

Applied Wireless Technology



Wi-Fi & 5G REDEFINE WIRELESS

**EXPANDING CONNECTIVITY
USING SPECTRUM SHARING**

PG. 10

**SUN SETTING ON
CHINA'S GLORY DAYS**

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SMART CITIES TRENDS

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**BRIDGING THE
BROADBAND DIVIDE**

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Trends

BY THE EDITORIAL STAFF

Of late, the term autonomous has largely been associated with vehicles in the high tech space. However, it is being widened, a bit, by an emerging trend called autonomous things. Largely enabled by AI, this includes robots, drones and autonomous vehicles that will use AI to automate functions previously performed by humans.

The trend is to move away from stand-alone intelligent things to a swarm of collaborative intelligent things. This means we will see multiple devices working together, either independently of people or with human input.

A similar trend is emerging in the augmented segment. Termed augmented analytics, this trend focuses on a specific area of augmented intelligence, using machine learning (ML) to better analyze how content is developed, consumed and shared. Augmented analytics automates the process of data preparation, insight generation, and insight visualization, eliminating the need for professional data scientists in many situations.

Digital Twins have been tending for some time now. However, progress has been slower than expected. Digital twins create a virtual entity of a real-world device or system.

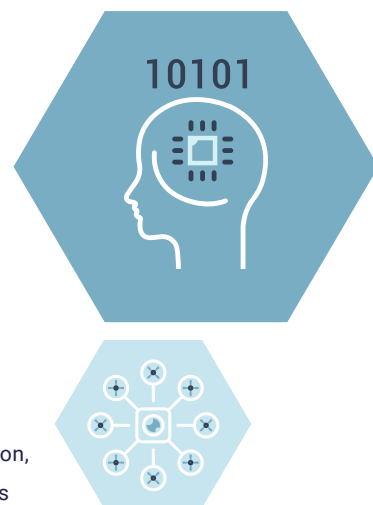
So far the trend has been, mainly, with sensors and endpoints since they are the easiest to digitize. As digital twins gain momentum over time, they will evolve to a higher proficiency in their ability

to collect and visualize the right data and apply the correct set of analytics and rules. The biggest challenge, at present, is to get players to embrace the platform and get them moving to implement the technology.

Another trend that has seen a lot of chatter, but has not evolved as fast as was expected is the edge. In an attempt to get the platform traction, it has been renamed as Multi-access Edge Computing (MEC) to better position it across multiple segments.

Missing is the ability to create real intelligence at the edge. Current hardware is not really up to the job. What will accelerate this trend will be specialized AI chips, greater processing power, and electronic storage advances. To get the edge going will require 5G to become more mature. The edge is where both low latency and ample bandwidths will enable that uber-dense node deployment, which is a critical requirement for such networks.

The term immersive experience is a trend that will take advantage of the evolution in virtual platforms and bring them all under one roof. For now, be it VR, AR, MR, or XR (virtual, augmented,



mixed, extended), they all suffer from the same malady – lack of sufficient hardware and processing capability except for the very high and expensive end.

Not that the technology is not available, but the components necessary to make it “real” are expensive and not as miniaturized and powerful as they need to be. To be truly immersive will require multichannel and multimodal approaches to connect the users to the hundreds of edge devices that surround them – from computing devices to wearables, automobiles, all types of sensors and consumer appliances.

Smart “X” will trend into a very wide swath of our lives. As this platform integrates intelligently enabled multiple elements and systems – including people, processes, service – things will come together in a smart space to create a more immersive, interactive and automated experience. This will also become more personalized and targeted across a myriad of ecosystems, including retail, entertainment, work, and play.

A trend that is both significant and extremely critical in today’s digital ecosystem is security and privacy. As more and more of us become digital entities, privacy and security will have to ramp up – and not just slowly. Lately, people are becoming more aware, and concerned, about how their personal information is being used by both the public and private sector.

This will trend, proactively, towards “trust” because it will become more difficult to police digital ecosystems as they evolve and proliferate. Trust will become the basis of how security and privacy models will evolve.



This is not the type of trust we are familiar with. It is the trust based on core components that will verify, authenticate, and validate the elements, whatever they may be, in the digital space. It will be a transparent and anonymous trust platform.

When it comes to wireless there are so many trends it is hard to keep up with them. But some of the more visible ones are not necessarily the ones getting the attention. For example,



integration. The trend here is towards reusability. Why? Because it drives down costs and accelerates time to market. Manufacturers’ reuse of the same hardware and software, as well as accumulated engineering knowledge across multiple platforms, mitigates risks and allows for rapid reconfiguration. It is also healthy for their bottom lines.

Short Takes

The massive MIMO trend shows no signs of slowing, either. 2019 is being touted as the year MIMO will go mainstream with significant investments and design supporting massively parallel MIMO designs.

NB-Internet of Everything/Everyone (IoX) will ramp up. The most predominant trend here will be in embedded devices that can operate across multiple wireless applications and devices.

Perhaps the most exciting wireless trend is Wi-Fi 6. A radical departure from previous versions, it is not, simply the next generation of Wi-Fi, but a new generation of Wi-Fi. The trend will be to look at Wi-Fi 6 for many of the applications that have been stuck with one of the LTE versions, as well as playing a role in enhanced mobile broadband (eMBB).

From the Editor



ERNEST WORTHMAN

Are Sagging 5G Smartphone Sales a Symptom of a Deeper Issue?

For two years now, smartphone sales have been in trouble. Sales are, for the first time in smartphone history, declining. Numbers are, definitely, show a softening trend.

There is a plethora of thoughts around this. I have discussed some of these in the eDigest from time to time. However, at the last few conferences I have attended I have picked up some perspective from others that help me get, what I believe to be, a high level of confidence in understanding the global picture, and why there is no frantic pace to pick up on emerging technologies and devices by consumers.

I have been skeptical of the 5G hype for some time. I was concerned, early in the hype cycle that users were not going gaga over 5G as the industry was expecting. The mistake the industry made was to assume that users would care about lower latency and faster downloads. As it turns out, most users were not all that unhappy with their current wireless device's performance. So trying to sell the next generation of technology was not a sufficient reason for users to rush out and jump on the 5G bandwagon.

As well, those promised faster downloads, less buffering (lower latency) and better reliability did not prove to be the case with initial 5G deployments.

On top of that, antics such as those by AT&T trying to create a 5G mirage by deploying "5GE and 5G+" did nothing but confuse the issue and trick consumers into thinking 5G was here. All the talk about mmWave and downloading an 8K movie in less than 10 seconds was, largely, shrugged off. So, now we know that 5G is not going to sell phones. However, there are other, current generation, issues.

One significant deterrent to users upgrading is device cost. Users are still satisfied with present device performance. Therefore, they are looking at these pricey phones with a bit of reticence.

Next, come features and apps. The value proposition for spending >\$1000 for a phone does not seem to be valid for the marginal network performance/screen/camera/apps/etc. improvements. Following that is the failure of the wow factors of these new phones; aka the recall of some foldable phones and the issues with others.

Finally, the majority of innovation has been under the covers and hard for consumers to understand. Therefore, they are, simply, no compelling reasons to spend money.

This circles back to the way the industry was assuming the user would understand why next-generation technology matters, and that would be a driver for upgrading. This even extends to Apple, who has been, fairly, bulletproof. The majority of Apple sales are for the cheaper XR model. That is quite telling about what the consumer's mentality is towards the current state of smartphones.

There are some interesting statistics that support this. According to a recent 451 research survey, over half (52 percent) of respondents are satisfied with their current phone. Another 24 percent pegged the cost of new phones or lack of interest in the new app. Another 11 percent simply have no need for better or new devices. That means nearly 75 percent of users are off the market for new phones; at least for the rest of the year.

One interesting statistic is around foldable phones. It is fairly certain that this number has to do with the failure of early models, but, according to the survey, 63 percent were somewhat

unlikely or very unlikely to purchase one. Interestingly, old standards such as battery life, camera, and basic functionality are what users care about most.

So, to get the user to find value in future generations of smartphones is more than just incremental improvements in isolated phone functions such as social media, multimedia, gaming, geolocation, etc. The integration of tangential platforms such as smart cities, autonomous vehicles, the Internet of Everything/Everyone (IoX), smart homes, etc., is what will move the consumer to purchase future generations of handheld communications devices, whatever their form factor, or whatever we call them.

Trying to make sense out of all of this is not rocket science. We have a next-generation wireless Titanic, of sorts, on our hands. Obviously, this ship is not going to sink. However, the pervasiveness of wireless communication is getting away from the non-tech type. They are no longer wowed by technology.

We know an iceberg is out there and the job, at hand, is to direct the ship so it does not run into it. The industry needs to stop focusing on technology and start focusing on what can be accomplished by it, by the user. That will provide compelling reasons for upgrading. Just selling 5G as the next generation of wireless will not succeed.



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Industry Watch

How Dynamic Spectrum Access Can Accelerate 5G Deployment

Spectrum sharing is a concept that promises to offer an elegant reuse solution that can be implemented, universally and globally. It is a geographic reuse methodology for efficient spectrum utilization

BY ADLANE FELLAH

The 5G era is quickly approaching. This next generation of mobile networks will provide high-bandwidth mobile broadband and underpin many converging technologies, and use cases. Some are: smart cities, smart factories, autonomous vehicles, augmented and virtual reality, video communications, the Internet of Things (IoT), and more. 5G promises to be the data backbone of the future economy.

In order for the benefits of 5G to be fully realized, 5G networks must be deployed as efficiently as possible. Unfortunately, this presents a difficult challenge. With its utilization of higher frequencies, 5G requires denser networks than previous generations.

Yet, even 4G, nearly ten years after its introduction, still has not achieved complete coverage in most countries. If the same rollout

techniques are used for the next generation, 5G networks will not be deployed effectively. Instead, new network architectures and solutions must be enacted.

Dynamic Spectrum Access

One challenge in deploying mobile networks is that populations are generally divided into two categories: urban, in which large populations are highly concentrated, and rural, in which smaller communities are spread further apart. Consequently, network coverage is both easier and more profitable in urban areas. This often means that rural areas are slow to receive sufficient coverage. However, a solution to this problem may lie in how 5G spectrum is regulated.



Many countries around the world have begun allocating 5G pioneer spectrum in the mid-band vicinity of 3.5 GHz. Europe has allocated 3.4 – 3.8 GHz, the United States will allocate 3.1 – 3.55 GHz, China is examining 3.3 – 3.6 GHz, and Japan is examining 3.6 – 4.2 GHz. The coverage of rural areas can be facilitated by applying an opportunistic Dynamic Spectrum Access (DSA) layer to these pioneer bands.

The Dynamic Spectrum Alliance (DSA) is a global organization advocating for laws and regulations that will lead to more efficient and effective spectrum utilization around the world. “The DSA is supporting dynamic spectrum access across a variety of complementary spectrum bands and promoting the use of geolocation databases and other interference protection mechanisms” Said Pasquale Cataldi, Head of Wireless at Nominet and member of the board of the Dynamic Spectrum Alliance.

The DSA works in liaison with organizations that pursue similar objectives; in particular the CBRS alliance and important founding members include Microsoft, Google, and Broadcom.

Coming back to the DSA (A as in Access, the same acronym refers to the alliance or the technology) is a method in which spectrum is allocated in real-time, in accordance with a central geolocation database. DSA allows different mobile network operators (MNOs) to use the same spectrum in different geographic locations. The availability of commercial, off-the-shelf software-defined radios (SDRs) enables such dynamic spectrum switching to be both feasible and cost-effective.

