5G and Wi-Fi 6: Stronger together

Two parallel paths to connect everybody and everything

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Connectivity is no longer just an amenity, something that makes life easier or more enjoyable. For many of us, it has become a basic component of our life, a necessity. We need to be connected for work, education, health care, social activities, and entertainment. For 49% of the world population, connectivity is equally valuable, but not yet available or too expensive.

Technological evolution is making connectivity more affordable, reliable and secure, improving both performance and coverage for all of us – and for all the IoT devices that we want to connect. Connectivity is becoming pervasive, and we have the technological tools to overcome the digital divide. But to extract the full benefits of this evolution, we need to find the right balance in the adoption of different technologies.

Access to connectivity has become wireless by default. Homes may have fiber, but people use their phones or laptops to connect wirelessly. In the workplace and public venues, people similarly rely on wireless access. Yet our connectivity depends on multiple technologies taking on different but crucial roles to make sure it all works seamlessly.

No single wireless technology meets all our connectivity needs – and this is not just an affordability issue. Each technology has specific features and strengths that make it well suited to some usage scenarios and not to others.

Wireline technologies are still essential. Wireline transport and wireless access depend on each other to provide capacity, scalability and reliability. We may use our phone to connect, but eventually our connection is handed over to fiber.

Wi-Fi and cellular networks carry most of the wireless access traffic and will continue to do so with the introduction of Wi-Fi 6 and 5G, available today, and, eventually, with Wi-Fi 7 and 6G. Better performance, higher efficiency and lower costs make it possible to connect more people and things, and to improve their connections. This is not just about the number of connections: it is the range of use cases that will grow – and in directions beyond those we can envisage today. The biggest growth potential in use cases is going to be in IoT and IIoT, with 5G supporting specific enterprise requirements and Wi-Fi 6 continuing to foster a wider adoption of smart-home applications.

Do we still need Wi-Fi 6 once we have 5G?

Yes, we will need still them both, as we do need Wi-Fi and 4G today. The performance improves for both, but their role in keeping us connected remains the same.

Do we still need 5G once we have Wi-Fi 6?

Not only will 5G and Wi-Fi continue to coexist – they will continue to strengthen each other. 5G brings the wide-area coverage and mobility support that we need for ubiquitous connectivity. Wi-Fi brings the capacity and speed we need when we are indoors or in high-density locations. This divide-and-conquer approach succeeds because the combination of licensed spectrum for 5G and unlicensed spectrum for Wi-Fi enables different models of spectrum use, different business models and different wireless infrastructure owners.

In this paper, we look at how Wi-Fi and 5G can jointly meet the needs of those already connected and of those who still need to be connected in a way that neither technology on its own could.

Converging performance, distinct roles: The benefits of diversity

Both cellular and Wi-Fi technologies have been evolving rapidly, driven by our growing need to get a fast and affordable connection, wherever we are, whenever we need it. With Wi-Fi 6, Wi-Fi has gradually moved closer to cellular in improving security and reliability, and in adding tools to better manage traffic and control performance. Similarly, 5G has increased throughput and expanded to higher frequencies and wider channels. The technological competition between cellular and Wi-Fi has been a healthy driver in accelerating the evolution and expansion of features such as M-MIMO.

The convergence in performance has led many to question the need to have both technologies. Could just one meet all our connectivity needs? Based on standards specifications, this could work. In the real world, this is neither desirable nor efficient. It would neither reduce costs nor increase spectrum utilization.

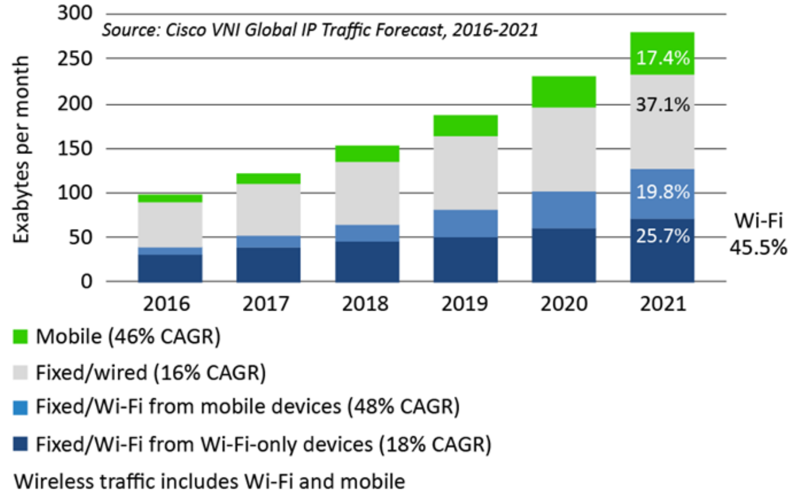
First, the coexistence of two strong wireless access interfaces with different standardization bodies and approaches to connectivity is valuable because it encourages technological and market competition, and the development of new service and business models.

