Unlicensed radio spectrum: case WLAN

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Abstract

The use of radio frequencies world wide is mainly regulated and monitored. This system is based on old technological limits. Some parts of the radio spectrum are however left outside the licensing system and free to use. The services based on IEEE 802.11 standard give a good example of the commercial potential of these unlicensed networks.

Key words: spectrum allocation, unlicensed spectrum, WLAN

1 Introduction

The use radio spectrum has been licensed and regulated for nearly a century. The history of licensing goes back into the beginning of the 20th century, the disastrous journey of Titanic in 1912 being one of the initiating factors. In that time radio receivers were primitive and their ability to distinguish different transmissions poor, which has been considered as one of the reasons why nearby ships did not respond to Titanic's distress calls. The public authorities responded by licensing the use of spectrum to broadcasters and by dividing the spectrum in bands with wide separation between them. [1]

That kind of reaction was justified by the technological capabilities of the devices and was probably the best approach at that time. However, the regulation stands still despite the technological development and has led to a situation, where radio frequency spectrum is treated as a scarce resource.

Although most of the radio frequencies are licensed, some parts of the spectrum has been left unlicensed and are thus available for free use. The purpose of this paper is to present the regulatory status of unlicensed radio spectrum in different markets and as a special case, study the commercial use of unlicensed spectrum by using WLAN as a case example. Also the relevance of licensing is discussed.

2 Technology overview

Although no licenses are needed, some regulation still exists. Open transmission is possible within technical parameters such as power limits. The most prominent unlicensed bands are in the 900 MHz range, the 2.4 GHz range and the 5 GHz range. This paper studies the usage of the two latter ranges from the point of view of IEEE 802.11 devices.

2.1 IEEE 802.11 standard

The institute of Electrical and Electronic Engineers Inc. (IEEE) created the IEEE 802.11 standard for Wireless Local Area Network (WLAN) technologies in 1997 [2]. The initial standard contained requirements for transmitters operating in the 2.4 GHz band (2400-2483.5 MHz). The first amendment, IEEE 802.11a – 1999, was developed to give higher data rate by using different modulation technique in the 5 GHz band (5150-5350 MHz and 5725-5825 MHz). The second amendment, IEEE 802.11b – 1999, introduced higher data rate in the 2.4 GHz band.

The standard includes protocols that enable changes to radiated power levels and channel frequencies to meet the requirements of a number of specified national regulatory regimes. Whilst the original standard was developed in the USA, it continues to be developed in partnership with the European Telecommunication Standards Institute (ETSI) and with certain individual regulatory bodies in Europe. [3]

3 Regulatory status

3.1 The concept of interference

The major concern of regulators is to avoid the radio communications interference defined by the International Telecommunications Union (ITU) Radio Regulation as the effect of unwanted electromagnetic energy on reception of radio communications, manifested by any performance degradation, misinterpretation or loss of information that could otherwise have been extracted in the absence of the unwanted energy [4]. Interference can be further divided into three subcategories: permissible, accepted and harmful interference.

The original use case of 802.11 devices was to provide wireless local area networks, with typically small cell deployments (10-50 meters diameter). The technology was designed to in some point cope with interfering signals arising in multiple deployments. However, as the number of users or other systems generating unwanted signals grow high enough in any local area, the data throughput and communication range will decline. To be able to keep the interference in a tolerable level, national regulatory arrangements have been carried out.

3.2 Regulation in the EU

The quarter making the recommendations to the European Union member states regarding spectrum management issues is the European Conference of Postal and Telecommunications (CEPT). The spectrum management arrangements for "Short Range Services" are described in the CEPT/ERC Recommendation Rec 70-30. This recommendation relates to allocation of frequency bands, maximum power levels, channel spacing and duty cycle. Normally the devices of this category do not require individual licenses, some exceptions however exist between the countries.

The telecommunications standards for the EU countries are coordinated by ETSI. The implementation of the frequency band licensing arrangements and adoption is however up to individual countries.

The 2.4 GHz band

The specifications for low power spread spectrum devices are set in the ETSI standard EN 300 328 [5]. The radiated power limits are significantly lower than the limits set down in FCC 15.247 [6]. IEEE 802-11a and 802.11b equipment must be configured to comply with the maximum radiated power requirements set out in the EN 300 382:2000, an updated version of the original standard.

In France and Spain an IEEE 802.11 device must be configured to operate in a substantially reduced frequency band to meet the requirements of those administrations. The band 2400-2500 MHz is designated for industrial, scientific and medical (ISM) applications across Europe.

