Abstract -- This draft document is intended to provide spectrum regulators with ways to improve the utility of future unlicensed allocations by improving the sharing of such bands between diverse systems. The prospect of such new allocations, and the experience of inter-system interference in existing bands, motivates revisiting current FCC Part 15 rules to cope with the fact that very disparate networks will need to co-exist in these bands.

Considerations & Objectives

Due to the proliferation of new wireless technologies and the push to allocate new spectrum for unlicensed operation, such bands will contain disparate networks and conformal devices operating in close proximity. There are two dimensions to spectrum sharing: using the nomenclature introduced by Kruys [8], one can distinguish between “vertical” sharing between systems with different levels of regulatory status, e.g. primary and secondary users, and “horizontal” sharing between systems with equal regulatory status, e.g. various unlicensed networks. In the horizontal sharing case, it is also useful to distinguish between “intra-system” sharing (between systems that are implemented using the same technology or technology family, e.g. Wi-Fi™ devices), and “inter-system” sharing (between technically distinct systems, e.g. Wi-Fi™ networks and ISM cordless phones). This draft focuses on horizontal sharing rules. With no loss of generality, the present draft doesn’t make a distinction between a (wireless) network and a point to point (wireless) connection such as a cable replacement.

Technical standards and coordination between Standard bodies to facilitate efficient shared spectrum use is necessary, but not sufficient. It addresses the intra-system sharing case, but not inter-system sharing. It falls to the regulator as the only common governing authority to coordinate intra-system sharing through the creation of suitable rules.

Heterogeneous networks will differ in several key system parameters: range (coverage), rates, transmit power, channelization, media access protocols, etc. Therefore it is
particularly important that in the interests of optimum utilization of a scarce resource (spectrum), a set of broad principles (aka sharing rules or an etiquette) be put in place that

   a. Allow different networks in close proximity to co-exist by reducing inter-network interference;
   b. Improve the reliability of systems by ensuring a minimum degree of fairness in channel access amongst users;
   c. Improve overall spectrum utilization by defining sharing rules that allow and encourage the introduction of new technologies

Sharing rules must pursue these goals without becoming a design specification; i.e., innovation at the PHY & MAC layers should not be compromised as a result. Any etiquette should be minimalist in its approach and should seek to be a neutral arbiter among the gamut of anticipated networks in unlicensed bands.

Further, sharing rules have an important role to play in mitigating the “Tragedy of the Commons” [5] caused by greedy users who over-use the common resource (e.g. using unnecessarily high transmit powers relative to desired rate/range; or occupying a channel longer than needed) which is individually optimal in the sense of increasing peak throughput for the user but is collectively sub-optimal (degrades aggregate network throughput). The specific solution to these problems depend in part on whether one is addressing vertical or horizontal sharing. While we focus on horizontal sharing, we expect that technology implemented to improve (say) vertical sharing (e.g., dynamic frequency selection) will also be usable to improve horizontal sharing.

Proposal

The sharing rules and associated constraints proposed below are purposefully minimalist and broadly general to indicate a belief in what parameters should be subject to rules without appearing to specify or limit the nature of the underlying physical and link layers designs.

We give specific parameters for the sake of concreteness. However, the reader should bear in mind that parameters will need to be decided in the context of a particular allocation.

More sophisticated rules that reward higher performance may be desirable; see [8] for examples. Moreover, choices of sharing rules parameters will require a more elaborate simulations that take into account various user and network scenarios. Therefore, in the definition of parameters we have used rough values.

**Definition of Parameters**

   a. Interference Threshold $I_{th} (-62 \text{ dBm/MHz})$: maximum aggregate interference (as sensed by a node) allowed for channel access.
b. **Maximum average power** (30 dBm) and **Maximum power spectral density** (p.s.d) (10 dbm/MHz): max. allowed (isotropic) radiated transmit power and p.s.d limits at each node.

**Sharing Rules**

1. *Non-Greedy Occupancy*: No user may occupy the channel with rate 0 (no data to send). This rule, for instance, prohibits devices to use jamming techniques to have exclusivity to a channel.

2. *Channel Select*: A channel is deemed accessible at a node if the aggregate interference power at the intended receiver is less than $I_{th}$. The rules recognize that a connection needs to be established between nodes before this rule can come into operation. The channel width chosen is at the discretion of the node. A node should be able to access any available channel in the allocation in question.

3. *Range & Power Select*: Nodes should reduce transmit power to the minimum necessary to achieve the link margin they require. For the purposes of compliance testing, for every reduction of transmit range by factor $A$, the node must reduce transmit power by a minimum of $20 \log_{10} A$ dB. Practical transmit power control should be operational over a dynamic range of 12 dB with step size of 1 dB.
References


