Spectrum Management Overview

Terje Tjelta
Ryszard Struzak

Abstract

Radio frequencies are of increasingly high value for wireless telecommunications services, as well as for science services. Spectrum simply must be efficiently utilized, and more so with the very high interest currently seen for radio applications. This involves developing good radio equipment, able to operate under challenging conditions; a high degree of spectrum reutilization of close-by spatial locations or temporal time slots; and, obviously, cost-effective spectrum-management regimes. The pressure to make suitable additional spectrum available is getting high, in particular for mobile data services. The management at all levels must address the new challenges. Some communities trust traditional command and control methods, other communities argue for liberalized market mechanisms. Some want to keep most of the spectrum for specific and well-defined radio services and systems; others want a free utilization in spectrum commons, and technology-neutral allocations. The way forward is preferably an evolutionary path where the laws of physics must be respected, but advanced technology allowed, and more flexible and efficient spectrum-management regulatory regimes put to work.

1. Introduction

The utilization of radio spectrum has been growing dramatically for many years. Broadband mobile data services and other personal wireless communication systems have become particularly heavy spectrum users in recent decades. In fact, fixed-broadband-access radio technology dominates with respect to first-meters technology choices, such as through wireless local-area networks (WLANs).

Along with the incredible growth of personal wireless communication, spectrum management has either changed as well or is in the middle of a process where new efficient regimes are sought. The pressure on management comes from several angles: to serve businesses, to deliver cost-efficient services to users, and to efficiently utilize 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 – are more appropriate, or should more common spectrum be available with no control other than determination of basic frequency bands and transmitting power limits? At present, there is a mixture of methods depending on the part of the spectrum and country, from almost no control, through regulations with detailed bureaucratic means.

This paper discusses aspects of the management mechanism, and indicates some possible routes for future improved spectrum management. It is a revision of the paper presented at the URSI General Assembly and Scientific Symposium in 2011 [1].

2. Demand for Spectrum

Ever since the radio 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 to increase the degree of utilization, such that the total gross capacity can meet the higher and higher demand for radio-based services. The latter point has resulted in radio systems that both make better use of radio waves in terms bit/s/Hz and gross area capacity, and that can tolerate more interference.

One of the most remarkable recent drivers towards improved spectrum utilization and demand for more spectrum is mobile data traffic, i.e., to use the mobile network for the Internet both using handsets (small screens), or laptops and stationary computers (large screens). The predictions from various sources indicate a dramatic growth in total mobile data traffic, as depicted in Figure 1 from the Cisco source [2] shown together with forecasts since 2008. Busy-hour Western European traffic is shown in Figure 2, from Telenor research [3, 4]. The exponential growth indicates total monthly mobile data traffic doubling rates of about a year, and also dramatic busy-hour traffic in Western Europe. Without identifying detailed spectrum

Terje Tjelta is with Telenor, Snarøyveien 30, 1331 Fornebu, Norway; e-mail: terje.tjelta@telenor.com. Ryszard Strużak is with the National Institute of Telecommunications, Wrocław, Poland; e-mail; struzak@gmail.com.

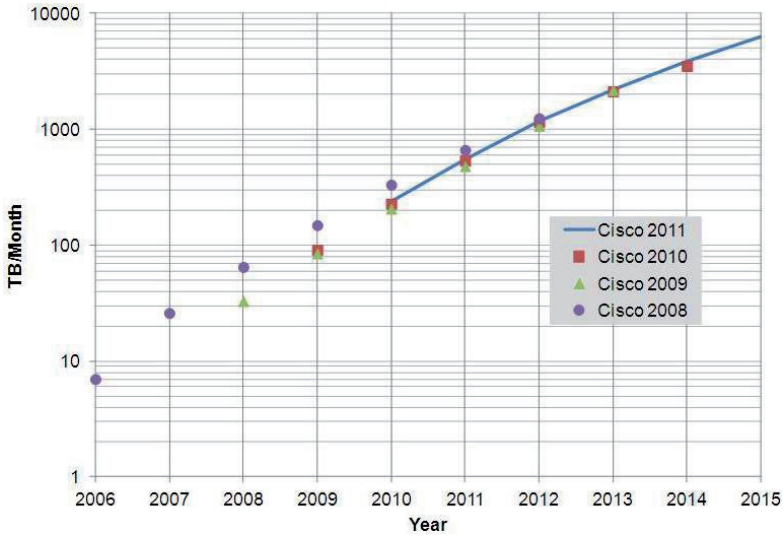

Figure 1. Mobile data growth in terms of total global traffic per month [2].

requirements, it is clear that mobile data traffic will become more and more demanding in its requests for spectrum resources in suitable frequency bands [5].

However, the trend indicates that the growth rate for mobile data [2] is reduced, with a traffic-doubling rate towards longer periods than a year, and that earlier year predictions somewhat overestimated the expected traffic. However, a challenge remains clear to make available, regulate, and manage spectrum for this branch of the radio business.

