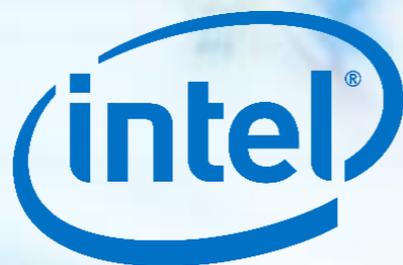# Next-generation Wi-Fi goes hand in hand with 5G

A conversation with Carlos Cordeiro, Senior Principal Engineer and Senior Director in the Next Generation and Standards Group, Intel

By Monica Paolini,
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(intel)

# Next-generation Wi-Fi goes hand in hand with 5G

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Wi-Fi is a remarkable success story. Wi-Fi has been around for decades, and yet it continues to evolve, add new functionality, and improve in performance. Today, it is difficult to imagine what wireless connectivity would be without Wi-Fi. And as we move to 5G, the two technologies will be the main pillars supporting our pervasive connectivity needs of the future.

I talked with Carlos Cordeiro, Senior Principal Engineer and Senior Director in the Next Generation and Standards Group at Intel, about the evolution of Wi-Fi and its role in supporting the IMT-2020 vision for the next generation of wireless connectivity.

**Monica Paolini:** Carlos, you have been working on Wi-Fi for a very long time. What are you working on at Intel these days?

**Carlos Cordeiro:** I work at Intel in the Next Generation and Standards (NGS) Group, which is responsible for all the wireless standardization at Intel.

Specifically, my responsibility there is to work on the Wi-Fi standards. Our team participates in every other organization that has to do with driving the Wi-Fi technology forward. That includes IEEE 802.11, where we define the lower layers, the medium access control (MAC), and the physical (PHY) layers.

We work within the Wi-Fi Alliance, which is responsible for bringing those technologies to market in an interoperable fashion, and for defining many of the upper-layer protocols that we have come to know and love, and that are slowly coming to market – such as Passpoint – and on strong security.

Finally, we also work with the Wireless Broadband Alliance, which does a lot of the end-to-end trials for carriers, and it is focused on making sure that Wi-Fi is suited for the managed-carrier user.

**Monica:** Intel has been working on Wi-Fi since before the Wi-Fi Alliance even existed, before the term Wi-Fi was introduced. Intel had a major role in promoting the technology.

What do you see as Intel's role right now, with the latest steps in the evolution of Wi-Fi? And how does it to relate to 5G?

**Carlos:** Wi-Fi has been around for over 20 years now. The standard has been around for a long time, and then products started showing up in the market. I think it's important to realize that in large part, Wi-Fi is what it is today, so popular, because of what Intel did as part of the Centrino launch about 15 years ago.

With Centrino, Intel made a strategic move with its decision to put Wi-Fi in every shipping laptop platform. That really transformed the use of Wi-Fi. It made it pervasive to this day.

We have more Wi-Fi devices in use today than we have people. Last year alone, about three billion Wi-Fi chipsets were sold in the market. Intel has been for a long time, since the Centrino days, and still is today, a very strong proponent and advocate of Wi-Fi.

We have a lot of stuff in the pipeline based on 802.11ax, 802.11ad and 802.11ay that's going to be pushing the boundaries of Wi-Fi going forward.

**Monica:** At the time of the Centrino announcement, many were skeptical about the need to have Wi-Fi on laptops and worried about the cost it introduced on laptops.

Today, the situation is reversed. Your next laptop will come, for sure, with Wi-Fi, but you might not have Ethernet. Back then, it would have been heresy to say you'd have a laptop with no Ethernet.

From a user perspective, Wi-Fi is attractive because adoption costs are low, it is ubiquitous in devices, and it is easy to set up and manage. With its massive footprint, Wi-Fi brings a huge economic benefit to society.

**Carlos:** You are touching on a very important point. For a few dollars, with Wi-Fi you can have a gigabit link in your home. It is a very low-cost technology, which is really what has made it so popular.

We have Wi-Fi today pretty much in every enterprise, in many homes, in coffee shops, airport lounges – you name it.