The adoption of DSA, with the 5G pioneer bands, has the potential to, dramatically, improve the efficiency of 5G networks. First, it

would allow the entire range of pioneer spectrum to be available at every location, increasing data capacity and speeds. Secondly, it would allow new network operators to use 5G pioneer spectrum in regions not covered by existing MNOs. Finally, incumbent spectrum users could retain their use of the spectrum in a specific location while making it available for others elsewhere.

DSA is a technology that has been used in the management of TV white spaces (TVWS). TVWS refers to the spectrum between channels in TV transmission systems around the globe. This spectrum is allocated dynamically through the use of a regulator-approved database.

Nominet indicated their dynamic spectrum database is DSA compliant and ready to use in a number of countries including the UK and USA. With this implementation, the DSA (alliance) aims at extending the use in 3.5 GHz 5G pioneer bands.

Market Expansion

The proposal to use DSA with 5G pioneer bands is a method of market expansion. In this solution, 5G networks can be more efficiently deployed by encouraging a higher number of network providers. To most effectively promote market expansion, a small portion of the available pioneer spectrum could be set aside as “anchor spectrum,” a lightly licensed band for new market entrants. For example, a regulator could allocate five, 20 MHz blocks of pioneer spectrum as opportunistic DSA. In this case licensed operators have priority over the spectrum and allocate a single 20 MHz block as open DSA – the anchor spectrum to be shared among all operators.

Anchor spectrum could be utilized in rural areas that are slow to receive coverage from MNOs. Even if all MNOs were to rollout their 5G spectrum, on all their current 4G masts, many rural areas would still find themselves in a no-coverage zone. New operators in these communities could deploy 5G networks using the anchor spectrum. Therefore, even if the area were to be covered in the future by existing MNOs, the local network could still function.

The market expansion model could also provide benefits in urban environments that are already sufficiently covered by existing MNOs. For example, organizations such as schools, hospitals, and office buildings could establish private small cells using anchor spectrum, thereby avoiding interference with existing networks.

Realizing the Benefits of 5G

New technologies now provide the ability to manage how and where spectrum is used in any given location, at any given time, through geolocation databases and spectrum sensing. This combination of centralized database and local sensors enable secondary, and tertiary, access by new users and applications while protecting the incumbent users.

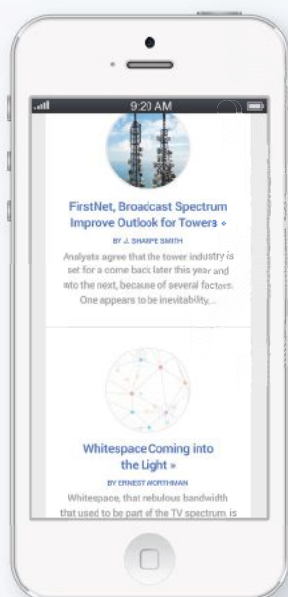
This technology also enables regulators to solve interference problems where they arise. To capitalize on 5G promises, it is important to deploy spectrum efficiently and effectively with dynamic spectrum allocation and sharing.



Adlane Fella is a Senior Analyst. He has authored numerous landmark reports on Wi-Fi, LTE, 4G and technology trends in various industries including retail, restaurant and hospitality. He is regularly asked to speak at leading wireless and marketing events and to contribute to

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Expanding Connectivity: The Evolution of Shared Spectrum

BY DAVE WRIGHT

Shared spectrum is going to be the basis of many spectrum plans in the new 5G ecosystem. It will be one of the great enablers to see the vision of 5G play out.

It is no secret that we are more dependent on wireless connectivity than ever before, and that this dependency is growing far beyond just mobile phones and laptops. This increasingly wireless world is dependent upon the radio frequency spectrum, and there is a, seemingly endless, desire for more spectrum to support the demand.

Traditionally, spectrum has been allocated in one of two ways; 1) for exclusive use via the auction of very expensive license rights, or 2) for unlicensed use available to all, but on a best-effort, uncoordinated basis. The licensed approach underpins today's mobile services, while the unlicensed approach has given us technologies such as Wi-Fi and Bluetooth. While wireless technology and services have evolved dramatically over the last 30 years, this bipolar choice between licensed and unlicensed spectrum has remained unchanged — until now.

An Introduction to Shared Spectrum

Using some impressive foresight, in April 2015, the Federal Communications Commission (FCC) established the Citizen Broadband Radio Service (CBRS) framework to open the 3.5 GHz spectrum band for new commercial services on a shared basis with existing incumbent users. In the new CBRS model, 150 MHz of underutilized spectrum is efficiently shared by taking advantage of advanced allocation and coordination techniques implemented as cloud services — a revolutionary, dynamic option that will become as important as the traditional approaches, not unlike the impact ride sharing has had to transportation.

Importantly, new commercial services are being introduced in two separate allocation modes: a portion of the band will be available for exclusive (Priority Access) use, while all spectrum, not being used by incumbents of priority access licensees, will be available for permissive (General Authorized) use. This model enables carriers, managed service providers, fixed operators, enterprises and industrial players to access this shared spectrum while protecting incumbent users, such as the military and fixed satellite providers. The spectrum is carefully managed to ensure there are no interruptions to either the incumbents' existing services or the exclusive uses at the priority tier. For operators, businesses, and consumers, this means a new alternative that delivers reliable and predictable connectivity at a lower cost than traditional approaches.

The Birth of the CBRS Alliance

In 2016, six companies with common interests, in the adoption of CBRS technology, came together to form the **CBRS Alliance** ▶. The focus of the CBRS Alliance is to support the commercialization of LTE and 5G solutions in the 3.5 GHz band of spectrum in all



aspects — from technology development, to market awareness, to product certification that ensures overall interoperability. Since its inception, the CBRS Alliance has amassed more than 120 wire-
less industry players, representing a broad and diverse ecosystem, ranging from chipset, hardware and software manufacturers to mobile and cable operators, solution integrators, and end-user organizations, all focused on the opportunities enabled by CBRS.

Massive Economic Value

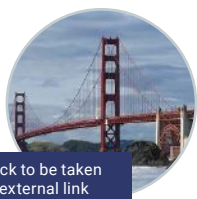
In late 2017, former FCC Commissioner and renowned economist Harold Furtchgott-Roth conducted the first economic analysis of the value presented by the 3.5 GHz CBRS band. He found that not only did the band add real value to the U.S. economy, but in fact, the estimated market value of the priority access spectrum licenses ranged up to \$15.6 billion. In addition, the report found that the estimated net present value of consumer surplus is between \$80 and \$260 billion. For context, at the time of this report, the combined valuation of Uber and AirBnB was around \$80 billion.

The **full report from Furtchgott-Roth** ► provides a thorough analysis of the economic value of the technology and highlights the fact that delaying the availability of CBRS could cost the U.S. economy between \$10-20 billion per year.



Commercial Deployment Outlook

Leading organizations across the country are already exploring how to take advantage of OnGo¹. The **city of San Francisco** ► recently announced its plans to use the 3.5 GHz band to power its smart city implementations, and the **PGA Tour** is conducting extensive field trials of an OnGo private LTE network to improve coverage and security at its tournaments. Even the **NFL** is considering an OnGo network at each of its stadiums to augment existing wireless networks. But when can we expect to see these deployments become a reality?



In July 2018, the FCC took the next step toward the first commercial deployments in the 3.5 GHz band by **announcing** ► an “initial commercial deployment” phase that would precede the full launch of OnGo services. In October 2018,



Ruckus Networks, Nokia, Ericsson, and Sercomm successfully achieved authorization from the FCC to operate their OnGo small cells in the 3.5 GHz CBRS band. These devices are also the first to receive OnGo Certification, indicating the products meet the standards that the CBRS Alliance has developed to ensure interoperability within the OnGo ecosystem. Since then, a number of additional Alliance member companies have received FCC authorization and OnGo certification on their infrastructure products.

In November 2018, the FCC issued the first end user device authorization for a CBRS client to Sierra Wireless for its CBRS IoT module. In the intervening months, several other devices have been authorized, representing the range of CBRS use cases. At this time, there are a variety of smartphones, push-to-talk handsets, IoT gateways, customer premise equipment, laptops and vehicular clients for CBRS, and many additional devices will be authorized through the remainder of 2019.

Collaboration is Key

The story of CBRS and OnGo is one of close industry and government collaboration. There has been an unprecedented

amount of coordination and joint development to implement the FCC's framework, prepare the industry for imminent deployments and certify the various components. The organizations that have been involved in these efforts include the FCC, the National Telecommunications and Information Administration (NTIA), the Institute for Telecommunication Sciences (ITS), the Department of Defense (DoD), the Wireless Innovation Forum (WIF), and the 120+ members of the CBRS Alliance. A recent **FCC report** ▶ to Congress highlighted this collaboration and detailed how these organizations have come together to make the commercialization of the 3.5 GHz CBRS band a reality.



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Summary

An entire industry has been hard at work laying the groundwork for the transition to shared spectrum. Over the last three-plus years, CBRS has been transformed from a high-level government framework to a soundly engineered, well-tested service that is supporting the next generation of wireless connectivity.

With final certifications underway and commercial service just around the corner, the industry is abuzz with the possibilities presented by OnGo for sectors ranging from mobile, cable and fixed wireless, to healthcare, retail, hospitality, manufacturing, mining, and transportation. The industry will be keeping a close eye on additional uses for CBRS' innovative spectrum sharing model as they emerge, ultimately validating the flexibility of this new approach to wireless connectivity.



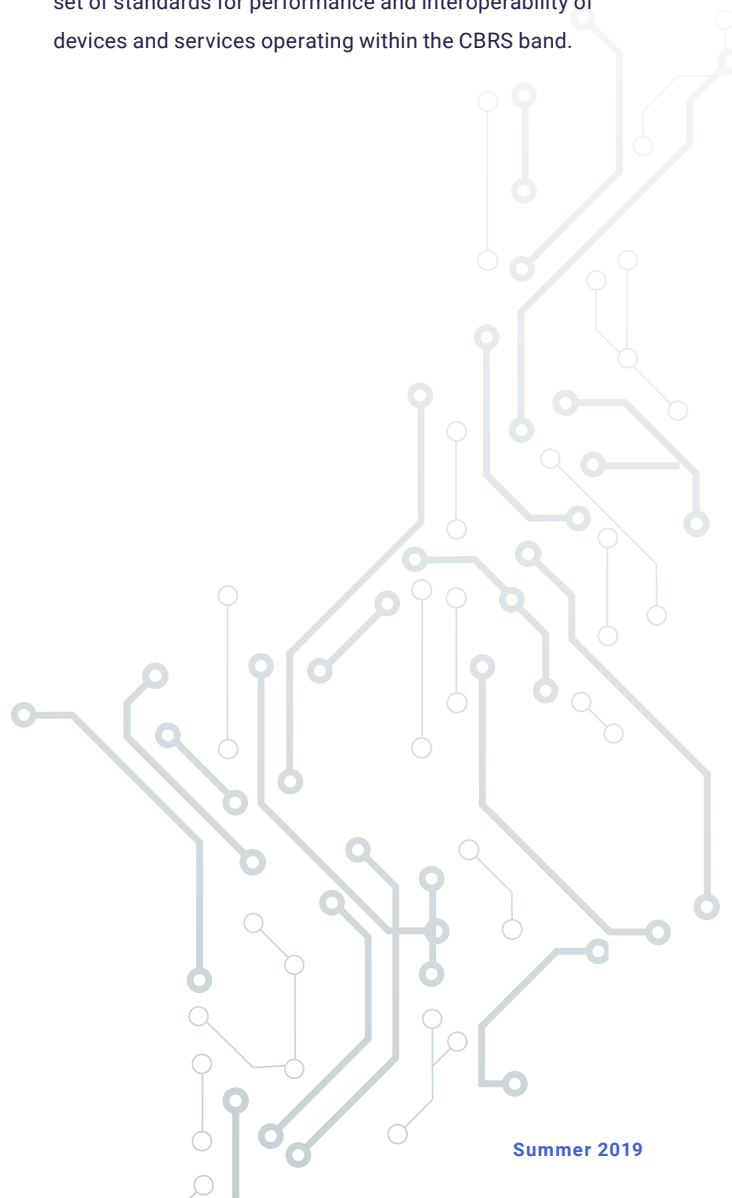
Dave Wright played an instrumental role in the formation of the CBRS Alliance, collaborating with other founding members to create a robust multi-stakeholder organization focused on the optimization of LTE services in the CBRS band. He served

