Authorisation Algorithm for Spectrum Use in the Context of the European Digital Single Market

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The proposal of the European Commission for a Regulation concerning the European single market for electronic communications contains ambitious pan-European targets. Among the most prominent are those set for wireless communications in terms efficiency, investments and innovation, while, at the same time, universal access, affordability and support to newcomers must be ensured. However, in their current form, auction and "beauty contest" procedures cannot fully contribute to meet the set objectives. A comparative SWOT analysis of both well-known authorisation algorithms is presented in this article.[1] *Based on this analysis, an optimized spectrum assignment algorithm is proposed, which brings together the strengths and opportunities and which eliminates threats and weaknesses of both popular algorithms.*

I. Introduction: Efficient use of spectrum for public benefit

A significant catalytic effect of wireless information services on growth can be observed in a number of spheres. Theoretical calculations[2] and practical analyses[3] show a positive contributory effect of mobile broadband data services on business processes and economic development, such as total factor productivity, GDP per capita, jobs, and innovations. A positive influence on the social sphere (e.g., education, health care, connection of rural and remote communities) has been documented to a lesser degree, but is not less important.[4] A strong correlation between mobile broadband take-up in the EU Member States (MS) and various Digital Agenda issues[5] have been observed,[6] especially taking into account the huge diversity between EU countries.

The increased usage of various services has resulted in a substantial growth of wireless traffic.[7] Projections show further rapid traffic growth at a compound annual growth rate (CAGR) of 60–70% in the mid-term future.[8] Therefore, the initiative of the European Commission (EC) on the European digital sin-

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1 I.e. the identifications of the Strengths, Weaknesses, Opportunities and Threats of the algorithms.

2 See, e.g.: H. Thompson and Ch. Garbacz, 'Economic impacts of mobile versus fixed broadband' (2011) 35 *Telecommunications Policy*, p. 999; I. Bertschek, D. Cerquera and G. Klein, 'More Bits – More Bucks? Measuring the Impact of Broadband Internet on Firm Performance' (2013) 25 *Information Economics and Policy,* p. 190; R. Crandall, W. Lehr and R. Litan, 'The Effects of Broadband Deployment on Output and Employment: a Cross-sectional Analysis of US Data' (2007). <www.brookings.edu/views/papers/crandall/200706litan.pdf > accessed 1 March 2014.

3 See, e.g.: 'What is the impact of mobile telephony on economic growth? (2012). <www.gsma.com/publicpolicy/wp-content/uploads/2012/11/gsma-deloitte-impact-mobile-telephony-economic-growth.pdf> accessed 1 March 2014; 'Wireless Broadband Infrastructure: A Catalyst for GDP and Job Growth 2013-2017' (2013). <www.pcia.com/images/IAE_Infrastructure_and_Economy2.PDF> accessed 1 March 2014.

4 N. Neuberger 'Advancing Healthcare Through Broadband: Opening Up a World of Possibilities', A White Paper for the Internet Innovation Alliance, 2007.

5 Digital Agenda for Europe Scoreboard 2013. <http://ec.europa.eu/digital-agenda/en/scoreboard> accessed 15 May 2014.

6 The correlation of mobile broadband take-up vs looking online for a job (sending job application) is 0,58, vs appointment with a doctor via a website – 0.65, vs interacting on-line with public authorities – 0.72; correlations of mobile take-up is much weaker – 0.37, 0,23 and 0.19 respectively.

7 Even terms like *explosion* or *tsunami* are used to characterize the process.

8 See, e.g.: S. Marcus and J. Burns, 'Study on impact of traffic offloading and related technological trends on the demand for wireless broadband spectrum'(2013). <http://bookshop.europa.eu/en/study-on-impact-of-traffic-off-loading-and-related-technological-trends-on-the-demand-for-wireless-broadband-spectrum-pbKK0113239/> accessed 1 March 2014.

gle market, which includes ambitious targets and objectives concerning wireless communications, is a very timely announcement.[9] As a consequence, there is a growing need for the electromagnetic spectrum that is used for data transmission. Because of the physical scarcity of spectrum, there is an increasing significance of its efficient exploitation.

The spectrum, as a fundamental electromagnetic phenomenon, is a national/public asset in a country. Therefore, national interests prevail in its management and governments' must "...promote efficient use and gain a net social benefit",[10] and ensure the highest return rate (facilitating of economic and social benefits) on that public asset, by means of rational spectrum management, including optimally allocated authorisations for private entities to use this public asset.

An intensive usage of the newly granted spectrum by the government can be achieved only if the authorized operators have the necessary high capacity and motivation for the wide and rapid deployment of a qualitative network, using advanced technologies and network topology principles. The selection of these operators has to be the primary objective of the spectrum assignment procedure, which, according to ITU and EU rules, is implemented by the National Regulatory Authorities (NRAs). There are several well-known spectrum assignment algorithms[11] to help with this task.

The *first come first serve* principle cannot ensure the attribution of a scarce resource such as spectrum to the most capable applicants because of the randomness of the procedure – an applicants' place in the queue would be the single determining factor. This principle is suitable only for the assignment of practically unlimited resources; in our case it relates to the *licence-exempt spectrum* bands. Actually, such a situation, where it exists, is without serious problems because frequency sharing provides for the possibility of simultaneous operation by several operators.

A comparison of applicants and competition among them is a tool to identify operators who would provide maximum public benefit by being entrusted with this scarce resource. There are two popular authorisation procedures that are based on fundamentally different algorithms – comparative bidding (one-stage contest of applicants, so-called *beauty contest*), and auctioning (multi-stage competition of cash bids).

