Beachfront Commons

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Abstract

Technology competition between wireless communication technologies can lead to new, more or less disruptive services. A potentially disruptive technology would be to have unlicensed transmission in the lower UHF bands at power levels up to, e.g. 2 W EIRP. This would give citizens a share of the best spectrum for free use. Tools against congestion could be based on mandatory stochastic channel back-off or, if multiple users are present, on adaptive power and bandwidth control. Compared to the FCC TV white space regulation, no back link would be needed as the spectrum would be used exclusively by wireless devices. In an environment of shrinking interest in terrestrial TV broadcasting, such a regulation is expected to create a new market for high-range consumer devices, competing with licensed communication, while also being suitable for offloading traffic from licensed operations. Furthermore, the approach will allow for efficient digitization of equipment for program making and special events (PMSE), but could also be made compatible with novel disaster relief services. To enable accurate interference prediction, it is proposed that, instead of only providing transmitter regulation, receivers should also be regulated, such as be required to adhere to a certain minimum selectivity. The proposal should be taken up in the WRC process.

INTRODUCTION

During the last 80 years, large and more-or-less disruptive innovations have resulted in big changes in spectrum use and have had a great impact on profits, wages, and lifestyle. Examples of such innovations are TV broadcasting, licensed cellular voice communications, the mobile Internet, and unlicensed communications such as WiFi, some of which have definitely been disruptive. The mobile Internet has been disruptive to SMS revenue (Weber et al. 2011), and WiFi has turned out to be disruptive to 3G in the sense that more bits are transmitted via WiFi than with licensed cellular wireless communications (estimate according to Rethink Wireless 2013). Furthermore, the Internet has the potential to disrupt terrestrial TV broadcasting. The trend towards abolishing the latter could be pushed in even more powerful ways than is currently the case, so this disruption is yet to come. Disruptive innovations such as the mobile Internet or WiFi took place while technologies were in competition, such as SMS vs.

email and W-CDMA vs. WiFi. This demonstrates that technology competition can be very useful in reducing costs or promoting new services.

In this paper, it is proposed for the spectrum freed by receding terrestrial broadcasting to be used for a new type of wireless commons, allowing long-range wireless applications that are not feasible given today's regulation of spectrum.

Currently there is a debate over how to use 200-300 MHz of UHF in the future. There is a clear trend towards cable and satellite broadcasting and towards Internet-based TV. The use of terrestrial broadcasting is declining in industrialized countries. In Germany, for example, there is discussion of replacing DVB-T by a tower overlay of 16 MHz via LTE, such as for sports broadcasting (Kürner et al. 2013). Private TV stations have lost interest in terrestrial TV transmission (Mediengruppe RTL Deutschland 2013).

There have also been efforts to use the white space of the TV spectrum, in particular in the U.S. (see Digital Trends 2012, TV Technology 2012, PCAST 2012, Forge et al. 2012). Due to the large cell size of terrestrial TV broadcasting, there are white spaces in the spectrum that can be exploited on a listen-before-talk basis. The approach followed by the FCC allows a high power device to be employed only if it accesses a geolocation database, creating the necessity of a link. The regulation has not, however, led to the creation of many new products, mainly due to its technological complexity. Because of the fear of interference, many bands cannot be used in many areas, employed only in some of the "holes of a Swiss Cheese" (Forde, Doyle 2013). There is also the risk that the operator of the database will remain in control of the white space, such as if an incumbent uses it for providing Internet access (as proposed by Fitch et al. 2011). Finally, providing licenses to users might lock that spectrum for many years to come, even if those TV stations were to stop operating.

It has been proposed previously that there be more commons on lower bands, such as by Lehr (2005; see also Benkler 2012). The UHF bands have very good propagation characteristics, that is, their electromagnetic waves pass through walls with low attenuation but do not travel beyond the radio horizon. However, it has typically been argued that this would either lead to congestion or not be economic.

This paper is structured as follows: First, there is a review of the workings and benefits of disruptions. Second, the crippling of commons by regulation and its justification in current economic thinking are discussed. Third, a concrete proposal for having commons on UHF bands is made, with tools against congestion, creating the potential for unprecedented low-cost communications. If desired, such an unlicensed use of UHF bands could become a secondary use of spectrum with, for example, program making and special events equipment (PMSE) or disaster relief services being the primary users.

