# edgeBoost™, bandBoost™ and coexBoost™ – Three Types of Wi-Fi Filters

These days, Wi-Fi designs often include filters. This paper addresses what types of filters are used and for what purposes.

While it may generally be thought that "a filter is a filter," there are actually many different filters that solve different problems for different types of use cases, and with different benefits. In general, of course, the purpose is to improve the quality of data communications. However, before making any decisions about including filters in your design, it might be good to understand what specific effect is desired. And since filters come at a cost, the benefit needs to be worth that cost.

To bring clarity to this analysis, we'll first look at noise and the effects of interference.

## 1. What Problem Do Filters Solve?

In a word, filter solve a noise problem. More specifically, a RF noise, or radio noise problem. If you have an old FM radio receiver, and you dial from one channel to another you hear the crackling noise in between. Modern FM radios suppress the crackling, as do internet radios. Noise is everywhere. And even "good radios" can create noise somewhere else. Consumers love connectivity but hate cables. So, when you consider the number of wireless devices people use in their homes, you can see that this noise problem will only grow worse over time.

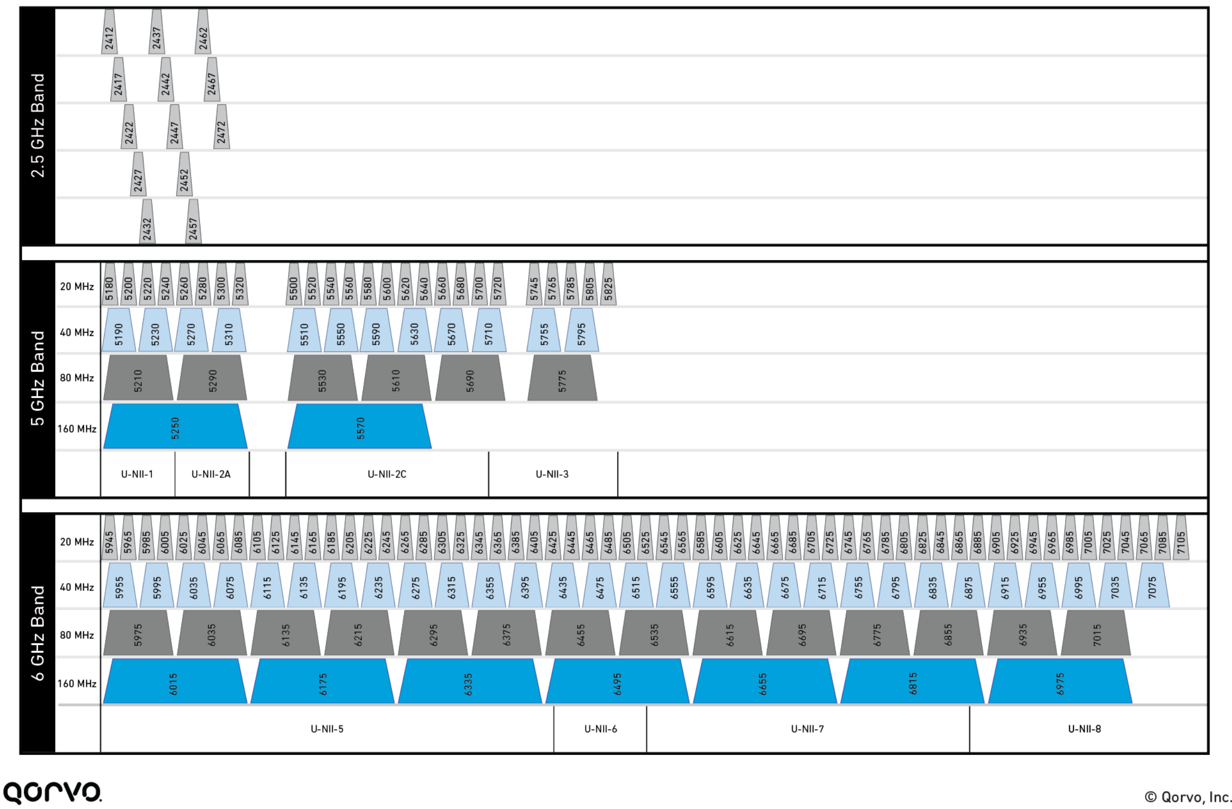
In this "noisy" environment, governing bodies around the world create specific rules and regulations to ensure that there is balance, as many different radios are transmitting at the same time for different reasons. One easy example are the radios that communicate with aircrafts as they are landing or taking-off definitely should not have interference from other radios, intended or not. So, for the safe operation of the aircraft and for the sake of the passengers, "please turn off your cell phones".