Both procedures were equally used in the EU countries to assign the 3G spectrum in 1999-2002. Unfortunately, a wide and comprehensive analysis of practical deployment of networks and services, which are based on the granted spectrum, was not made; only a few authors have carried out some early comparative studies.[12]

Instead of carrying out a careful analysis, economists and game theory specialists have widely advocated auctions, – maybe because "... from an auction theory viewpoint, spectrum auctions are both challenging and interesting",[13] or because "... economists have no well-developed theory of beauty contests, but their critique of this method contains implicit predictions".[14] Currently, it is quite common to call comparative bidding "an administrative bureaucratic procedure", in contrast to auction as being perfectly compatible with liberalized market principles; thus the preference for auctions seems inevitable.

As a result, in practice, only auctions are used for the assignment of 4G bands – 800 MHz and 2.6 GHz. Discussions are going on only on the auction format and the corresponding bidder strategy.[15]

Currently, after more than ten years of operation, it is the right time to assess the residual impact of the allocation procedure (as the start activity) on 3G broadband mobile communications market, by comparing the market's progress (broadband coverage, take-up, usage) of a group of seven EU countries, which preferred beauty contests in 1999-2002,[16] and

9 Proposal for a Regulation of the European Parliament and of the Council Laying down Measures Concerning the European Single Market for Electronic Communications and to Achieve a Connected Continent, and amending Directives 2002/20/EC, 2002/21/EC and 2002/22/EC and Regulations (EC) No 1211/2009 and (EU) No 531/2012; COM(2013) 627 final.

10 M. Cave, C. Doyle and W. Webb, *Essentials of Modern Spectrum Management* (Cambridge University Press, 2012) p. 278.

11 See, e.g.: 'Going Mobile: Managing the Spectrum' in C Blackman and L. Srivastava (eds.) '*Telecommunications Regulation Handbook'* (The World Bank, 2011) p. 241.

12 See, e.g.: P. Klemperer, 'How (not) to Run Auctions: the European 3G Telecom Auctions' (2002) 46 *European Economic Review*, p. 829; T. Borgers and C. Dustmann, 'Awarding telecom licences: the recent European experience' (2003) 18 *Economic Policy*, p. 215; A. Monte 'European UMTS Licence Allocation: Why Economic Theory Has not Worked' in R. Arena, N. Salvadori and A. Graziani (eds.) '*Money, Credit and the Role of the State*' (Ashgate Pub Ltd, 2004) p. 391; H. Gruber, '3G mobile telecommunications licenses in Europe: A critical review' (2007) 9 *Info*, p. 35.

13 P. Cramton, 'Spectrum Auction Design' (2013) 9 *Review of Industrial Organization*, p. 161.

14 See n. 10, T. Borgers and C. Dustmann.

15 See n. 11.

16 Finland, Spain, Sweden, Portugal, France, Ireland, Luxembourg.

of a group of eight countries, which assigned 3G spectrum by auctions.[17] The comparison of groups of entities provides for a credible and objective evaluation, the role of individual disparities of each entity being minimized.

A full and profound analysis would be the subject of a special review, but a first comparative evaluation can be developed by using the values of five indicators and the corresponding rankings of Member States on a EU27 scale[18] (Croatia is not included in all data tables yet). On this basis, the average rank of countries of both groups on the each indicator is defined as:

$$R_{av} = \frac{\sum_{i=1}^{n} R_i}{\mathbf{n}}$$

where:
R_{av} – average rank;
R_i – rank on this indicator of country i among 27 EU countries;
n – number of countries in the corresponding group (n = 7 for the beauty contest case; n = 8 for the auction case).

The result is overwhelming. The average level of indicators in *beauty contest* countries is much higher in comparison with *auction* countries in all categories (Table 1). Indicators of Sweden and Finland (both countries applied beauty contest) show that these countries are mobile sector leaders in Europe, while three of the four less successful countries (Belgium, Germany, Italy) have used auctions.

In summary, current indicators of the national mobile broadband markets show real weaknesses of the auction procedure; this indicates that operators in *auctioned* countries are less successful, and the offered services are less attractive and less beneficial to society as a result. Without any doubt, the investment of huge auction payments in infrastructure, service quality and affordability of tariffs would help mobile operators to become more successful.

An astute explanation of the Swedish NRA (PTS) says nothing on the reasons of a drastic change of position for the 4G spectrum auction.[19]

The current economic crisis has highlighted many substantial market failures of the neo-liberal system; this is the right time to review the marked preferences for spectrum auctioning as well.[20]

II. EU spectrum policy

EU policy documents clearly show that the existing spectrum assignment practice is far from optimal.

As soon as 1994, it was stated in a COM Green Paper[21] that MS administrations increasingly require spectrum users to pay a price for the use of radio spectrum so as to reflect the market value and the actual need for those services to be provided. At the same time, concerns were voiced that a market-oriented approach alone may hamper technological innovation and competition, and may possibly lead to increased consumer prices.

Eight years later, the idea of harmonization of the radio spectrum management at the European Community level was put forward by a Radio Spectrum Decision.[22] Nevertheless, it stated that harmonized spectrum technical management does not include spectrum assignment procedures; this issue comes under the competence of the Member State. The only requirement asked of the Member State was to publish full information concerning the use of radio spectrum, except for confidential information.

To disseminate information regarding spectrum use in Europe, the European Commission suggested to make use of an EU-wide portal containing information on assigned spectrum rights (national registries), on the availability of tradable spectrum, as well as relevant national regulation and legislation.[23] It concluded that the issuing of technology and ser-

17 United Kingdom, the Netherlands, Italy, Belgium, Denmark, Germany, Austria, Greece.

18 See n. 3.

19 Open invitation to apply for licences for use of radio transmitters in the 2500–2690 MHz band (2008). <www.pts.se/upload/Ovrigt/Radio/2500_2690_Open_invitation_080117.pdf/> accessed 1 March 2014.

