

# European Challenges towards Forming and Promoting an Innovative Radio-Spectrum Policy in a Fully Converged Electronic Communications Market

**The rapid development of technology and the convergence of telecommunications, information technology and media content delivery, create an active environment where spectrum is becoming an ever more important resource.**

**The European Union has recently adopted a new strategic approach towards promoting an optimal use of radio spectrum in liberalised and competitive European markets; this can be realised via reducing access barriers to frequencies, and by allowing convergence to become a reality by removing existing artificial restrictions.**

## The European Dimension of the Spectrum Market – an Introduction

The information technologies, communication and media industries sector is currently on the verge of a distinct phase of growth, based on the widespread convergence of high-speed broadband networks, audiovisual media and enhanced end-user devices. Novel information and communications technologies (ICT) are becoming vital for the health of the wider European economy<sup>1</sup>. The adoption of new services and products increases productivity, generates new consumer services, advances market competition, and generates employment opportunities. Communications networks and services form a large component of the ICT landscape, thus creating the elementary environment for a flourishing e-communications sector<sup>2</sup>. Their role is essential in improving the quality of life for all citizens (in areas such as public services, enterprises and households) and for overcoming social exclusion and isolation.

Wireless communications is one of Europe's strongest technology sectors that further emphasises Europe's interest in communications, transportation, security and environmental protection<sup>3</sup>. Although many of today's cutting-edge wireless technologies promise new possibilities for evolution, the entire industry relies mainly on the proper and effective use of the underlying radio spectrum – a 'raw material' in short supply. The background for radio spectrum policy is changing rapidly, as a result of fundamental technological, market and regulatory developments. A number of innovative (broadband) technologies and applications contributing to the 'Lisbon goals', are actually based on the efficient use of the radio spectrum. Consequently, it is a concept of considerable economic importance both in terms of market value as well as in creating employment opportunities. Since many of these areas are covered by current policies, the European Union (EU) has demonstrated at a very early stage<sup>4</sup> – and continues now to exhibit – a substantial interest in and continued support for the development of a consistent radio spectrum policy.

The globalisation of services and of market players (through mergers, alliances or world-wide business deployment) has introduced a new dimension to the radio spectrum policy that addresses the specific concerns and needs of consumers and businesses. New commercial networks based on radio technology have been rapidly introduced and yet are still in the market scene with very promising options, for the benefit of the economy. They can very effectively combine telephony, data transmission, Internet applications and localised functions, to provide new value-added services; they also have the potential to stimulate economic growth, create employment and promote general welfare. The environment for governing policies has

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been modified considerably, to take into account all varying interests and/or requirements. As radio services and equipment are being developed for global rather than national markets, radio spectrum availability is therefore considered a key issue in trade negotiations. Furthermore, international co-operation on radio spectrum is critical in order to facilitate the introduction and provision of new services and the adoption/use of the latest equipment. A number of significant sector-specific European policies depend on radio spectrum being made available and safeguarded adequately<sup>5</sup>.

Measures that govern radio spectrum access, and its proper use, must meet the terms of a certain number of clearly defined 'horizontal' policies at EU level, particularly those supporting the advance of the internal market, providing guarantees for competition, developing social standards, and preserving public interest(s). Many of the latest national (and international) policies and applied measures in the radio sectors are directly aimed at the establishment and effective functioning of a single European market.

Radio spectrum is a 'key resource' for a number of essential services in society, e.g. mobile, wireless and satellite communications, TV and radio broadcasting, transport, radio location (global positioning system (GPS)/Galileo<sup>6</sup>), scientific applications (meteorology and weather satellites, earth observation, telemetry, radio astronomy and space research), and various other applications, such as alarms, remote controls, medical equipment, e.g. implants and hearing aids. Radio technologies also support and sustain 'public services' of prime importance – defence, security, (road, air and maritime) safety, emergency, law enforcement, and scientific-oriented activities. As a result, an efficient and coherent use of spectrum in all these sectors can, by stimulating growth and competitiveness, contribute towards realising priorities and establishing commonly acceptable policies, that lead to

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building a 'fully inclusive' information society, based on the extensive use of ICT. In view of the requirement of the information society for instantaneous access to, and dissemination of, information, irrespective of time and/or location, radio spectrum is a factor of unlimited importance for the further advance of the European economy.