## 2. About Filters

We are all familiar with glass and cellophane paper. There is "clear" glass or cellophane that let all colors go through transparently. This means that all the colors of the spectrum (the "light band") are let through. But there is also colored glass or cellophane, e.g. red or yellow, letting only red light through, or only yellow, etc. Each color in the light band can be called a channel, e.g. the red channel or the blue channel. A channel is a part of the band, and the whole band is usually split up into multiple channels.

The different Wi-Fi bands (915 MHz, 2.4 GHz and the 5 and 6 GHz) are similarly split into channels.

Figure 1. Wi-Fi Frequency bands and channels.




The intention of a channel is to enable two (or more) transceivers to communicate with each other by finding by both tuning in on that specific channel. This is done by adding bits (0s and 1s) to a carrier that is sending energy between the transceivers. These bits are bundled together in packets of information, and both the sender and the receiver need to be very precise, because we are quickly talking about multiple billions of bits (Gb/s) going through the air at the same time over the different channels. The general purpose of a filter is: (1) to make sure that this communication channel stays very clean, i.e., keeps other signals out of the band (channel) and (2) to prevent wanted communication from creating noise outside of the band (channel).

When there is noise in the air, parts of the packet get garbled (destructed), forcing the receiver to “re-transmit.” This process of detecting a communication problem usually takes time, and the user perceives this as the network “slowing down” or that they have “bad Wi-Fi.”

## 3. How Does Noise Get in the Air?

First of all, there is always noise in the air, as a natural (thermal) phenomenon. Beyond that, electrical equipment and modern radios add noise. Turning on and off electrical equipment creates noise, microwave ovens create noise, etc. Although radio transmitters are supposed to work only in a specific frequency channel, in reality they can also send signals in other channels in other bands, creating noise there. That is why radios need to be approved not only to send wanted signal with limited strength, but also to not spread signals above certain strengths elsewhere.

The world of radios is not black and white, and from time-to-time can be quite unpredictable, as the noise level also depends on the strength of the noise source, as well as the distance of the noise source. Going to a nature reserve in the middle of nowhere, most likely there will only be natural (white) noise, though even there the sun, or cosmic events, can create spikes in the spectrum. But in urban areas, the noise level goes up, because of the multiple radios that are being used – a number that continues to increase over the years.

## 4. Interference

Interference is how noise becomes the enemy of high-performance wireless data communication systems. A noise spike or continuing interference from a nearby radio, at the allowed output power level, can create packet loss and performance degradation, leading to customer complaints and service calls. Worse yet, these problems are sometimes very difficult to diagnose and resolve. (Technical support engineers can tell horror stories on this topic!) This is where good, resilient product design can really help, and this is where filters come into play.

Filters are like the colored glass or cellophane mentioned earlier. They can make sure that only wanted signals are transmitted or received, and the number and the strength of unwanted signals is reduced. Filters are quite magic solutions, they not only mitigate problems, but the effect on the performance with the reduction of packet loss can be stunning. There is, however, a trade-off when including a filter in a design, and that is insertion loss. To use the glass or cellophane example again, there is some of the intensity that stays in the filtering medium. For instance, a receiver loses some sensitivity (its ability to pick-up weak signals), when it has a filter included in the design.

## 5. Types of Filters

There are many types of filters, both from a technology perspective (not covered in this paper) and from an application perspective – in other words, what the filter is trying to achieve in the product design. In some instances, a filter (or combination of filters) is used to create multiple benefits.