Second, 5G and Wi-Fi 6 meet two coexisting and complementary sets of connectivity needs in different ways. Wi-Fi 6 provides the capacity we need, especially in indoor environments – homes, workplaces, and public venues. 5G, along with legacy networks, gives us the ability to stay connected wherever we go.

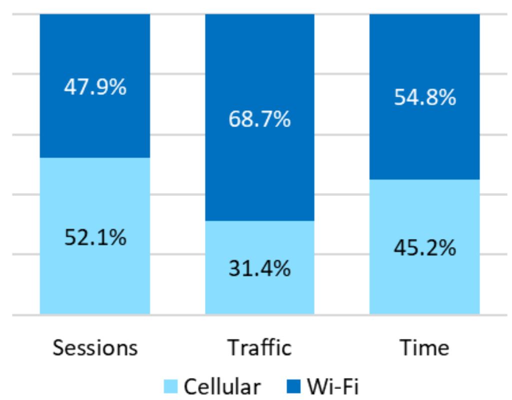
Cisco VNI estimates that Wi-Fi carries a stunning 45.5% of global IP traffic. This percentage is expected to increase as wireless access accounts for an increasing portion of overall traffic. Within wireless access, Wi-Fi traffic exceeds cellular traffic by far. Depending on the estimates, Wi-Fi accounts for 60% to 85% of wireless traffic (63% according to the Wi-Fi Alliance), depending on operator and country.

This does not mean that Wi-Fi is more valuable to users, however. The bottom graph on the right shows that, in the US, cellular accounts for more sessions than Wi-Fi and for almost the same connection time. Users preferentially use cellular to stay connected and for applications with limited traffic loads, but they may switch to Wi-Fi when they want to watch videos. This choice is not entirely – or primarily, in markets like the US – due to the fact that Wi-Fi is usually cheaper. Users with unlimited cellular plans still use Wi-Fi more than cellular, because many get better performance and battery life or want

Global IP traffic by local access technology



Wi-Fi and cellular traffic on mobile devices in the US



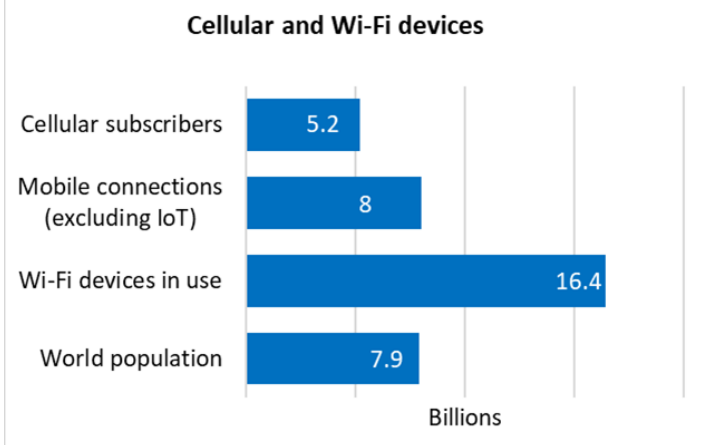
Source: P3, Telecom Advisory Services, Senza Fili to have more control over their traffic.

Third, Wi-Fi 6 and 5G will continue to enable different service models and use cases. The use of unlicensed spectrum gives users more control over what they do with Wi-Fi and which devices they use. Every laptop has Wi-Fi, but few have cellular, and this is not likely to change with 5G. Most home IoT devices use Wi-Fi or Bluetooth because this reduces the cost and complexity of connectivity. Users can manage their devices – commonly through their phones – without having to set up an account with their mobile operator.