A REVIEW OF DISRUPTIONS

It is widely believed that the iPhone created a major disruption in mobile communications. However, most of its initial services, including the flat rate going with it, had been invented in Japan earlier, between 1999 and 2004 (Weber and Wingert, 2006, and Weber et al., 2011). Examples of novel services were mobile email, mobile browsing, mobile applications, mobile music, and the inclusion of digital still and video cameras. In the Japan, these innovations were marketed in fierce competition between various groups of operators, each specifying their radio interface, their services, and their handsets. Each operator tried to benefit from its chosen radio technology as long as possible. As a result, the competition for instance between PDC and PHS and between cdmaOne and W-CDMA became very important. Operators felt uncertainty and learned to specify networks, services, and handsets. For example, PHS operators were able to undercut prices and reduce the weight and size of handsets, while PDC operators were able to offer handover (which PHS initially was not capable of), browsers, and video cameras (a surprise on 2G). Furthermore, it was relatively cheap to provide music downloads by updating cdmaOne, while this was a challenge for W-CDMA. Technological competition thus led to the discovery of the mobile Internet, multifunctional handsets, and flat rates. Email turned out to be disruptive to earlier messaging services, flat rates were disruptive to earlier pricing models, etc. In 2007, Apple "only" needed to polish the user interface and distribute these innovations worldwide, causing problems for old businesses based on pricing data as if it were water in the desert, as was common with SMS and data tariffs in, e.g., Europe (Sutherland 2005).

Another example of disruption can be seen in the repercussions that WLAN has had on W-CDMA. Wi-Fi has contributed to a reduction in average revenue per user although operators of the Universal Mobile Telecommunications System had originally hoped that it would be used almost exclusively – universally – by businessmen, who, however, in many cases preferred to search for a hotspot instead. The competition posed by Wi-Fi led to a large upturn in the number of Wi-Fi-enabled devices, and unlicensed communication even overtook licensed communication in terms of the volume of bits transmitted (Rethink Wireless 2013). In the end, unlicensed was even used to offload traffic from licensed operations. These disruptions led to the creation of new and profitable business, and to the related destruction of incumbent business.

Hence the challenge: Are more disruptions possible in the future which would contribute to a further reduction in the cost of communications or to the development of new devices and markets?

To study the issues, the authors did desk research, conducted expert interviews, and organized a workshop (Weber, Scuka 2011).

A CRITIQUE OF THE CRIPPLING OF COMMONS

Common knowledge, according to scholars such as Cave et al. (2007), suggests that spectrum commons can be used where congestion is unlikely to occur, as in short-range communications (p. 211). These authors also argue that the regulator can regulate power and politeness protocols in order to reduce congestion (pp. 207, 211). In line with this, commons is typically used in bands above 2 GHz, with a firm limit on the equivalent isotropically radiated power (EIRP). Such justifications have crippled WLAN in terms of power, in the EU much more so than in the U.S. Figures 1 and 2 show the current WLAN spectrum regulation for TV white space as well as for 2.4, 3.7, and 5 GHz WLAN in Germany and in the U.S. Similar frequency ranges and constraints can be found all over the world.

The question arises whether spectrum below 2 GHz should be licensed or unlicensed. Taking Cave et al. literally, it appears at first sight that any band could be used with commons using politeness protocols. The usual answer, however, is that such spectrum can be used for licensed services, thus creating a market and contributing to GDP (following Coase 1959).