## Evaluation of the Current State – Economic Impact – Radio Spectrum Access, Use and Management

Current technological progress, recent market trends and the development of policy/regulatory approaches – all interrelated – have a significant influence on the perceived availability of radio spectrum. Radio spectrum is a source of considerable significance and importance. A variety of applications – commercial, public safety, national security, cultural, social and scientific – depend on proper and effective access to frequency bands. The development of wireless communications technologies has been a major innovation of the last century. It has enabled new and effective forms of voice and data communication, between both people and machines<sup>7</sup>. An indisputable example of the great importance of spectrum policy decision-making is its obvious impact on European development in the mobile communications sector. The direct economic contribution of industries using the radio spectrum is already estimated to be between 1–2% of national gross domestic product (GDP) in the EU<sup>†</sup>, and could greatly be increased if national regulators and all market stakeholders can identify common approaches at EU level. The final goal is to create a single market for equipment and services, using radio spectrum. Despite its economic and social importance, spectrum has often been overlooked in the past by policy-makers, since it involves many sectors and there are undisputed technical concerns. Allowing markets to decide the utilisation and distribution of spectrum for converged communications services can be expected to substantially improve its efficiency, as the latter constitutes a key policy objective in the broader sector of electronic communications<sup>8</sup>.

Harmonisation of spectrum usage at EU level has been effectively implemented in some spectrum bands to ensure rapid implementation of certain modern

technologies and to obtain the benefits of economies of scale<sup>9</sup>. Access to radio frequencies is regulated among the 25 EU Member States, but not in the same way in each country. Some frequencies are 'open' and 'free' subject to certain technical constraints (e.g. power of radio signals), while others can be considered as 'exclusive' and often expensive. This results in diverging national policies which continue to 'limit' the development of the internal market. As a consequence, common rules are required for a number of promising new mass-market applications which can include, *inter alia*<sup>‡</sup>:

- ultra-wideband (UWB)-enabled products offered through potentially pervasive low-power/high-bandwidth technology, both in telecommunications and consumer goods;
- broadband wireless access (BWA) technologies together with enhanced 3G mobile communications;
- short-range devices (SRDs) to enable an EU-wide mass-market of low-cost radio equipment to develop and promote innovation for everyday applications, such as 'wireless barcodes' for radio frequency identification tags (RFIDs), personal area networks, etc.

A stable regulatory environment is essential to provide predictability for investors and borderless functionality of user equipment. Simultaneously, appropriate methodologies are needed to assess the economic and societal implications of any specific decisions taken. In fact, technical and market applications tend to migrate towards those frequencies to which they are 'best suited'. While high 'quality of service' applications (e.g. cellular networks, aviation, military) have price exclusivity, there has been intense expansion of products that benefit from low barriers to spectrum access in 'licence-free' bands (e.g. 2.4 GHz).

The EU Member States have recognised<sup>10</sup> the importance of a common policy in all the above domains, for the adequate establishment and proper

<sup>†</sup>In 2004, the European mobile industry has achieved a GDP contribution of €105.6bn for the EU 15 alone, while more than 2.8 million jobs have been created all over Europe during recent years. Other international studies (e.g. 'The economic costs of spectrum misallocation', Jerry Ellig, May 2005, <http://cadep.ufm.edu.gt/telecom/ingles/interior.asp?menu=lecturas>) claim that spectrum reforms in the USA would give consumers an annual welfare gain of as much as \$77bn as a result of lower prices for mobile voice services.

<sup>‡</sup>Other important areas may comprise technologies for independent living and health or applied technical facilities for an 'intelligent car'.

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functioning of the market. Improving the flexibility and responsiveness of spectrum management necessitates a long-term, policy-based approach, with a view to increasing competitiveness and fostering development, while taking into account general interest objectives. In the past, radio spectrum was seen as a 'scarce resource', and has been used by a few public sectors only (like defence and broadcasting)<sup>11</sup>; today, the number of wireless applications (private and public) has been drastically increased. Access to spectrum has become a 'prerequisite' for any further evolutionary ventures. Due to its impact on the development and offering of new applications, the availability of radio spectrum and its efficient use is now a key factor<sup>12</sup> for stimulating competition, sustaining innovation and growth, and, ultimately, creating jobs.

