Organization: Cisco Systems, Inc.

Q1: Do you agree that the spectrum commons of a technology should be based on its interference characteristics?

Cisco supports Ofcom's endeavors to establish a new model of spectrum management for future license free spectrum. Spectrum sharing is gaining more attention, fueled by the enormous market success of licence-exempt devices generally, by innovations such as Dynamic Frequency Selection technology for 5 GHz Wireless LANs that share the band with governmental radars, by other emerging cognitive radio technologies, as well as by the "technology neutrality" principles that are increasingly being applied to licensed bands. These developments lead to more research and to a better understanding of the problem space that should inform policies like Ofcom's on Spectrum Commons. Our comments below should be understood in this perspective.

In Cisco's view, spectrum sharing is more than dealing with interference and involves the broad ability of wireless systems to function in the presence of others. A better method of spectrum commons classification would take into account the ability of different wireless systems to share spectrum with their own kind and with others. In today's marketplace, there are various ways in which unlicensed devices share spectrum, from the most primitive (e.g., low power) to highly sophisticated (e.g., DFS). Dissimilar sharing methods are likely to prevent efficient spectrum sharing. But over time, new and improved cognitive technologies could make efficient spectrum sharing easier. For example, software defined radio transmitters can be modified by uploading new software versions. In some cases, future technologies may employ radio beacon technology to control subservient base stations within a geographic area. Improved sensing technologies could well emerge.

Classifications based on interference potential as measured by frequency use, time, and geographic reach, while informative at one level, amount to a rough and approximate view of how technologies can share spectrum. Interference is a two-way street that involves both transmitters *and* receivers. Therefore, a spectrum commons policy should look at the transmitter and receiver side separately: a system with a low duty cycle transmitter but a noise sensitive receiver may not be able to share spectrum with other systems, except if those would all operate at low power levels. Conversely, a system with a very robust receiver can tolerate more interference and not suffer from other systems.

In sum, the classification should recognize that there are different methods and levels of spectrum sharing, and that these methods and levels are going to evolve and become more capable over time.

Q2: Do you think that the ratio of channel bandwidth to the width of the band is a good representation of the use of the frequency domain resource and the interference potential of a technology in this domain?

No. The relative amount of spectrum used is a very primitive and therefore a very inaccurate measure of interference potential. A single powerful narrow band source can easily prevent the operation of wideband systems over a very large area whereas the narrowband system will hardly be affected by the wideband systems. Therefore, a measure is needed that takes this asymmetry into account, e.g. power density – the higher the power density, the larger the victim area.

Q3: Do you think that the duty cycle is a good representation of the use of the time domain resource and the interference potential of a technology in this domain? Do you agree that the duty cycle should be evaluated at the busy hour?

No. Duty cycle is only relevant for systems with low duty cycles and therefore it can not be used as a generic indicator or as a component of a composite indicator.

Adding “busy hour” to the duty cycle measure compounds the inaccuracy of the latter by adding a highly subjective factor – one based on fear at the victim side and one based on wishful thinking on the part of a proponent of a technology.

An integral approach to assessing the time dimension of spectrum sharing should take into account frequency of access, duration of access and probability of access. If the latter is adaptively determined by a system, its ability to share the time dimension determines its overall potential of efficient spectrum sharing.

Q4: Do you think that the interference coverage plus the density of transmitters give a good representation of the use of the space resource and the interference potential of a technology in this domain?

Potentially, the interference coverage is a useful measure in assessing sharing behavior.
We agree that the conventional “EIRP” based measure is both neither accurate nor technology neutral because it denies systems the benefit of using dynamic beamforming to limit interference caused as well as interference received. Hence we agree with the approach of paragraph 5.27 in the consultation document that links antenna directivity to inference potential.

The US Federal Communications Commission similarly recognized this in a 2004 decision that allowed dynamic beamforming systems to have up to 8 active beams without requiring a reduction in output power.[1]

Adding “density” to the power factor adds a highly subjective factor that is not very useful for the same reasons that “busy hour duty cycle” is not very useful. It should be noted that the success of a license exempt technology is to a very large extent determined by its ability to survive in a shared environment – IEEE 802.11 is a prime example of what a well designed system can achieve, including both “listen before talk” technology and “acknowledgment” packets that cause the re-transmission of dropped packets.

Q5: Do you agree with our method to calculate the interference coverage area of a transmitter? What is your view on a threshold level of -80 dBm/MHz to determine the interference range? Do you think the threshold level should be expressed as power density (dBm/MHz) or as power (dBm)?

No. While power density is a better parameter than total power on which to evaluate interference probability, a “reference receiver approach”, although simple, is not justifiable. With specific reference to paragraph 5.34 in the consultation document, a threshold set in dBm/MHz favors narrowband systems: a wideband device would detect a single narrow band device but the same is not true the other way around. Only a fraction of the power of the wideband device is received by the narrow band device.

Q6: Do you agree with using a busy yet realistic scenario to derive the transmitter density of a technology?