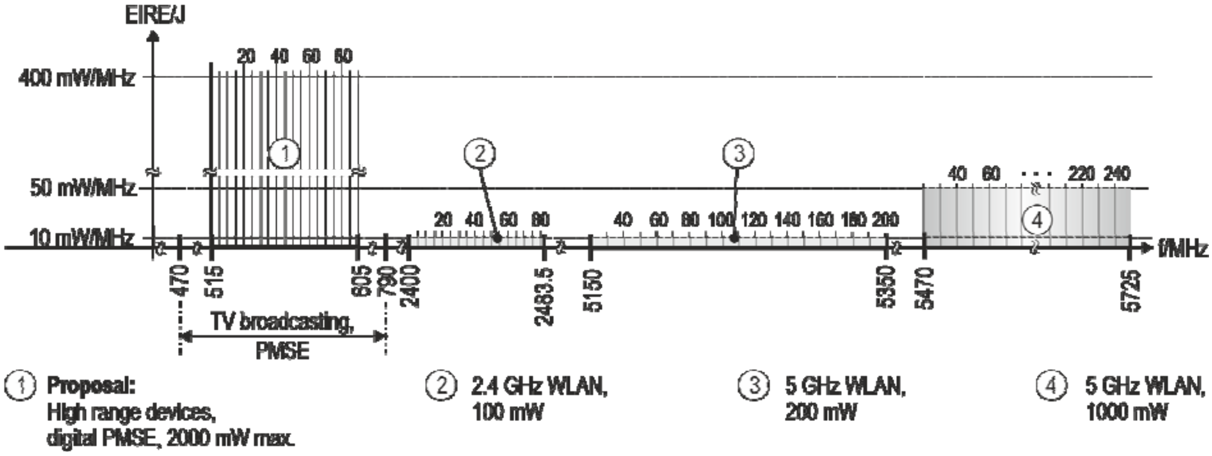

Figure 1: Current and proposed regulation of unlicensed wireless networks, German frequency ranges. The 515–605 MHz range is an example based on German and U.S. spectrum regulation (Bundesnetzagentur 2011).

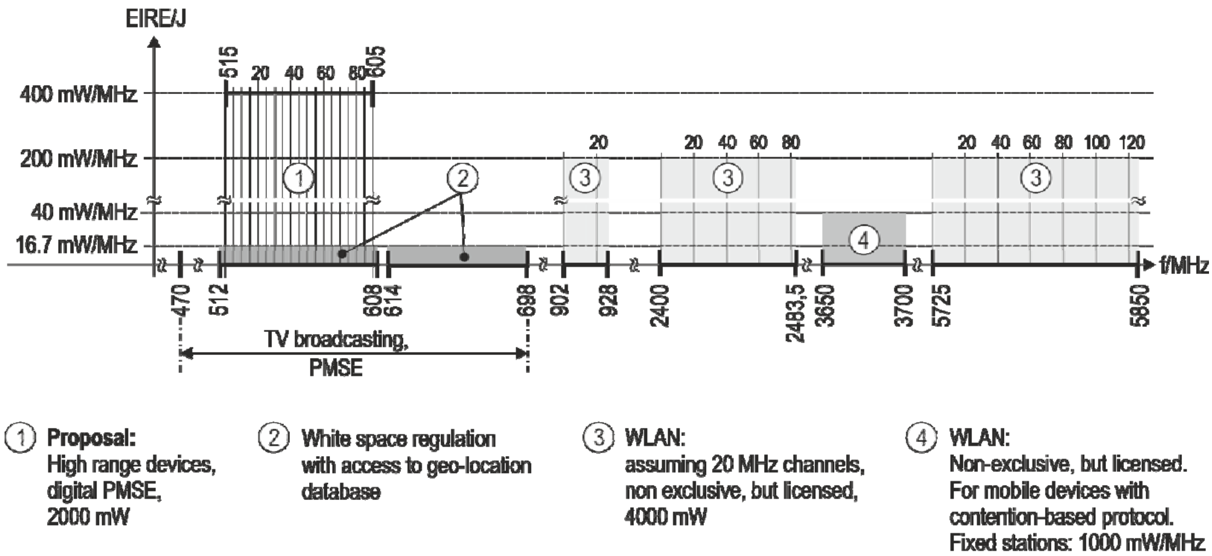

Figure 2: Current and proposed regulations for unlicensed networks, U.S. frequency ranges (FCC 2010, GPO 2013).