### The economic impact of radio spectrum use

The intrinsic value of spectrum cannot be estimated precisely, as usage may vary considerably; however, related numbers<sup>†</sup> are always large. Comprehensive and objective economic data on the impact of separate policy measures on the use of the radio spectrum are hard to come by, given that radio technologies affect many other sectors indirectly and that any 'decision' influences (or even precludes) a large number of alternative current (and/or future) uses which are not necessarily substitutable.

Modern society's dependence on advanced electronic communications contributes to an ever-increasing demand for radio frequencies. In economic terms, the importance of radio spectrum can be estimated by the 'value' of the services which can be provided over it. Concurrently, further efficiency improvements<sup>13</sup> are possible across the public sector and in all areas of industry. The development of an integrated market for innovative wireless devices and services provides an assurance of enhanced investments, improved economies of scale, support for trade flows, reduced prices and ever widening choices for consumers. Information relating to radio spectrum is a key requirement<sup>14</sup> for many players in the electronic communications

<sup>†</sup> Recent estimates put the value of US spectrum at \$771bn, and the US consumer welfare gains associated with introducing a suitable system of issuing spectrum usage rights at about \$77bn/year. Some European countries have also estimated the value of spectrum use per year for their economies (around £24bn in UK; €2bn in Ireland; kr16bn in Denmark).

market, including network operators and service providers, equipment manufacturers and vendors, broadcasters and regulators.

Improvements to the quality and accessibility of such information, together with spectrum liberalisation and trading, can encourage entrepreneurs and innovators to enter the market, deploy new technologies (and applications), and compete with existing players, in an environment where risks and uncertainties could be significantly reduced. To this end, market forces can react faster than regulation to redistribute spectrum to higher-value uses, as technology and consumer preferences change, and make it available for new services/products. More competition and innovation will emerge in the delivery of services (and products) as the markets become more transparent and access to them less complicated<sup>15</sup>. Consequently, there is a greater likelihood of pan-European networks and services emerging, both strengthening the European market for electronic communications and supporting the strategic goals<sup>16</sup> of the European 'digital inclusion'.

An appropriate removal of restrictions to accessing spectrum by emerging radio technologies will assist in their timely take-up, create better trading conditions, and so provide a more attractive environment for continual and balanced economic progress and employment. Therefore, the need for a gradual and systematic liberalisation of radio spectrum use, together with further development of liberalisation measures and practices in the market(s), can be considered as absolutely essential.

### Moving Towards New Approaches to Spectrum Management – Redefining Traditional Models of Spectrum Distribution

Addressing radio spectrum policy issues at the EU level is deemed necessary in view of the following objectives:

- to agree on the need for harmonisation of its use;
- to evaluate and balance needs imposed by the various users' communities in a more transparent manner.

The management of radio spectrum<sup>17</sup> in Europe, however, has not always kept pace

with the need to promote potential evolution and development. Until recently, radio spectrum management could not effectively, systematically and consistently take into account the requirements of existing policies, especially the achievement of the internal market, and conformance to liberalisation and competition objectives. This has led to a contradiction – while many of today's most active and useful technologies are 'radio-based', their use is still, more or less, constrained by national rules and non-flexible procedures. As a result, some market-players 'under-use' the radio spectrum to which they have rights, while new sectors can be constrained by severe 'spectrum scarcity'.

Organisations with 'legacy spectrum' also have a clear market advantage over new entrants, with a high probability of further limiting innovation and efficient spectrum use.

Despite voluntary co-ordination between Member States, national rules can effectively 'fragment' the EU single market. Radio spectrum regulation must therefore be brought up to date in a more co-ordinated and optimised way across Europe, if further undue fragmentation is to be avoided and new success stories, such as GSM or third generation (3G) mobile communications<sup>18</sup>, are to be realised. Previous initiatives<sup>19</sup> have required the promotion of harmonisation measures to reinforce the European market. The overall objective was to make possible the rapid take-up of new applications by providing industry with the opportunity to target a larger market, backed by a clear, legal framework, aimed at ensuring harmonisation across all sectors and guaranteeing a suitable legal certainty.

The EU Radio Spectrum Decision<sup>20</sup> has laid the basis for a more generalised approach. The principal objectives were to ensure:

- an adequate co-ordination of relevant efforts,
- harmonised conditions for the availability and efficient use of frequency bands,
- the provision of appropriate information on spectrum usage and the co-ordination of EU interests in international negotiations<sup>21</sup>.