3. Management Methods for Radio Frequencies

In the first years of utilization of radio frequencies for communication or broadcasting, there was no harmonization or management. However, it did not take long before it was necessary to manage the spectral resources, and to reach agreements, in 1903, to regulate the utilization of the spectrum [6, 7]. The main driver was probably avoiding destructive interference.

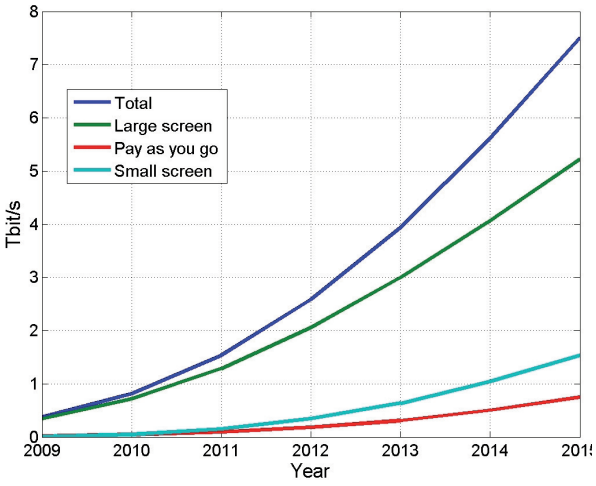

Figure 2. Busy-hour traffic for Western Europe [3].

Today, there are three spectrum-management levels: the global, the regional, and the national levels. The Radiocommunication Sector of the International Telecommunication Union (ITU-R) issues Radio Regulations (RR) [8] every three or four years. The Radio Regulations give the basic set of rules for the utilization of the radio spectrum, for radio-based services such as mobile or fixed, and for international-coordination procedures. The main spectrum-allocation table just split the world into three regions, but numerous footnotes make many of the allocations valid or invalid at national levels, irrespective of the table's allocations.

The Radio Regulations have a major impact on global business, in the sense that radio systems and services are developed according to their allocations. For global systems such as satellite and mobile services, it is desirable to achieve common frequency bands for the whole world, or for areas as large as possible. The more fragmented the allocations are – for example, set by countries in footnotes to the Radio Regulations allocation table – the more complicated the radio system becomes. The Radio Regulations were created in a highly democratic process, taking into account the interests of all interested parties, treating the radio spectrum as a common heritage of all of humanity. At the national level, the practical management is done to provide a right to use part of the spectrum for a specified service. The regional level is used for harmonization 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, which some call "command and control," allows the authority to decide in much detail to whom to give rights to use the spectrum, for how long, and for what purpose**.** The authority will normally follow the ITU-R Radio Regulations with respect

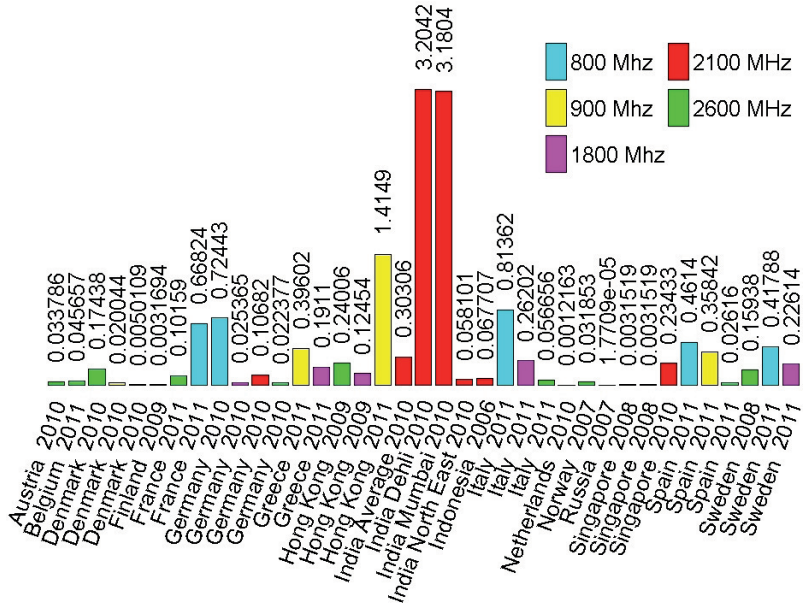

Figure 3. Auction prices given in EUR/MHz/Pop for paired spectrum, using exchange rates at the time the auctions were held. (Note: This is for paired spectrum. EUR/MHz/Pop was based on historical exchange rates when the different auctions were worked out. When calculating EUR/MHz/Pop, the sum of uplink and downlink bandwidth was taken into account. In auctions where paired/unpaired spectrum was sold in bundles, the amount of paired spectrum was used.)

to frequencies for type of service, but may deviate. Operators may apply for use of the spectrum with a certain proposal, and if there are more applicants than can be offered rights, it is sometimes called a "beauty contest" to obtain rights. This is not easy to judge, and not easy to apply, either. The trading approach replaces the beauty contest by a market mechanism, and is commonplace today in most developed countries and in some developing countries. Operators are willing to pay a lot of money for spectrum, although this varies from country to country. Figure 3 shows example auction prices in Euros (EUR) per MHz and population (Pop) for paired spectrum for mobile operations over a five-year period. However, there have been cases where in spite of paying a large amount in an auction, the operators did not deploy the service as promised, for one reason or another.