However, is it really the best approach to license services below 2 GHz instead of using the commons approach? Traditional thinking, again following Cave et al., suggests that the economic value of a band should be maximized (pp. 3, 227), which can be judged based on the willingness of users to pay. However, society might be interested in maximizing the effect on GDP. This means that a regulatory regime which leads to lower communications costs or higher revenues through the sales of related equipment or services can be better for GDP growth. In more detail, having high-range commons on UHF bands may have various effects:

- Communication costs may be lower, thus making it possible for a country to produce more cheaply and therefore become more competitive internationally. This is much like it happened with classic Wi-Fi, but under the new regime commons could replace a significant share of local communications over a distance of up to one or two kilometers, and more with meshing in suburbs etc. If a user does not find enough spectrum of sufficient quality in that new free band, a user could still resort to paid high-range services or higher frequency WLAN instead. Devices could automatically select what is best.
- All things being equal, operators would, however, have fewer bands to use and hence would have higher costs for setting up transmitters, which might have an adverse effect on communications costs (cf. Chen 2012).
- On the other hand, operators could use surplus capacity on the new band for offloading traffic from mobile devices, much like with Wi-Fi, but over longer distances, and thus save costs.
- New services might emerge, which following Schumpeter would not be known a priori, but could lead to revenues or at least user satisfaction. “If we fail to allocate additional spectrum for unlicensed use in the highest value, lower frequency spectrum, we will never know what might have been”, as Lehr put it in 2005. For instance, if nodes are open and if meshing is easy, relatively large free mesh networks could emerge.
- The production of related components or new services for wide area commons communication could contribute to GDP growth, at least in the countries where the new products are produced. This would be a comparative advantage, much like how traditional Wi-Fi producers earned their profits. Using such a band for licensed services or traditional low-range WLAN might also lead to additional sales, such as of updating equipment, but not to new types of products building on the novel character of free large area services.

It appears impossible to reliably estimate a priori the net effect of such a reform on GDP (see Nattawut 2010 and 2013 for the difficulty of this approach). Given the widely regarded positive effects of Wi-Fi, a positive effect of high-range commons can however be anticipated.

Yet one can also argue on a different level. One could say that the public should determine what it prefers. GDP maximization need not be the only guidance for the population to follow. Coase wrote (1959, p. 14):

"It is true that some mechanism has to be employed to decide who … should be allowed to use the scarce resource. But the way this is usually done in the American economic system is to employ the price mechanism."

This is a reminder that the pursuit of economic maximization is not a natural law. Citizens could rather argue: "Free communication with Wi-Fi turned out to be very useful and provided good competition to 3G. Let us do the same thing with greater reach. Give us at least a small share of the best spectrum for free use."

COMMONS ON UHF UP TO THE RADIO HORIZON

There would, of course, be the option to exclusively provide a certain UHF band to commons. However, there are some competitors emerging for these bands. One is PMSE. Since PMSE equipment is currently a secondary user of the terrestrial TV spectrum, PMSE devices would need to adapt if that spectrum were to be used for something else. The current PMSE spectrum masks allow for 200 kHz transmission channels (Bundesnetzagentur 2011). A change to this spectrum mask is necessary since efficient digitization can only be achieved with broader channels. For example, in Germany it has been proposed that a 46 MHz band around 600 MHz be made available for the exclusive use of PMSE operators (Kürner et al. 2013). Another type of use of the UHF bands is presented by novel types of disaster relief services (Public Protection and Disaster Relief – PPDR). CEPT is discussing using some frequencies between 678 and 758 MHz for PMSE and PPDR services (cf. ECC 2013). If PMSE or PPDR were to obtain a band for their exclusive use, it would leave that band sitting idle in most areas for most of the time. An attractive possibility would therefore be to designate PMSE and/or PPDR as primary users and commons as a secondary use. This would mean that the public could use the commons service in most regions most of the time.

In this paper one option with commons and PMSE is worked out in some detail. A 90 MHz fraction of the current UHF bands would be freed for commons with a transmission of up to 2 W EIRP (see Figures 1 and 2). Tools against congestion could be based on mandatory stochastic channel back-off or, if multiple users are present, on adaptive power and bandwidth control. In light of the current 2G/3G/4G standards and transmission properties, a channel bandwidth of 5 MHz is appropriate, with optional channel aggregation at the same radiated power and hence lower spectral density. A 90 MHz band would amount to 18 orthogonal channels, allowing six cellular-like networks to be operated with a frequency re-use factor of three.

