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Wireless

Spectrum Needs of Emerging License-Exempt Technologies

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Introduction

The wireless industry is entering an era of unprecedented innovation and growth. The continued proliferation of mobile wireless technologies and protocols like Wi-Fi along with the advent of 5G have combined to drive incredible growth, in terms of new applications, number of network-connected devices and overall data usage. As with past implementations of new wireless applications, spectrum usage and availability are the primary considerations to ensuring the global success of these deployments.

There is a growing debate within wireless industry circles regarding how to balance the useable wireless spectrum between licensed frequency bands and license-exempt or unlicensed bands. On the one hand, those parties arguing for a stronger focus on licensed spectrum designations believe that a greater amount of licensed spectrum would result in higher quality services to address a larger segment of the mobile market. On the other hand, many of the new innovative applications, be they gesture control or Augmented Reality/Virtual Reality (AR/VR), are so localized that the idea of leveraging licensed spectrum for their use could make the costs of these applications a non-starter. This debate is very likely to heat up in the coming months, due to the amount of spectrum under consideration in international regulatory bodies. There is also international deliberation around regulatory action at WRC-19 with respect to 66-71 GHz, a band which the FCC[1] and the EC[2] have designated as unlicensed. Finally, while many telcos are rightly sounding the alarm for greater availability of exclusively licensed spectrum, the FCC[3] and the EC[4] are also considering opportunities in the 6 GHz range as potentially new spectrum for license-exempt applications in addition to new opportunities for licensed mobile broadband systems in other bands.

Is All Spectrum Equal?

At first glance, a balanced approach to the issue of exclusively-licensed versus license-exempt spectrum in the form of approximately the same amount of spectrum for licensed and license-exempt technologies seems to be a fair proposition. However, two points should be taken into account. Firstly, license-exempt applications are generally considered as secondary to licensed applications in any given band. Therefore, often times the entire band designated to a license-exempt application cannot be used, or cannot be used at all times or can only be used with restriction (hence lower performance) to protect incumbents, e.g. in parts of the 5 GHz band where protection of radars requires license-exempt systems to deploy Dynamic Frequency Selection (DFS) and vacate the band upon detection of a radar signal. Similarly, some of the 5 GHz sub-bands are restricted to limited transmit power and/or indoor only operation. Secondly, uses of radio waves have dramatically changed over the past few decades. The trend towards wirelessly connecting anything with any level of computational power leading to the generation of astronomical amounts of data is already underway[5]. Given the largest amounts of data usage happen indoors, this trend demonstrates heavy reliance on license-exempt applications[6]. With the emergence of 5G use cases, we are witnessing an impact on regulations and spectrum management methods[7].

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The argument about equal need for spectrum could have been valid at a time when exclusively-licensed technologies were used in lower frequency ranges for deploying noise-limited wide-area networks delivering voice and data capabilities, while license-exempt technologies mainly focused on local area coverage in the form of Wireless LAN (WLAN) for enterprise and home uses. Moreover, with the introduction of LAA, and soon NR-U, use of the same technological infrastructure in both licensed and license-exempt spectrum is now possible.

Nowadays, mobile radio technologies have also expanded into higher spectrum bands including millimeter wave (mm-wave) frequency bands. In such high frequencies, physical properties of radio waves causing much higher path loss than traditional cellular bands naturally limit interference, reducing the need for a license to protect against interference from other users. In these higher bands, very large channels could support many new use cases, including those of vertical industry segments, above and beyond mobile broadband connectivity.

When Is a License Needed?

With crowding of the airwaves, especially those in low- and mid-ranges traditionally suitable for mobile services, and emergence of many wireless applications competing over the same spectral resources, the challenge of spectrum allocation and assignment is an *optimization problem*[8]. There is no regulatory or licensing regime better than or superior to the other ones; what matters is how suitable the regulations are for the applications running over the spectrum governed by those regulations. With technologies and use cases in a perpetual evolution and change, the challenge is in how to make regulations future-proof as much as possible, and more importantly, how to react to the evolution of technologies in a timely manner without disrupting the operation of existing and legacy services. This is not an easy task, but there have been important attempts in recent years to address it.

A licensing scheme needs to be looked at in the context of the applications delivered over the spectrum governed by the licensing scheme. Wide area, outdoor applications such as cellular communications in traditional bands need exclusive rights to the use of airwaves in order to control interference and provide QoS. These exclusive licenses are generally protected from interference generated by other licensees through either frequency separation (e.g., separate blocks of spectrum) or through geographic separation (e.g., EAs and PEAs in the US[9]). Each licensee is then required to comply with a certain emission level outside its spectrum block and outside its license area boundary.

Local area applications such as Wi-Fi have traditionally been operating under license-exempt rules, taking advantage of smaller coverage footprints in combination with restrictions on unwanted emissions as mechanisms to control interference to other services in adjacent bands, as well as any other in-band restrictions required by regulations to protect primary services.

