Physical, technical, practical, economical, and regulatory aspects of spectrum management

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Abstract

The radio spectrum is a highly value resource that call for efficient utilisation. This involves developing both good radio equipment able to operate under challenging conditions and cost-effective spectrum management regimes. The pressure on available suitable spectrum is getting high, in particular for mobile data services. The management at all levels need to address the new challenges. Some trust traditional command and control methods, others argue for liberalised market mechanism. Some want to keep most of the spectrum for specified radio services and systems, others want a free utilisation in spectrum commons and technology neutral allocations otherwise. The way forward is an evolutionary path where laws of physics must be respected, but advance technology allowed and more flexible regulatory regimes put into work. It is however, not obvious that liberal spectrum trading only is the right answer.

1. Introduction

The utilisation of radio spectrum is growing dramatically, in recent decades particularly within mobile and other personal wireless communication. Even for traditional fixed broadband access wireless technology dominates regarding the first meters technology choices, such as through wireless local area networks (WLAN) at homes.

Along with the incredible growth of personal wireless communication the spectrum management has changed. Perhaps it is more correct to indicate it is in the middle of a process where new regimes are sought for, efficient spectrum management to meet the demand from the users of radio spectrum. The pressure on management comes from several angles to serve businesses, to deliver cost efficient services to users, and efficiently utilise the electromagnetic wave frequencies. The discussion includes to what extent regulatory authorities shall control the spectrum and its use, or whether other mechanisms such as commercial spectrum trading is more appropriated, or more common spectrum should be available with no control other than basic frequency bands and transmit power limits. At present there is a mixture of methods, depending on part of the spectrum and country, from almost no control through regulations to detailed bureaucratic means.

This paper discusses aspects of the management mechanism and indicates some possible routes for improved spectrum managements.

2. Demand for spectrum

Ever since the radio system first was invented more than a hundred years ago, there has been an increasing demand for radio frequencies for various purposes. The trend is to both use higher frequencies and increase the degree of utilisation such that the total gross capacity can deal with the higher demand for radio-based services. The latter point has resulted in radio systems that both make better use of the radio waves and tolerate more interference.

One of the most remarkable recent drivers towards improved spectrum utilisation and demand for more spectrum is mobile data traffic, i.e., to use the mobile network for Internet both using handset (small screens) or laptops and stationary computers (large screens). The predictions from various sources indicate a dramatic growth as depicted in Figure 1a from the Cisco source [1] and in Figure 1b from Telenor research [2-3]. The exponential growth indicates total monthly mobile data traffic doubling rates within periods shorter than a year, and also dramatic busy hour traffic in Western Europe. Without identifying detailed spectrum requirements, it is clear that mobile data traffic will become more and more demanding in requests for spectrum resources in suitable frequency bands [4].

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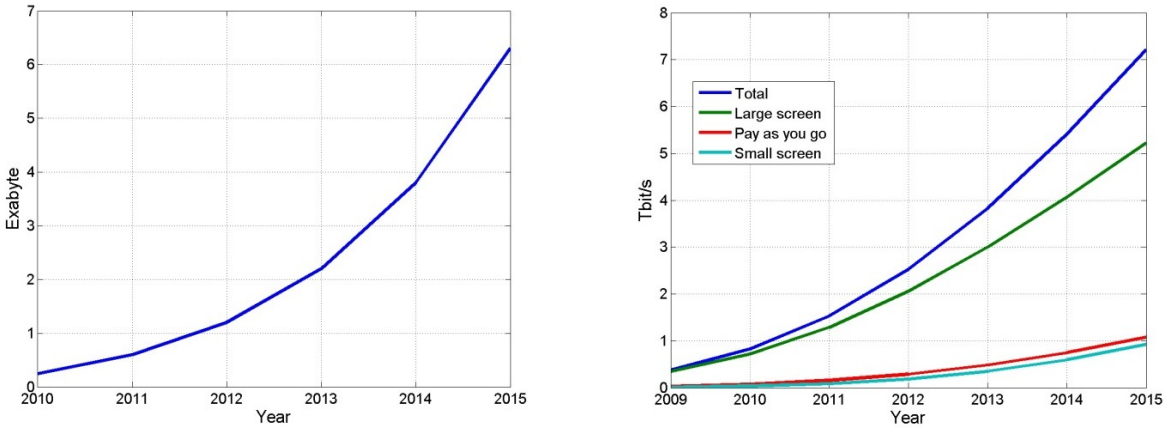

a) b)