This approach would allow efficient digitizing of PMSE. Allocation of about 90 MHz would provide enough spectrum for a few hundred PMSE devices operating at one single event. PMSE devices need to be given higher priority than commons, for example according to a listen-before-talk protocol, and possibly higher power allowances than other devices operating in this band. A bandwidth of 90 MHz would allow significant amounts of such communication, and a larger channel bandwidth of 5 MHz would allow for digitization, increasing the robustness of wireless links compared to analogue PMSE equipment since analogue PMSE equipment is too fragile to make efficient use of this spectrum in the presence of interference.

An important regulatory measure for all kinds of overlay systems, but especially for wide area networks, is the definition of the minimum requirements for all receivers operating in shared spectrum channels. A minimum quality of service can only be guaranteed to a secondary (and primary) user if a receiver exhibits the necessary selectivity. These requirements should be defined in terms of filter responses, selectivity, and total noise figure. This technical information will make it possible to accurately estimate the effects that subsequent changes in spectrum regulation will have on incumbent users. Today such forecasts are largely left to the studies of lobbyists for conflicting interest groups. The approach presented here would result in a more accurate estimate of an effect. This approach represents a major change in traditional transmitter-only regulation, but provides a scientific basis for predicting interference in heterogeneous spectrum environments. High-range devices also offer a solution to the needs of the next generation of digital PMSE equipment for spectrum that, due to delay constraints, cannot utilize the features of digital transmission with the current spectral masks. Furthermore, the use of higher frequencies is undesirable due to higher body and material attenuation. A change in technology and spectrum mask regulation is necessary to achieve efficient digitization.

As mentioned, the current PMSE spectrum masks allow for 200 kHz transmission channels. Due to the high quality and low delay requirements, high rate channel coding with long interleavers is not acceptable in digital PMSE systems. A digital PMSE system operating in the spectrum mask designed for analogue frequency-modulated systems needs to carry a 48 kHz, 16 bit signal. Assuming a coding rate of R=2/3, one needs to support a data rate of 1024 kbit/s in a 200 kHz channel, or a spectral efficiency of 5.12 bit/s/Hz. This corresponds to 64 QAM, for example, which is technologically difficult to realize and requires a high SINR, thus leading to short transmission ranges. Efficient digitization can hence only be achieved by broader channels, for which a change of the spectrum mask is necessary.

Supporting the same data rate of 1024 kbit/s, as discussed above, in a 5 MHz bandwidth leads to a spectral efficiency of 0.20 bit/s/Hz, an information density that can be easily realized with robust constant envelope modulation at high ranges. Furthermore, the overall system capacity can be significantly increased by digitization and making use of time division multiple access (TDMA) or code division multiple access (CDMA). This amounts to a 50% increase, assuming that an FM signal needs a guard band of 100 kHz and that 25 audio signals are multiplexed in 5 MHz. Using short frame lengths, the additional TDMA delay can be lower than 1 ms, while CDMA would not even introduce any additional delay at the cost of higher technological complexity. Finally, while today's analogue PMSE devices are very susceptible to interference, as every kind of interference is directly converted to an audible audio signal, digital PMSE devices will be able to mitigate interference through source and channel coding and thus minimize audible artifacts. Thus, 90 MHz would allow efficient digitization of PMSE. This band could, for example, be situated between 515 and 605 MHz, but 678 to 758 MHz would also be suitable, a band considered by CEPT for PMSE and PPDR services in 2014 (ECC 2013).

CONCLUSIONS

In summary, it is proposed that parts of the lower UHF bands that are currently used for terrestrial television and PMSE equipment be opened to high power unlicensed access as secondary user, with digital PMSE or PPDR services being the primary users. It has been shown that such unlicensed "beachfront" spectrum can be regulated in a way to avoid congestion. Such a combination will be more efficient than a band used exclusively for PMSE or PPDR. At the same time, it would create competition to licensed communication and scope for innovative ways of backhauling and meshing. Surplus capacity could be used for offloading mobile traffic, as with current Wi-Fi. It is therefore proposed that these suggestions be taken up in the context of the World Radio Conferences so that the technical details can be discussed with all stakeholders.

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