In the past several decades, many short-range applications have emerged, leading to the definition of a new category of devices, namely Short-Range Device (SRD). Realizing the specific needs and stark differences of these applications, many regulators developed a new regulatory framework to accommodate SRDs, which almost exclusively are governed under a license-exempt regime[10]. The fundamental reasons for a license-exempt regime for SRDs are as follows:

1. Interference does not travel far due to low transmit powers needed and allowed.
2. There is no incentive for one to pay a license fee for deploying a system where operation of one such system is possible even in close proximity of other such systems without causing harmful interference.

For these reasons, a license-exempt regime has been the dominant regulatory regime for short-range applications.

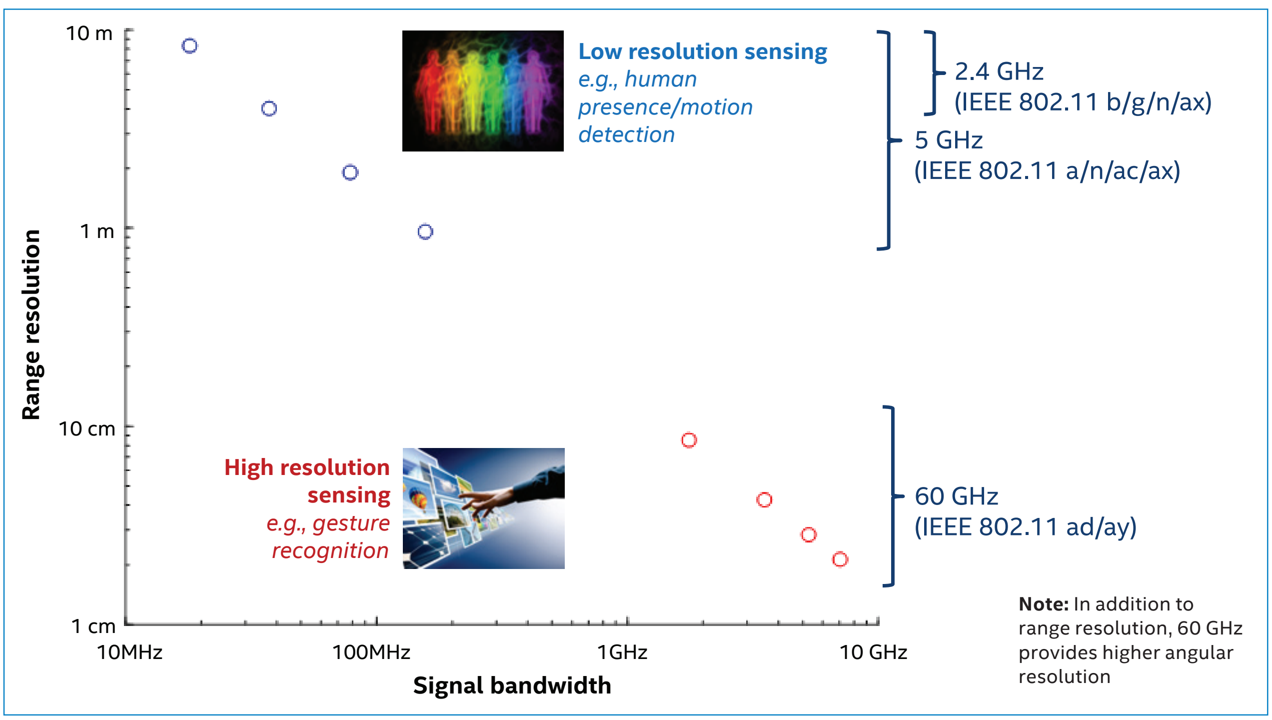

Figure 1. Relationship between range resolution and signal bandwidth

Application is King!

Emerging applications from a diverse set of use cases, which affect Key Performance Indicators (KPI) of the underlying radio interfaces, have caused a major shift in industry plan and design for future wireless systems. By now, the fact that applications drive spectrum needs and also the regulatory means of achieving those needs is well documented[11]. We can now confidently say the era has come in which application is king, particularly when it is believed that future market growth increasingly relies on non-smartphone applications and services, and therefore understanding such applications and services is of utmost importance for well-planned spectrum regulations.

Among the new use cases emerging in the 5G era, there are prominent ones that do not lend themselves to a traditional exclusively licensed regime. Sensing technology for gesture recognition and control[12] is one such example best suited to be done in license-exempt bands due to its short-range nature. The required resolution for recognizing complex and subtle movements, however, is believed to require a lot of bandwidth in the order of multiple GHz. Figure 1 depicts the relationship between required resolution and the amount of bandwidth needed to perform gesture recognition.