Compared to its global competitors (USA, Japan, China, etc), the EU now suffers from very highly fragmented and slow 'decision-making' on spectrum use, with different timing and assignment

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mechanisms (various types of auctions, comparative bids or mixed approaches) resulting from sporadic unilateral approaches. This leads to the situation where European enterprises face difficulties in reacting quickly to providing competent solutions, offered via interoperable (occasionally standardised) terms, and at low costs. Radio spectrum is therefore an important enabling factor to 'attract' the substantial private commitment for development of the underlying market, both for radio equipment and services. In fact, probable inefficiencies in the allocation and use of spectrum can create significant costs, lead to lost opportunities for business activities, and decrease the start of innovative services to the disadvantage of both investors and consumers.

The latest European strategy is aimed at overcoming the rigidity of previous, traditional radio-spectrum management approaches, where regulators or administrations 'linked' usage rights of individual spectrum bands to 'specific' transmission technologies and extremely narrow service definitions (such as broadcasting or mobile communications). A greater flexibility in access to frequency bands can correspondingly provide the market players with more freedom to use radio resources as they choose, in a fully 'converged' environment. This is an indispensable condition for achieving the full potential of radio spectrum resources and for keeping pace with technology. Reorganisation of spectrum management is increasingly important to the economic well-being of society<sup>22</sup>. Current policies and strategic issues for spectrum management mainly concern:

- the 'core' underlying regulatory framework, i.e. those provisions under which matters for access to frequencies and the authorisation of communication network services are effectively managed;
- information on how to properly notify conformity of radio equipment<sup>23</sup> offered in the market by various manufacturers or vendors (including, for example, interface requirements and possible constraints on transmitters and receivers);
- authorisation policies<sup>24</sup>, i.e. approaches to granting rights of use for radio frequencies (also including information for licence duration and imposed spectrum fees), as spectrum markets are expected to have an impact on the value of existing licences, whether tradable or not, as well as expected related investments;

- spectrum strategy, i.e. information on the planned future use of frequency bands, and of the time schedule for possible changes of use;
- spectrum 'refarming' policy<sup>25</sup>, i.e. information on how regulatory authorities would deal with the transfer of spectrum from an existing user to a new one, especially to introduce new services to follow up evolutionary challenges;
- spectrum trading policy and relevant information-access requirements, together with similar international issues, especially within the scope of competition law (to provide adequate and sufficient remedies, if and when necessary).

In the context of modern deregulatory approaches, it should be expected, as far as possible, to guarantee that spectrum should be free of technology and/or any specific usage constraints. Policy constraints should only be used where they are properly justified, according to the ordinary market practices. This implies that a 'radical redefinition' of existing licences is essential to make them 'technology-neutral' with a minimum of imposed technical restrictions; additional measures should aim to make available 'licence-free' radio frequencies to allow different users to share bands (as is already the case for Wi-Fi radio access<sup>26</sup>). Simultaneously, it should be simple and transparent for licence holders to 'modify' their ownership and use of spectrum, to comply with developments in market needs and technologies.

Liberalisation (i.e. removal or easing of limitations on frequency use) can be further extended in some specific bands, in particular those suitable for mobile and broadband services. Rights of spectrum users should be clearly defined and users should feel quite comfortable that they will not be changed without good cause. A proper reaction to the above challenges is to apply a market-based model allowing more freedom to market players to decide how spectrum should be used, and lowering the barriers for access to authorised spectrum rights by making possible the trading of these. Considerable gains (around €8-9 billion/year<sup>27</sup>) can be achieved by introducing market mechanisms in order to make spectrum available for the most promising uses. A better use of the spectrum can also be achieved by actively seeking to

free up some of its parts for new uses. The main activities in this context are aimed at ensuring that innovators can place technologies on the European single market immediately and with legal certainty, co-ordinating the introduction of spectrum trading, and exploiting opportunities provided by, for example, the spectrum freed up by the switch-over from analogue to digital TV, leading to a considerable 'spectrum dividend'<sup>28</sup>.