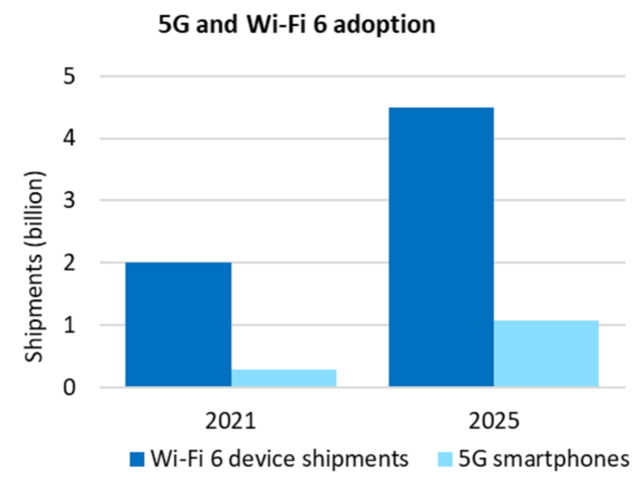
As a result, there are more Wi-Fi devices than cellular smartphones (and they virtually all have Wi-Fi), and many users have more than one Wi-Fi device (see top graph on the right). This trend will continue with the adoption of Wi-Fi 6 and 5G, with Wi-Fi 6 devices outnumbering smartphones, although with the increase in IoT connections in 5G networks, we expect the gap between 5G and Wi-Fi to shrink.

As 5G becomes more widely available, an increasing number of applications and services will become available in the new devices, with 5G rather than Wi-Fi used as the primary access channel. This may be the case for AV/VR applications that require tighter traffic management and connectivity to a public network for mobility and support for application features.

However, similar to smartphone access, we should expect that 5G IoT devices will dominate in outdoor, wide-area environments, while Wi-Fi will continue to prevail in indoor environments. 5G devices will also become more prominent in IIoT applications – including indoor ones – with stringent latency, reliability and security requirements.



Source: UN, Wi-Fi Alliance, GSMA, Senza Fili



Source: IDC, Wi-Fi Alliance, Ericsson, Senza Fili

Synergies and differences

	5G	Wi-Fi 6
Where it is used	Outdoors, wide-area coverage, mobility support, public networks.	Indoor, carries most traffic, residential/enterprise private networks.
What's new	High-frequency mmWave bands are supported, and greatly increase 5G capacity in areas with high traffic density.	Expansion of unlicensed spectrum to include the 6 GHz band. In the US, the 6 GHz has almost twice the bandwidth of the 2.4 GHz and 5 GHz bands combined.
Spectrum utilization	Licensed: 600 MHz to 90 GHz (multiple bands, depends on country). Unlicensed: 5G NRU can be deployed in unlicensed bands used by Wi-Fi, but adoption will be limited, at least in the short- and mid-term. Shared spectrum arrangements are increasingly available (e.g., CBRS in the US, enterprise/location-based bands in Germany and the UK).	Unlicensed: 2.4 GHz, 5 GHz, 6 GHz, 60 GHz. In unlicensed bands, spectral efficiency (bits/s/Hz) is lower because of coexistence requirements (e.g., listen-before-talk mechanisms), but spectrum utilization is higher (bits/sqft) because networks cover areas with high traffic density and have to coexist with competing ones.
Performance	10 Gbps DL, 1 Gbps UL throughput, up to 100 MHz in sub-6 GHz, up to 800 GHz in mmWave bands.	Up to 9.5 Gbps, within a range up to few hundred meters outdoors.
Security	SIM-based security built in for all devices, but if using a public network, data goes through the mobile operator core network.	Robust security with WPA3, and 192-bit cryptographic strength with WPA3-Enterprise. Wi-Fi users have more flexibility with encryption and data sharing.
Strengths	Mobility support up to vehicular speeds, with seamless handoffs. Low latency, deterministic behavior, fine control over RAN transmission. Network slicing and QoS reduce latency and jitter and increase reliability.	No spectrum costs, interoperability, open ecosystem, low IP costs. Easy and low-cost to deploy and to manage. Low latency and jitter, but difficult to control if traffic load is high and multiple contending networks coexist. QoS Management is now available and provides functionality comparable to network slicing.
Weaknesses	In licensed bands, only license holders can deploy 5G. More complex to deploy and operate, even more so for a multivendor network.	Coexistence of multiple networks at a given location reduces ability of network operator to control traffic and makes it more difficult to manage congestion.
Costs	Cost effective to cover wide areas. Equipment costs will come down as the technology matures.	Lower costs in indoor or dense outdoor environment. Expensive for WAN coverage.
Next-gen technology	6G – New 3GPP standard, deployments in 5–10 years.	Wi-Fi 7 – Standardization for IEEE 802.11be to be completed in 2024, with Wi-Fi Alliance certification and shipments within two years after.