There was a recent study from Wi-Fi Forward, and I have to give a shout-out to them. In that study, they show that Wi-Fi generated about $550 billion in the US economy last year. That's an unprecedented number. If you look at it globally, that number will easily exceed $2 trillion.

Not only have we come to know and love Wi-Fi, but it also generates huge value to the economy, which makes the technology that much more important.

**Monica:** Let's look at the evolution of Wi-Fi. What do you see as the major steps moving forward?

**Carlos:** We are working on many different aspects of Wi-Fi, from the lower layers, trying to increase the data rates and provide a richer user experience, all the way to the highest layers, where it's more about manageability, as well as addressing new use cases and new markets.

The major new thing that is coming to the market is around the next evolution of Wi-Fi with 11ax. We all know 11n and 11ac technologies, and we can get them today, if you go to a Best Buy, if you go to any retail shop.

Now we are working on 11ax, which is going to provide much higher data rates compared to 11ac, the previous generation. It's going to include new technologies that are going to make Wi-Fi even

more usable in dense environments, where you have dozens of devices.

For example, in your home you not only have your cellphones, your laptops, but, now, you also have IoT devices. You have your cameras, you have your thermostats, game console, tablets and so on. That density of devices requires the technology to evolve. Densification is really the value proposition for 11ax.

The additional capacity and density at the same time is a major differentiator of 11ax, compared to the previous generation.

In addition, 11ax will provide better power efficiency. That allows IoT devices, which are very low-power, to sleep for longer periods of time to save power. This is all being done on top of the existing generation of 11ac.

That's going to be a major revolution in the Wi-Fi market, a major new stat in the evolution of Wi-Fi.

At the same time, in the higher-frequency bands, we have other technologies, like 11ay. The high-frequency 60 GHz spectrum band is driving the speeds we need to address use cases for AR or VR, which is something very exciting that is happening today. It also supports other use cases that need wireless docking and high-speed networks.

**Monica:** In many ways Wi-Fi is evolving along lines which run in parallel to 5G, as both technologies try to meet the IMT-2020 requirements.

It's not surprising that both Wi-Fi and 5G are moving in the same direction, because they are both trying to meet the same demand out there for pervasive connectivity that we are seeing in the market everywhere in the world.



*Source: Intel*

**Monica:** How does the next generation of Wi-Fi relate to the evolution of cellular with 5G?

**Carlos:** In talking to many people over the years, it's always this discussion around how Wi-Fi fits with 5G. At Intel, we think Wi-Fi is critical in meeting many of the 5G needs and use cases.

We see these two technologies as complementary. Wi-Fi has a huge penetration indoors. Enterprises, homes, coffee shops, and airport lounges, for example. Cellular, of course, is prevalent outdoors. Of course, with cellular you can also get coverage indoors, but signal quality is lower.

Where the quality of the cellular link falls short indoors, Wi-Fi picks up the tab, and can supplement the use case for cellular in offering 4K video streams, AR or VR.

Technologies like Passpoint support Wi-Fi offloading. Passpoint has been around for a few years, and it's increasingly being deployed by carriers.

This year, Passpoint was readily deployed at the MWC conference halls. Wi-Fi transferred over 2.3 terabytes of data during MWC. There was a huge number of Wi-Fi devices at MWC.

Offloading is something that Wi-Fi can do for cellular. Even if there is cellular connectivity, the high capacity of Wi-Fi complements cellular, and together they deliver a better user experience.

We see this complementary relationship growing with 5G. 5G is going to open up even more opportunities for Wi-Fi, because the 5G capacity and latency requirements suit the Wi-Fi technology that is being developed today.

**Monica:** A key aspect of 5G is to have an integrated network that combines multiple access technologies. Wi-Fi is going to get even closer to cellular with the integration with 5G.

**Carlos:** Absolutely. In the past, in 4G, there were a lot of technologies developed to look at integration of Wi-Fi and cellular. We had LWA, which is LTE Wi-Fi aggregation, and LWIP, which is LTE and WLAN integration with IPsec tunnel.