as the Alliance's first Secretary from its launch in August 2016 and was elected as the President of the Alliance in February 2018. Dave is a champion of Open Spectrum, including both unlicensed

and dynamic sharing regimes, while acknowledging the vital role that all spectrum management regimes play in our increasingly wireless world. Dave is a Cisco Certified Internetworking Expert (CCIE) Emeritus (#2062) as well as a Certified Wireless Network Administrator (CWNA).

References

1. In May 2018, the CBRS Alliance announced the launch of the OnGo™ brand and certification program which will drive interoperability between vendors and amongst the various components that comprise an overall CBRS solution. The launch of OnGo is reminiscent of the birth of the term "Wi-Fi" in the late 1990s as a market-friendly brand that encompasses a technology and its solutions. The CBRS Alliance's certification program, supported by CTIA – a trade association representing the U.S. wireless communications industry, along with a number of global test labs, has established a set of standards for performance and interoperability of devices and services operating within the CBRS band.



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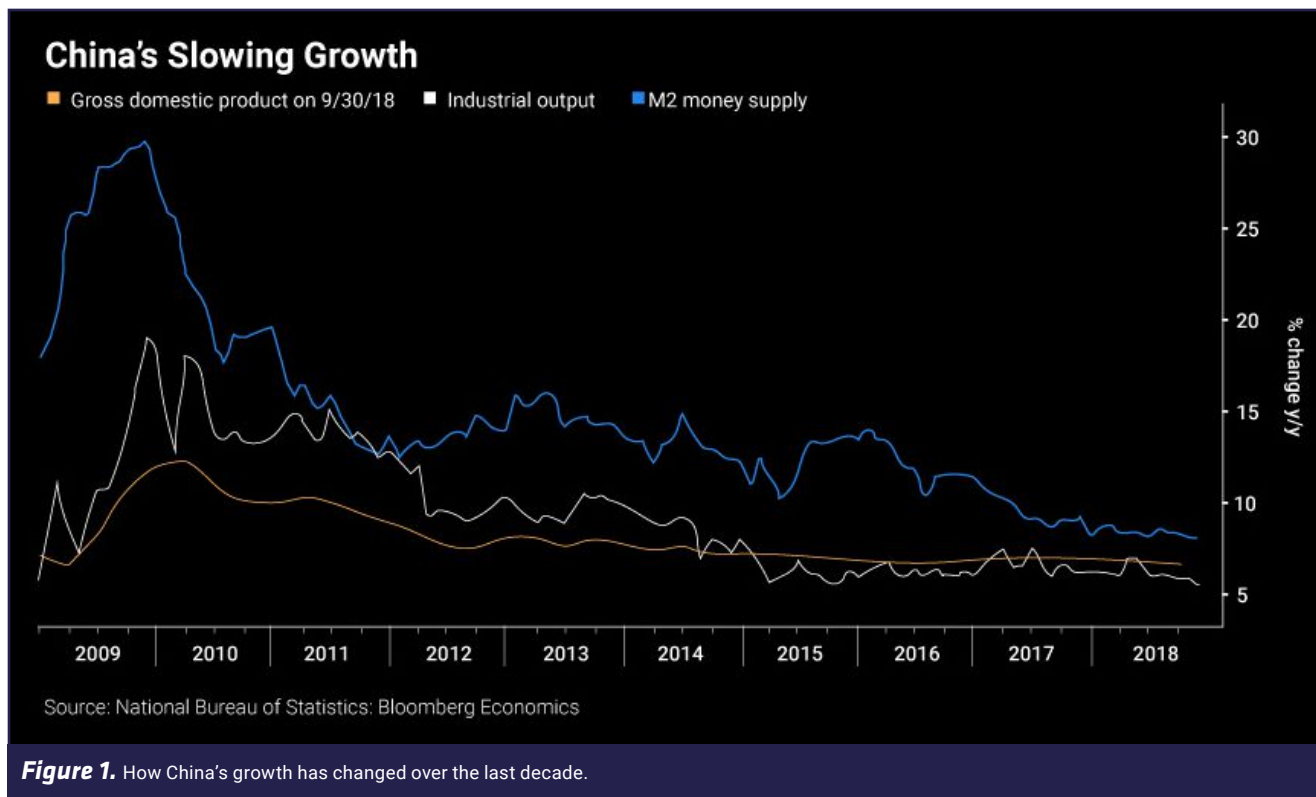


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Is the Sun Setting on China's Glory Days?

BY OSVALDO COELHO

It is no secret that China is experiencing a number of challenges, including a flattening of its economy. Are they heading for the same fate as many other nations?



The idea of the Chinese glory days ending is based on what happened in the 1980s when the general perception was that Japan was about to take over the world. In addition to their rocketing growth, people were learning Japanese and moving to Japan to feel the revolution, only for that euphoria to end as Japan tanked in the 1990s.

To paraphrase Andy Warhol: In the future, every country will be a powerful nation for 15 minutes. So has China had its day in the sun and is now returning to its natural state (see Figure 1)?

This article looks at the overall picture of China's position in the world. What makes this a discussion pertinent is some of the

cracks that have been appearing across China's economic and political landscape.

For example, Tencent, the poster child for China's unprecedented economic boom, shed more than \$200 billion of market value after regulators choked off its games pipeline, leading the biggest selloff in Asian technology shares in a decade. And, the MSCI Asia Pacific Information Technology Index dived 21.2 percent in 2018 – the biggest annual drop since the 2008 recession.

Less quantifiably, China is in the throes of the most severe digital crackdown in its history; a censorship push that shows no signs of letting up. That will force virtually every internet

player to invest time and money training bots and staff to root out content that the ruling communist party deems taboo.

In the face of such a conundrum, and the caustic relationship with the United States, how will businesses continue to profit from the end of the Chinese era?

Looking Forward

Emerging markets became indebted during the Chinese era as they engaged in infrastructure projects financed and built by the Chinese. One of the impending concerns is how can China continue to grow despite that debt load? And, realizing that, how can one continue to serve these emerging markets with one's solutions? Let us step back a bit to understand how the Chinese era played on and based on that, see where the new opportunities lie.

The end of the Japanese era, in the late 1980s, created the Southeast Asian miracle in the 1990s, which was followed by the Asian Meltdown and led to the China era.

The Japanese era ended when automation, mechanization, and the introduction of numerical control machines, allowed superior flexibility in the localization of factories.

High tech products no longer needed to be produced in highly developed countries, where the necessary qualified manpower was available.

One of the remarkable opportunities that new technology, generally speaking, creates is the ability to operate computer-controlled equipment, which can be learned very quickly – in a matter of days – with no previous experience or special aptitudes¹.

There are vast opportunities for westerners, and Chinese alike, in the post-Chinese era. Only that the stakeholders have to leave the past behind. Cut the cord with the past and embrace the new. The Chinese era is not going to come back.



The Chinese era was infrastructure-heavy. The profits from the Chinese exporting machine were plowed back into the economy to build the infrastructure – the tripod: energy, communications, and transport, to support industrialization. The next wave will be service-heavy. In any country, the service sector provides upwards of a 60 percent share of the GDP.

The Chinese era hallmark was to export their model and make countries construction sites. For example, China's One Belt, One Road initiative is nothing more than to engage in massive construction projects, irrespective of there was a market or not.

This exporting of construction companies also occurred during the end of the western post-war construction boom era. They sought out other countries to build infrastructures that coincided with the oil boom of the 1970s. The big western construction companies started looking to build in OPEC countries.

As the Chinese era ends, one should stop, think and seek investment opportunities only where it makes economic sense. Seek the bright spots in an overall dark outlook, keeping in mind the service sector.

China's era, which started with Deng Xiao Ping's reforms, created a subsidy for the whole world. Anything that was not

profitable to produce in the west was sent to China. This cheap labor became a subsidy for the western companies and kept them profitable.

The Chinese Model

- » Deng Xiao Ping's reforms
- » The rural population as a reserve army and, last but not least,
- » The technologies and computer controlled equipment which can be learned very quickly without special skills



Look at the TESLA Model, Today

Elon Musk breaks ground in a Shanghai factory ▶

Elon Musk's electric car project acquired land for a factory on the outskirts of Shanghai for about \$140 million in October 2018.

In the 90s, if your competition was moving to China, it was prudent for your company to move to China as well. If not, one risked the potential of going out of business.

A quote from the Tesla article notes:

"Producing vehicles in China would reduce costs from tariffs and ocean transport for Tesla, as it faces rising competition from local electric automakers."

—Evelyn Cheng

The Tesla example shows, precisely, what happened starting in the 1990s. Companies that followed that philosophy included ABB, Siemens, GE, Hitachi, Nokia, Ericsson, Bosch, Cisco – virtually every company one can name.

But that subsidy, and the success that resulted from inexpensive Chinese labor, did not come without consequences or

costs. The west is just now coming around to realizing just how high that cost is. That is what this tech/trade war is all about.

Here is how this unfolds. The Chinese will implement a “gate” fee for entrance into the cheap labor market, permitting a company to sell in the Chinese market. This allows the industrial ecosystem to be at the company's disposal. However, as the technology is developed, the price to have them manufacture is that the technology is handed over to the Chinese.

In other countries, building a factory would cost more and their market is not nearly as big as China's. But other models exist, such as royalties or licenses for one's technology. But one gets to keep it proprietary.

As well, the Chinese way of doing business is to have a “facilitator”, the person(s) to whom one hands over the technology. As well, there will be a Chinese “partner” in the factory one is building. They will smooth the way and be the one to obtain the technology.

All of this Chinese efficiency costs. Not in dollars necessarily, but in other payments such as technology. In exchange, they will build, or supply – in record time, one's needs, roads, power, interconnect, water, and other resources. This is the typical model countries, with closed economies, follow.

When the Model is Exhausted

The United States is suffering from the decades-long, cheap, Chinese labor market. It has decided to put an end to this technology transfer model and enforce IP protection. However, after a quarter of a century of the supply chain being established, it will be costly and will take time to revert.