Wi-Fi 6 and 5G: Where do they belong?

We made a case that both Wi-Fi 6 and 5G have crucial, yet different, roles in meeting our connectivity needs. So what are the environments and use cases where each fits best?

Home

Wi-Fi 6 will continue to carry most of the wireless traffic to and from homes where a fixed broadband connection is available. Many cellular devices automatically switch to Wi-Fi once the user gets home. Increasingly, however, Wi-Fi traffic is generated and exchanged among devices in the home – e.g., laptops, TVs, cameras, thermostats, and wearable devices worn by the occupants. Parks Associates estimated that US households had on average 12 Wi-Fi devices in 2020 and projected that number to reach 20 by 2025.

Some of these devices, however, will also have 5G, and most users will use 5G to manage these devices and their applications, especially when they are not at home. For instance, users may use 5G to check their security cameras, set the home heating temperature when they are away, or track their activity while at home and elsewhere.

The coexistence on phones of 5G and Wi-Fi will increase the value, ease of use and availability of this constellation of devices for their users. Many of these devices are shared by the people living in the home. Typically 5G devices such as phones are linked to an individual, but Wi-Fi makes it easier to share access among users. This creates a home connectivity cloud where people living in the home or visiting can get the access they need to the devices available.

The increasing availability and speed of 5G will let some users cancel their fixed broadband subscription and rely entirely on 5G for connectivity. This may be an appealing alternative to people with limited connectivity needs from home, or who cannot afford fixed broadband, or who have short-term housing arrangements – e.g., students. In this case, the 5G phone becomes the main access channel from home, and other connected devices may use Bluetooth or Wi-Fi to connect through the phone.

Cost comparison: Is Wi-Fi cheaper than 5G?

Wi-Fi uses freely available spectrum, and an AP can cost less than $20. This is due to larger volume, a more open vendor ecosystem and lower IP costs. Adding a Wi-Fi module to a device has a minimal impact on its retail price. Does this make it cheaper than 5G? Not necessarily.

In a home or small business, Wi-Fi is a cost-effective, easy-to-deploy solution. 5G is unlikely to change that. Mobile operators may push residential 5G small cells, but they tried this with 4G small cells and did not work beyond niche markets. Most homes have Wi-Fi and will upgrade to Wi-Fi 6 when they need a new AP, so the benefit of a 5G small cell is minimal to the residential user and a potential cause of interference for the operator. In the residential and small business market, Wi-Fi is likely to remain the most cost-effective solution.

In large businesses, however, the cost of deploying and operating enterprise-grade Wi-Fi is considerably higher than in small enterprises, especially if the network supports mission-critical or latency-sensitive applications. If the enterprise has access to 5G spectrum – e.g., with CBRS in the US – the cost of the 5G network may be comparable to that of Wi-Fi. The availability of shared spectrum that is free (e.g., CBRS in the US) or cheap (e.g., Germany's 3.7–3.8 GHz band) further reduces the cost of deploying 5G. However, even in large enterprises, the per-bit cost for Wi-Fi is likely to be substantially lower than for 5G because of the wider spectrum channels available for Wi-Fi.

In the WAN, the cost of Wi-Fi escalates quickly as the traffic density declines. For this reason, the use of outdoor Wi-Fi is limited to well-delimited areas where the traffic demand is too high to be met cost effectively by cellular networks alone. In suburban and rural areas, Wi-Fi is rarely used for access. (Unlicensed bands, however, are used for fixed wireless access, or FWA, and may even use the IEEE 802.11 standard, but they do not use certified Wi-Fi.) In areas without high traffic density, 5G is going to be more cost effective than Wi-Fi – and, in fact, 4G may have a better TCO there than 5G because traffic demand is low.

Enterprise

In the enterprise, Wi-Fi is ubiquitous and will continue to be used in the Wi-Fi 6 and 5G era, but 5G will have a clear role as enterprises increase their use of wireless connectivity to run their operations. This is not limited to the carpeted enterprise, but extends to all verticals, including, for instance, industrial manufacturing, utilities, mining and oil, and ports.

Wi-Fi will continue to provide access for employees and IoT devices such as cameras and other monitoring devices. Often when we talk about private networks and IoT, we restrict our focus to cellular networks, but Wi-Fi networks are by far the most widely deployed private networks and support most of enterprise IoT and IIoT applications today.