The trading model can be taken further in dealing with spectrum rights (to use as any other good model [9]) and in allowing these to be sold to others. That is to say, the market mechanisms are not limited to the primary access to spectrum, but spectrum can be treated also as a good that can be traded on a secondary basis. The regulator may again try to ensure that spectrum is used for its original purpose, but it is the market that is in control and not the authority, unless explicit in national regulations. Some see this as necessary for the future, not only to efficiently handle the spectrum, but to also get new technology into use. New technology is apparently assumed to make better use of the spectrum [10].

4. Future Development Trends

Global radio regulations remain very important for the vendor industry and operators for developing new radio systems, in particular to lower the cost of services. Obviously, no one will develop a system that cannot be widely used. For example, mobile-communication vendors and operators will hesitate to develop unique products for small national markets. Depending on circumstances, the services offered may become expensive. Expensive services lead to less spectrum utilization. In such cases, a spectrum-management problem is solved, but society is not served as well as it should be.

Market mechanisms have increasingly been recently deployed, although this is not a new concept [9]. Several argue for more spectrum to become available under a liberalized market-mechanism regime, to both promote development of new radio systems and to 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. However, note that there are also examples of WLANs where no service is possible, simply because of spectrum pollution due to interference.

Market laws are not good enough on their own: the laws of physics must be respected. Radio waves propagate according to physical laws under particular technical designs such as spectrum occupied, transmitted power, and the antenna radiation pattern. Regulatory or economic principles have no influence once the radio transmitter is turned on, i.e., the radio system is put into operation. The radio transmitter 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, which would better improve quality of life. Today, not only is the importance of public goods provided by nature recognized, but it is known that the production of market goods inevitably degrades them.

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

Radio-communication services can very much look the same, whether they are provided by a fixed, mobile, or even broadcast technology. The traditional allocation to such services is becoming obsolete as convergence takes place such that it is not really possible to distinguish among them. At local levels, spectrum rights should be provided while 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 make decisions based on their views of market development, while not regulating at a too-detailed level. Developments clearly point toward higher pressure on the most suitable parts of the electromagnetic spectrum, such as for mobile data services. How should spectrum management deal with the future: use command and control, trading, or free commons? Considering mobile data, the context is global business for convergent services.

Clearly, an administrative approach at national levels has severe drawbacks when focusing only on a small geographical area. A market-oriented approach can quickly lead to fragmentation of the spectrum for various services, and, if there is a motivation for alternative air interfaces, a large number of complex radio systems will have to deal with broadband traffic as well as difficult interference scenarios. With fragmented spectrum spread over several frequency bands, the equipment has to deal with very variable radio channels, as well as with the complexity created within the radio circuits themselves, to communicate using an aggregated number of narrower bands taken from a much wider total bandwidth. The commons approach is obviously attractive as long as the radio system works; the opposite is equally obvious, since many users can simply result in congestion and blocking.

Growing total gross traffic leads to careful consideration of how much spectrum 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 radio-based business 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 are also possible, but concomitant destructive interference will increase the more services in such bands are used, and, in such cases, it is difficult to guarantee satisfactory quality of experience.

6. Acknowledgments

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7. References

1. T. Tjelta and R. Struzak, "Physical, Technical, Practical, Economical, and Regulatory Aspects of Spectrum Management," Proceedings of 2011 XXXth URSI General Assembly and Scientific Symposium, Istanbul, Turkey, August 13-20, 2011.
2. Cisco, "Cisco Visual Networking Index: Forecast and Methodology, 2010-2015," Cisco White Paper, June 1, 2011.
3. K. Stordahl, "Long-Term Mobile Broadband Traffic and Subscription Forecasts," Proceedings of the 31th Annual International Symposium on Forecasting, Prague, Czech Republic, June 26-29, 2011.
4. K. Stordahl, "Market Development up to 2015," Celtic project MARCH Deliverable D3.4, December 2, 2010; available at http://projects.celtic-initiative.org/ march/march/UserFiles/file/CP5-013-MARCH-D3_4-final.pdf.
5. M. Lazarus, "The Great Spectrum Famine," *IEEE Spectrum*, **47**, 10, October 2010, pp. 26-31.
6. E. Lie, "Radio Spectrum Management for a Converging World," ITU Workshop, February 16-18, 2004.
7. R. Struzak, "Trends in Use of RF Spectrum," *Journal of Telecommunications and Information Technology*, **4**, 2009, pp. 95-100.
8. ITU-R, "Radio Regulations," Geneva, ITU, 2012.
9. R. Struzak, "Spectrum Market or Spectrum Commons," Proceedings of EMC Europe 2010, September 13-17, 2010, Wroclaw, Poland.
10. I. Chochliouros, A. Spiliopoulou, S. Chochliouros, and T. Doukoglou, "European Challenges Towards Forming and Promoting an Innovative Radio-Spectrum Policy in a Fully Converged Communications Market," *Journal of the Communications Network*, **6**, Part 2, April-June 2007, pp. 60-67.