### Spectrum trading

Recent competition policies suggest that spectrum rights in bands used for 'terrestrial electronic communication services' (including mobile, broadcasting and data communications) have to be 'tradable', according to the commonly accepted EU market practices<sup>29</sup>. This implies that, in those specific bands, a licence to use spectrum could be 'freely' transferred between authorised holders, under distinct business-oriented agreement terms, so that they can make a well-versed choice on where in the spectrum they want to operate and whether the cost of the spectrum rights makes this effort meaningful and worthwhile. Consequently, holders of a distinct spectrum right should also be able to choose how it is used, given that they do not interfere with other users. This can be a more convenient option for innovators to access radio frequencies and to 'place' their suggested new services/products in that part where they stand the best chance of being technically and commercially successful. Trading may be beneficial in certain spectrum areas, subject to sufficient safeguards to ensure that potential benefits are not offset by adverse consequences and can contribute to reach the strategic goals of contemporary policies. The non-existence of European and/or national terms and rules for realising such trading activities could lead to additional fragmentation. Benefits will be greater if such opportunities are provided in a co-ordinated way, especially by allowing companies to target pan-European services, thus realising economies of scale.

### Spectrum management

With the same objective of stimulating emerging markets, a coherent strategy for competent and efficient management of radio spectrum is more than simply necessary<sup>30</sup>. Spectrum management needs

to be totally reformed, to be able to confront modern challenges both at the technical and at the commercial level. The digital revolution together with the development and adoption of ICT have transformed the distinctive boundaries between telephony, television and the Internet; therefore, previous traditionally segmented and – in some way – inflexible approaches for organising the exploitation of frequencies have now become ineffective, as new technologies are capable of delivering combinations of services and since these are becoming substitutable, at cross-border dimensions. Consequently, as spectrum use has extensively evolved, traditional regulatory approaches have unwittingly produced barriers to innovative suppliers of applications and services. Furthermore, the progress of both the European and the global market(s) depends on the applicability and the diffused usage of radio-based services, together with guarantees for avoiding any possibly harmful interference. A proper response requires methods that support innovation and provide more choice to users. Some possible models for spectrum management, either ‘traditional’ or new, are described below.

- The ‘administrative’ model  
This is the long-established norm, where public authorities regulate and standardise all the features of radio emitters, while simultaneously issuing licences to spectrum users, on the basis of assignment of individual spectrum rights and allocation of the various bands to defined service categories, with the avoidance of interference being the primary objective. Alternatively known as the ‘command and control’ model, this depicts the case in which the authorised regulatory authority plans, supervises and controls:
  - which part of the radio spectrum shall be used for which proper service as a function of its technical characteristics (allocation decisions);
  - in which time frame (strategic planning of radio spectrum use);
  - who is able to use a specific frequency band;
  - for what purpose (assignment decisions);
  - under which conditions (licensing decisions).

In this way, regulatory authorities can decide how spectrum is used. The ‘core’ aim is to avoid interference (e.g. where several applications are using similar frequency bands), primarily for services of public interest. The approach intends to issue individual rights to use

frequencies by segmenting the available spectrum into suitable ‘specific’ bands, reserved exclusively for particular technologies. Normally, any additional entry is blocked, unless additional spectrum becomes available on the basis of future allocations and assignments, or secondary trading of spectrum is permitted.

In the wake of market liberalisation, however, different approaches to the management of rights to use radio spectrum have been developed and currently appear as ‘alternatives’ to the traditional administrative model. These other models are aimed at looking for co-ordinated answers to common problems and satisfying serious requirements for an immediate market adoption of modern technical advances. In any case, each separate management model can be seen as a promising and useful tool, developing the right ‘mix’ for achieving contemporary policy objectives. Two ‘core’ alternatives are described below.

- The ‘trading and flexibility’ model  
This is where spectrum users are given a fully ‘tradable’ right. In fact, market forces (especially within the communications industry) are participating in competing activities where rights for access and usage are transferred to ‘users’ through auctions, trading and/or incentive pricing with a minimum of restrictions imposed on spectrum use<sup>31</sup>. The intention is to certify that the best and most efficient use of spectrum prevails. Such an approach seems very appropriate where certain commercial suppliers of wireless applications and services truly compete for gaining exclusive rights to overcome any artificial scarcity of resources. The model gives power to a spectrum rights holder to decide on the specific use of frequencies, according to market demand(s)<sup>32</sup>.
- The ‘unlicensed’ model  
This is where several (local) users are jointly using the relevant spectrum bands without an official licence or any other strict authorisation; however, there is no proper guarantee of ‘interference-free’ operation. In such a licence-exempt use<sup>33</sup>, the relevant actors have a ‘free’ access to spectrum although normally subject to certain technical conditions and restrictions (e.g. on power output). Interference effects have to be considered and tolerated; however, to a certain degree, they can be mitigated by the use of appropriate technical means, so that they do not have any serious