In recent years, we see even more work around integration and convergence between Wi-Fi and cellular. We believe 5G offers new opportunities for that integration to happen.

Many of the experts at Intel are looking at these opportunities. One of them is the separation between control units and distributed units adopted in the 5G architecture. That opens a new level of integration of Wi-Fi into the 5G core that did not exist in 4G. The industry is working hard on this, and users are going to be able to take advantage of that in coming years.

**Monica:** What does integration mean for the user? Right now, we still have Wi-Fi and cellular on our phones. We already use both of them. How will the user experience change with a closer integration?

**Carlos:** The integration comes in different flavors. We can talk about integration at the component level that will simply offer lower-cost devices.

You can imagine that some components of Wi-Fi and cellular can be reused. You can reuse antennas. We can share RF components.

You can think of higher-layer experiences that can be offered when you have Wi-Fi and cellular integrated in the same device. One very simple example which really resonates with people is the mobile worker. When you are going from an outdoor to an indoor environment, or from a place where you have great coverage with cellular to where the coverage is not so good, for instance in an airport, and you are taking that call, you are making a presentation, you really need that connection to be seamless.

With tight integration, you can drive those connection times and those latencies down, so that there is a seamless rolling between Wi-Fi and cellular, so that the user won't really notice the handoff.

Today, some of this integration is realized through Passpoint, but we still have a ways to go. 5G and Wi-Fi can be integrated to a level that makes it possible for an operator to treat Wi-Fi as a 5G radio access technology (RAT).

That will offer new opportunities for a richer user experience, not only when you are talking, but also when you may be watching a movie, and going between Wi-Fi and cellular. That should be completely seamless for the user.

**Monica:** Moving beyond users, what are the additional benefits that the tighter integration with 5G will bring to enterprises and operators?

**Carlos:** 5G introduces the edge compute and network slicing components that bring the network closer to the enterprise.

Enterprises will have a much finer control of the network. They want to have very predictable service and dedicated quality, and to be able to manage their own devices. With 5G, they can do that.

The combination of the Wi-Fi enterprise network with edge services provided by the operators or deployed by the enterprise allows a closer

integration between the Wi-Fi infrastructure and the 5G core.

This is not available today, but 5G is making this possible, where you can, in a way, mix and match. Operators and enterprises can use elements of that 5G core, if they want to, so that they can manage their devices in the enterprise, or outside, when you have a mobile worker scenario.

At the same time, this will leverage the huge install base of Wi-Fi that has been there for a long time, and it's going to remain into the future.

Being able to marry the elements of the 5G core with the existing and future installed base of Wi-Fi, is a differentiator for 5G – something that was not possible until now.

**Monica:** How do you see the evolution of Wi-Fi to meet the requirements of the enterprise – not just in terms of the basic connectivity, but also for IoT applications?

**Carlos:** This is a great question. Enterprises are evolving. They have requirements and needs that keep evolving over time.

The sheer number of devices is rapidly growing. It used to be only laptops and your phones. Now there are the projectors, devices to control HVAC and lighting, and other types of devices.

That essentially introduces a requirement to support high density, a huge number of devices in the enterprise, with different quality of service requirements. Some devices need high speed, some of them need low latency. Others, like sensors, don't transmit much data, but whenever they wake up to transmit data, they need access to the channel.

These are sets of requirements that we are trying to address with 11ax. 11ax can support high density and scheduled service, and it's really going to be a major revolution for enterprises.

Also, one of the great features of 11ax is that it uses a technology called OFDMA, which allows you to allocate resources to devices in a granular way that is conducive to low power consumption. This capability addresses the high-end, as well as the low-end, devices used for IoT applications.