20 See, e.g.: 'Trade and Development Report 2012; Policies for Inclusive and Balanced Growth', Report by the Secretariat of the United Nations Conference on Trade and Development. http://unctad.org/en/PublicationsLibrary/tdr2012_en.pdf> accessed 1 March 2014.

21 Towards the Personal Communications Environment: Green Paper on a common approach in the field of mobile and personal Communications in the European Union; COM (94) 145.

22 Decision No 676/2002/ EC of the European Parliament and of the Council of 7 March 2002 on a regulatory framework for radio spectrum policy in the European Community, OJ 2002 L 108/1.

23 Communication from the Commission to the Council, the European Parliament and the European Economic and Social Committee and the Committee of the Regions 'A market-based approach to spectrum management in the European Union'; COM (2005) 400.

Table 1: Comparison of mobile broadband development in EU countries
Source: European Commission data

Indicator	Year	Average rank of		Sweden		Finland		EU27
		7 beauty contest countries	8 auction countries	Percentage	EU27 rank	Percentage	EU27 rank	Percentage
3G coverage (% of population)	2010	7.93	11.88	100%	1-4	100%	1-4	89.9%
HSPA coverage (% of households)	2012	10.29	13.5	99.7%	2	99.5%	5	96.3%
Mobile broadband take up, all active users (% of population)	Jan 2013	9.21	11.94	106%	2	107%	1	54%
Mobile broadband take-up, dongles (% of population)	Jan 2013	11.07	13.0	22.3%	2	70.9%	1	9.0%
Access to Internet through mobile phone via 3G (% of individuals 16-74)	2012	8.0	10.25	46.1%	1	39.2%	3	18.4%

vice neutral spectrum rights would ensure flexibility in the use of the spectrum, which is a pre-requisite for strengthening the wireless sector's capacity to boost Europe's economic growth and competitiveness.[24]

The first multiannual Radio Spectrum Policy Programme[25] is based on three pillars: the harmonisation of spectrum access conditions to enable interoperability and economies of scale, more efficient use of spectrum, and availability of actual information on spectrum use. The principal means to implement the Programme mentioned were promoting investments and competition as well fostering innovation, while at the same time protecting objectives of general interest.

Despite these policy making activities, only about two-thirds of the spectrum which is allocated for the wireless broadband, has been effectively assigned by the MS until November 2013,[26] which substantially hinders the roll-out of next generation wireless networks in Europe. It was concluded that many obstacles relate to the inconsistency among aspects of spectrum assignment:[27] such as prices paid for spectrum licenses, conditions (e.g., auction design), obligations (e.g., coverage), legal uncertainty concerning network sharing, spectrum sharing and spectrum trading and/or leasing. The only formal tool available to the EC to enforce frequency assignment process is through ex-post infringement action, which could add unpredictability for investors after the frequency assignment has taken place.

Therefore, the EC hopes to strengthen and harmonise the normative and regulatory environment for the authorisation system; it is an essential part of the European single market for the electronic communications initiative.[28] To achieve the desired long-term benefits for business, health, cultural, public administration and other economic and social sectors, several necessary action lines have been defined:

– to ensure the most efficient use of spectrum resources;
– to foster efficient long-term investments and innovation in the capacity and quality of networks and services;

24 Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions 'Rapid access to spectrum for wireless electronic communications services through more flexibility', COM (2007) 50.

25 Decision No 243/2012/EU of the European Parliament and of the Council of 14 March 2012 establishing a multiannual radio spectrum policy programme, OJ 2012 L 81/7.

26 Status of spectrum assignments in EU harmonised bands; Radio Spectrum Committee; Public Document RSCOM13-72.

27 Commission Staff Working Document: Impact assessment accompanying the document "Proposal for a Regulation of the European parliament and the Council laying down measures concerning the European single market for electronic communications and to achieve a Connected Continent, and amending Directives 2002/20/EC, 2002/21/EC and 2002/22/EC and Regulations (EC) No 1211/2009 and (EU) No 531/2012"; SWD (2013) 331.

28 See n. 7.

– to ensure wide territorial coverage and high level of penetration and consumption of services (i.e., affordability of prices);
– to promote the competition in new and enhanced networks and services;
– to achieve specific objectives of general interest determined at national level;
– to avoid the discrimination and ensure equality of opportunity between operators, including between existing and potential operators.

The type, procedures and conditions of the authorisation process remain under the competence of the MS; nevertheless it was suggested that the EC can provide comments, block acceptance of usage rights, or adopt binding decisions requiring withdrawal of any draft measure, similarly to the market notifications according to the well-known Articles 7 and 7a.

Such an approach creates a very contradictory situation. On the one hand, the Impact Assessment directly announces[29] that the "...suitability of auctions to efficiently assign spectrum to market players is not questioned". On the other hand, the same Impact Assessment does not hide the fundamental problems related to auction as the assignment procedure: "High spectrum prices have an effect on market outcome, either in the form of higher prices than would otherwise apply, and/or in lower investment capacity of operators in improved network capacity. Auction designs that aim at revenue extraction may conflict with the goal of maximizing social welfare and with EU rules on optimal use of spectrum resources". Let us also recall the statement by Neelie Kroes, Vice-President of the European Commission: "Some Member States [see] auctions as merely revenue-raising, rather than seeing the wider public interest for consumer prices and network investment".[30]

Because of traffic growth, many valuable spectrum usage authorisations will be held in the future (e.g., 700 MHz, 1.5 GHz and 3.8-4.2 GHz). To optimize them, it is necessary to analyse much more carefully the experience acquired in various spectrum assignments and to discuss some key issues:
– Could targets, which relate to the use of spectrum within the single market be achieved without an improvement of existing authorisation algorithms?
– What is the basic goal and respective tasks of the authorisation process?
– What kind of authorisation algorithm guarantees the most perfect achievement of the set goals?
– Is it possible to improve existing popular authorisation algorithms?
– If yes, what would be the optimized algorithm?

