Why DSA is better deployed and modified rather than modelled in detail

Professor William Webb

CTO, Neul
Cambridge, UK

Abstract — **The approach adopted so far to enabling dynamic spectrum access (DSA) is to undertake detailed modeling of the worst case interference and set in place conservative rules. However, even this approach cannot guarantee that all factors are taken into account, is hard to specify in any license and very difficult to monitor in practice. A more pragmatic approach is to implement systems and modify their allowed operating parameters should interference occurs. This paper discusses why this may be both the only practical approach and one that is also likely to reach the optimal position much more quickly.**

Keywords-component; dynamic specturm access, DSA, white space, interference, spectrum management, regulation, spectrum usage rights, SURs.

I. SHARING IS ON THE BASIS OF AN ACCEPTABLE OR AGREED AMOUNT OF INTERFERENCE

Dynamic spectrum access (DSA) involves sharing of spectrum and any arrangement other than the very simplest form of sharing is made on the basis of interference. For TV white space, DSA devices are allowed to access the spectrum as long as the interference they generate does not materially impact on the services delivered by the incumbents. In unlicensed spectrum, coexistence between different systems is on the basis of the impact of their interference on each other. Even when systems are in neighboring frequency bands, the impact of interference across the band edge is a key metric for defining spectrum licenses.

So simplistically, when enabling DSA, we might expect that we could define what an allowable level of interference between different systems is, enshrine this in appropriate regulation and police actual behavior to ensure it stays within defined limits.

As this note discusses, while simple in theory, this is extraordinarily difficult in practice.

II. WE CAN DEFINE INTERFERENCE USING TOOLS SUCH AS SURS

Defining interference levels has been much studied. A good example is the Spectrum Usage Right (SUR) approach developed by Ofcom in the UK [1]. This allows a license to be defined in terms of the interference caused to others rather than the allowed transmit power. A license typically has limits setting out the statistical behavior of both the in-band and out-of-band power levels experienced throughout a geography. For example, a license might specify that signal levels of -80dBm/MHz must not be exceeded in more than 5% of locations throughout a country when measured 1.5m above ground level.

Ofcom looked in detail at how such license conditions might be verified and concluded that the best approach was via modeling rather than actual measurement. All interested parties would agree a propagation model to adopt and each would make available details of their transmitters such as location, antenna patterns and power levels. A propagation tool could then predict the signal level at any location and then determine the statistical distribution of the interference.

There has only been limited experience with SURs but sufficient work has been undertaken to give a strong indication that they can be practically adopted, at least for licensed use of spectrum. Whether they can apply to unlicensed use is less clear, although there have been papers addressing this [2].

III. UNANTICIPATED FACTORS SUCH AS TV AGC CAN DOMINATE

Recent experience, though, shows that measurement of signal levels may not necessarily provide an accurate guide to the impact of any interference. For example, it has become clear that digital TV receivers are much more susceptible to burst-like interference than to continuous transmissions. This appears to be because the automatic gain control (AGC) in the TV receiver is confused by the sudden appearance of a burst and quickly reduces the gain such that the TV signal level falls. Some measurements suggest that some TVs may be 10-20dB more susceptible to burst-like signals. In this case, specifying interference purely in terms of the average power levels seen across a geography would enable higher interfering powers than could actually be tolerated.

It could be argued that this is due to poor design on the part of the receiver and that the spectrum sharer should not be penalized as a result. While theoretically sound, the politics of allowing significant interference to occur into domestic TV receivers would be controversial!

This leads to the conclusion that the impact of interference can only be characterized with certainty when considering one particular transmitter, with a certain waveform, and one given victim, with particular susceptibility. Even then, the transmitter waveform may be variable (eg depending on cell loading) and there may be myriad models of receiver with differing susceptibility. This has all the appearance of a near-intractable problem. Testing every new technology into a band against every existing receiver that is using the band would be a hugely costly exercise and a major impediment to the innovation that DSA is aiming to introduce.

IV. Measurement of interference will generally be near-impossible

Even if it is decided to regulate on the basis of measured signal levels, measuring them is near-impossible. The difficulty in making measurements over large geographies of time-varying signals in any practical and meaningful manner was what persuaded Ofcom to select modeling rather than measurement as the verification process for SURs. However, modeling can only work effectively where there are fixed and time-invariant transmitters. For DSA, the allowed interference levels might vary according to location and the use of spectrum by license holders. There may not be base stations. If there are multiple DSA users the means by which the allowed signal generation is divided among them may need definition. So modeling is unlikely to provide a particularly useful approach.

To understand the problem with measurement, consider a type of Wi-Fi used in TV white space. Measuring the signal level caused by millions of nodes scattered throughout a country would require huge number of measurements across a wide area taken for long periods to capture the fact that traffic levels may vary dramatically. Measurements would need to be at 10m from ground level to understand their impact on TV receivers using external antenna. These measurements might need to be frequently repeated as penetration levels of DSA devices grew. It seems unlikely that anyone would have the inclination or budget to undertake this.

V. Noticing and reporting on interference may be difficult

A different approach would be to note that interference is only a problem if it can be noticed. It may not be particularly relevant to worry about whether a DSA device is exceeding its allowed or intended interference levels if it is having no actual impact on any licensed user. This might be because there was no licensed user in the vicinity, because their equipment was superior or because the assumptions made on interference were conservative and there were adequate margins to accommodate the increased interference. Users could indicate when the experienced interference and action taken accordingly.