During the mid-1980s, advanced countries worried about labor displacements – calling microchips “job killers.” This was offset by the possibility of creating additional activities in emerging markets. That slowed down and distorted the process of moving out production to emerging markets – until the one billion Chinese showed up at the end of the Cold War.

Today, the Chinese case is subject to a new set of circumstances. The Chinese model is exhausted. The western advanced countries brought in Industry 4.0 and everything connected, creating

the embryo of the post Chinese era. Countries need to keep that in mind to profit from the post-Chinese era.

The Chinese will not, from one day to another, say “OK, now we will let you access our market and use our factory base, plus all the infrastructure,” without charging a gate fee to be paid and the transfer of technology.

They also want to scale up and produce higher value-added products and keep up to date technology coming. Keep in mind that made in China 2025 and Industry 4.0 will require that they keep high technology flowing in.

China will still want to build new factories. And new entrepreneurs will want to build upon the technology to compete with any recently opened western factories. The Chinese know that they have the advantage of having the factories and the whole supply chain humming along.

The Chinese model will become exhausted, even without the advanced countries’ pressure. Eventually, they will run out of cheap labor, just as other emerging countries have, or will. In short, the Chinese will go Japanese. The Chinese lost decades will start after 2030.

Let us look at how the Chinese are at the end of an exhausted model

- » Deng’s reforms took back seat as Xi Jinping reverted to the Mao model
- » Reserve army not being replenished. Demographics: Population dividend ended plus the results of the one-child policy. The population is aging quickly.
- » Technologies that entered freely and were absorbed, now are subject to close scrutiny

In the End

The world never grinds to a halt at the end of an era. We should keep in mind how the previous cycles started to be able to recognize the next set of cycles.

The old eras were started by the industrial revolution and focused only on the last century. The factories, described above, ended up in China because of a set of circumstances – new technologies, the end of the post-war boom of the west, and the end of the Cold War.

The Chinese are aware of this. Learning from what happened in the United States, Japan, and Europe when their eras ended. Their reaction is the new Made in China 2025 and implementing big research and development pushes as their appetite for the newest technology increases. They assembled a state-sponsored hacking machine.

And here we are today...



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Wi-Fi and 5G Redefine Wireless

Convergence creates a pervasive connectivity fabric.

BY MONICA PAOLINI



| | | | | | | |
|----------|--------------|---|----------------|---|-------------|--|
| GLOSSARY | 3GPP | 3 rd Generation Partnership Project | IEEE | Institute of Electrical and Electronics Engineers | QAM | Quadrature Amplitude Modulation |
| | AI | Artificial Intelligence | IETF | Internet Engineering Task Force | RAN | Radio Access Network |
| | ANDSF | Access Network Discovery and Selection Function | IIoT | Industrial IoT | RF | Radio frequency |
| | AP | Access Point | IMT | International Mobile Telecommunications | SAE | Simultaneous Authentication of Equals |
| | AR | Augmented Reality | IoT | Internet of Things | SIM | Subscriber Identity Module |
| | BEREC | Body of European Regulators for Electronic Communications | IP | Internet Protocol | TCP | Transmission Control Protocol |
| | BSS | Business Support System | ITU | International Telecommunication Union | TRAI | Telecom Regulatory Authority of India |
| | CAGR | Compound Annual Growth Rate | LBT | Listen-Before-Talk | UL | Uplink |
| | CDMA | Code-Division Multiple Access | MAC | Media Access Control [Layer] | VNI | Cisco Visual Networking Index |
| | DL | Downlink | MIMO | Multiple-Input Multiple-Output | VR | Virtual Reality |
| | ETSI | European Telecommunications Standards Institute | mmW | Millimeter Wave | WBA | Wireless Broadband Alliance |
| | FCC | Federal Communications Commission | MU-MIMO | Multi-User MIMO | WECA | Wireless Ethernet Compatibility Alliance |
| | GSM | Global System for Mobile Communications | NGMN | Next Generation Mobile Networks [Alliance] | WPA | Wi-Fi Protected Access |
| | GSMA | Global System for Mobile Communications Association | OFDMA | Orthogonal Frequency-Division Multiple Access | | |
| | | | PHY | Physical [Layer] | | |

Do you remember back when you had to get online to check your email? Or when you could claim you could not be reached because you could not get connected? Connectivity used to be a deliberate choice, and often one that entailed an effort and a cost. Today, most of us (56 percent according to ITU) have a wireless broadband connection and are almost always, effortlessly, connected to a Wi-Fi or cellular network. Wireless connectivity has become the default access channel to communicate with each other. Yet, there is more to come. We are entering a world of pervasive connectivity in which the reach of wireless networks keeps expanding beyond our phones and laptops. New types of devices, terminals, and sensors connect us to our environment and change the way we interact with each other and the environment.

Why hail a cab on a busy street when you can book it through your phone in less time and at a lower cost?

To complete the transition to pervasive connectivity that is already underway, all wireless networks have to continue to evolve to provide the coverage, capacity, latency, reliability, security, and cost efficiency that we need for new wireless use cases, and to meet the demand for massive connectivity to people and things, and to reach the remaining 46 percent of the world population that is not yet connected. From a technology perspective, it is a demanding task. But because of the increasing reliance of our society and economy on wireless connectivity, it is also a great responsibility. No single wireless access technology can

support this transition on its own. Multiple technologies, each with its different strengths, have to work together to realize the IMT-2020 vision for pervasive connectivity.

Wi-Fi and 5G are by no means the only wireless technologies we need, but they are the most powerful ones in redefining wireless connectivity, because of their expected share of wireless traffic, their technological evolution, and their ability to support many of the existing and new use cases. Wi-Fi and cellular have jointly created the wireless fabric that supports broadband connectivity. Wi-Fi carries most of the traffic — cellular covers most of the land. Wi-Fi is best indoors — cellular is best outdoors. Wi-Fi started as a data technology — cellular was initially only about voice. With 5G and Wi-Fi 6 (IEEE 802.11ax), this relationship between cellular and Wi-Fi will remain largely unchanged, but they will get closer to each other, as they expand their capabilities. Cellular and Wi-Fi will remain complementary in addressing different traffic demands and application requirements, and become more integrated to share the traffic between them more efficiently.

This paper overviews the evolution of Wi-Fi and how it addresses the new connectivity requirements driven by increased data volumes, latency-sensitive traffic, and IoT applications — and how it will meet the IMT-2020 vision together with 5G. With the introduction of new functionality and improved performance, Wi-Fi evolution continues, unabated, since the ratification of the IEEE 802.11 standard in 1997. The upcoming Wi-Fi 6 captures most of today's attention with its increase in throughput, spectrum efficiency and device battery life, but the evolution of Wi-Fi covers more ground — including traffic management, security, new spectrum

bands, and integration with cellular — to accommodate new use cases, especially for IoT applications, smart-city deployments, and latency-sensitive traffic.

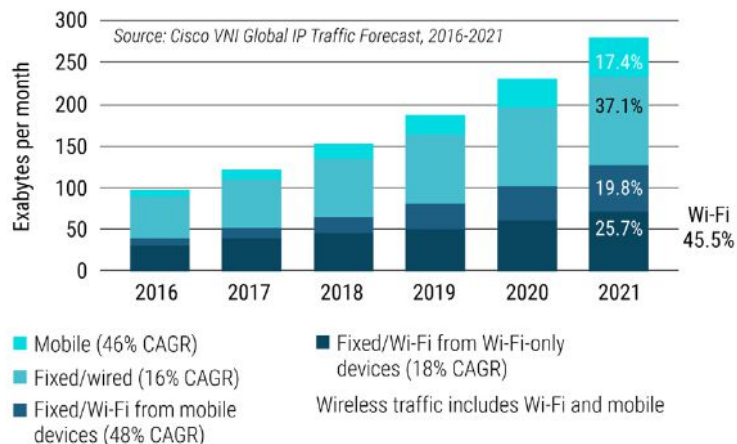
Wi-Fi, the Powerhouse Feeding our Data Connectivity

It is easy to take Wi-Fi for granted, in the same way most of us take electricity or water for granted. Aw well, just like electricity and water, we know Wi-Fi is not available everywhere, but we expect to have Wi-Fi at home, at work and in many public places — the places where we generate most of the traffic. However, even within the wireless industry, we often need to remind ourselves that Wi-Fi carries most of the wireless traffic and that wireless networks carry more traffic than wireline networks. According to Cisco VNI, Wi-Fi will account for 45.5 percent of traffic by 2021, and cellular for 17.4 percent.

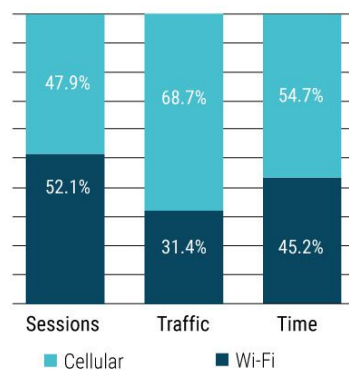
Going back in time, it was Wi-Fi that convinced subscribers that wireless broadband was possible. When Apple launched the first iPhone, Wi-Fi stole the show — data experience over cellular was limited and networks got quickly congested. Even as capacity and throughput increased with 4G, Wi-Fi retained its dominant position as a data access technology. This is a remarkable achievement if we consider that all this traffic relies only on the 2.4 GHz and the 5 GHz unlicensed bands; it shows how Wi-Fi enables an intensive and efficient use of spectrum resources.

Of course, cellular networks are essential to our overall wireless experience. They keep us connected throughout a much wider

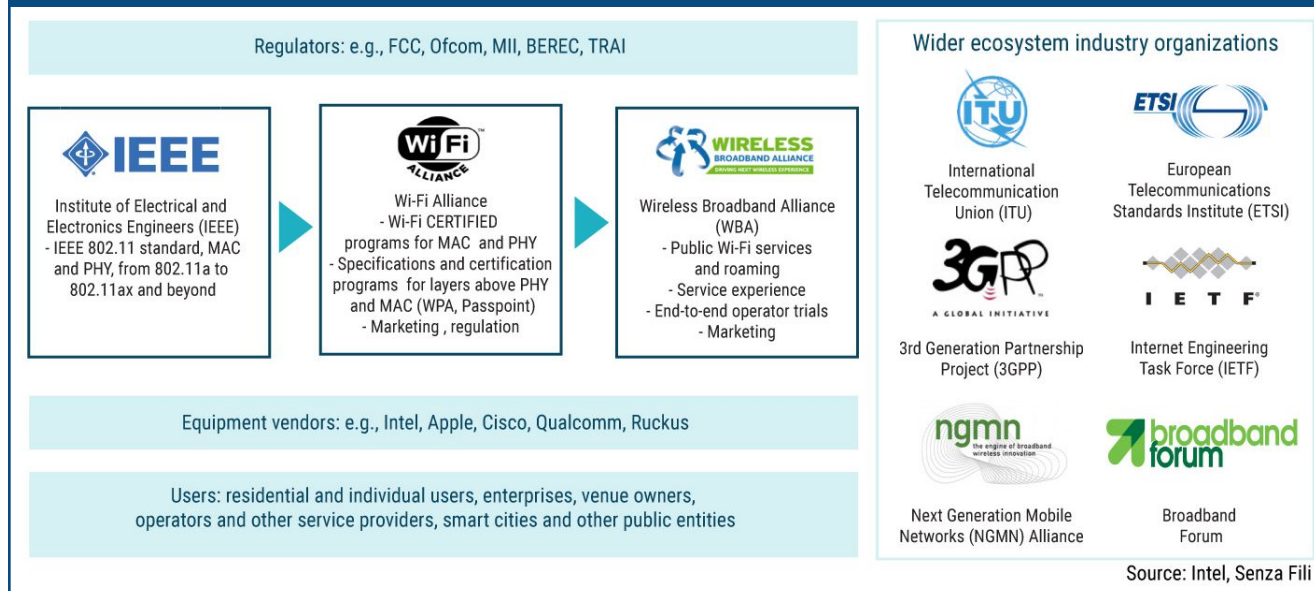
Global IP traffic by local access technology



Wi-Fi and Cellular Traffic on Mobile Devices in the US



The Wi-Fi ecosystem: The role of IEEE, Wi-Fi Alliance and Wireless Broadband Alliance



footprint, and to do so, service providers have to face a steeper, per-bit, cost for cellular than for Wi-Fi, without Wi-Fi's level of spectrum reuse.