Figure 1. Mobile data growth a) total global traffic per month [1] and b) busy hour traffic for Western Europe [2]

3. Management of radio frequencies

In the first years of utilisation radio frequencies for communication or broadcasting there were no harmonisation or management. However, it did not take so long before it was necessary to somehow manage the spectrum resources and agreements were reached in 1903 to regulate the utilisation of the spectrum [5-6], perhaps the main driver was to avoid destructive interferences. Today there are three spectrum management levels: the global, the regional, and the national level. The Radiocommunication Sector of the International Telecommunication Union (ITU-R) issues Radio Regulations (RR) [7] every three of four years. The RR has the basic set of rules for utilisation of the radio spectrum, for radio-based service such as mobile or fixed, and international coordination procedures. The main spectrum allocation table just split the world into three regions, but numerous footnotes makes many of the allocation valid or invalid at national levels irrespective of the table allocations. The RR has a major impact on the global business in the sense that radio systems and services are developed according to its allocations. For global systems, such a mobile services, it is desirable to achieve common frequency bands for the whole world or for as large areas as possible. The more fragmented the allocations are for example set by countries in footnotes to the RR allocation table, the more complicated the radio system becomes. The RR have been created in a highly democratic process, taking into account the interests of all parties interested, treating the radio spectrum as a common heritage of the whole humanity. At the national level the practical management is done, to provide right to use part of the spectrum for a specified service. The regional level is used for harmonisation within a geographical area, and sometimes to align policies.

National regulatory authorities manage spectrum following an “administrative model”, a “trading model”, or a “free model”. The administrative model, of some called command and control, allow the authority to decide in much details who to give the rights to used the spectrum, for how long and for what service. They will normally follow the ITU-R RR with respect to frequencies for type of service, but may deviate. The operators apply for using the spectrum with a proposal, and if there are more applicants than can be offered rights it is sometimes called a “beauty contest” to get the rights. It is not easy to judge and not easy to apply either. The trading approach replaces the contest by market mechanism and is commonplace today in most countries. Operators are willing to pay a lot of money for spectrum, although it varies from country to country, see Figure 2 showing example auction prices in USD per MHz and population for paired spectrum for mobile operations over a ten-year period. However, there were cases that, in spite of paying a large amount in the auction, the operators did not deployed the service as promised. The trading model is taken further dealing with spectrum rights to use as any other goods [8] and allow it sold to others. The market mechanisms are not limited to the primary access to spectrum, but also treated as goods and can be traded on a secondary basis. The regulator may again try to ensure that it is used for its original purpose, but it is the market that is in control and not the authority. Some see this necessary for the future, not only to efficiently handle the spectrum but also to get new technology into use, apparently assumed to make better use of the spectrum [9].

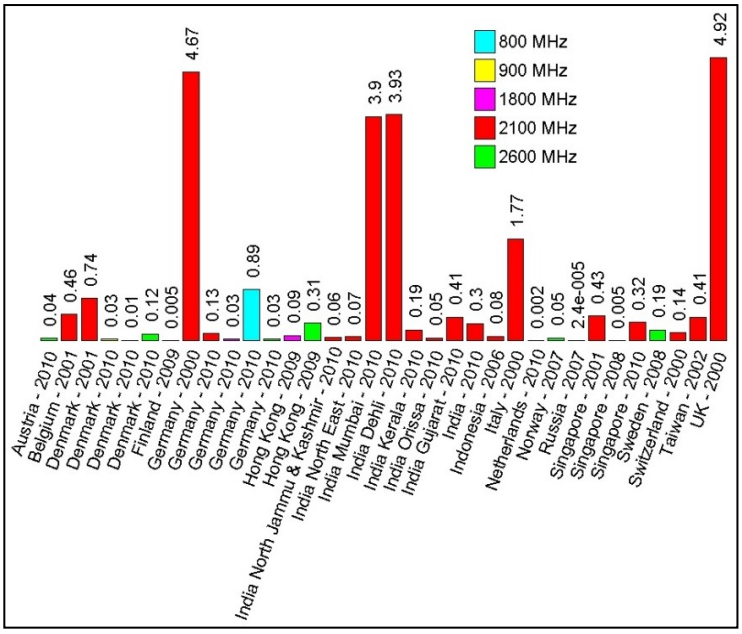

Figure 2. Auction prices given in USD/MHz/Pop for paired spectrum using exchange rates at the time the auctions were hold (Note: Paired spectrum. USD/MHz/Pop based on historical exchange rates when the different auctions were worked out. When calculating USD/MHz/Pop the sum of uplink and downlink bandwidth is taken into account. In auctions where paired/unpaired spectrum were sold in bundles, amount of paired spectrum is used.)