We will now focus specifically on Wi-Fi filters. This paper will use the terminology that we use at Qorvo to specify the types of filters in our portfolio. There are essentially three types of filters, all increasing the capacity of the total Wi-Fi system, improving the system performance in terms of range and throughput, and eliminating the risk of unexpected performance degradation:

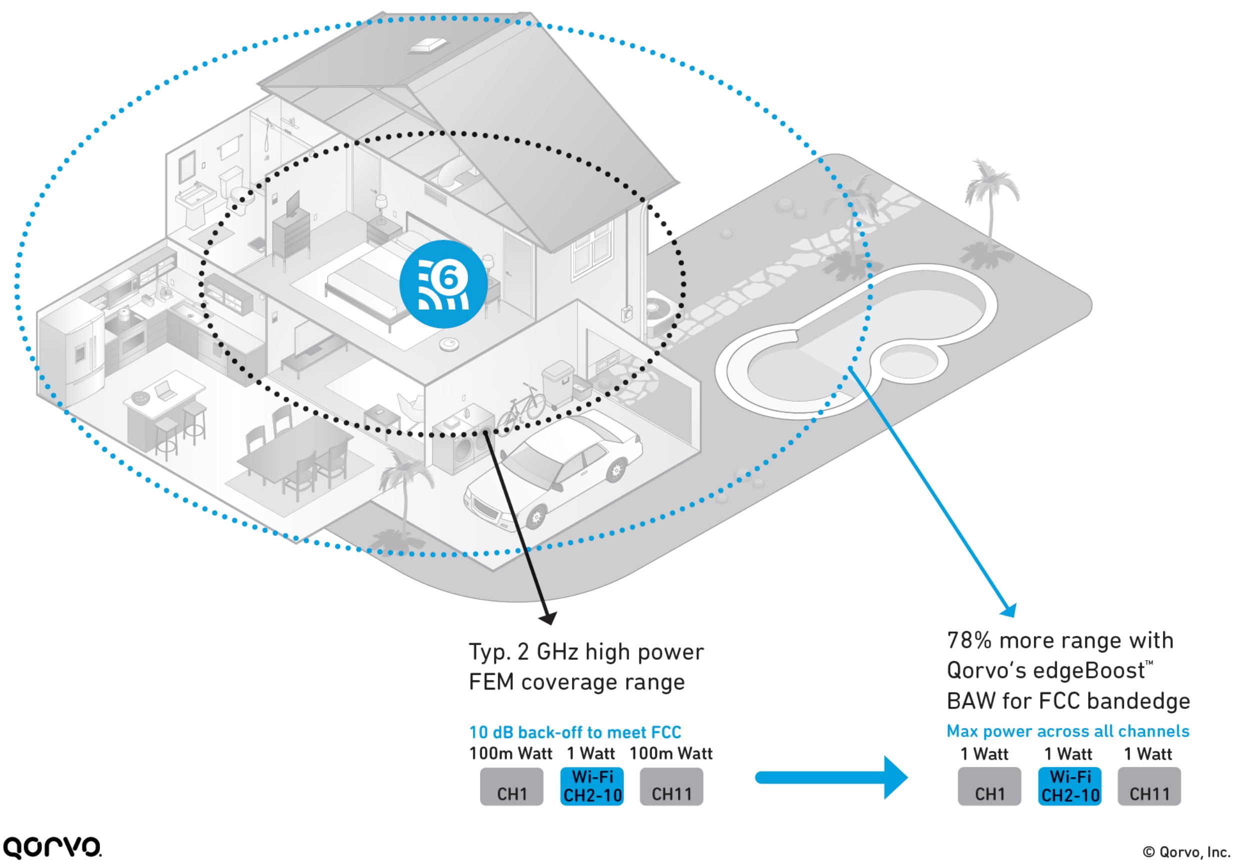
- **edgeBoost filter:** maximizing output power at channels close to the band edge
- **bandBoost filter:** maximizing channel isolation in multi-band mesh networks
- **coexBoost filter:** maximizing coexistence between different radios in the same band (LTE, IoT, etc.)

## 6. edgeBoost Filters

edgeBoost filters added to the transmit chain of a radio help to get better performance, particularly in the range of the channels that are close to the edge of the band. The concept is fairly straightforward. Radios are not allowed to create noise outside the band, but when the channels close to the edge of the band are used at full power, they tend to “bleed noise” outside the band. The common practice is to significantly limit the output power in these channels close to the edge of the band, so the requirements for radio approval can be reached. This is fine, but it also means that the range of the users using these edge bands is significantly reduced, and with that the total capacity of the system is affected. Specifically, it forces more users to use the channels in the middle of the band, crowding these bands and effectively slowing the internet for all the users in the network.