III. Achievable goal: benefit for society v business value for providers

The need for the intensive usage of a definite granted amount of a resource leads to the concept of spectrum efficiency, namely that efficient use of spectrum should always be declared as the primary spectrum authorisation criterion, in order to achieve the mentioned public benefits. This concept is based on present and future intensification of data transmission needs.

Technically, the term "efficiency" implies an amount of data that would be transmitted using an occupied frequency band during a definite time period. There are a number of theoretical research papers on spectrum efficiency.[31] ITU has substantiated a practical definition and a universal functional dependency of spectrum utilization efficiency:[32]

$$SUE = \frac{\mathbf{M}}{\mathbf{B} * \mathbf{S} * \mathbf{T}} = \frac{\mathbf{DR}}{\mathbf{B} * \mathbf{S}}$$

where
SUE – spectrum utilization efficiency;
M – useful effect obtained with the aid of the communication system; for technical evaluation – usually the amount of transmitted data (bits);
T – time (sec);
DR – data rate, amount of transmitted data per time unit (bits/sec);
B – frequency bandwidth (Hz);
S – covered area (km²).

In economical terms, efficiency implies the value of goods and services produced using the transmitted

29 See n. 25.

30 'Smashing barriers and thinking big', Speech Neelie Kroes, Vice-President of the European Commission in Mobile World Congress 2013/Barcelona. <http://europa.eu/rapid/press-release_SPEECH-13-159_en.htm> accessed 1 March 2014.

31 E.g.: W. Lee, 'Spectrum Efficiency in Cellular' (1989) 38 *IEEE Transactions on Vehicular Technology*, p. 69.

32 Definition of spectrum use and efficiency of a radio system (2006). Recommendation ITU-R SM.1046-2. <www.itu.int/dms_pubrec/itu-r/rec/sm/R-REC-SM.1046-2-200605-I!!PDF-E.pdf> accessed 1 March 2014.

information, including the valuation of public outputs provided by the government or other public authorities.[33] The economical aspect of spectrum efficiency is shown by the real functional usage of spectrum, where customers are the real beneficiaries. This aspect should not be included directly in efficiency assessment, because it depends on the needs and habits of customers. Indirectly, the covered area (i.e., accessibility) partly indicates the potential achievable benefits.

Previously published assessment criteria for comparative bidding are typically based on parameters of the SUE – coverage of area and/or population, roll-out speed, minimum guaranteed data rate, etc. By following these criteria, applicants are motivated to achieve the highest spectrum efficiency. Winners are determined by competition between efficiency-driven applications; thus the contest is primary directed to the active facilitation of benefits for society.

In the case of auctions, an algorithm is used that is based on several principles. It is based on the business value of the spectrum for a concrete applicant, which is expressed in terms of cash bids. Because the valuation is made by the applicant, its potential benefit becomes the real determining factor.[34] In addition to the real business value, the bidder would include in his valuation confounding factors which are also relevant for him, e.g. reputation, keeping the spectrum away from an existing or potential competitor,[35] or increasing stock value of the bidding company.[36]

The spectrum efficiency-driven algorithm is in effect replaced by the spectrum value for a bidder driven algorithm; the monetary factor becomes a sole and decisive driver. "... the difference between private and social incentives in the allocation process can be quite large".[37] Practice (Table 1) shows a real gap between the huge bids and the ensuing successful and efficient usage of the spectrum obtained.

The problem is exacerbated by seller's (the government) interest to receive the highest price for spectrum,[38] in order to generate maximum revenues for government budget, and thus obtain additional funding for financing public expenditures: "The economic analysis of spectrum policy focuses on government revenues in license assignments...".[39]

Yet, real revenues are relatively insignificant in the GDP context.[40] This kind of income is not sufficiently substantial for the financial policy and stability of any country (e.g., in comparison with the Maastricht stability criterion – budget deficit below 3% of GDP). The achievement of the above mentioned impact of advanced wireless services on economic and social welfare and development is much more significant.

At the same time, payments for 3G spectrum exceeded several times the investments required to construct networks.[41] These high expenditures could even be destructive for the operators and lead to a serious financial crisis – increase of debt, decrease of credit ratings, etc. For instance, after participation in 3G auctions, *BT* and *Sonera* were pressed to sell their most valuable assets; hereto, even huge capital injections of the Finnish State could not help *Sonera*. A number of operators asked to soften licence terms and/or to partly refund licence fees shortly after the auctions took place.[42] Although a premise is often voiced that spectrum efficiency, as a benefit for society, has equal value for the private bidding company and has become sort of an axiom, both algorithms are very different. Both objectives (spectrum efficiency and high revenues) "... are not always compatible – auction rules that focus on revenue extraction may conflict with the goal of maximizing social welfare".[43] If so, the natural question is – which is the primary goal? The answer is direct and logical: "The goal for

33 See n. 9.

34 C. Bazelon and G. McHenry, 'Spectrum Value' (2013) 37 *Telecommunications Po*licy, p. 737.

35 G. Ozanich, C. Hsu and H. Park, '3-G Wireless Auctions as an Economic Barrier to Entry: the Western European Experience' (2004) 21 *Telematics and Informatics*, p. 225.

36 P. Cramton, E. Kwerel, G. Rosston and A. Skrzypacz, 'Using Spectrum Auctions to Enhance; Competition in Wireless Services' (2011) 54 *Journal of Law and Economics*, p. 167.

37 S. Borenstein, 'On the Efficiency of Competitive Markets for Operating Licenses' (1988) 103 *The Quarterly Journal of Economics*, p. 357.

