Spectrum management trends to satisfy the growing mobile data traffic

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Abstract

It is generally expected that the mobile data traffic will continue to grow very much the coming years. This paper covers the options a) allocating of new frequency bands, b) improving spectrum-sharing methods, and c) allocating more radio spectrum for commons. We discuss physical and technical aspects, and provide some comments concerning regulation and trading aspects.

1. Introduction

Since the digital mobile communication was rolled out in the early nineteen nineties it has become commonplace all over the globe. Together with the Internet mobile communication has now become a general-purpose technology and it is difficult to see the society without it. Numerous predictions indicate heavy mobile data growth in coming years. The penetration of smart phones, tablets and machine-to-machine communication devices increases, as does the traffic they generate. The exponential growth of mobile data traffic severely challenges network operators. Intelligent transport systems (ITS) and cloud computing applications make it even more severe. To deliver mobile data services in a cost-efficient manner one of the key factors is radio spectrum availability and efficient utilization. See [1] for a brief introduction to radio spectrum management.

The world is now in the midst of a major debate about the public policy goals. In 2000 the UN Millennium Goals have been formulated, with universal (broadband) connectivity as an essential element of sustainable social and economic development. The Millennium Summit was followed by a number of initiatives, activities, and projects, leading all to a great progress. However, in spite of the progress made, the "digital divide" has not disappeared and continues to exist. Especially rural and developing areas, inhabited by a large part of the society, suffer economic and social disadvantages due to problems of distance and remoteness and just in these regions the communication services are most needed.

One of crucial factors here is the cost and in many cases digital mobile communication is the least expensive. Sure, newer less expensive technologies will certainly appear in future. High frequency millimeter bands will become more popular for mobile terminals. High-altitude communication platforms and low-earth orbiting satellites [2], proposed several years ago, may finally be used in the years to come, with less tension concerning other spectrum users. Cable-based technologies, popular in densely populated areas are too expensive for application in regions of low population-density. In regions with some 500 people per squared kilometer or less, the radio-based access is the least expensive, from two to four times cheaper than other technologies. The total cost of radio access consists of the equipment, infrastructure, and licensing costs taken together, with the latter one depending on the way the radio spectrum is managed and regulated. A recent study of International Telecommunication Union (ITU) shows that the satellite and terrestrial wireless technologies together share only about 2% of the market [3]. A question arises why these technologies are not more popular? Answering that question exceeds the scope of this paper; we have, however, to indicate that mobile communication technologies contribute significantly to closing the gap in developing countries.

According to one of the major vendors broadband mobile subscriptions will grow much more than alternative broadband and will pass traditional mobile subscriptions in a few years [4], see Figure 1. The access to radio spectrum has always been limited. For mobile applications, the most attractive frequencies are those that easily can cover a large physical area and also to some degree penetrate or pass around obstacles. As they have already been allocated and utilized by other radio based services, the community may decide to provide more radio spectrum for mobile data traffic at the expense of other utilization. A second approach is to improve methods for spectrum sharing such that the total spectrum utilization efficiency is higher; more data is transported per frequency-area unit. Important factors to get this to workable methods include regulatory regimes and the dynamics of these actions, as the sharing regime must change within very short time slots. A third wave is to strengthen the role of spectrum commons, to allow for replicating the successful way pioneered by the Wi-Fi approach.

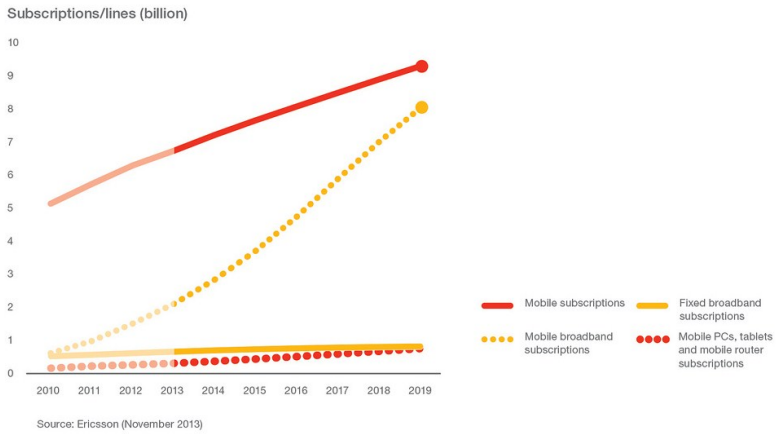

Figure 1. Number of mobile subscription and fixed broadband subscriptions with forecast until 2019, as seen by Ericsson [4]

This paper elaborates on these three radio spectrum management trends options: new mobile radio frequency bands in Section 2, improved methods for spectrum sharing in Section 3, and more radio spectrum for commons in Section 4.