Here is where edgeBoost filters help. These filters reduce the bleeding of the radio signals outside of the band, so that the radio can transmit in these edge channels at maximum power, avoiding a range reduction in these channels, and resulting in reduced traffic congestion and improved capacity overall.

Figure 2. how edgeBoost filters improve range (and capacity).




Let's look at a practical example. In 2.4 GHz, Wi-Fi is given a spectrum from 2412 MHz to 2484 MHz, and within that band there are 11 defined Wi-Fi channels you can transmit and receive on. When you are transmitting on a channel in the center of the frequency range, let's say channel 6, the likelihood that you are creating noise outside the band (below 2412 MHz or above 2484 MHz) is pretty low.

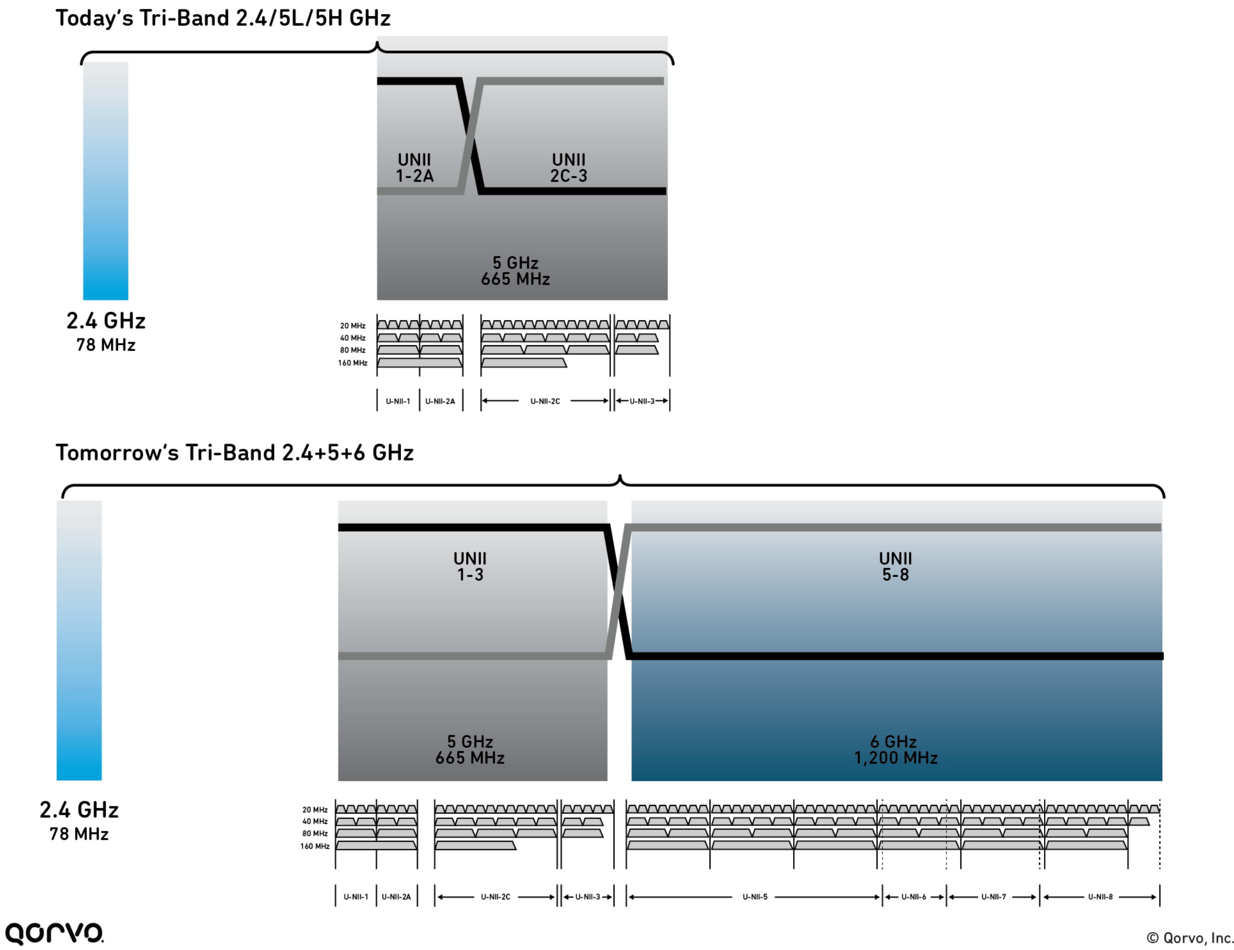
However, if you are transmitting at the lowest channel, Channel 1, the likelihood that you are interfering below 2412 MHz is high. The same applies to transmitting on Channel 11 and creating interfering above 2484 MHz. What happens if your interference is too high outside of the band? The regulatory body and the certification lab will require you to lower your transmit power until you are compliant. The effect to the Wi-Fi router user is less range. But with an edgeBoost filter, the bleeding outside the band is reduced, allowing for higher output power and better range.

