IMPACT OF SOFTWARE RADIO ON EFFICIENT SPECTRUM SHARING

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***Abstract**: The radio spectrum is a limited resource shared by various types of services, for some of which the allocation of frequencies was decided several decades ago. Since, then, a drastic progress has been accomplished in technology. As a consequence, a much more efficient use of the frequency spectrum can be contemplated. SDR techniques seem to have considerable potential in solving today's disarrayed frequency allocation and therefore efficient and flexible frequency management as described in this article.*

1. Introduction

The telecommunication market is increasing dramatically and is heavily influenced by the standards and radio spectrum issues. Demand for radio spectrum is growing steadily due to technological, market and regulatory developments and spectrum availability will become soon a key element for future systems. This is not balanced by additional radio spectrum becoming available through the introduction of new and more, efficient technologies such as digital radio systems in the areas of broadcasting and mobile/personal communications. The consequence is that the scarcity of radio spectrum is increasing. Where the radio spectrum is congested, choices need to be made to balance the demand and supply for radio spectrum [1-2].

The use of the radio spectrum is regulated and the assignment procedures are changing. Given the increasing importance of commercial applications and market considerations, nowadays all the players such as regulatory bodies, operators and manufacturers are being involved as the co-ordination and management tasks have grown more complex than in the past. Rapid changes in technology, liberalisation of markets, globalisation and the public welfare are all dynamic forces that present a dramatic challenge to regulators. However, it is also a challenge that can be met through strategic planning and recognition of the same fundamental principals that can lead to optimal spectrum usage . These are, namely:

- Market driven allocation and assignment,
- Competitive service promotion,
- Regulatory flexibility and technological advances,
- International co-ordination.

The crucial factors for efficient spectrum management in radio communication systems include spectrum pricing, spectrum funding, harmonization, regulation and licensing, assignment, allocation and also advances in technologies such as Software Defined Radio (SDR). SDR techniques seem to have considerable potential in solving

today's disarrayed frequency allocation and therefore more efficient and flexible frequency management in future [3].

To maximise the benefits associated to SDR technology, more flexibility is also needed in current spectrum management rules and practices need to evolve in parallel with the technological evolution. Thus, an additional challenge for SDR success will also reside in the design of new rules for a more flexible spectrum allocation management. The full benefit of SDR technology will only be reached if new spectrum engineering practices are developed to maximise efficient and effective use of the scarce radio spectrum resource, taking into account the diversity of Radio Access Technologies (RATs), the multiplicity of operators and the existence of regulator rules across the different regions.

In this article, we mention first, present spectrum sharing problems along with existing sharing schemes and then future priorities. Furthermore, SDR technological solution is given as one of the key approach in achieving efficient spectrum.

2. Basic Facts

Spectrum is a basic natural resource as water, air energy, and so on, which has to be shared as the other natural resources. However, spectrum has some specific characteristics:

- It can be reused nearly indefinitively as we increase the number of the base stations and so the infrastructure cost (**Major role of economic factor**),
- The service given by spectrum usage is dependant on infrastructure design (MS to BS distance) and on highly variable propagation conditions (**a service does not correspond to a fixed spectrum part**),
- Different parts of the spectrum have different characteristics in particular in propagation (**no full spectrum trading**).

In general sense, it is important to note that various actions will be needed to optimise spectrum usage between applications which are expected in the near future and which will use current technologies. However, changes will have to go even further when today's research reaches the industrial stage. Consequently, we must prepare a flexible spectrum management process that can rapidly adapt to forthcoming requirements. One of the potential solution is the Software Defined Radio (SDR) as outlined in this article.

3. Present Allocation Situation

Spectrum is allocated in bands « owned » by users due to technical differences, for simplicity of equipment design (antennas and filters,…) and also to master interference simply.

Every network is run independently with basically no sharing. For each design, it is presently more economic to ask for more spectrum rather than increasing the density of the network. The only exception could be the UMTS licences in some countries. But their rationale was not spectrum efficiency and such high price tags can induce

network strategies only if all spectrum band are taxed similarly in proportion of their technical values in network design. Consequently, spectrum is poorly used although it is fully occupied. In other words, very few bands are really used at a given time and at a given place. There is a paradox: ***a highly demanded limited resource is in fact poorly used***.

When spectrum efficiency and new bands cannot satisfy the increasing demand another possible resource is to share the same band between different systems. This is a normal case of the ITU table of allocations but, the intent was that the different systems would be disseminated and so would rarely interfere. A better sharing scheme is necessary taking spectrum characteristics into account but, also getting closer to the sharing strategy of other natural resources [4-5].

With present radio systems sharing rather means "***accepted interferences***". Indeed when sharing appears to be the only way out to start operation of a system, all interested parties may prefer a cumbersome situation with acceptable interference rather than no operation at all. Currently, sharing is done case by case basis and often country-by-country basis. NATO bands basically is not negotiable for sharing purposes in Europe. In the mean time, some civil applications are chasing military de facto.

Presently, if we look at the sharing that can be achieved between two or more radio services occupying the same portion of the frequency spectrum in one of the following ways:

- **Time Sharing**: Use of the same frequency by different services at different times,
- **Frequency Separation**: Simultaneous use of different parts of a shared frequency band by different radio services,
- **Geographical Separation**: Simultaneous use of the same parts of a shared frequency band but in separated geographical areas,
- **Non-Interference Basis (NIB) Sharing**: Simultaneous use of the same parts of a shared frequency band but at the same time in the same place but on a non-interference basis operation.