38 E.g., A. Prat and T. Valletti, 'Spectrum Auctions versus Beauty Contests: Costs and Benefits' (2000). <http://istituti.unicatt.it/economia_impresa_lavoro_OECD-draft.pdf> accessed 1 March 2014.

39 T. Hazlet and R. Munoz, 'A Welfare Analysis of Spectrum Allocation Policies' (2009) 40 *The RAND Journal of Economics*, p. 424.

40 Budget revenues from European 2.6 GHz auctions (2010-2011) are significantly less than 0.1% of GDP (e.g., Sweden – 0.074%, Denmark – 0.066%, while Finland – 0.0023%, NL – 0.0005% of GDP). Even abnormally large payments in 3G spectrum auctions in Germany and UK (2000) generated less than 2.5% of GDP.

41 W. Melody, 'Spectrum auctions and efficient resource allocation: learning from the 3G experience in Europe' (2001) 3 *Info*, p. 5.

42 See, e.g., 'Pass the Painkillers' (2001) 358/8220 *The Economist*.

43 J. Gómez-Barroso, A. Mochón, Y. Sáez and C. Feijóo, 'Simulating Digital Dividend Auctions: Service Neutrality Versus Dedicated Licences' (2012) 29 *Telematics and Informatics*, p. 11.

the government should be efficiency, not revenue maximization. The government should focus on ensuring that those, who can put the spectrum to its highest use, get it".[44]

The real situation is different: "Indicators of auction 'success' are typically some measure of participation (more is better), an absence of collusive bidding behaviour and that winning prices accurately reflect, more or less well, the 'true' value of the spectrum to winning bidders (that the auction is efficient)".[45] Nothing is mentioned about the spectrum efficiency achieved, namely on the expected public benefits from the leased public resource.

The Spectrum Efficiency Working Group of the Federal Communications Commission (FCC) is a developer and pioneer in the usage of auctions for spectrum assignment. Their attitude is that the goal of NRAs is to promote efficient spectrum access and use, and the ITU's Recommendation has to be used as the basis for this.[46]

Since the principle *most money for spectrum* is not directed to efficient use of the spectrum granted, it cannot ensure the attainment of maximum benefits for society. A step in the right direction might be the injection of an auction's revenues in predefined sectorial projects of public interest.[47]

It is true that the payment for a spectrum licence is in line with market economy principles; the presence of market elements, interest and motivation of private business in any commercial activity is understandable and necessary. In our case, cash bids not only cover some administrative expenditures; they are a strong additional indicator, which confirms the sincerity of a bidder's application and separates occasional applicants, who do not have a serious purpose in bidding, from serious ones. Cash bids play a significant disciplinary role, because future failures are connected with the threat of financial losses. Nevertheless, the replacement of spectrum efficiency by spectrum value as the goal of the tender is the principal weakness of auctions.

IV. Spectrum tendering – Competition issues

Competition is a magic word; promotion of competition is always used as an indisputable axiom of any liberal market activity and spectrum tenders are not an exception.

Two kinds of competition will be discussed here:
- competition among the applicants during the tender – competition for the market;
- competition among the operators exploiting previously granted spectrum blocks – competition in the market.

Competition among the operators is a most important feature. There are limits to competition in the wireless broadband business, since it is based on a scarce resource. Physical design of the network demands some minimal spectrum bandwidth – a threshold; if the spectrum band is more fragmented, or if the granted spectrum block is below this threshold, it is impossible to develop a qualitative network. Actually, the competition level is predetermined by frequency allocation (which determines the size of the frequency band) and by pre-approved *rules of game* for a concrete tender (size of frequency blocks and maximum for one applicant); the spectrum assignment algorithm does not have any impact here.

Competition among applicants during a beauty contest is characterized by a typical feature of such contests – a larger number of applicants means that there may be a chance to identify those that would provide a more perfect fit to the set goal. It means that increased competition during the comparative bidding process will result in more efficient spectrum usage.

A higher number of bidders increases the valuation threshold and thus the auction outcome. Due to high interest of bidders in Sweden and Belgium in the 2.6 GHz auctions, the revenues are above the trend line, while a lack of competition in Finland and the Netherlands resulted in payments that are below the trend line.[48] Fixed and equal spectrum efficien-

44 See n. 11.

45 'An Econometric Analysis of 3G Auction Spectrum Valuations' (2010). <http://fsr.eui.eu/Documents/WorkingPapers/Comsn-Media/2010/WP201055.pdf> accessed 1 March 2014.

46 Report of the Spectrum Efficiency Working Group (2002). <http://transition.fcc.gov/sptf/files/SEWGFinalReport_1.pdf> accessed 1 March 2014.

47 E.g., FCC is planning to spend part of auction 2014 revenues for development of the *FirstNet* – specialized network for public security goals. But this is only a unique case, not the system.

48 E. Karnitis, A. Virtmanis, G. Rutka and J. Jelinskis, 'LTE take-up in Baltic States and the European context: urban first' (2012) 14 *Network Industries Quarterly*. <http://mir.epfl.ch/page-92607-en.html> accessed 1 March 2014.

cy standards are pre-defined for all auction applicants. It means that increasing competition for the market will not influence the spectrum efficiency.

In addition, competition for the market is distorted. There is an asymmetry in any type of algorithm between an incumbent and an entrant. The incumbent has a brand, a formerly granted spectrum, an existing customer base, a developed network infrastructure; in case of loss there is a real risk to lose existing business. An incumbent's motivation to obtain a new spectrum block – and therefore his subjective valuation of that block – is much higher than an entrant's valuation. Even more, the necessary investments in new infrastructure are smaller (even by 30%) for an incumbent;[49] hence he can afford to invest more in auction cash bids (even including *overbidding*).