The faster speed and capacity of Wi-Fi 6 and the addition of 6 GHz spectrum in many countries will enhance Wi-Fi's ability to meet most enterprise connectivity needs. Wi-Fi can not only keep the entire workforce connected, it can also support most services and applications with its extensive device ecosystem.

Enterprises have ample experience in deploying and managing Wi-Fi networks, either directly or through service providers, but they realize that Wi-Fi may meet the requirements for applications and services that have strict latency, reliability or security requirements in environments where they do not control the use of unlicensed spectrum. For instance, to operate robots, AGVs or drones safely and effectively, the enterprise needs a level of precision, latency and reliability that licensed spectrum is better suited to provide. In either case, however, full control over spectrum use is essential for these applications. For 5G, this means the use of private networks or network slicing. For Wi-Fi, this means the ability to control the Wi-Fi networks that operate within the premises – and this is going to be easy to achieve in the newly available 6 GHz band in locations where the enterprise has control over the real estate.

5G will be critical to use cases that require licensed spectrum, and enterprises are keen to deploy private networks to serve those needs. However, the process is going to take longer than the adoption of Wi-Fi 6, because it requires the deployment of greenfield networks that are more complex than Wi-Fi.

Many vendors now offer solutions aimed at the enterprise market to reduce the complexity of 5G and adapting features such as edge computing, automation, virtualization and device onboards to the specific needs of individual enterprises. While

Enterprise use cases

	5G	Wi-Fi 6
Workforce data and video communications	◔	●
Workforce voice communications	●	◕
Workforce communications, safety and critical communications	●	○
Video surveillance	○	●
Building sensing, monitoring, remote control	●	●
On-premises high-bandwidth data transmission	○	●
Robotics, automated manufacturing, on-premises logistics	●	◑
AR/VR/XR	●	◕
Visitor access and services	◑	●
Wide-area tracking, sensing and control	●	○
Automated guided vehicles (AGV)	●	○
Autonomous vehicles	●	○
Drones	●	○

Good ● ◕ ◑ ◔ ○ Bad

these solutions may not make 5G networks as easy to operate as Wi-Fi, they will accelerate the adoption of 5G private networks in the enterprise.

Just as enterprises need unlicensed spectrum to deploy Wi-Fi, the availability of licensed spectrum is a key enabler for 5G private networks. While it is possible for enterprises to lease spectrum held by others, such as mobile operators, license holders are typically reluctant to lease they spectrum because they need it or want to keep it in case they will need in the future. The increased availability of shared spectrum regimes and spectrum allocations for enterprises are effective paths towards an expansion of 5G in the enterprise and the adoption of applications that cannot be supported by other wireless technologies.

Public venues, smart cities

Wi-Fi networks in public venues are just as common as in enterprises, but in addition to serving the venue itself, often they also provide connectivity to visitors and tenants. Cellular private networks are still rare, although public venues such as stadiums have DAS or small cells to increase capacity. These are usually not managed by the venues, but by mobile operators or neutral hosts on their behalf.

With 5G and Wi-Fi 6, the capacity density, speed and reliability of wireless connectivity will improve and will remedy some of the congestion challenges that many of these venues face. Congestion is unlikely to vanish, though, because traffic loads historically depend on network capacity. Once the capacity of the network increases, users quickly figure out how to use it and traffic goes up. The effect is more prominent in public venues, which more often operate at capacity. The move toward higher-frequency bands will alleviate this issue as better frequency reuse increases spectrum efficiency.

As in other environments, Wi-Fi 6 and 5G will address distinct use cases. Internal venue applications will be handled similarly to the enterprise ones noted above – venue networks operate like enterprise networks. For public access, Wi-Fi 6 will be used for the free access that visitors now expect and also for applications – e.g., location-based information, marketing or entertainment – that the venue or its tenants want to offer. It is easier and cheaper for the venue and tenants to host and manage these applications on a Wi-Fi network they control.

At the same time, 5G networks may provide a better connection where the Wi-Fi 6 network is congested (but it may also work the other way around, if the

A new regulatory approach

Regulation enables and encourages the deployment of wireless networks. As our connectivity needs change – not just the traffic volumes, but also, and more importantly, the use and value of wireless applications and services – so is the regulatory approach evolving to enable more flexible and efficient use of spectrum and to expand the availability, affordability and quality of connectivity across markets.