The edgeBoost filters are valuable for maximizing range simply by enabling the ability to transmit at full power on all channels throughout the whole band. Traditionally for the outer channels, the power is reduced to even a quarter of the capability, losing range and coverage. With edgeBoost filters, the highest throughput can be maintained over the whole band and full home coverage can be supported at the highest levels possible.

## 7. bandBoost Filters

Qorvo's bandBoost filters are band isolation filters that enable simultaneous multi-band operation of a specific radio type (e.g. Wi-Fi) to multiply the capacity and throughput of the network for each split. In the example of multi-band Wi-Fi 6 and Wi-Fi 6E networks, they help to split up the 5 and 6 GHz bands into different sub-bands, so the channels used in these bands can continue to be used simultaneously at maximum power, without bleeding signal into each other and causing (Wi-Fi) self-interference between the different channels.

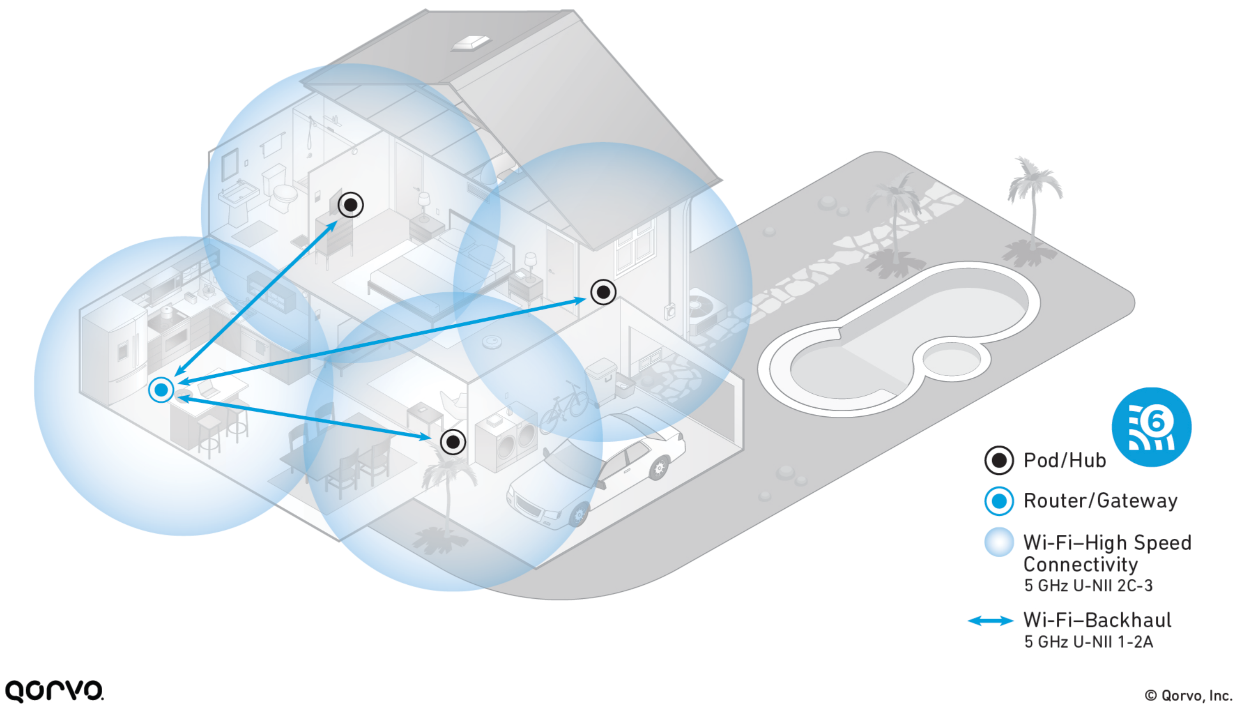
Figure 3. SMR BAW power and heat handling.