The two access technologies address different and complementary connectivity needs, and use patterns demonstrate this. In the United States, for instance, Wi-Fi carries almost 70 percent of traffic to phones and SIM-based mobile devices. It accounts for slightly less than 50 percent of sessions and about 55 percent of the time. For activities that require more bandwidth and longer times and are not perceived as urgent, subscribers prefer Wi-Fi. If they have more urgent and time-sensitive things to do, subscribers are more likely to use the cellular network. Across geographies, the ratio may change, but the pattern is consistent. And, as we will see in the rest of the paper, 5G is unlikely to reverse this trend, because it is rooted in a close, and mutually supportive, relationship between Wi-Fi and cellular.

The Wi-Fi Ecosystem: from Standardization to Deployment and Access

The success of Wi-Fi rests on a large and mature ecosystem that spans from regulators across the world allocating unlicensed spectrum, to vendors, service providers, enterprises and many types of users. Wi-Fi has an enduring commitment to interoperability, backward compatibility, coexistence, and ease of access. The development of standards, specifications, certification

programs and best-practice recommendations has been, and continues to be, essential to the evolution and expanding adoption of Wi-Fi. Three industry organizations — IEEE, Wi-Fi Alliance, and (WBA — have central roles in the continued evolution of Wi-Fi. IEEE created the 802.11 standard for the MAC and PHY layers for Wi-Fi, and continues to expand it, currently with 802.11ax (now branded as Wi-Fi 6) and 802.11ay. The Wi-Fi Alliance develops Wi-Fi CERTIFIED programs which define test specifications and ensure interoperability through optional certification programs covering not only MAC and PHY layers, but also upper layers to offer consistent user experience and security. The WBA has worked with operators, service providers, and neutral hosts to develop a roaming platform and to give subscribers easy and seamless connectivity. Other industry organizations — ITU, 3GPP, NGMN, ETSI, IETF, and the Broadband Forum — do not have a direct role in defining Wi-Fi, but act as liaisons to the rest of the wireless ecosystem — for instance, to support the coexistence of Wi-Fi with cellular and other wireless technologies.

A Successful Balance of Continuity and Innovation

Wi-Fi is the most widely adopted wireless technology, with an installed base of 9.5 billion devices and over 3 billion new device shipments in 2018, according to ABI Research and Wi-Fi Alliance. There are more Wi-Fi devices than people in the world (7.6 billion), or unique cellular subscribers (5.2 million; GSMA), and about the

same as the number of mobile connections (9.2 billion, including M2M; 60 percent are broadband, GSMA). The number of Wi-Fi devices will continue to rise, along with the number of connected devices per person. Cisco VNI predicts that by 2021, the number of devices and connections per capita will be 12.3 in the United States and 3.5 worldwide. Wi-Fi's ubiquity, flexibility, and affordability have been instrumental in the growth of connectivity in emerging markets, where it has been a powerful tool for bridging the digital divide, as well as the driver for many IoT and machine-to-machine applications.

The success of Wi-Fi caught the industry by surprise. It was developed initially as a fixed wireless technology, and then as a wire-replacement solution. Wi-Fi rapidly moved to become the dominant wireless broadband access technology — and in fact, created that market — as IEEE and the Wi-Fi Alliance expanded its functionality and worked to ensure interoperability and backward compatibility. Following Intel's introduction of the Centrino platform, in which Wi-Fi was built into every laptop, Wi-Fi became a mass market technology and vendors started adding Wi-Fi to other types of devices beyond laptops.

Wi-Fi has continued to evolve since the standard's ratification in 1997. Standard updates have improved the air interface (802.11n, 802.11ac, and eventually 802.11ax), added new spectrum bands (WiGig in the 60 GHz band with 802.11ad and 802.11ay), and kept up with security needs (WPA, WPA2, WPA3). In addition, the Wi-Fi Alliance and the WBA have introduced new functionality to improve traffic management, ease of user access and authentication, roaming, voice calls, and, more generally, support for new use cases.

After decades, Wi-Fi is still at the forefront of innovation and performance in wireless networks. Crucial to its success are backward compatibility and interoperability, which provide a continuity that has set the foundation for market growth and that benefits vendors, service providers, and users alike. Wi-Fi networks can gradually evolve to include new functionality and improved performance while supporting legacy devices. For instance, there will be no need to replace devices in order to connect to a Wi-Fi 6 AP, and a new Wi-Fi 6 device will still be able to connect to legacy APs. In the future, as the number of connected devices per user or per household and the number and variety of IoT devices grow, the ability to support a greater number and range of devices

The Evolution of Wi-Fi

| | |
|------|--|
| 1971 | ALOHAnet in Hawaii: fixed wireless access |
| 1985 | ISM band released for unlicensed use by FCC |
| 1997 | IEEE 802.11 standard ratified |
| 1999 | WECA founded, becomes Wi-Fi Alliance in 2000 |
| 2000 | WiFi branding introduced, 11 Mbps 2.4 GHz |
| 2002 | 54 Mbps in 5 GHz |
| 2004 | WPA2 (security) |
| 2007 | 802.11n, iPhone released |
| 2012 | Wi-Fi in 25% of homes, Wi-Fi passpoint |
| 2013 | 5 million hotspots, 802.11ac |
| 2014 | Over 20,000 certified products |
| 2016 | WiGig (60 GHz) |
| 2018 | WPA3 (security) |
| 2019 | 802.11ax, 802.11ay |

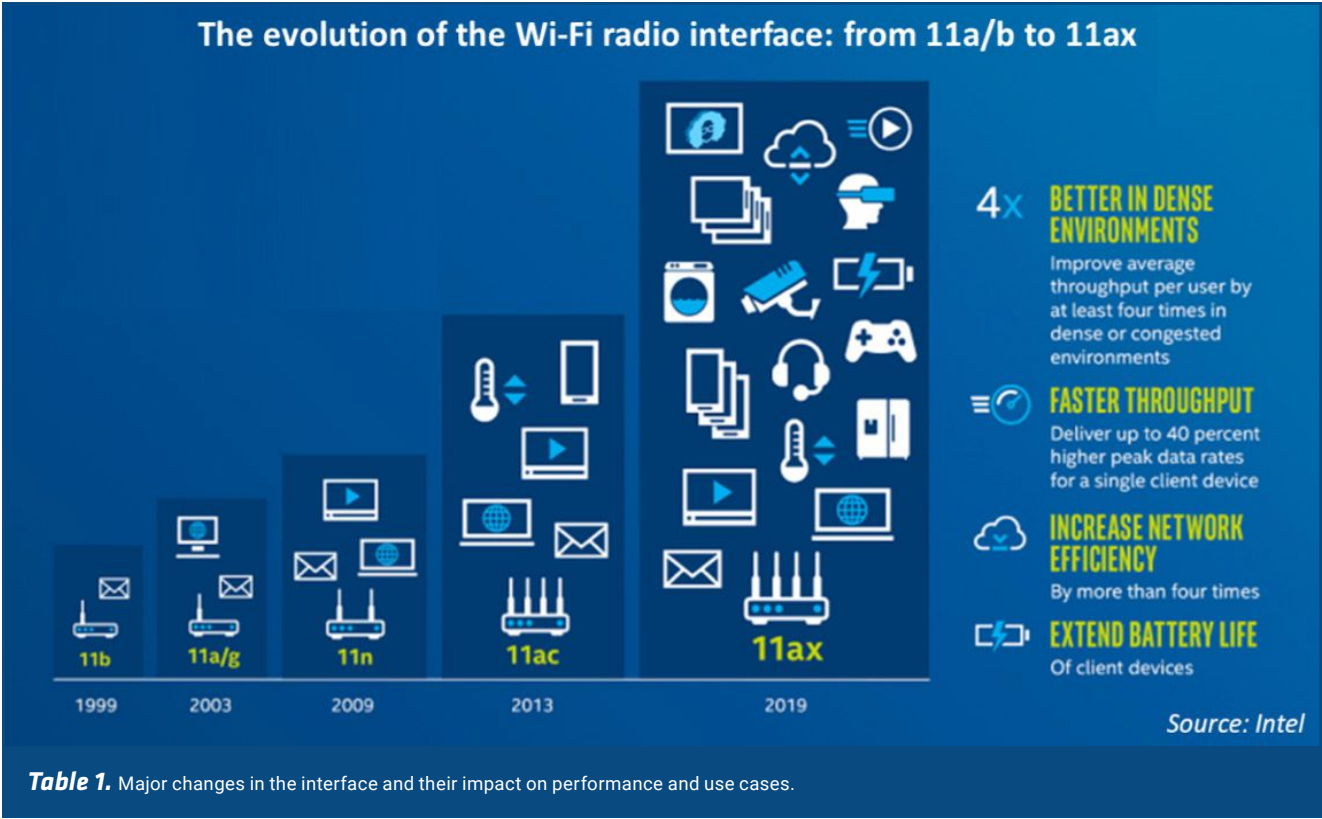
Source: Wi-Fi Alliance, Wikipedia, Senza Fili

per network will become even more valuable. For instance, a residential user can install a Wi-Fi 6 and still use the Wi-Fi legacy devices already installed without making any change and can add new Wi-Fi 6 devices gradually, as desired.

The New Wi-Fi Radio Interface: Wi-Fi 6, aka IEEE 802.11ax

Wi-Fi evolution proceeds in multiple directions, but the air interface is the one that attracts the most attention because it has a direct impact on the user experience. The evolution from 802.11b to 802.11ac has profoundly changed the performance of Wi-Fi in terms of increased capacity, ability to manage devices and infrastructure resources, and efficiency of spectrum use.

With Wi-Fi 6, devices may see a 40 percent increase in peak rates that come from an enhanced air interface. Overall network capacity will grow as well, due to an increase in network efficiency. The new Wi-Fi 6 air interface strengthens the Wi-Fi's ability to meet new traffic requirements, connect a wider range and number of



devices, and serve new use cases. Table 1 presents the major changes in the interface and their impact on performance and use cases.

Dense, High-traffic Environments

Here Wi-Fi 6 shines the brightest – stadiums, airports and transportation hubs, retail locations, and college campuses. The combination of higher capacity in both the downlink and the uplink transmission, more efficient use of network resources, and better frequency reuse further increases Wi-Fi’s capacity density – the amount of traffic it can transport within an area (e.g., Gbps/km²). The lower latency of Wi-Fi 6 also benefits high-traffic environments where it improves the experience for real-time traffic (e.g., video and VR/AR), which is sensitive to latency.