Another example of a new use case with emerging applications is Industrial IoT (IIoT). This is a very broad area, encompassing a diverse set of use cases. One segment with a promising future is the automated manufacturing. While there was once quite a lot of buzz about smart and connected appliances taking over the planet, now applications such as smart and connected industrial helmets with Augmented Reality/Virtual Reality (AR/VR) capabilities seem to be a more realistic, nearer future possibility. This is yet another application requiring multi-gigabit connectivity within short range with very stringent latency requirements. Table 1 below contains traffic and throughput requirements for wireless AR/VR.

To meet the requirements needed for wireless VR/AR applications, it is widely believed that wireless-induced latencies should not be higher than 2 millisecond. In addition to stringent latency requirements, even with modern compression techniques, more than a Gbit/s user throughput is required, which points to significant bandwidth requirements currently not addressable in the 2.4 GHz and 5 GHz ranges. To put the matter in perspective, a single WiGig channel in the 60 GHz range is 2.16 GHz wide, more than twice as large as the entire 2.4 GHz and 5 GHz spectrum used by Wi-Fi 6 combined.

Requirement	Min	Target	Notes/Gaps
Resolution and Refresh	4K @ 120Hz		>1Gb/s throughput w/compression (5-10:1)
Wireless Range and Coverage	5m @ 360°	7m @ 360°	Full in-room, 360-degree coverage
End-to-End Latency **Pipeline Latency** **3D Render/Decode** **Wireless Display (out)** **Wireless I/O (in)**	≤20ms motion-to-photon ≤1-frame (8.33ms for 4K @ 120Hz) ≤5ms adder ≤3ms adder	≤15ms motion-to-photon ≤3ms ≤2ms	Worst case latency <= 2ms
Power/Thermal Fit **Wireless Tax (overhead)**	≤10% of source platform's budget		
Wireless Resiliency **Error Recovery** **Missed Frames**	≤2 frames ≤2 non-adjacent frames per second	≤1 frame	Max # frames a visual artifact may persist Sink-side Time Warp to compensate
Fidelity (Visual, Audio)	≤MOS 4.0 (integrated) <MOS 4.5 (discrete)	<MOS 4.5 (integrated)	Perceptually lossless across key usages and targeted wireless environments

Table 1. Traffic and throughput requirements for AR/VR

Conclusion

Short-range, gigabit-hungry applications are emerging, pushing radio systems to move towards mm-wave frequencies where ultra-wide channels could be available. The short-range nature of these applications lends itself better to the license-exempt regulatory regime due to several reasons including limited propagation. Data is presented here on spectrum needs for two emerging and promising short-range applications, namely gesture control and AR/VR. From this data, it is concluded that going forward, there is need in the mm-wave bands for making more license-exempt spectrum available than traditional exclusively licensed spectrum, the latter being something more suitable for lower frequency ranges where control of interference is key to providing QoS. As a result, a new look at spectrum regulations in light of emerging applications to be implemented in each band is in order.

[1] Federal Communications Commission (FCC), Spectrum Frontiers, Report & Order, August 2016, https://docs.fcc.gov/public/attachments/FCC-16-89A1.pdf

[2] ERC Recommendation 70-03, 7 June 2019, https://www.ecodocdb.dk/download/25c41779-cd6e/Rec7003e.pdf

[3] US Federal Communications Commission, Notice of Proposed Rulemaking [insert docket number and date].

[4] European Commission, Mandate to CEPT, http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=50343

[5] For instance, see: "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2017–2021."

[6] Cisco Visual Networking Index, 2019, https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-738429.html, published in Jan 2019

[7] For instance, in response to the needs of industrial automation, German regulator (BNetzA) has set aside 100 MHz of spectrum, separate from those publicly auctioned for mobile broadband services, to be awarded on a local basis to applicants for industrial or similar use.

[8] In mathematics, an optimization problem is that of finding the best solution from all feasible solutions. This is generally done by defining various cost functions which, given a set of constraints, can be minimized.

[9] EA: Economic Area, PEA: Partial Economic Area. The smallest geographical unit of a license in the US.

[10] For CEPT, see ERC Recommendation 70-03.

[11] See, for instance:
-NGMN 5G white paper, February 2015, https://www.ngmn.org/fileadmin/ngmn/content/downloads/Technical/2015/NGMN_5G_White_Paper_V1_0.pdf
-ITU-R, Recommendation ITU-R M.2083, September 2015, IMT Vision – "Framework and overall objectives of the future development of IMT for 2020 and beyond."
-4GAmericas, August 2015, http://www.5gamericas.org/files/6514/3930/9262/4G_Americas_5G_Spectrum_Recommendations_White_Paper.pdf
-5GAmericas, April 2017, http://www.5gamericas.org/files/9114/9324/1786/5GA_5G_Spectrum_Recommendations_2017_FINAL.pdf

[12] For example, see: https://atap.google.com/soli/ , and also: https://www.cnet.com/news/project-soli-is-the-secret-star-of-googles-pixel-4-self-leak/

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