effect on transmission. The pros and cons of the current ‘interference-avoidance’ process need to be well expounded to achieve a more appropriate balance between protection of existing services and support of innovation. This management model (also known as the ‘commons’ approach), already used in certain domains (e.g. for cordless phones, Bluetooth and Wi-Fi applications), has considerably lowered the radio resource access barriers for current applications and allowed the creation of thriving new radio sectors using relatively small amounts of spectrum. Meanwhile, modern broadband technologies<sup>34</sup>, already developed and adopted by the consumer market, extend the range of further and complementary spectrum management approaches such as ‘self-governing’ systems via ‘intelligent’ radios, or ‘underlay’ use of spectrum.

## Conclusions and Future Activities

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Spectrum is a highly generic resource in the sense that one part of it can replace any other part in the provisioning of wireless services.

Up-to-now the slow turnover of wireless technology has ‘frozen’ large amounts of spectrum for specific applications. This does not have to be the case in the future. For example, taking into consideration the common European interests<sup>35</sup>, the switch-over from analogue to digital television can potentially make available additional capacity in the most valuable part of the

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radio spectrum. Current EU policy measures together with related market feedback, in the context of openness and transparency, aim to:

- facilitate technological innovation and competition;
- pursue well-defined objectives with regard to radio spectrum within a predictable and legally certain regulatory framework;
- ensure the 'proper balance' of various interests of the individual countries of the European Community and of the various user communities when deciding on the distribution of radio spectrum;
- safeguard European interests in selected areas of the international arena, where radio spectrum is discussed.

Developing and commercialising new wireless technologies necessitates availability of funds, significant effort and other resources, especially for mass-market applications. Under suitable conditions, such implementations can lead to large markets benefiting from economies of scale. Regulatory initiatives have created a satisfactory legal basis for spectrum harmonisation. However, due to continuous market and technical responses, it is essential to integrate new approaches and to clarify spectrum-related concepts (like efficiency and interference). So, common rules for spectrum trading need to be considered, together with new dimensional approaches with respect to licensing. Existing differences on management issues at national level may harm (or even prevent) the evolution of services offered through wireless technologies (in the EU or globally). In the same context, prices are observed as being significantly higher than they could be and the free movement of goods and services among countries is radically impeded.

A common approach to spectrum management issues can help to construct a single EU market in this sector. However, appropriate policy guidance is needed to ensure that the various interests are appropriately balanced. Furthermore, co-ordination is essential in order to raise political awareness and support for technical radio spectrum management objectives, at the international level.

Spectrum is still managed at a national level, but the responsible European authorities have a key role to play, mainly in supporting a co-ordinated pan-European approach. Reforms are being actively discussed in most countries, and several approaches are now under consideration, albeit mainly from a national perspective on a number of specific issues. A co-ordinated

spectrum policy will enhance a genuine single market for both radio services/facilities and equipment, while a transparent collaboration can enable Europe to take a strategic and coherent path towards an efficient spectrum reform. The removal of barriers to mass markets and the lowering of prices that national rules place in the way of business and consumers, constitute fundamental issues. A common EU approach on managing spectrum resources will be critical for the future technological and economic developments of the information society.

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Dr Ioannis P Chochliouros is a Telecommunications Electrical Engineer. He graduated from the Polytechnic School of the Aristotle University of Thessaloniki, Greece, and also hold a PhD and an MSc from the University Pierre et Marie Curie, Paris-VI, France. Since 1997 he has been working at the Competition Department and then as an engineer-consultant of the Chief Technical Officer of OTE (Hellenic Telecommunications SA), for regulatory and technical matters, where he has been involved in major OTE national and international business activities, particularly for the evaluation/ adoption of innovative e-Infrastructures and e-Services. He currently works as the Head of the Research Programs Section of the Labs and New Technologies Division, of the Network Strategy and Architecture Department, where he is involved in different European and international projects/ activities. He has published more than 80 international scientific and business papers, studies and reports. He is an active participant of various scientific and business international and national associations.

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