Outdoor Environments

More capacity and higher throughput for devices at the edge of the AP coverage area make Wi-Fi more attractive for outdoor deployments by service providers, real-estate managers, and smart cities.

Connected Homes

As traffic and the number of devices increase within households, better resource and device management, lower power consumption, and lower latency improve the overall performance and coexistence across multiple device types with different traffic profiles (e.g., IoT dev and laptops).

Enterprise, the IoT, and the IIoT

More capacity, lower latency and more flexible and efficient use of network resources appeal to enterprises as they, increasingly, rely on wireless connectivity for their voice and data connectivity and enterprise-based services and applications. In particular, IoT and IIoT applications benefit from 802.11ax’s support for a high density of devices with different requirements (e.g., surveillance cameras and sensors) and variable power availability.

Real-time, Latency-sensitive Traffic

Lower latency and more granular management of devices and network resources improve the ability to support real-time content and applications, such as voice, conversational video, and gaming.

Transportation

Higher capacity and improved traffic management strengthen Wi-Fi's role to provide in-vehicle connectivity (e.g., in cars, or in trains, where Wi-Fi is, often, used for access, and cellular for backhaul), automated vehicle services in the enterprise, and applications for parking, toll payments, and other transportation activities.

WISPs and Fixed Broadband

The increased capacity and edge peak rates will make Wi-Fi a better-suited candidate for fixed broadband connectivity. The expected availability of the 6 GHz band for unlicensed access will further promote the use of Wi-Fi among WISPs. With fixed broadband, Wi-Fi can help bridge the digital divide in rural, and low-density, areas as a cost-effective and easy-to-deploy solution that brings broadband to underserved households.

The Evolution of Wi-Fi

The air interface (802.11ax), security (WPA3,) and manageability (Passpoint, multi-band operation — see Figure 1), are some of the prominent directions the evolution of Wi-Fi is taking as its ecosystem adapts to a heavier and more diverse use of Wi-Fi networks. But there are many additional evolutionary paths that extend the functionality, flexibility, and efficiency of Wi-Fi and improve its performance in specific use cases.

A major development is the expansion of Wi-Fi in two directions:

- » Multi-gigabit connectivity in the 60 GHz band (WiGig, 802.11ad, 802.11ay), to provide even higher capacity density in the highest-traffic environments, in wireless backhaul and fixed wireless access (e.g., Facebook's Terragraph), or in home or other indoor environments where some applications, or
- » Devices require very high throughput over short distances (e.g., AR/VR, 360-degree video, a home video projector). 802.11ay enhances that initial WiGig standard by supporting peak data rates in excess of 100 Gbps through the use of channel bonding and 8x8 MIMO.
- » Long-range, low-power, low-bandwidth connections to devices (HaLow, 802.11ah) that will set the stage for some IoT or IIoT deployments. While connections may be in the kbps range, devices may have challenging battery life requirements in the order of months or years. HaLow operates in the unlicensed 900 MHz band.

What's new in 802.11ax: impact on performance

OFDMA DL/UL — Lower latency; more supported devices per AP; more capacity; and more efficient use of spectrum and network resources in dense environments.

8x8 MU-MIMO DL/UL — Serving up to 8 simultaneous users, doubling capacity over 4x4 MIMO, both in the downlink and in the uplink.

1024 QAM — Higher per-device peak speed, higher capacity (25 percent increase over 256 QAM). More efficient use of network resources.

Uplink resource scheduling — Better management of network resources, lower latency. Better support and performance in dense environments, increased battery life.

Long OFDM symbol — Higher efficiency and capacity. Improved outdoor performance, 4x increase in data speed at the cell boundaries.

Long OFDM symbol — Higher efficiency and capacity. Improved outdoor performance, 4x increase in data speed at the cell boundaries.

BSS color — Better spatial frequency reuse by coordination among neighboring APs — Increased capacity in high-traffic environments with a high density of APs.

Target wake time — Device-specific, more flexible management of wake/sleep cycles. Longer battery life, leading to improved support for IoT applications.

6 GHz band support — More spectrum available to Wi-Fi. More capacity and ability to serve more diverse use cases.

Together, WiGig and Wi-Fi HaLow expand the reach of Wi-Fi to new spectrum bands (60 GHz and 900 MHz) while retaining backward compatibility to Wi-Fi networks in the 2.4 GHz or 5 GHz bands. As is typically the case in Wi-Fi, devices using WiGig can seamlessly associate to any Wi-Fi network operating in the 60 GHz band, and any Wi-Fi HaLow device will be able to associate with any HaLow network when HaLow will be commercially available.

Traffic management and efficient use of network resources are other areas of innovation. Wi-Fi is evolving to a more active approach to connect devices to the best band, channel or AP, depending on the device requirements and network conditions. Roaming functionality is also expanding to enable devices to stay connected as they move from one network to another. It also makes it easier to choose and connect to roaming networks, and to improve Voice over Wi-Fi handoffs with cellular networks.

Wi-Fi Protected Access 3 (WPA3): Raising the bar on security

Security is a top priority for Wi-Fi. Not only is Wi-Fi ubiquitous, but mobile Wi-Fi devices typically connect to multiple networks, and it can be difficult for users to independently verify which networks should be trusted or are secure. Wi-Fi provides robust technology that does not require a significant direct intervention by the user, yet protects traffic and allows devices to connect to secure networks and to verify that the devices do not present a security threat. Security requirements and threats change through time – and changes in use cases may require different approaches and solutions. For instance, headless IoT devices create multiple security challenges that access technologies like Wi-Fi have to address forcefully.

WPA3 was introduced in June 2018 to address the security needs created by new use cases and the increased reliance on wireless connectivity. WPA3 will ultimately replace WPA2, which was introduced in 2004, but for the next few years the two will coexist, until both APs and devices have all transitioned to WPA3. WPA3 comes in two flavors:

- **WPA3-Personal** for residential and small business networks. Simultaneous Authentication of Equals (SAE) improves protection when users use weak passwords, and it strengthens the initial key exchange. WPA3 makes it easier for users to select passwords that are easy to remember and improves ease of use for security features.
- **WPA3-Enterprise** to protect enterprise, government and defense networks. It introduces 192-bit encryption to protect networks with the tightest security requirements.

The Wi-Fi Alliance has released two complementary certification programs to strengthen Wi-Fi security:

- **Easy Connect** simplifies the security configurations for IoT devices and other devices with limited display capabilities.
- **Enhanced Open** supports individualized data encryption in open networks.

Figure 1. Wi-Fi 6 security and priority.

Because of the extensive use of Wi-Fi for cellular offload, Wi-Fi keeps expanding the support for service providers (e.g., SIM-based authentication, encryption, roaming) and simplifying subscriber access in service provider networks (e.g., authentication, network selection, security).

Finally, Wi-Fi has been developing standard-based, interoperable meshing capabilities. Vendors have been offering mesh Wi-Fi networks for some time, but as proprietary solutions that put restrictions on the hardware that can be used. In early 2018, the Wi-Fi Alliance introduced EasyMesh to enable the deployment of self-organizing Wi-Fi networks that use APs from different

vendors to expand the reach and performance of multi-AP networks. Households with many high-traffic devices or a challenging RF environment may need more than one AP to have uniform coverage and sufficient capacity. With EasyMesh, users can add a new AP and create a mesh network with the other AP(s) at the same location. With a mesh architecture, APs autonomously coordinate transmission and manage device connectivity, taking into account the overall network conditions and device requirements. Mesh networks facilitate the introduction of new home entertainment and IoT devices, especially ones with demanding traffic requirements (e.g., video distribution) or requiring uniform coverage throughout the house (e.g., sensors).

Wi-Fi and 5G Convergence

Wi-Fi has to continue to innovate and improve performance to meet our connectivity needs, to expand its reach to more users and devices, and to satisfy new use cases. Not surprisingly, the evolution of Wi-Fi is well-aligned with the IMT-2020 vision of next-generation connectivity, which is grounded on ambitious and demanding requirements for capacity, latency, density, coverage, efficiency, reliability, spectrum, and the number of devices.

To meet the IMT-2020 goals, multiple technologies have to converge and contribute. Wi-Fi 6 and 5G are the two main players in terms of market and traffic share and their ability to support a majority of use cases. Wi-Fi 6 and 5G are complementary because each brings a different contribution to creating a pervasive connectivity fabric. At the same time, the transformation of Wi-Fi and cellular expands the capabilities and performance of both technologies in ways that bring them closer to each other in some respects as they aim to meet the same performance targets. But unlike what happened in the past with the harsh competition between GSM and CDMA, or between LTE and WiMAX, not only will Wi-Fi and 5G coexist, but, as discussed in the previous section, the industry has developed the tools to integrate them to increase overall wireless efficiency and create a better user experience.

The current equilibrium between Wi-Fi and cellular will be fundamentally preserved as we move to 5G. The main strength of Wi-Fi is to provide in-building connectivity to users who may be either stationary or nomadic. According to most estimates, this accounts for over 70 percent of overall wireless traffic. The use of unlicensed spectrum, the ability to deploy Wi-Fi quickly

and cost-effectively in stand-alone networks that do not require a centralized core are attractive to residential users, enterprises, and cities that want to deploy a network in a confined environment that they largely control. With Wi-Fi, everybody can afford to take control of their own wireless infrastructure. Wi-Fi will retain this advantage because of its massive installed base, its ability to gradually evolve without the need to replace the existing infrastructure, and its performance improvements.

At the same time, small stand-alone Wi-Fi networks provide valuable islands of connectivity. However, they do not have the citywide or countrywide coverage or the support for vehicular mobility that cellular networks have. 5G brings together multiple generations of cellular networks that have the extensive outdoor coverage and mobility support that Wi-Fi will never match. Wi-Fi is cost effective in high-traffic environments, but it can be expensive when used for wide-area coverage, even with its improved range and edge peak rates. Because wide-area networks are expensive to deploy, complex to operate, and have to serve a large set of subscribers, mobile operators or other service providers will still be the primary entities deploying 5G.

Another distinction between Wi-Fi and cellular that will remain is, that because it uses unlicensed bands, Wi-Fi has better spectrum reuse, even though in licensed bands 5G — or LTE — is more spectrally efficient. The unlicensed regime encourages users to share spectrum and this naturally leads to contention among users. To ensure fair coexistence among users, Wi-Fi uses LBT mechanisms that impose an overhead in performance that is absent in licensed bands. However, network utilization is typically lower in cellular networks because the operator has exclusive use of the channel. Where there is contention among Wi-Fi networks, Wi-Fi can pack more bits than 5G in licensed bands because the throughput benefits of spectrum reuse outweigh those from the higher spectrum efficiency.

While Wi-Fi and 5G/legacy cellular will retain their relative strengths and continue to complement each other, there are also several areas where technological evolution is converging.

New Spectrum Bands

Both Wi-Fi and 5G have moved into new spectrum bands to accommodate new use cases (especially for the IoT) and hyper-dense traffic locations. Wi-Fi targets more spectrum in

Wi-Fi and 5G integration

There is much standardization and developments work to integrate Wi-Fi with 5G and other cellular networks because integration between these access technologies will increase the efficiency of both technologies and will improve the user experience.