New trends in regulation specifically encourage the deployment of Wi-Fi 6 and 5G for both private and public networks:

- Increased availability of spectrum in high-frequency mmWave bands, which can provide excellent frequency reuse and high capacity in dense areas, both indoors and outdoors.
- Allocation of more spectrum to unlicensed use. The wide availability of the 6 GHz band for unlicensed use is going to have a massive impact on the ability of Wi-Fi to meet existing and new demand. Even though the channels reserved for unlicensed use vary to some extent across markets, the ecosystem for Wi-Fi 6E equipment that supports the 6 GHz band is quickly growing. Most regulators are under intense pressure from mobile operators to release new spectrum for licensed use, and have to find the right balance between licensed spectrum (which brings in revenues) and unlicensed spectrum (which provides an economic benefit to the country).
- Spectrum sharing is gaining wider support, with regulators trying different approaches. This will enable the wireless ecosystem to refine spectrum sharing regimes and expand their adoption to more bands. Spectrum use has been shared in many cases in the past, but the new spectrum sharing approaches allow for a more efficient, multi-tiered sharing with incumbents (e.g., CBRS in the US, or white spaces). Spectrum sharing gives access to new types of users (e.g., enterprises, cities and other public entities, fixed wireless service providers). With spectrum sharing, these players finally have access to 5G, as well as to other 3GPP cellular technologies, in addition to Wi-Fi.

5G network is the congested one). 5G can also support applications such as AR/VR whose latency and reliability requirements demand a level of deterministic behavior that is difficult to achieve in unlicensed bands.

Smart cities will also expand their wireless networks along a path similar to that followed by public venues for dense hotspots, with the difference being that more locations will be outdoors. For example, cities and public agencies could expand their use of wireless networks to manage public transportation, parking and other services, both in monitoring, automating and remotely managing the services, and in providing access for their residents or visitors.

With 5G – and especially with spectrum sharing regimes such as CBRS – smart cities will have the opportunity to deploy their own 5G private networks for applications and services in a wider area than they can today with Wi-Fi. They can also use public 5G networks as a complement or alternative to private networks.

Public networks

Mobile operators are going to direct most of their investment and effort to the 5G infrastructure. The pace of the transition to 5G varies across markets and operators, depending on spectrum availability, user demand, and financial resources, but the transition itself is pretty assured for all operators.

Mobile operators indirectly rely on Wi-Fi as an offload channel that they do not have to pay for. If all traffic through mobile phones would go through the cellular networks, mobile operators would see the traffic demand triple overnight. Their existing networks would not have enough capacity to meet the demand. Expanding network capacity to transport all mobile traffic would be prohibitively expensive, and result in higher costs or use limitations for the subscribers. Even if they do not own extensive Wi-Fi networks, operators (and indirectly their subscribers) will benefit from Wi-Fi 6 availability and higher capacity.

Many operators, however, manage Wi-Fi networks in hotspots where they want to further increase the Wi-Fi offload. They may continue to do so with Wi-Fi 6, but they will also have the opportunity to deploy 5G NRU in unlicensed bands. With 5G NRU, operators can use unlicensed spectrum as a complement to their licensed networks, and manage both licensed and unlicensed traffic within a single network – with the same RAN interface and a shared core network.

Opening wireless networks

In parallel with the growth in our use of – and reliance on – wireless connectivity, there is an increased demand for openness in the network infrastructure, from users, enterprises and operators. Vendors are increasingly supporting the opening of the network infrastructure.

5G – Operators have been vocal in requiring vendors to work together to open interfaces and to enable multi-vendor networks. Open RAN is the initiative that has gained the most support to disaggregate and virtualized the RAN.

Shared spectrum frameworks also open wireless networks, by enabling operators and users to share spectrum and increase the overall spectrum utilization.

The growing use of private networks in the enterprise, often managed by neutral hosts or other operators, will further open 5G networks, by creating new types of networks which are separate from public networks, but can be connected to them.

Wi-Fi 6 – Interoperability has been one of the defining (and initially entirely novel) features of Wi-Fi networks since the beginning, so disaggregation is already used in Wi-Fi.

But the Wi-Fi ecosystem is pushing to open network planning and operations further with TIP's OpenWiFi, which allows operators to manage a multivendor Wi-Fi network within a single platform.

Open Roaming is an initiative from the WBA to allow seamless access across Wi-Fi networks and roaming with cellular networks. With OpenRoaming, Wi-Fi devices, including IoT ones, will be able to connect automatically, without the intervention of the user to trusted networks to both Wi-Fi and cellular networks.

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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.senzafili.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).