4. Time and Space Sharing

A radio network is dimensioned for worse traffic situation in time and in space with the limit:

- The peak traffic is not served if it does not generate direct or indirect revenues to cover the infrastructure costs,
- More generally, quality objectives are set (lost traffic, delay, error rate, speech quality,…).

Obviously, since networks do not experience the same traffic peaks in time and/or space sharing is necessary over the larger portion of the spectrum.

5. Some Early Sharing Schemes

- **PAMR** (Public Access Mobile Radio for professional) : Many small traffics are trunked.

- **DECT** is intrinsically able to dynamically share the same spectrum for very high efficiency. However, it is of little use since its success is limited to domestic or intra-company networks.
- National Roaming for GSM : Although GSM terminal can roam on the whole GSM band (or even bands) operators limit usage to their bands, only a few agreements to share cost in low density areas.
- Some users happen to share the same band. For example, military and GSM or WiFi in France. But, this is accepted when the usages are geographically separated.
- Ad-Hoc systems such as Bluetooth and WiFi.
- **UWB** (Ultra Wide Band): The resulting sparse and complex use of spectrum have lead to the UWB proposal. By spreading over very large band, the noise introduced in all bands is either with no harm if the band is not used (at this place and at this time) or with an acceptable harm if is used. This is acceptable for few users – if this method is generalised the noise level will raise in all used bands bringing difficulties: (**UWB is a false solution to real sharing problem**).

6. Required Sharing Scheme and Priorities

Sharing conditions should be carefully examined and basic rules should be established. Sharing conditions must be explicitly defined and not case by case basis. New ways could be explored.

The key strategy for sharing of other natural resources is two-fold:

- Provide infrastructure to satisfy in normal situation all demands (water, electricity, roads,….) using eventually various incentives (price variation..)
- In case of exceptional situations/temporary situation, set the priorities.

If we consider the first case – satisfy all demands-, the most efficient method to handle all traffic is that Erlangs laws apply fully to give the best efficiency. Of course, this means to group the maximum of radio access system in the largest available bandwidth. This is the strategy opposite to the present strategy. ***A step in that direction is to introduce flexible Radio Access to different networks (a need for capacity of SDR)***. The economical limits will still impose a « tail » congestion to be treated with priorities.

« Normal » conditions will still have exceptional situations due to accidents, network failures, special events, etc. In that situation, traffic cannot be satisfied and as in other natural resource distribution, we can

- Lower the quality such as waiting time, delays, usable rate, error rate, etc. Many radio systems have already introduced such schemes (for example GSM has HR/FR –Half/Full Rate codecs).
- Set the priorities : This is of course difficult because it is mostly application dependant, but simple rules can help such as privileges for some particular cases, higher cost categories and control mechanism.

7. SDR for Efficient Spectrum Sharing

It is foreseen that terminals will soon be able to digitally process a large part of the RF signal and therefore decode simultaneously many different signals from different systems (example: DECT, GSM, TETRA…). The terminal will download the software required by a specific system and then act as any terminal of this system. However, why not then adjust locally the band required by all systems and adapt dynamically to the local traffic, including implementing priorities between different applications? Then

spectrum is no more linked to any specific application, which does not therefore need a pre-assigned band.

SDR can easily be programmed to transmit and receive on multiple frequencies using various transmission formats. This capability will change the way users traditionally communicate across wireless services and hence promote more efficient spectrum use. In the SDR concept, functions previously carried out in hardware (generation of transmitted radio signal and tuning of the received radio signal) are performed by software in high speed digital signal processors.

As all functions are carried out by software, the radio is programmable, allowing it to transmit and receive over a wide range of frequencies and to emulate virtually any desired transmission format. The operating parameters of such a radio can be readily modified by a simple software change. The greater efficiency of communication links that software defined radio technologies will offer has considerable potential to enhance the participation of countries in the global economy, to improve access to new services and also to make more efficient use of the frequency spectrum.

The benefits of SDR for major players can be depicted in Table 1 [6].

Manufacturers	**Network Operators**	**Customers**
• reduced set of HW platforms developments for each radio system and for each market, • cost reduction, reduced inventory, scale economy, • possibility to correct and improve SW in successive phases.	• faster introduction of new services, • services differentiation, • possibility to reach an open standard, releasing proprietary ones, • simultaneous implementation of more standards on the same BS, • coverage flexible upgrade.	• new services and their personalisation, • worldwide roaming improved and guaranteed, • reduction of terminal obsolescence time.

Table 1

8. Conclusions

Spectrum sharing is still in a feudal system of the Middle Age, i.e. every network has full right on its « *territory*». However, as the radio spectrum optimisation for the upcoming omnipresent applications can not be avoided, this « *cake slicing*» approach that has prevailed in most instances must rapidly evolve to a flexible, evolutive coordination between users. Consequently, new sharing schemes are necessary and this paper proposes a few tracks to pursue , viz:

- Grouping radio access (Software Defined Radio),
- Variable negotiated tariffs depending on congestion,
- Right to use allocated bands and also **SHARE**.

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