When Wi-Fi and cellular coexist in the same location but are not integrated, devices typically connect to one or the other, regardless of applications or services used, or network conditions. Devices often do not connect to the best available network at a given time and location, and this results in poor performance and experience.

Multiple tools and approaches are available to integrate Wi-Fi and 5G at different levels:

- **Devices** — With dual connectivity, devices can simultaneously connect to both a Wi-Fi AP and a 5G (or 4G) cell, and use the channel that is most efficient and gives the best user experience. With IETF-driven multipath TCP, a mobile device connected to both Wi-Fi and cellular can retain the TCP connection as transmission shifts from one access interface to the other, so that the transition at the application level is seamless to the user. ANDSF allows mobile devices to scan the environment to see what networks are available, and to decide which one to associate with. Mobile operators can then use policy rules to manage device access with ANDSF.
- **RAN** — The cellular link manages the control plane to allocate traffic to Wi-Fi and cellular, and Wi-Fi carries only data traffic. This arrangement makes it possible for mobile operators to optimize offload. For instance, they can preferentially use Wi-Fi for specific application types, e.g., those that require streaming video. There are also parallel, ongoing development efforts to use Wi-Fi as the anchor for cellular (instead of using cellular as the anchor for Wi-Fi) and they will further expand the integration options of Wi-Fi and cellular and enable new use cases.
- **Core** — Wi-Fi can also use the 5G core for deeper integration, in which Wi-Fi is one of the access technologies that the 5G core manages. This approach enables mobile operators to include Wi-Fi traffic in edge computing and network slicing, thus increasing their impact and efficiency gain. At the same time, Wi-Fi and 5G integration does not require all Wi-Fi traffic to go through the core, hence helping to avoid core overload, added costs, and increased latency. With local breakout, traffic from the RAN can be routed to the Internet without having to traverse the core network, but the 5G core still manages both cellular and Wi-Fi traffic.
- **Roaming** — SIM-based authentication with Passpoint enables cellular devices to roam onto trusted Wi-Fi networks that have a roaming partnership with the user's mobile operator.

The work on standards and specifications for Wi-Fi and cellular integration is shared across multiple organizations — including 3GPP, Wi-Fi Alliance, WBA, and IETF — and has wide participation from the Wi-Fi ecosystem, including mobile operators.

| Differentiation: What each Technology Does Best | |
|---|-----------------------------------|
| Wi-Fi | 5G and legacy cellular |
| Unlicensed spectrum sharing | Licensed spectrum |
| In-building coverage | Wide-area coverage |
| Stationary or nomadic access | Mobile access |
| Higher frequency reuse | Higher spectral efficiency |
| Lower per-bit cost | Lower cost for wide-area coverage |
| Residential and enterprise networks | Mobile public networks |
| Shared evolution: What Wi-Fi and 5G increasingly have in common | |
| New spectrum bands | |
| Unlicensed access | |
| Distributed architectures, edge computing | |
| IoT, private networks | |
| Mutual offload | |
| Real-time traffic management, automation, AI | |

low frequency bands (e.g., 900 MHz for Wi-Fi) and in mmWave frequencies (e.g., 60 GHz for WiGig).

Unlicensed Access

Historically, cellular has relied exclusively on licensed access, and Wi-Fi has been the main access technology in unlicensed bands. While the commitment of Wi-Fi to unlicensed spectrum has not changed, there is a growing interest in using 4G and, eventually, 5G in unlicensed bands. This is to support local, private networks, or to offload traffic from licensed bands.

Distributed Architecture, Edge Computing

5G is moving toward a distributed architecture, in which edge computing plays a prominent role in keeping latency low. This creates the opportunity for Wi-Fi and 5G to share the edge infrastructure, which in turn increases the benefits of Wi-Fi and 5G integration. In smaller Wi-Fi networks, a distributed architecture, with most content and processing kept on-premises and using local breakout, has been the default all along.

The IoT, IIoT and Private Networks

5G will be able to support a wide range of IoT and IIoT applications and will fuel growth in private networks in the enterprise. We should keep in mind, however, that Wi-Fi has been supporting IoT applications for a long time, although in most cases — e.g., surveillance — they were not labeled as such.

Similarly, nearly all Wi-Fi networks are private networks, paid for and operated by the enterprise, and used to support enterprise services and applications. Both Wi-Fi and 5G will be crucial technologies to support the enterprises' needs to own, control and operate their own networks and use them to optimize and automate their process.

Mutual Offload

Initially, it was cellular networks that offloaded traffic onto Wi-Fi networks — often treated as an inferior alternative to be used opportunistically, that was cheaper, but not as secure and reliable. Even with the improved performance of 5G, there will still be a need to offload. However, it will be a bidirectional process, with 5G networks sending traffic to Wi-Fi and Wi-Fi networks sending traffic to 5G, depending on network conditions or any other criteria (e.g., cost, roaming relationships, policy or availability) that the service provider chooses.

Real-time Traffic Management, Automation, AI

Today's wireless networks — regardless of the technology — could be more efficient in their use of network and spectrum resources. The growth in traffic is so strong that new air interfaces and new spectrum allocations cannot keep up with it. IoT will further exacerbate the need to increase capacity and to support a massive number of connections. Increasing efficiency is both imperative and cost-effective. Both Wi-Fi and 5G are making major strides toward improving efficiency with real-time management, automation, and AI. These are all evolutionary trends that are new to both technologies, and a ground where there is much they can learn from each other.

Implications

We are entering a world of pervasive connectivity, in which wireless technologies will not only reach more users and devices, but will redefine the way we deploy and use wireless. No single technology can achieve this transformation: Wi-Fi and 5G are both needed to meet the IMT-2020 requirements.

Wi-Fi carries most wireless data traffic and it will continue to do so, by combining continuity — i.e., backward compatibility and interoperability — and innovation — i.e., new air interface, improved performance, and support for new use cases. The most anticipated innovation in Wi-Fi is Wi-Fi 6, based on IEEE

802.11ax, a new air interface expected to bring a 4x increase in capacity in high-traffic environments, a more efficient use of network resources, and better support for IoT applications.

Wi-Fi evolution goes beyond Wi-Fi 6. It includes a new security certification program (WPA3), expansion to 60 GHz (WiGig), better support for IoT (HaLow), improved traffic management and roaming, and mesh capabilities (EasyMesh).

As Wi-Fi and 5G/cellular continue to develop, they will retain their role in the wireless fabric. Wi-Fi will mostly serve indoor traffic in residential and enterprise locations. 5G/cellular will continue to dominate carrier wide-area networks and to support mobile access.

Wi-Fi and 5G convergence spans multiple domains and reflects the potential that both technologies have to jointly redefine wireless connectivity as they both carve their own role within the wireless infrastructure.

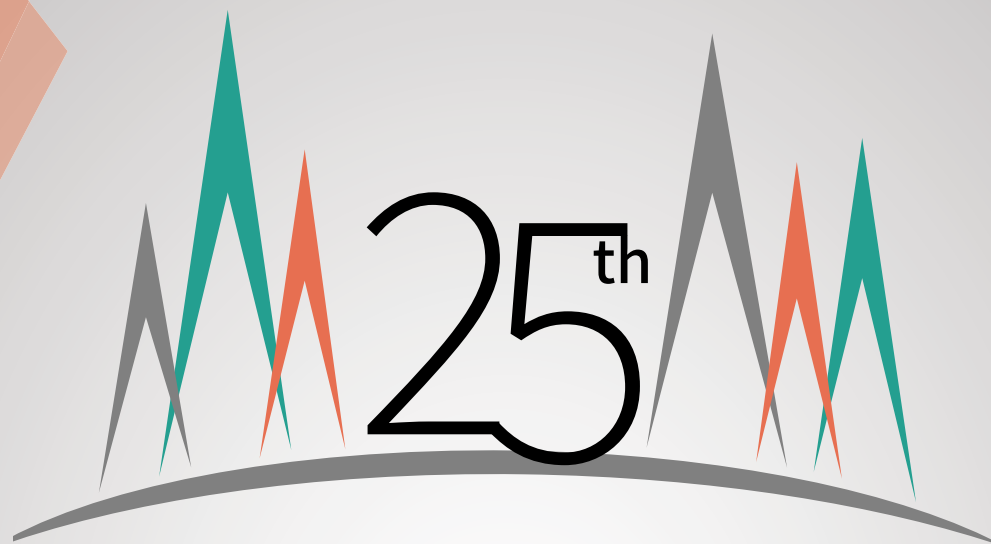


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and products, and estimate the market size and revenue opportunity of new and established wireless technologies. She frequently gives presentations at conferences, and she has written many reports and articles on wireless technologies and services. 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).

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A 5G Vision for the 4th Industrial Revolution



BY VICKI LIVINGSTON

How 5G will play in the this brave, new iteration of the industrial revolution.

Where we have come from:

- » **1st Industrial Revolution – 1760 and the steam engine created factories**
- » **2nd Industrial Revolution – 1860 steel, oil and electricity, introduced the light bulb and telephones**
- » **3rd Industrial Revolution – 1960's for the Digital Revolution and the introduction of computing**
- » **4th Industrial Revolution – Industry 4.0 arrives – 5G mobile wireless technology is a driver**

The rationale for the development of the 5th generation of mobile communications (5G) goes beyond the expansion of mobile broadband connectivity. 5G will provide advanced wireless connectivity for a wide variety of vertical industries, such as the manufacturing, automotive and agricultural sectors, with the massive Internet of Things (M-IOT) comprised of billions of connected devices.

Klaus Schwab, founder and executive chair of the Geneva-based World Economic Forum, published a book in 2016 titled *The Fourth Industrial Revolution* and coined the term in Davos that same year. At the World Economic Forum, January 2019 in Davos, the 4th Industrial Revolution (4IR) was at the center of discussion. It was agreed that a combination of technologies are changing the way we live, work and interact, such as Artificial Intelligence (AI), autonomous vehicles, and IoT. These are among key technologies for societal transformation.

Largely dependent upon advanced mobile wireless communications, the fourth industrial revolution or "Industry 4.0" will usher in the trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet

of Things (IoT), autonomous vehicles, cloud computing and cognitive computing (aka, AI). The term "automation" stands for the control of processes, devices or systems in vertical domains by automatic means.

Communication, for automation across vertical domains, comes with demanding and diverse requirements with respect to latency, data rates, availability, and reliability, and in some cases high-accuracy positioning. To achieve this, 5G supports three essential types of communication: enhanced Mobile Broadband (eMBB), massive Machine-Type Communication (mMTC), and Ultra-Reliable Low-Latency Communication (URLLC).

Connectivity is a key component of Industry 4.0, which aims at significantly improving the flexibility, versatility, usability, and efficiency of future smart factories, integrates the IoT and related services in industrial manufacturing, and delivers seamless vertical and horizontal integration down the entire value chain and across all layers of the automation pyramid.

Meeting these objectives will greatly depend upon the 5G technical performance such as supporting a peak data rate of 1-20 Gbps; connections density 1 thousand – 1 million devices/km²; reliability of 99.999 percent (five-nines); enhanced battery life of up to 10 years; higher position accuracy; low latency (1-10 ms); and strong privacy and security.