**Monica:** Security is absolutely crucial for the enterprise. What is the Wi-Fi Alliance doing in this area?
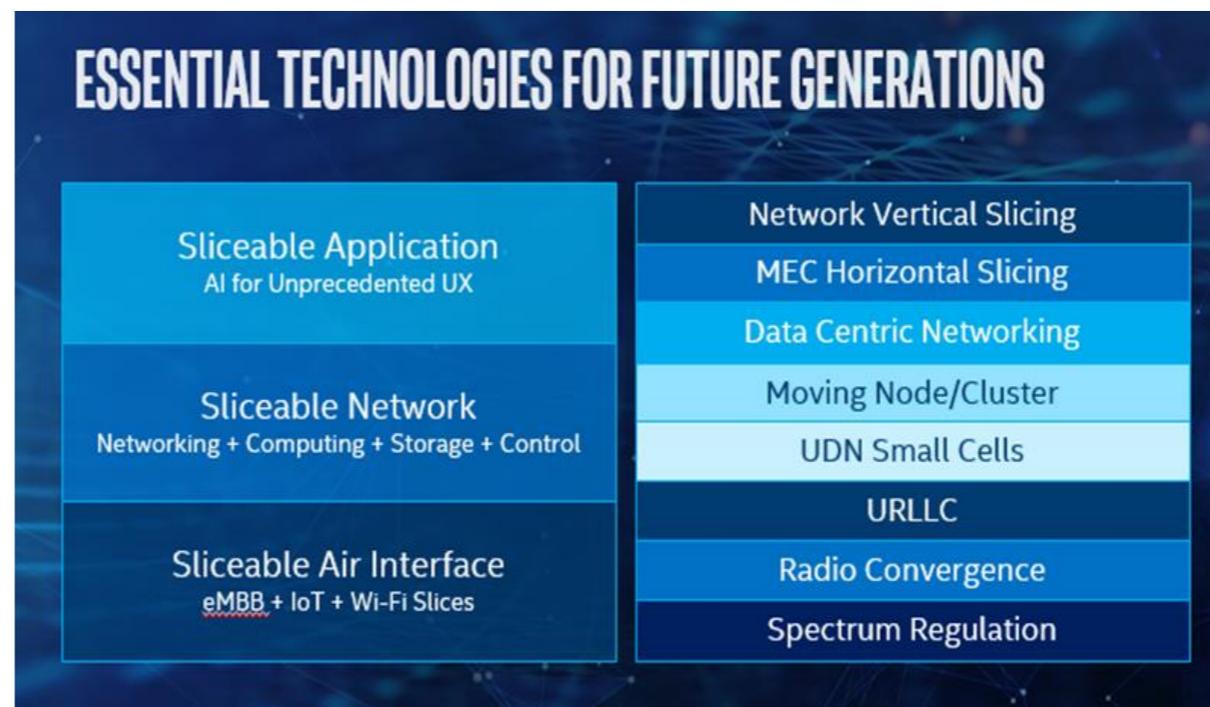
**Carlos:** Too much security is never enough. Wi-Fi has had a very successful track record with security over the years with WPA2. That's the current generation of security.

Recently the Wi-Fi Alliance announced WPA3, a certification program that offers new and unprecedented security for Wi-Fi.

WPA3 really brings a new security mechanism that will make Wi-Fi even safer, and even more secure to use. We are introducing one new technology called SAE, or Simultaneous Authentication of Equals. SAE technology makes it much harder to launch dictionary attacks, in which an attacker makes several attempts to identify a password.

Also, WPA3 introduces a stronger 192-bit encryption, which is a government-grade type of encryption. This is something that government agencies can use and so can enterprises. The combination of stronger encryption and SAE makes WPA3 a key technology to provide the security that Wi-Fi users require for many years to come.

For Intel, as within the industry, this is something



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UDN Small Cells
URLLC
Radio Convergence
Spectrum Regulation

*Source: Intel*

that we believe will be better with 11ax, so that when you get the newest technology for 11ax, you're also going to have the stronger WPA3 security.

**Monica:** When we look at the evolution of Wi-Fi and 5G, what do you see moving forward?

**Carlos:** One of the great things at Intel is that Wi-Fi and 5G work side by side within the company. I put on my Wi-Fi hat when I talk to the 5G team. We have a number of projects where we are trying to bring the elements of 5G, other cellular technologies and Wi-Fi technology all together.