The 5 GHz band

The 5 GHz band has been the preferred radio standard in the United States, because of the higher throughput and greater channel diversity. In Europe its use has been more restricted and the regulations have varied by country [7]. The main reason has been the concerns about interference with airport radar, operating in Europe in the 5 GHz band. The situation changed not until July 2003, when the agreement over the frequencies and power levels took place in the FCC World Radio communications Conference (WRC-03). Due this harmonisation the EU countries and the U.S. agreed to common rules for Access Point (AP) transmit power limits.

In practice the agreement means implementation of two new technologies: Transmit Power Control (TPC) and Dynamic Frequency Selection (DFS). TPC enables IT managers to control the transmitting power of the APs (cell size). In Europe the maximum transmitting power is 100 mW (20 dBm). DFS is used before an AP transmits on a channel to see if radar is in use nearby. If active radar is detected, the AP is shut down. This feature is required by all countries in the EU by the year 2004. A more detailed band allocation is presented in the table 3.1 [7].

Table 3.1: Band allocation of 5 GHz devices in EU & U.S.

Band (GHz)	Channels	Use
5.15-5.35	8 (36-64)	Common between Europe & the US. Used in almost every European country.
5.47-5.725	11 (100-140)	Expected to be available in all European countries by late 2004. Made available in the US in late 2003.
5.725-5.85	5 (149-165)	Available in US and China, not permitted in the EU.

From this total of 450 MHz, the first 100 MHz (5.15-5.25 GHz) is allocated for indoor use only, while the remaining 350 MHz is allocated for mixed indoor/outdoor use.

3.3 Regulation in the U.S.

In the U.S. the responsible body for managing radio frequency spectrum usage for non-federal government purposes is The Federal Communications Committee (FCC). The IEEE 802.11 devices are not specifically referred within the requirements of the FCC Rules and regulations, although the content of Part 15, providing the requirements for the operation of license-exempt devices, has been taken into account.

The requirements for the 2.4 GHz devices are presented in section 15.247. As mentioned earlier, the harmonization of the 5 GHz band makes the differences between Europe and the U.S quite minimal.

4 Open vs. licensed spectrum

As pointed out in the first chapter, the impetus to frequency spectrum licensing came from the technological constraints of radio transceivers. In the beginning of the last century radio receivers were able to listen to only one amplitude of a signal at a time and all the other signals at or near that frequency could confuse the receiver. This is what generally is called interference, although the real problem is not the interference between signals, but the insufficient ability of the terminal to separate the interesting signal from the others. As an outcome, an imaginary concept of spectrum was created to help the regulators to monitor that only one signal would be transmitted in each carrier frequency, assigned to a certain entity.

4.1 Problems of spectrum licensing

The exclusive licensing model has made the spectrum scarce, or this is what it looks like. Because the number of carrier frequencies available is limited, not everyone can have a frequency of their own. During the years several strategies from competitive hearings and lotteries to auctions have been developed to help the regulator to assign the licenses among competing users. For a long time, however, has the technology not been the constraining element or the driver to these different experiments. But this was still the situation in the first half of the 20th century, when a common agreement was, that spectrum is scarce, and that the only way to be able to use it efficiently was by regulation done by an expert agency. FCC published Federal Radio Act in 1927 and Communications Act in 1934. These were originally made to regulate ship-to-shore communication after the horrible Titanic accident, but were pretty fast adopted as the foundation of several other industries based on radio technology.

4.2 From scarce to common

The development of technology has made it possible to handle spectrum as something else than a scarce physical resource. Such techniques as spread spectrum, co-operative networking and software-defined radio make it possible to efficiently use a wide range of frequencies and make the terminals wise in a way, which they are capable of adapting to the changing environment.

The tragedy of commons [8], a concept developed by an ecologist Garret Hardin, is widely know and suits also well to describe the problem of spectrum allocation. Too many sheep in the same meadow will use up the grass and too many cars on a highway will cause a traffic jam.

The use of spectrum is, however, different. A more suitable metaphor would be to think ships traversing the seas. In spite the chance of collision, the oceans are huge relative to the volume of shipping, which makes the risk suitably small. Also the crew, just like a modern radio device, observes the environment continuously, which gives the ship a chance to change course if a collision risk was discovered. This gives a reason to argue, that the seas, as well as the frequency spectrum, can not be used efficiently if the users were allowed to use only certain routes. Another thing, similar to the use of radio spectrum, is the use of acoustic spectrum. For example, in a room full of people, conversation can be carried on as long as people speak at a normal volume. Despite the many simultaneous conversations, one is able to distinguish one conversation from another, because people are modulating their conversation in an appropriate way [1]. This end-terminal intelligence, that makes the device able to communicate even with other sources in the vicinity, is the main reason why the frequency regulation is not necessary anymore.