Moreover, an incumbent can potentially limit entry to others and hence competition, by purchasing additional spectrum blocks that would otherwise go to new entrants. Hoarding of spectrum during auctions is not only a theoretical opportunity.[50] In conclusion, an entrant is in a disadvantageous position for spectrum auctions; therefore incumbents are typically winners in such auctions'.[51]

There are many theoretical studies on more complicated auction models to foster entry of new participants.[52] Sometimes NRAs are trying to favour new entrants (monetary privileges, dedicated spectrum portions, etc.), but in practice (several FCC's auctions, Czech and Dutch 4G auctions, etc.) these activities have failed. The single real chance for an entrant is a deep shareholder's pocket (e.g., Norway 4G auction). The question remains, whether a shareholders' money means competence in the telecommunications business.

When a beauty contest procedure is used, licence fees are much smaller;[53] in addition, an entrant could partly compensate payments by innovative applications (entrants usually are more innovative).

An analysis[54] indicates that only 68% of 3G licences, auctioned in 1999–2003, in 9 European countries, remained in service in 2007, against 79% of the granted licences in 8 countries that preferred beauty contests. Moreover, the total number of auctioned 3G licences remaining in service is by 18% lower compared with 2G licences (decreasing competition!); while the same indicator has remained unchanged in countries that applied beauty contests.

The conclusion is that only by increasing competition in comparative bidding algorithms, some real positive impact on spectrum usage efficiency could be achieved.

V. SWOTs of tender algorithms

There are several substantial differences between both algorithms.

Reducing payments (including the use of illegal methods) is a natural desire of any applicant. The risk of collusion during an auction's multi-stage procedure is much higher than before applying for a beauty contest procedure.[55] Since the risk of corruption and/or favouritism among comparative bidding organizers is a real threat because of low transparency and subjective decision making, there is a fairly low trust in the beauty contest algorithm.

Huge cash bids[56] in auctions have to be recovered from the bidder's income. The economy theorists have developed a concept of cash bids as non-recoverable sunk costs that cannot be included in the tariffs, because of competition.[57] Practitioners think otherwise; for instance, the Czech NRA (CTU) stopped a 4G auction because "... high bids would lead to dramatic high price for the new telecommunications services and essential time delay in network development".[58]

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49 E. van Damme, 'The European UMTS Auctions' (2002) 46 *European Economic Review*, p. 846.

50 E.g., M. Cave, 'Anti-competitive Behaviour in Spectrum Markets: Analysis and Response' (2010) 34 *Telecommunications Policy*, p. 251; the Canadian Industry Minister announced his readiness to reclaim spectrum from authorized operators for disuse of the assigned spectrum (Nov. 2013).

51 E.g., an outcome of Italian 3G auction is defined as "… rather remarkable result that one of the existing GSM incumbent operators did not receive a licence" (see n. 36).

52 E.g., H. Āzacis and R. Burguet, 'Incumbency and Entry in Licence Auctions: the Anglo-Duch Auction Meets Another Simple Alternative' (2008) 26 *International Journal of Industrial Organization*, p. 730.

53 See n. 10 (H. Gruber).

54 Ibid.

55 See n. 36.

56 Payments for the 3G licences in the UK and Germany several times exceeded the necessary network investments (see n. 39); also in India's 2010 3G auction operators paid sum that is equivalent to two or more years of the investments made by all mobile operators.

57 E.g., M. Park, S. Lee and Y. Choi, 'Does spectrum auctioning harm consumers? Lessons from 3G licensing' (2011) 23 *Information Economics and Policy*, p. 118.

58 Český telekomunikační úřad rozhodl o zastavení aukce (2013). <http://www.ctu.cz/aktuality/tiskove-zpravy.html?action=detail&ArticleId=10139> accessed 1 March 2014.

Table 2: SWOT analysis of authorisation algorithms

	Beauty contest	Auction
Strengths	Spectrum efficiency driven algorithm; Adequacy to national interests;	Defined and quantified competition criterion; Well defined determination of the winner; Certainty, transparency, trust;
Opportunities	Contest of applications' efficiency; Spectrum efficiency driven assessment criteria; Support of efficient and innovative applications; Pre-contest requirements;	Compliance with market principles, competition of bidders; Adequacy to bidders' business interests; Pre-competition requirements; Defined term of bank transfers of cash bid;
Threats	Low interplay of assessment criteria; Favouritism, corruption; Non-compliance with the applicants' business interests; Weak control of the implementation of applications;	Hoarding of spectrum; Collusion among bidders; Single criterion – the cash bid; Increasing tariffs and slow investment process; Not guaranteed efficient spectrum usage;
Weaknesses	Softly defined, uncertain contest criteria; Subjective assessment; Low transparency;	Value for bidder driven algorithm; Competition among bidders raises prices; Generated revenues are not significant for the State budget;

The theory on the non-recoverability of sunk costs does not work in our case, because all operators have to pay for auction bids – their inclusion in the tariffs cannot influence competition among operators and the situation in the market.

There is a possibility of a different development of the market conditions after obtaining authorisation to spectrum usage in comparison with ex-ante expectations and following objective difficulties (even un-profitability) to act on the original promises. Sometimes, this presumption is mentioned as a disadvantage of the beauty contests. It would apply to the auction case as well – market-related problems are external factors that are independent of spectrum assignment algorithms.

The definition of an auction winner is based on precise figures; this is a principal advantage of any auction. In contrast, vague descriptive criteria and subsequent weak control of the implementation of applications is a real problem of comparative bidding. The quantification of quality criteria is an indispensable precondition for objective, transparent and trusty assignment algorithms.

The above described analysis clearly shows the main strengths and weaknesses of both algorithms (Table 2).