Unfortunately, this is also far from being as simple as it sounds. If we again take the example of a TV viewer, they may experience interference but might (1) ignore it, (2) assume it is due to their receiving equipment and purchase a new receiver or (3) not know to whom they should report the interference. If the interference is sporadic, as is normally the case, it may be difficult for anyone investigating the issue to replicate the problem or to have sufficient time to track it down. Further, it cannot be assumed that the interference is due to a DSA device – it could be due to anomalous propagation, weather conditions, failures at the TV transmitter or many other causes.

In some cases, determining interference may be simpler. Professional users such as emergency services can be told where to report interference issues, can typically be relied upon to have well-installed equipment and can potentially have monitoring devices attached to the equipment to perform diagnosis over time. The same may be true for some types of military usage.

If the problem is widespread then it is likely that whatever the difficulties it will be noticed and resolved over time. The more difficult cases are where the interference impacts only a small number of users in a manner that is annoying but does not completely prevent reception. Perhaps, in a world of blogs and on-line discussion groups, even these issues will bubble up to become visible to the regulator eventually. Indeed, through a website that can be readily found by users and allows them to enter simple details of the interference experienced, aggregating this information across a large number of users might allow patterns to be spotted and diagnosis to be performed without measurements. Development of such websites and tools might be an important part of implementing DSA.

VI. With these uncertainties better to take some risks and address issues post roll-out as needed

The analysis above suggests we can broadly adopt one of two approaches:

1. Exhaustively test any new technology against all existing receivers in the target band, construct detailed sharing scenarios and build conservative models to lead to allowed usage.

2. Use generic approaches such as SURs and set in place mechanisms to monitor interference should it occur as far as possible.

In the TV bands the first of these approaches has been adopted. This was for two reasons. Firstly, the difficulties with this approach were not understood and it was assumed it could be made to work effectively. Secondly, a political "bargain" with the broadcasters where they were guaranteed no interference was necessary in order to progress the required regulation. This political bargain may have significant repercussions in limiting the efficiency of use of this vital band, but was likely the only way ahead at the time.

Selecting between these two approaches is a choice between risk and reward. The first – exhaustive testing – is low risk. It results in the least likelihood of interference or that the rules of DSA will need subsequent modification. But it is conservative, leading to a lower benefit of the use of the spectrum. This lowers the GDP contribution of spectrum, innovation and growth. The converse is true of the second. It seems likely that the risk in this case falls mostly on the DSA user. If there is severe interference to the licensed user then, subject to the points noted earlier, it will inevitable eventually be noticed and the rules of access modified. If this results in, for example, a change in the allowed transmitter powers for the DSA system this could be highly problematic for a system designed with overlapping cellular coverage. The shrinking of cells as power levels are reduced could leave a coverage gap around each cell that might require massive network re-planning to resolve. The balance of risk toward the DSA user is generally simpler to manage since the license holder typically has a deployed and stable system and is in low-risk mode whereas the DSA user is implementing a new system, technology and service and the risk of changed spectrum access is just one of many that they face.

Selecting between them will also depend on the risk-aversion of the licensed service, the political difficulties in introducing DSA and the level of experience gained with DSA operation. If DSA access in TV bands is successful it might be expected that the perceived risk of DSA access in other bands will reduce while the evidence of the reward of this approach will increase. Hence, it is likely regulators and users will move from the first to the second approach over time.

History and instinct also suggests that the second approach is better. History tells us that excessively cautious regulation can prevent innovative new services being deployed by raising the costs unsustainably. This has been true in many frequency bands, especially in the US, and with technologies such as ultra-wideband (UWB). History also tells us that interference in licensed spectrum bands is very rare due to a worst-case analysis of a situation that is extremely unlikely to occur. As a result, large margins are built into operation. In practice, systems can work adequately with high levels of interference as Wi-Fi and Bluetooth have shown. This high intensity of usage has led to a very large economic value and utility for users. If the 2.4GHz band had been planned by regulators, they would have concluded the systems could not share and indeed that Wi-Fi needed careful planning. So we can observe that in systems planned by regulators interference almost never occurs and that in unplanned systems interference can be tolerated unexpectedly well. The risk-averse approach is currently much too risk-averse. A move towards an approach that embraces greater risk is overdue.

Finally, consider the practicalities of relaxing rules under the first approach versus tightening them under the second. Relaxing rules would require modeling, measurement, consultation, lobbying and more. There is little benefit for anyone except the DSA user. It seems likely that regulators would be unwilling to do this and it would be very slow, costly and burdensome. Tightening rules in the face of evidence of interference could be done immediately. If we assume that getting to the optimal set of rules will require experience and iteration, we will get there faster and more simply by starting with more relaxed rules and tightening them.

This is why a new approach to spectrum regulation is needed that embraces greater risk of interference, balanced with stronger powers to address it should it occur.

REFERENCES

[1] See, for example, http://stakeholders.ofcom.org.uk/spectrum/spectrum-management/spectrum-usage-rights/

[2] M Cave, W Webb, "The unfinished history of usage rights for spectrum", Telecommunications Policy 36 (2012) 293–300.