4.3 Internet as a pioneer

Internet can be used as a good example of an "uncontrolled" system. It is not owned by any single entity and the intelligent terminals communicate with each other using widely accepted routing protocols without anyone having to control it. Also can it be pointed out, that the driver of innovation and growth has been the competition in the equipment market, not the competition in the infrastructure market. The bandwidth has been regarded as a common rather than as a controlled resource.

Internet can also be used as an example of decentralized intelligence, where the network infrastructure is kept as simple as possible and the intelligence is moved towards the edge of the network by giving the end-user devices more responsibilities.

5 Open spectrum in practise: Case WLAN

The conversation around the open, or unlicensed, spectrum has been vivid especially in the United States. The unlicensed bands of 2.4 and 5 GHz have been designated over there for ISM applications for many years ago, but it can be said that the first important communications technology based on those frequencies was not invented until 1997, when the IEEE 802.11 standard was published. The market evolution has been rapid. The size of the U.S. Wi-Fi market is estimated to grow up to $2.8 billion before 2006 [9a].

5.1 Variety of solutions

One of the key reasons to the success of Wi-Fi has been the versatility of the technology. It is capable to operate in two totally different modes, infrastructure and ad hoc, which make it possible to provide wireless local area network services based on the 802.11 standard, as well as use the same devices in occasional machine-to-machine data transfer.

The infrastructure based WLAN networks can be further divided into environment divisions as follows:

- *The Public* environment is an area where the public presence is unrestricted, including outdoor areas, streets, transportation centres, retail stores, hotels, restaurants and public spaces and lobbies in major civil buildings.

- *The Corporate* environment includes offices and factories where the users are restricted to employees of the business. Restricted visitor access may also be accommodated. The services are primarily provided for internal users and access to other networks may be screened.

- *The Residential* environment includes individual homes and apartments where the users are restricted to the residents and their guests. The WLAN access point owner and user are most likely the same, but a multi-user solution is also possible. For example one access point may serve several users in a multi-tenant building.

5.2 Outlook of WLAN

From the commercial view point, the public environment is the most interesting one. The public hotspot market has experienced enormous growth, in 2003 the number of hotspots in the world was almost 28.000 and it has been estimated to grow up to 160.000 until the end of the year 2007 [9b]. This growth continues also in the end-user sector, the number is estimated to grow from 9.3 million to 30 million between the years 2003-2004 [9c].

In the manufacturer side the business has been enjoying continuous growth already for several years, although the life cycle is reaching the state of maturity. Dell'Oro Group has predicted a 23% growth for the manufacturer industry, which should last till the year 2006 [9d] (Figure 5.1). This prediction is based on assumption, that in the future the radio device will be embedded into the terminals.

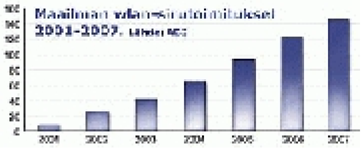

Figure 5.1: WLAN chip deliveries worldwide 2001-2007

Conclusions

The licensing of radio frequency spectrum in the beginning of last century was based on pure need, resulting from the inadequate technical quality of the radio receivers to be able to cope with several adjacent frequencies. As a consequence, a whole new industry model was born as licenses were admitted to only few entities.

Nowadays, the relevance of licensing can not be explained by technological constraints. Especially in the U.S., the conversation about open spectrum is vivid and the demand of new unlicensed spectrum intense. Currently, the use of unlicensed frequencies is carefully monitored and various functional limitations exist. For example the limited transmitting power marks the limits of possible applications and services quite heavily, because the range of the devices is relatively short. The rapid growth of WLAN industry points out the potential behind the technology and has also revolutionized the operator industry by giving almost everyone a chance to become a service operator.

On the other hand, the idea of allocating exclusive transmitting rights to only selected parties includes a lot more, than just the possibility to avoid interference. In the telecommunications industry, the companies providing telecommunication services are responsible of a whole lot more, than just maintaining the communication networks. They are also responsible of guaranteeing a certain quality of service, maintaining customer databases in order to be able to mediating and billing services and so on. By allocating the licenses through some kind of comparison process, the regulators can be sure, that the operator is capable to provide all the services needed.

WLAN and 3G networks are providing basically the same services. WLAN can not provide mobility, partly because of the lacking handover mechanisms, but also because of the limited transmission power. The cell size of WLAN network is so small, that building a large enough network coverage is economically not profitable. However, the telecom operators are still struggling with the costs of 3G auctions, which have delayed the launching of new networks. At the same the public WLAN business is growing rapidly demonstrating the potential of open spectrum technologies.

A total cancellation of the frequency regulation can not be justified at the moment, but sufficient evidence supporting the open source model exists plenty. At least, the current amount of unlicensed spectrum should be increased and new frequencies below 2 GHz should be allocated. This would improve performance.

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