4. Future developments

Global radio regulations remain very important for vendor industry and operators to develop new radio systems, in particular to lower the cost of services. Obviously, no one will develop a system that cannot widely be used. For example, mobile communication vendors and operators will hesitate to develop products for small national markets. If done the services offered are expensive. Expensive services leads to little spectrum utilisations. May be a spectrum management problem is solved, but the society is not served as it should.

Market mechanisms have increasingly been deployed recently, although not a new concept [8]. Several argue for more spectrum to become available under a liberalised market mechanism regime to both promote development of new radio systems and lower the cost. Some indicate that more frequencies should become spectrum commons, using the same type of arguments. One success story is WLAN, beyond no doubt used by very many for first meter broadband access. Note however, that there are also examples of WLANs where no service is possible simply because of spectrum pollution due to the interference created. Market laws are not good enough on its own, the laws of physics must be respected. Radio waves propagate according to physical laws under the particular technical design such as spectrum occupied, transmit power, and antenna radiation pattern. Regulatory or economical principles have no influence once the radio transmitter is turned on, i.e., the radio system is put into operation. It can cause destructive interference to others using the same portion of the spectrum, and it can be affected itself.

Market institutions are geared toward economic growth and provide only private goods at the expense of public goods. In the 1950s John Kenneth Galbraith argued that society was too focused on the market provision of private goods and neglected public goods such as education, infrastructure, public health, and so on that would best improve quality of life. Today, not only do we recognize the importance of public goods provided by nature, but we know that the production of market goods inevitably degrades them.

The technology is evolving quickly such that the radio systems will increasingly be able to adapt to the environment, and it is possible to increase the spectrum utilisation. A modern radio system can handle more interference – up to some limits. If pushed further the gross throughput will be reduced and even ultimately, no service can be provided in that part of the spectrum.

Radio communication services very much look the same either they are provided on a fixed, mobile or even broadcast technology. The traditional allocation to services of this kind is getting out of date as convergence takes place where it is not really possible to distinguish between them. At the local levels spectrum rights should be provided not specifying technology, they should be technology neutral. Trends like these put spectrum management under pressure to change. From a regulatory authority point of view it might look easier to let the actors decide based on their views on the market development. Not regulate at a too detailed level. The development clearly points towards higher pressure on the most suitable parts of the electromagnetic spectrum such as for mobile data services. How should the spectrum management deal with the future: use command and control, trading, or free commons? Considering the mobile data the context is global business for convergent services. Clearly, an administrative approach at national levels has severe drawbacks only focussing on a normally small geographical area. A market-oriented approach can quickly lead to fragmentation of pieces of spectrum for various services and if it is true that there will be motivation for alternative air-interfaces a large number of complex radio systems have to deal with broadband traffic as well as difficult interferences scenarios. With fragmented spectrum parts spread over several frequency bands, the equipment has to deal with very variable radio channels as well as the complexity created within the radio circuits itself to communicate using a number of small bands found within a much wider total bandwidth. The commons is obviously attractive as long as the radio system works; the opposite is equally obvious as the many users simply results in congesting and blocking.

Also the growing total traffic, gross traffic, leads to careful considerations of how much a certain system, needs in a geographical area. There is a limit, hard or soft, where the load is too high and throughput will be reduced and even blocked. Technical and operational characteristics of various services need to be precisely coordinated, more and more in an automated way, to cope with that challenge.

5. Conclusion

The pressure on suitable radio frequencies is increasing in several areas. Spectrum management is challenged to become more efficient, to adapt to a technology world with convergent services and fast developing technology. It is possible to become more efficient and still respect physical and technical constraints. Spectrum trading along with administrative command and control may well be the road to continue to follow. More spectrum commons is also possible, but destructive interference will increase the more services in such bands are used, and it is difficult to guarantee satisfactory quality of experiences.

6. Acknowledgments

Many thanks Kjell Stordahl and Terje Ambjørnsen who provided busy our traffic and auction prices data.

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