The relationship between transmitter density and interference is very much technology dependent. Given the predictive nature of the principles discussed in the consultation, transmitter density

[1] Modification of Parts 2 and 15 of the Commission’s Rules for unlicensed devices and equipment approval, ET 03-201, Report and Order, July 12, 2004 at paragraphs 12-17.

should be kept out of the equation that determines the interference potential. At best, it can be used as a “what if” question when analyzing the possible consequences of putting certain systems or technologies in the same class.

Q7: Do you agree with the Interference Indicator being a product of the frequency domain factor, the time domain factor, the interference coverage area and the transmitter density?

No. As stated in response to Q1 above, each of the factors that make up the interference indicator fail to convey the ability of the technology to share spectrum with other transmitters of its type and with other technologies. As a result, the interference indicator concept will fail to deliver benefits of efficient spectrum use and continued innovation.   As designed, the interference indicator does not capture improvements in cognitive radio technologies, and therefore, fails to provide incentives to develop them.

One of the examples given in the consultation document is illustrative: Bluetooth and IEEEE 802.11b get the same rating yet they cannot share spectrum very well –because they use incompatible medium access protocols.

Q8: Do you think that three classes of spectrum commons is the right number? What is your view on the proposed boundary values for the three classes?

As noted above, the consultation’s proposed approach to classification of systems will not deliver the expected benefits. Therefore, the number of classes can not be determined or estimated without a change in the underlying concept.

Instead of the Interference Indicator, Ofcom should encourage the development of new spectrum sharing technologies by making available “experimental spectrum” - for two or three types of systems – that can serve as technology incubator. A major success of a new technology could be a reason to create spectrum commons class for that type of technology.

A real-world example, even though it was applied unwittingly, is Wireless LANs, which developed from an interesting idea that leveraged the 2.4GHz ISM band into a multi-billion industry and is now enlarging its de facto spectrum commons in the 5GHz band into large scale use. Declaring that spectrum an LBT commons with power limit of 1 W (along with existing rules designed to ensure the technology will not interfere with radars and satellite use) will go far to allow that technology to develop further and avoid future 5 GHz band uses which, although possibly compatible as measured by an Interference Indicator, would prove to be significant interferers once deployed.

Q9: Do you agree with our definition of fairness and that all systems should be required to behave in a fair manner?

The fairness principle may be intuitively "right" but in practice it does not work. A limitation on resource utilization is a better basis for encouraging the development of new methods spectrum sharing.

As the consultation document recognizes, resource utilization has three dimensions: frequency, power and time. Overall efficiency can be expressed in terms of bits/W/Hz/sec. Different mixes can deliver the same overall "efficiency factor". Low duty cycle systems operating at high power can share spectrum with high duty cycle, low power systems. Because of the W/Hz component, power in this case is actually power density.

Similarly, narrow band systems can share with wide band systems if there is a limit on the maximum "amount" of spectrum a given device can use at the same time. Also, the time dimension can be shared in different ways: statistically as in “aloha type” protocols or intelligently - based on spectrum sensing or pre-determined transmission opportunities. The point about the latter is that systems designed to share spectrum intelligently must, by necessity, be based on the same concepts and talk the same language. Note that there is no need to require spectrum sensing: the resource constraint drives systems with higher demands towards higher efficiency and higher efficiency is served by knowing what other do.

By imposing the same limitations on all users of a given class, all systems are motivated to maximize the use of the resource.

Q10: What is your opinion on the effectiveness of blind detection sensing techniques compared to signal specific techniques?

Effectiveness needs a context in order to be meaningful. There are three methods of sensing: none, primitive and smart. Resource sharing is more effective when more information is available. The need for high efficiency increases with the load on the resource. Physically, primitive (energy) sensing is far less accurate than signal sensing and therefore its usefulness is limited to system is that do not exhaustively use a resource. Mixing energy sensing systems and smart sensing systems under the umbrella of a utilization limit is likely to push the former down to lower resource access levels.

This comment illustrates that Ofcom may want to exclude detailed considerations like methods of spectrum sensing and instead focus on more general and more powerful notions such a smart adaptive medium access based on feedback from receiver to transmitter. This feedback approach is very valuable since it allows the sender to determine its level of efficiency for a particular receiver and this in turn can be used to select another mode of transmission, etc. Feedback allows systems to become adaptive and therefore optimally adjusted to their environment. It should be noted that the feedback is relevant only intra-system: it is sufficient for a receiver to report interference; the source of that interference is irrelevant.

Q11: Do you agree with the proposed polite rules?

There is a more abstract view that is also enlightening: a quadrant based on the dichotomies dumb/smart and low/high use. Dumb/high use is bad, dumb/low use is ok, smart/high use is good and smart/low use is overkill. Dumb/low use and smart/high use can go together because the latter has to be tolerant for unpredictable transmission failures.

We agree with the basic ideas but we see a need for refinement that takes into account physical constraints as well as technology neutrality. In fact, we think that within a commons class, dissimilar systems can be mixed with each other provided the class rules impose the appropriate limits on resource access.