bandBoost filters are great for improving the capacity in Wi-Fi multi-user MIMO networks, because they essentially create zones of multiple Wi-Fi networks supporting different users simultaneously on different channels in the same space. By splitting up the bands into sub-bands the interference of these networks on each other while using the maximum output power, is minimized. It is as if different users are using different Wi-Fi colors, and users with different colors do not bother each other. The bandBoost filters can be optimally used with a frequency band management system, understanding how the different sub-bands have been isolated and to assure proper channel assignment of different users/applications.

Again, let's look at an example. These filters are prominently used in today's tri-band Wi-Fi systems (2.4/5L/5H GHz configurations) to improve the system capacity, because these channels can all be used at the same time. For instance, concurrent usage of the 5 GHz spectrum split into upper and lower band for simultaneous enablement of a dedicated backhaul link throughout the home network on one channel, and client communication link (mobile, laptop, play-station, thermostat, etc.) on the other. The potential exists to do something similar in future Wi-Fi 6E systems, which, for instance, will dedicate backhaul transmission at 6 GHz frequencies, and client communications within the 5 GHz spectrum. This leads to increased capacity – more users using more devices simultaneously over a larger quantity of channels for the radios to choose from – in an increasingly congested wireless environment.

Figure 4. How bandBoost filters increase the Wi-Fi capacity in the home by creating multiple zones.

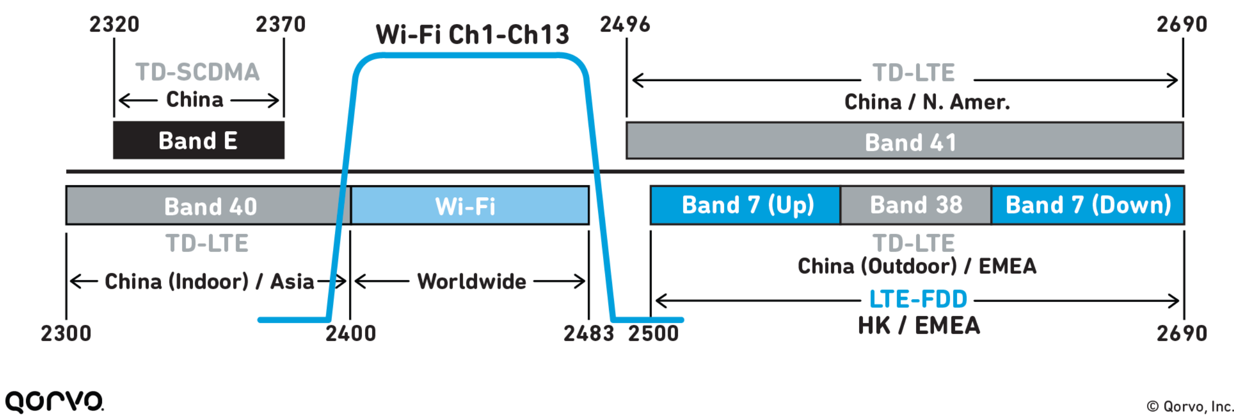



## 8. coexBoost

coexBoost filters are added to the transmit or receive chain of a radio to allow simultaneous use of additional radios using a different connectivity technology. When transmitting through these filters, the system is prevented from interfering with the adjacent radio; and when receiving, the system is protected from the same adjacent radio. Creating an environment of simultaneous, different, non-interfering radios is coexistence.