Wi-Fi and 5G will go hand in hand into the future. They're going to be tailored to different usages, to different requirements. Whenever the industry needs to bring those tools together to the benefit of the user, that's something we will do.

I see a great future for Wi-Fi in the 5G world. Whenever cellular moves beyond 5G, we're going to be there, head to head, trying to offer compelling new use cases, compelling new experiences, and making sure that the industry is always moving forward.

All I can say here at the end is, long live Wi-Fi and long live cellular, because these technologies are here to stay.

**Glossary**

| | |
|---|---|
| **AR** | Augmented reality |
| **IEEE** | Institute of Electrical and Electronics Engineers |
| **IMT** | International Mobile Telecommunications |
| **IoT** | Internet of things |
| **IPsec** | Internet Protocol security |
| **LTE** | Long Term Evolution |
| **LWA** | LTE WLAN aggregation |
| **LWIP** | LTE Wi-Fi Radio-Level Integration with IPsec Tunnel |
| **MWC** | Mobile World Congress |
| **NGS** | Next Generation and Standards |
| **OFDMA** | Orthogonal Frequency Division Multiple Access |
| **RAT** | Radio access technology |
| **RF** | Radio frequency |
| **SAE** | Simultaneous Authentication of Equals |
| **VR** | Virtual reality |
| **WLAN** | Wireless local area network |
| **WPA2** | Wi-Fi Protected Access 2 |
| **WPA3** | Wi-Fi Protected Access 3 |

## About Intel
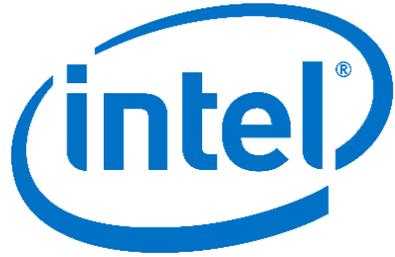


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## About Carlos Cordeiro



Dr. Carlos Cordeiro is a Senior Principal Engineer and Senior Director in the Next Generation and Standards Group within Intel Corporation. He is responsible for Intel's Wi-Fi standards activities and standardization for unlicensed millimeter frequencies. In the Wi-Fi Alliance, he is a member of the Board of Directors and serves as its Technical Advisor. He is the technical editor to the IEEE 802.11ay standard and was the technical editor to the IEEE 802.11ad standard. Due to his contributions to wireless communications, Dr. Cordeiro received several awards including the 2017 IEEE Standards Medallion, the prestigious Intel Inventor of the Year Award in 2016, the IEEE Outstanding Engineer Award in 2011, and the IEEE New Face of Engineering Award in 2007. Dr. Cordeiro is the co-author of two textbooks on wireless published in 2006 and 2011, has published over 100 papers in the wireless area alone, and holds over 150 patents.

# About Senza Fili

Senza Fili provides advisory support on wireless technologies and services. At Senza Fili we have in-depth expertise in financial modeling, market forecasts and research, strategy, business plan support, and due diligence. Our client base is international and spans the entire value chain: clients include wireline, fixed wireless, and mobile operators, enterprises and other vertical players, vendors, system integrators, investors, regulators, and industry associations. We provide a bridge between technologies and services, helping our clients assess established and emerging technologies, use these technologies to support new or existing services, and build solid, profitable business models. Independent advice, a strong quantitative orientation, and an international perspective are the hallmarks of our work. For additional information, visit www.senzafiliconsulting.com, or contact us at info@senzafiliconsulting.com.

# About Monica Paolini

Monica Paolini, PhD, founded Senza Fili in 2003. She is an expert in wireless technologies and has helped clients worldwide to understand technology and customer requirements, evaluate business plan opportunities, market their services and products, and estimate the market size and revenue opportunity of new and established wireless technologies. She frequently gives presentations at conferences, and she has written many reports and articles on wireless technologies and services. She has a PhD in cognitive science from the University of California, San Diego (US), an MBA from the University of Oxford (UK), and a BA/MA in philosophy from the University of Bologna (Italy). You can contact Monica at monica.paolini@senzafiliconsulting.com.