIW). This is due to the fact that NTL presents more than 3% higher comparative evaluation value, than TIW [1]. Additionally, for some pairs of leverage factors the 3G licence assignment involves two new entrants (awarded with licences A & C). It is observed that these pairs hold a linear dependency. Thus, there is a line above which NTL or TIW win 3G licence C over the weakest incumbent (i.e. Orange) for any $a \leq 30\%$ [1]. Second, in all cases, the sum of the final winning bids in our simulation is lower than the total licence fees -resulted from the 3G UK auction- up to 15%. Thus with the right selection of weights in the proposed model, the UK 3G auction would have resulted in increased competitiveness (two new entrants) and cheaper licences.

V. Conclusions

In this paper, the existing 3G licensing models were described and compared, while their implications on the business roles involved in the 3G TMS chain were exposed. Additionally, an enhanced licensing scheme was proposed that demonstrates the advantages of the traditional licensing mechanisms, while avoiding most of their disadvantages. Thus, it constitutes a valuable tool in the hands of the governments that wish to proceed to spectrum licensing.

This scheme is transparent for all candidates and it takes into consideration both comparative and financial criteria. It is extremely flexible, as via the values of the criteria weights and the leverage factors, the regulatory authorities may accomplish any of their objectives. The right selection of weights may (a) guarantee high efficiency of licensees, (b) favor the candidates that valuate the licence higher, (c) increase the government revenues or accelerate the network rollout, (d) introduce high competitiveness incentives, (e) reduce the collusion possibilities and the credit risks taken by the governments. The regulatory authorities must simply select the weights that reflect their social, financial and market policies.

The simulation experiment performed based on input data of the 3G licensing of the United Kingdom, verifies that the implications of the actual 3G auction, could have been avoided. Thus, the proposed scheme awards the licences to the candidates that are more efficient and present a higher licence valuation, with regards to their financial status, while being completely transparent and irreproachable. In the next stage of our study, we aim to proceed with the design of formulas that automatically estimate the values of the appropriate weights of the proposed model, based on the potential policies and objectives of the state authorities.

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