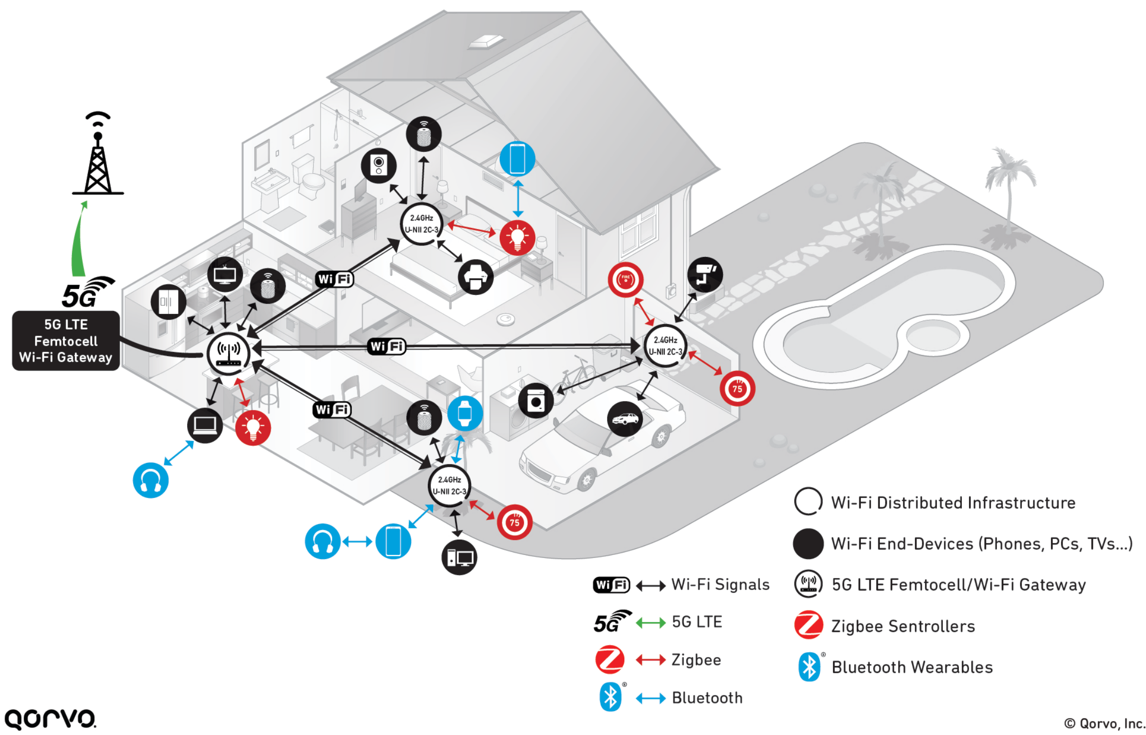
Mobile phones or hotspots are examples of products that include multiple cellular radios, GPS, Wi-Fi, ***Bluetooth***® – all packed into a very small product. They frequently make critical use of these types of filters. Today's wireless routers, range extenders and access points do the same, integrating Wi-Fi, IoT and Bluetooth, and radiating as much power as possible to get the best range and performance on all radios to offer a seamless user experience with the least amount of latency regardless of any of the radios. Some service providers that depend on 3G/LTE/5G to provide broadband internet access to a home or business have a modem with LTE (and soon 5G) radio given to the house, with an ethernet port for connection to a standard wireless Wi-Fi router, which is assumed to sit next to the modem, or they may issue a gateway that integrates all three functions in the same box. In all cases there are multiple radios in close proximity, transmitting and receiving in channels that are adjacent to each other.

Figure 5. How coexBoost filters keep FTE signals out the Wi-Fi band.




A common industry trend is to make physically smaller-sized products. This is not helpful to the product designers challenged to avoid interference and mutual destruction of data communication packets that hinder the user experience. An example of such a user experience is slower data speeds when surfing the internet or latency when touching a wireless light switch and having a noticeable delay in the light turning on or off. coexBoost filters solve these problems by helping designers pack more radios in a smaller space and deliver sleek and fashionable products with great performance and seamless interaction.

Figure 6. How coexBoost enables maximum capacity range.




## Summary

It is clear today that good Wi-Fi designs must include good filtering capabilities to provide the expected performance in range and throughput that the Wi-Fi 6 and 6E standards has been designed for. But probably most important is that including good filtering it is necessary to avoid unexpected and intermittent performance degradation that leads to increased support calls and major customer dissatisfaction. For Qorvo based Wi-Fi products, filtering is one of the key technologies that maximizes the quality and performance of the user experience and assures uninterrupted and high-performance connectivity.