Organizers of tenders understand that both algorithms are one-sided. Therefore, a practice has developed to supplement tender criteria by some fixed predetermined requirements. A flat licence fee for beauty contest winners is set in many countries; yet the process is not always smooth as was exemplified by the 3G contests in France and Spain. To comply with the spectrum efficiency and public interest, non-tendering requirements (such as area or population coverage, roll-out dynamics, download speed, etc.) are introduced in auctions.[59]

In both cases these are minimum requirements that are not included in the set of assessment criteria; their better application cannot influence the value of an application/bid. Therefore, they cannot affect the tender and do not motivate applicants to increase the quality of the application.

VI. Optimized algorithm: A roadmap

The SWOT analysis shows a challenging way to improve the spectrum assignment algorithm by integrating strengths (opportunities) and eliminating weaknesses (threats) of both primary algorithms. The natural question is – is it possible? Definitely yes.

Development of an optimized algorithm is shown in Table 3. The authorisation procedure is divided into successive stages (column 2). Functionalities, which are the essence of each stage, as well as every

59 E.g., in all European 4G auctions (2011-2013) some version of coverage requirements were included, more than 60% of auction rules contained minimum download speed requirements.

Table 3: Development of the optimized tender algorithm

Stage		Beauty contest		Optimized algorithm		Auction	
				Goal, task	**Characteristic**		
1	2	3		4	5	6	
1.	Strategic concept	Spectrum efficiency driven algorithm	→	**Adequacy to national interests**	**Spectrum efficiency driven algorithm**		Value for bidder driven algorithm
2.1	Format of the tender procedure	Contest of applications' efficiency	→	**The highest achievable spectrum efficiency**	**Contest of combined applications**		Competition of cash bids
2.2				**Reflection of bidders' business interests**	**Consideration of bidder's spectrum valuation**	←	Business interests of bidders
2.3		One-step procedure	→	**Elimination of possible collusion among applicants**	**One-step procedure**		Multi-step procedure
3.1	Pre-tender requirements	Demands on technical, economic, financial, human capacity and competence	→	**High probability of the implementation of the application**	**Demands on technical, economical, financial, human capacity and competence**	←	Demands on technical, economical, financial, human capacity and competence
3.2		Mandatory minimum quality parameters	→	**Guaranty of the quality of the network and services**	**Mandatory minimum quality parameters**	←	Mandatory minimum quality parameters
4.1	Assessment criteria	Spectrum efficiency driven criteria	→	**Efficient use of spectrum**	**Unified set of criteria**	←	Cash bids
4.2		Uncertainty of criteria		**Certainty**	**Precisely defined and quantified contest criteria**	←	Defined and quantified competition criterion
4.3				**Reflection of bidder's spectrum valuation**	**Cash bid as criterion**	←	Adequacy to bidder's spectrum valuation
4.4		Efficient usage driven assessment	→	**Flexibility, support of innovative applicants**	**Qualified majority of assessment points is formed by spectrum driven criteria**		
4.5		Small licence payments	→	**Avoidance of increased tariffs and slowdown of investment process**	**Non-determining relative weighting of the cash bid**		Huge cash bids
5.1	Assessment stage	Low interplay of assessment criteria		**Transparency of the process and trust in the results**	**Mathematically strongly defined relative weightings of the criteria**	←	100% assessment on cash bids
5.2		Efficient usage driven criteria	→	**Unification of interests of society and applicants**	**Consolidation of criteria in cash-to-quality credit point system**	←	Cash bid as the single criterion
5.3		Subjective assessment		**Objective assessment, elimination of possible corruption and favouritism**	**Assessment formulas, mathematically strongly defined determination of winner**	←	Strongly defined determination of winner
6.1	Control of implementation	Softly described criteria		**Enforcement of the implementation of the application**	**Physical determination/measurability of all criteria**	←	Defined term of bank transfers
6.2		Punishment for the failure to comply with the application	→	**Punishment for the failure to comply with the application**	**Normative basis and NRA's capacity**	←	Punishment for the non-payment of the cash bid

step of a stage, for both primary procedures are shown (column 3 for beauty contest and column 6 for auction). To illustrate the creation of the combined algorithm, column 4 shows the goal/task for every step of the assignment procedure. Arrows show which is an appropriate approach for implementation of the corresponding step of the combined algorithm according to the SWOT analysis; the sequence of characteristic functionalities of the created algorithm is presented in column 5.

There is an analogous procedure that is far more mature and proven – the public procurement. The single real difference is in the government position in the procedure – a buyer in procurement, while a seller in spectrum tender.

Efficient and economical spending of public money is a duty of any government. On the other hand, it has been extensively examined and shown that the buy-low-bid rule results in low product quality.[60] US government integrated both concepts in an economically most advantageous tender procedure two decades ago. EU policy changed slower; **the** updated Public Procurement Directive[61] that was adopted by the EU parliament at first reading in January 2014 says: "...contracting authorities shall base the award of public contracts on the most economically advantageous tender"[62]; i.e. "... on the basis of the price or cost ... and may include the best price-quality ratio, which shall be assessed on the basis of criteria, including qualitative, environmental and/or social aspects".[63]

Spectrum efficiency has to be the basic goal of any tender. At the same time, a cash bid reflects the bidder's interest, his motivation to participate in the tender and to develop a spectrum enabled business; it is also a strong disciplinary pressure to implement applications. Therefore both efficiency driven criteria and the cash bid have to be included in the application for unified assessment.

Experience from public procurement leans towards a preference for the price-to-quality score against another option – or quality-to-price score in case efficiency (public benefits in our case) is a more important criterion in comparison with the cash bid. The assessment of applications can be made using the credit point system; the cash bid then also has to be transferred into credits.

The credit point system demands a strong definition of objective, measurable criteria. Because efficiency criteria are the basic ones, their summary has to form a qualified majority.[64] The payment, as criterion, should not become a determining one; therefore, its specific weight should be below 30%.