2. New Mobile Frequency Bands

It is the ITU that allocates frequency bands to services through the mechanism of the World and Regional Radio Conferences. An exercise to identify new frequency bands for mobile services took place in at the World Radio Conference in 2007 (WRC-07), and now a similar study has been done preparing for the WRC-15 [4]. The study indicates some 300 to 400 MHz of new spectrum has to be made available by 2020 for the traditional IMT-2000 and IMT advanced technologies, in practice in the lower frequencies bands say below 6 GHz. When approved at WRC-15, the spectrum authorities will then make available these bands for the national areas, and other types of services may be denied, reduced, or moved to other bands. For instance, a number of frequency bands allocated originally to television have been recently made available for other applications.

This way of radio spectrum management represents now the traditional method and is also currently the dominating. Mobile network operators get the right to use it for many years and use this as an incentive to invest in costly network infrastructure where it may take several years before it becomes profitable. The authority usually sells the right through auctions and often an operator pay a lot for spectrum. However, if the spectrum in the end is not used as planned or promised, the regulator may include rules to allow other users access. The traditional command and control regimes start to enter into a more flexible spectrum opening up for spectrum sharing if the spectrum is not satisfactory efficiently utilized, or its use was postponed for too long time.

3. Better Frequency Sharing

By taking better radio spectrum sharing methods into use its degree of utilization will greatly improve. Advocators underline that current methods to change or share the spectrum use rights are far too slow, and as indicated in the previous section it may involve changes to the Radio Regulations (RR). The latter takes usually many years. But even without change of the RR to get the right to use spectrum involve slow processes.

The sharing methods have been suggested under various names, see [6] for an overview. It is called authorized shared access (ASA), licensed shared access (LSA), or priority access (PA). These methods are related to secondary use in bands already occupied by another server, such as broadcast white space bands, where a dynamic spectrum access (DSA) method is suggested. New ideas have been launched to combine radio technology that dynamically can adapt to the environment and change operation frequency (and other parameters) on the fly still respecting rules such as unacceptable interference thresholds [7]. Such methods may use micro-trading techniques [8] to allow secondary users trade on the spot when the resource is needed. See [9] for a comprehensive review of regulatory issues, technologies, and methods suggested for dynamic utilization of TV white spaces - frequency bands freed after changing from analog to digital television.

Other schemes include shared license and a system for the parties to get access to the frequency when needed. The proposals all suggest that sharing can take place while keeping some basic rights and ensuring that

no harmful interference for own service. The sharing shall be beneficial for all parties and the degree of spectrum utilization increases at the same time: all stakeholders win.

4. More Frequency Commons

Allocating new frequency resources on an exclusive (or primary) basis using radio regulation (Section 2) represents a traditional spectrum management method controlled by national governments together for the global and regional scale, and individually per country respecting international agreements. It ensures long term planning and investments by the actors; it may well be argued that these schemes have made it possible to establish the large and anywhere mobile networks. Nevertheless, this type of classical spectrum management scheme is criticized to be inefficient and that large portions of useful radio frequencies are not fully used at any location and instant of time. A radical rethinking is needed and that spectrum can be and must be used far better in the future.

One of approaches to spectrum management bases on the concept of sharing the common frequency resources, with the most popular example being the license-exempted Wi-Fi family of technologies. Breaking away from selling/auctioning licenses lowered significantly the access cost. It also evidenced the practicability of the shared spectrum commons above any doubts and showed numerous benefits in comparison with the exclusive/ private spectrum promoted widely in recent decades. In 2013, more Internet traffic was carried over Wi-Fi than via any other path in the U.S., resulting in some $222 billion in Value Added to the U.S. economy alone. A recent study by WiFiForward estimates that technologies operating in unlicensed spectrum bands in the United States generated a total economic value of $222 billion in 2013 and contributed $6.7 billion to the nation's Gross Domestic Product (WiFiForward is a group of companies, organizations and public sector institutions, including Google, Microsoft, Motorola and others.) [10]

Since launched just before 2000 the Wi-Fi technology using radio spectrum called commons. Here very simple rules apply most importantly everyone is allowed to transmit a signal as long as it is within a specified power. It may be said that there is not so much spectrum management needed either. Under this regime the Wi-Fi technology currently transport a major part of the traffic between user terminal and some fixed point in the network. How can it be that just a fraction of the useful radio spectrum carries at some instant a clear majority of the data traffic? The answer is simple enough: the distance served is short and the communication protocol eliminates mutual interference. Moreover, as there is no individual license required, so the barrier entry is low. But as anyone can transmit a signal, and so is done in practice, talking here about the ISM band (e.g., 2.4 GHz) the concern at the start and more now is that congestion will eventually kill the service at some point. In the end the traffic will try to grow beyond what is possible to deliver. Hence new bands must be identified, may be then with assured quality included, roles for how the band is shared. This represents a new type of commons with other features than the classic ISM one. Presently, the unlicensed (ISM) part of the spectrum is extremely small and becoming congested. To continue enjoying it, there is a lot of work to be done here.

The concept of commons started to revive as a reaction to the privatization wave and the case of Elinor Ostrom is the best example: she has got a Nobel Prize in Economics in 2009 for her analysis of economic governance of the commons. In her opinion, commons can be best managed by the owners' community itself. It is interesting to note that, without knowing her theory, the international radio community does that with great success since 1906 in the framework of the ITU World/ Regional Radio Conferences, where the spectrum access is offered to any country for free. And it works!

5. Conclusion

With the expected and also in many respects wanted mobile connected world the data traffic will grow dramatically. Radio spectrum plays one of the most significant roles as the enablers, and most likely to be more and more congested must be managed significantly more efficient in the future than done at date. It seems that new regimes for spectrum sharing will be implemented and made workable along with smart radio technologies, as illustrated in Figure 2. The incentives for business will be kept one way or the other, but a combination of commonly shared rules and trade is more likely than an extreme regime either fully controlled by trade or fully controlled by exclusive rights.

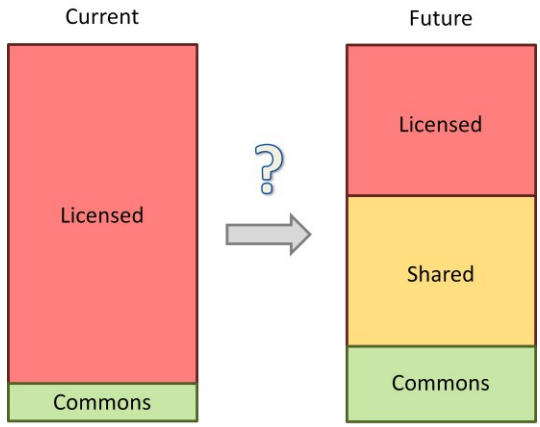

Figure 2. Possible categorization of radio frequencies for broadband mobile networks below 6 GHz (not to scale)

It is generally accepted that improved spectrum availability benefits the society at large, and the improvements are sought in device hardware and software, and in the way the spectrum is managed. These directions have to complement each other and match local conditions. Even the best technology is useless if the regulations do not allow for its operation. It seems, future wireless devices would "negotiate" among themselves how to "best" use the available spectrum resources, following the principles, criteria, and algorithms embedded in such automates. One expects, however, the principles and criteria to still be mediated at conferences to balance conflicting interests of all the parties interested.

The DSA, Cognitive Radio (CR) and self-organizing systems (SOS) are first steps in that direction. For the time being much of the related regulatory work has been left for national authorities. Setting national radio regulations for DSA, CR and SOS separately in each country may lead to national differences and legal uncertainties in an inherently borderless medium. Harmonization of national regulations is necessary to avoid a patchwork that would fragment the market and make the international commercial success and benefits to the society much harder to achieve. Without such a harmonization, national decisions about DSA, CR, and SOS may be mutually inconsistent, which would put us back some hundred years ago when cross-border communication was a serious problem. Such a harmonization may be difficult to achieve in the framework of intergovernmental organizations like the ITU. While the governments reserve the right to decide for themselves, the companies invest large amounts in research and take the whole business risks. It is thus natural they seek the innovation (Schumpeterian) rent and try to keep the monopoly as long as possible, but this in turn puts other companies into disadvantage. When the particular interests and interests of the whole society are mutually contradictory, it is not easy to find a properly balanced spectrum management policy.

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