The assessment criteria and process are of critical importance. A strong, exact and measurable definition of each indicator is a necessary precondition for that indicator's inclusion in the set of assessment criteria. Detailed methodologies for the measurement of indicators as well as for assessment should be elaborated and publicly available. Such approach will ensure objective assessment and trust in the results, wins in subsequent court actions, and avoids accusations of corruption, favouritism and subjectivism. If any social activist can check all bids and their assessment, transparency is guaranteed.

In our case, the above mentioned SUE equation contains two drivers, which are determined by an applicant, as network developer:

- a territory S that is covered by the network;
- a guaranteed data rate that depends on technological parameters of the network.

It is useful to define them separately in rules of tender, because these are different factors on principle. Both of them are used for spectrum tenders already.

There are many different types of coverage definitions, the population coverage in many cases is a more important indicator than the area coverage, and the dynamics of roll-out are often also taken into account. Technically, coverage means existence of the electromagnetic field that meets the actual sensitivity of the equipment utilised.[65]

The relative coverage of area and/or population is used as one of the basic assessment criterion for beau-

60 M. Bergman and S. Lundberg, 'Tender Evaluation and Supplier Selection Methods in Public Procurement' (2013) 19 *Journal of Purchasing & Supply Management*, p. 73.

61 Position of the European Parliament adopted at first reading on 15 January 2014 with a view to the adoption of Directive 2014/.../EU of the European Parliament and of the Council on public procurement and repealing Directive 2004/18/EC; P7_TC1-COD(2011)0438.

62 Directive 14/24/EU on public procurement and repealing Directive 2004/18/EC, OJ 2014 L 94/65, Art. 67(1).

63 Directive 14/24/EU, Art. 67(1).

64 According to EU principles it would be 70–75% of total available credit point count.

65 Demands of PTS for 3G tendering "field strength, measured on the pilot signal from the base station, outdoors at a height of 1.7 m, is equal to or exceeds 58dB V/m/5MHz" is an example of exact definition what coverage means; see: P. Andersson, S. Hulten and P. Valiente, 'Beauty Contest Licensing Lessons from the 3G Process in Sweden' (2005) 29 *Telecommunications Policy*, p. 577.

ty contests; it encourages applicants to deploy the network more rapidly and completely. A minimum coverage is frequently included in pre-competition requirements for auctions. Nevertheless, in that case, it does not motivate bidders to achieve a higher percentage of coverage; remote and sparsely populated rural regions and areas with a lower purchasing capacity definitely will not be profitable.

There is a complex dependency of data rate on technologies and network topology. Considering that:
- a high data rate of the channel is in the interest of any customer;
- the maximisation of the customer base is one of the fundamental targets of any operator, a small number of customers means low turnover and unprofitability;
- the data rate of a customer's channel is measurable correctly, as opposed to data rate in the whole spectrum block;

there is already an established practice to use the data rate of customers' channels as the efficiency indicator. Parameters that describe the quality of data flow have to be pre-defined, e.g., download/upload ratio, packet losses, latency, and jitter.

If the tender is technologically neutral, this indicator is widely affected by the preferred standards (e.g., LTE theoretically ensure up to seven times higher data rates in comparison with HSPA), the technology used (e.g., channel coding methods), the network topology (e.g., structure of cells), etc. There is a lot of room for advanced technologies and technological innovation to increase the spectrum efficiency.

Today's problem is in a lack of methodology of measurements, especially relating to the data rate. Not one of the organizers of 4G auctions has determined the measurement methodology to use, so these requirements become senseless. These are challenging the activities of the Electronic Communications Committee related to further improvement of the common coverage criteria and the coverage measurements.[66] This work could be extended to data rate measurement as well.

The assessment of tender applications has to be based on clearly defined and transparent mathematical formulas to exclude any subjectivism. Of course, a complete assessment algorithm has to be published before the tender.

And last but not least, explicit penalties for default of applications and/or tender requirements have to be defined including the cancellation of the rights to use the spectrum band without any compensation for expenditures. The capacity of the NRA to monitor constantly and to enforce the implementation of all parameters is of critical importance.

VII. Conclusions

Prognoses on the very dynamic growth of demand for information services have been followed by a political/normative initiative – the European single digital market concept. In practice, many activities will be necessary to implement the proposed concept in all EU Member States so as to achieve benefits for society. Meeting the demand for wireless broadband services is one of the key issues of the concept, while the efficient usage of allocated spectrum resource is an indispensable precondition to achieve it.

The SWOT analyses we have performed show that the actual authorisation algorithms for spectrum usage do not motivate winners to achieve maximum efficiency. The beauty contest algorithm, due to soft and vague requirements, remains unreliable and non-transparent, it allows for a non-binding attitude to the obligations subscribed. Various versions of the auction algorithm are directed to high profitability for the bidding companies; the algorithm does not motivate them to maximize the efficiency of spectrum usage.

The proposed optimisation of authorisation is based on the integration of strengths and opportunities of both actual algorithms in one unified algorithm, while weaknesses and threats are eliminated.

The algorithm is spectrum efficiency-driven, while the spectrum valuation of applicants is considered. A unified set of precisely defined and quantified criteria has to be formed; it contains both the efficiency criteria as well the amount of cash bid, as criteria. All criteria are consolidated in a cash-to-quality credit point system, the efficiency criteria forming a qualified majority of assessment points. Mathematically strongly defined assessment formulas for the determination of a winner as well physical definition/measurability of all criteria, will ensure the trust in the algorithm and guarantee of implementation.

66 UMTS Coverage Measurements (2007). <www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP103.PDF> accessed 1 March 2014.

The currently remaining problem is unified methodologies for the measurement of efficiency criteria (actually, coverage and data rate are the most habitual indicators). Challenging the activities of experts, including those of Electronic Communications Committee, would close this gap.