Key vertical domains and associated use cases with a compelling need for automation include the following:

- » Rail-bound mass transit
- » Building automation
- » Factory of the future

- » eHealth
- » Smart citiesElectrical power distribution
- » Central power generation
- » Program making and special events

Market segments for automation are still emerging and are expected to ignite growth within the next 12 to 30 months. Industry will continue to drive the inflection point with the following key objectives in mind:

- » Narrowband Internet of Things (NB-IoT) technologies will help to drive lower costs
- » 5G will further enable a new range of opportunities
- » New technologies such as blockchain, AI and Multi-Access Edge Computing (MEC) will further overcome technology limitations
- » Ecosystem players will move towards more collaborative approaches

Communications in this sphere must support applications for production in the corresponding vertical domain (for example, industrial automation and energy automation, but also transportation). This needs to be incorporated into new security standards and mechanisms for dependable communications.

The 3GPP standards organization has analyzed vertical use cases that resulted in several vertical communication requirements.

The well-understood Key Performance Indicators (KPIs) for latency, jitter, reliability, communication service availability, and data rates apply for verticals, as well. In addition, there are other requirements that should be considered and folded into the potential new service requirements for 5G systems.

Ultra-Reliable, Low Latency Communication

The new services and applications requiring lower latency, better reliability, massive connection density, and improved energy efficiency are emerging in an unprecedented fashion. A variety of advanced features makes 5G uniquely well positioned to meet all of these requirements and capitalize on these market opportunities. URLLC provides a set of features designed to support mission-critical applications such as industrial internet, smart grids, remote surgery, and intelligent transportation systems.

With 4G LTE, latency is currently in the 4-millisecond range under 3GPP Release 14. URLLC is part of Release 15 and has a target of 1-millisecond. URLLC also is ideal for applications that require end-to-end security and five-nines reliability. Moreover, it is almost deterministic in time bounds on packet delivery. This combination of capabilities requires almost a fundamentally different approach to system design and operations compared to previous mobile wireless technologies.

The physical layer is, unquestionably, the most challenging because URLLC must satisfy two conflicting requirements: low latency and ultra-high reliability. This combination is a vastly different type of quality of service (QoS) compared to traditional mobile broadband applications.

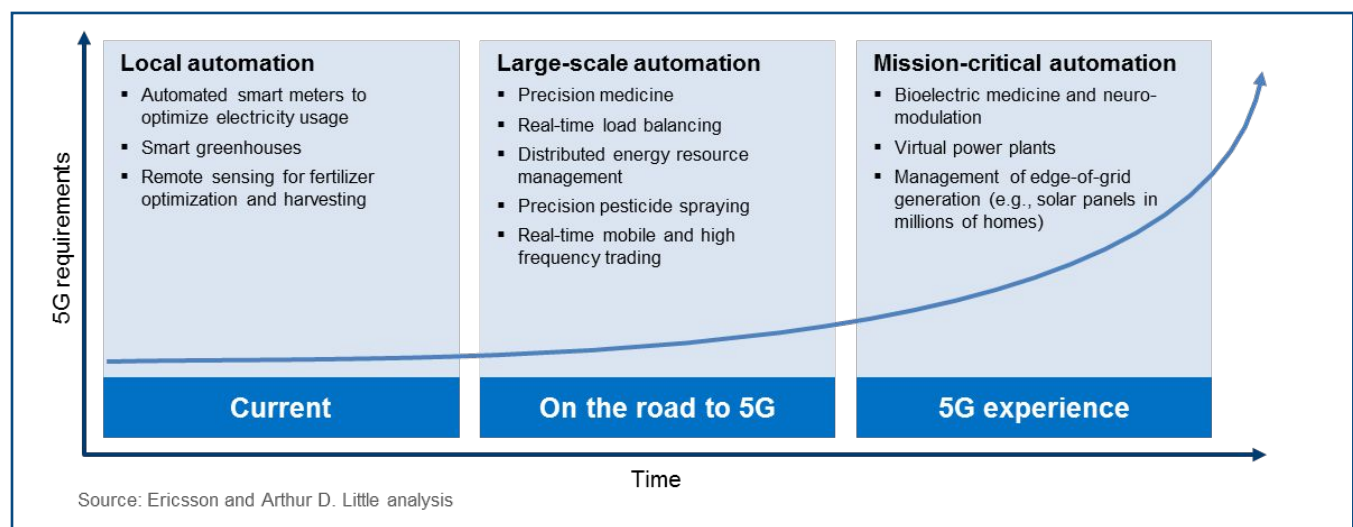


Figure 1. The 5G evolution of real-time automation.

As we move to 5G, real-time automation scales out from local compute, to distributed large-scale compute, to mission-critical experience. Ericsson and Arthur D. Little depict the 5G evolution of real-time automation, Evolution of 5G Real-Time Automation Cluster (see Figure 1).

Evolution of 5G Real-Time Automation Cluster

Within Critical IoT applications, monitoring and control occur in real time, end-to-end latency requirements are very low (at millisecond levels) and the need for reliability is great. These performance objectives will be applied to workflows such as the automation of energy distribution in a smart grid, and in industrial process control and sensor networking where there are stringent requirements at the application layer. Security is paramount.

Security in Automation

Security in mobile wireless networks has long been a strong market differentiator against other wireless technologies. 5G takes the security focus to another level.

Industrial IoT security threats include threat actors such as cyber attackers, Bot-network masters, industrial spies and organized crime, terrorist groups, national governments, and insiders. If that is not worrisome enough, the types of attacks include malware-triggered ransomware, network protocol attacks, cryptographic algorithm, and key management attacks, spoofing/authentication attacks, unauthorized endpoint control to trigger unintended control flows, denial of service, data corruption, physical security and access control attacks (privilege escalation). Understanding the source and style of attacks allows for the planning for cyber-security for confidentiality, integrity, authentication, non-repudiation, availability, and privacy.

5G offers new and enhanced capabilities to provide secure solutions, however, in automation for vertical domains these responsibilities are more complex, as they are shared by several actors and need to be managed by credential pairs or certificates from different sources.

5G authentication and verification are implemented using the Extensible Authentication Protocol (EAP) framework including native support.

Flexible and efficient subscriber access management (permissions) is important for 5G User Equipment (UEs) that provide communication across automation systems. For example, machinery on a factory floor can be added or removed from the subscription base.

Devices in many verticals operate over long usage periods (in industrial environments typically 10-20 years). Automation application systems must be easily maintained for this duration without the requirement for physical access for upgrades; it is critical that UEs are upgradable or can be patched (including firmware, security-related algorithms and long-term keys) to keep the devices and systems secure. State of the art encryption is standardized in 5G to protect the user plane, control plane, and management traffic; also, 5G supports user privacy protection.

Network slicing provides further security provisions; a dedicated slice can be used for IIoT and protected from malware that may reside in another slice through isolation measures.

3GPP Automation Design

Since 2017, Technical Specification Groups (TSGs) within 3GPP have been working on the standardization of 5G systems in the new, vertical application domains involving automated control. 3GPP Release 15 provided a sound basis for automation communications; Release 16 developed normative requirements and the architectural impact to meet these new requirements. Vertical industries are now participating in the development of the standards bringing new insights into how 3GPP technology can be utilized in new industries such as streaming services, A/V production, critical medicine, asset tracking, unmanned aerial vehicles and more. While the application fields of these new studies are different from automation communication, there are similarities in the underlying system requirements needed to meet communication needs. Release 17 will focus on identifying new requirements specific to the applications that go beyond what is already supported in Releases 15 and 16.

New Industrial Vision

First came steam and early machines that mechanized some of our ancestors' work. Next was electricity, the assembly line and the birth of mass production. The third era of industry was

the digital age of computers and the beginnings of automation, when robots and machines began to replace human workers on those assembly lines.

Now we enter Industry 4.0, in which computers and automation join in a totally new way. This will bring robotics connected remotely to computer systems, equipped with machine learning algorithms that can learn and control the robotics with very little input from human operators. Industry 4.0 introduces what is being called the “smart factory,” in which cyber-physical systems monitor the physical processes of the factory and make decentralized decisions. The physical systems become IoT, communicating and cooperating, both with each other and with humans, in real time via the wireless web.

Considerations for a factory or system to be considered Industry 4.0 include:

- » **Interoperability** — machines, devices, sensors and people that connect and communicate with one another
- » **Information transparency** — the systems create a virtual copy of the physical world through sensor data in order to contextualize information
- » **Technical assistance** — both the ability of the systems to support humans in making decisions and solving problems and the ability to assist humans with tasks that are too difficult or unsafe for humans
- » **Decentralized decision-making** — the ability of cyber-physical systems to make simple decisions on their own and become as autonomous as possible

5G mobile wireless technology will offer the opportunity for the Industrial IoT to, effectively and successfully, deliver on a vision for the global fourth Industrial Revolution.



Vicki Livingston, Head of Communications and Analyst Relations, 5G Americas. Vicki Livingston is the Head of Communications and Analyst Relations for 5G Americas and supports the organization's mission to provide a unified voice for LTE and its evolution

beyond to 5G throughout the Americas. In her role, she directs all communications, media and analyst relations and conferences for the association as well as strategic planning and liaison with global organizations. Ms. Livingston has over 20 years of experience in public relations and marketing, strategizing and executing the launch of eight new companies or international brands throughout her career, including two wireless companies, 3G Americas which evolved to 4G Americas, and now 5G Americas. Other career experiences include Head of Business Development for not-for-profit organizations as well as one of the largest business-to-business full service agencies in the U.S. She began her career as the first executive level female in the brewing industry as Marketing Manager for Miller Brewing Company, a subsidiary of Philip Morris, Inc. where she first became involved in brand development, market segmentation and supported the launch of the Lite beer brand. Ms. Livingston is an active volunteer having served on Boards of Directors including the Arthritis Foundation, AFS and Easter Seals (Past President). She is an avid sailor. Ms. Livingston earned her Bachelor's degree from the University of Miami in Communications and Business Administration and later attended the Graduate School of Journalism at Marquette University in Milwaukee, Wisconsin, and has academic and philanthropic honors.

Keybox:

Much of the technical information in this article was sourced from 5G Americas white papers that are available on their website for free download.

WHITE PAPER

5g Communications for Automation in Vertical Domains

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WHITE PAPER

New Services & Applications with 5G Ultra-Reliable Low Latency Communications

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CommScope

Smart Cities Trends in 2019



BY MORNE ERASMUS

Smart communities will enrich the lives of residents and make local governments more efficient in responding to their citizens' needs. From security to convenience to revenue generation, smart city applications will change the way cities operate and the way we live and work. It all starts with connectivity – smart city residents, vehicles, systems, and applications must be connected. In addition, in most cases that involves fiber infrastructure. There are three key trends that will impact smart cities in 2019. Let us take a look.

Longer-term Planning

Companies have traditionally built out specific, siloed applications like surveillance cameras, smart lighting or traffic sensors. In 2019 they will start to take the longer view and think about building a basic infrastructure to support all smart city applications. It only makes sense; otherwise, the city is digging up the same streets every year, or so, to add infrastructure for each new application. For example, one city installed basic security cameras on light poles, but did so without installing fiber connectivity that would enable adding small cells or implementing facial recognition applications for the cameras to those poles. Now, the city must upgrade its light pole connectivity network – a painful and costly process.

To avoid having to upgrade networks in the future, city planners are now educating themselves about future possibilities, consulting with IoT vendors and network connectivity vendors, and working to develop a plan for the long term. For example, Stockholm as well as Chattanooga, Tennessee and Lincoln, Nebraska have built high-speed fiber networks around their cities with enough bandwidth to support new IoT devices and applications well into the future.

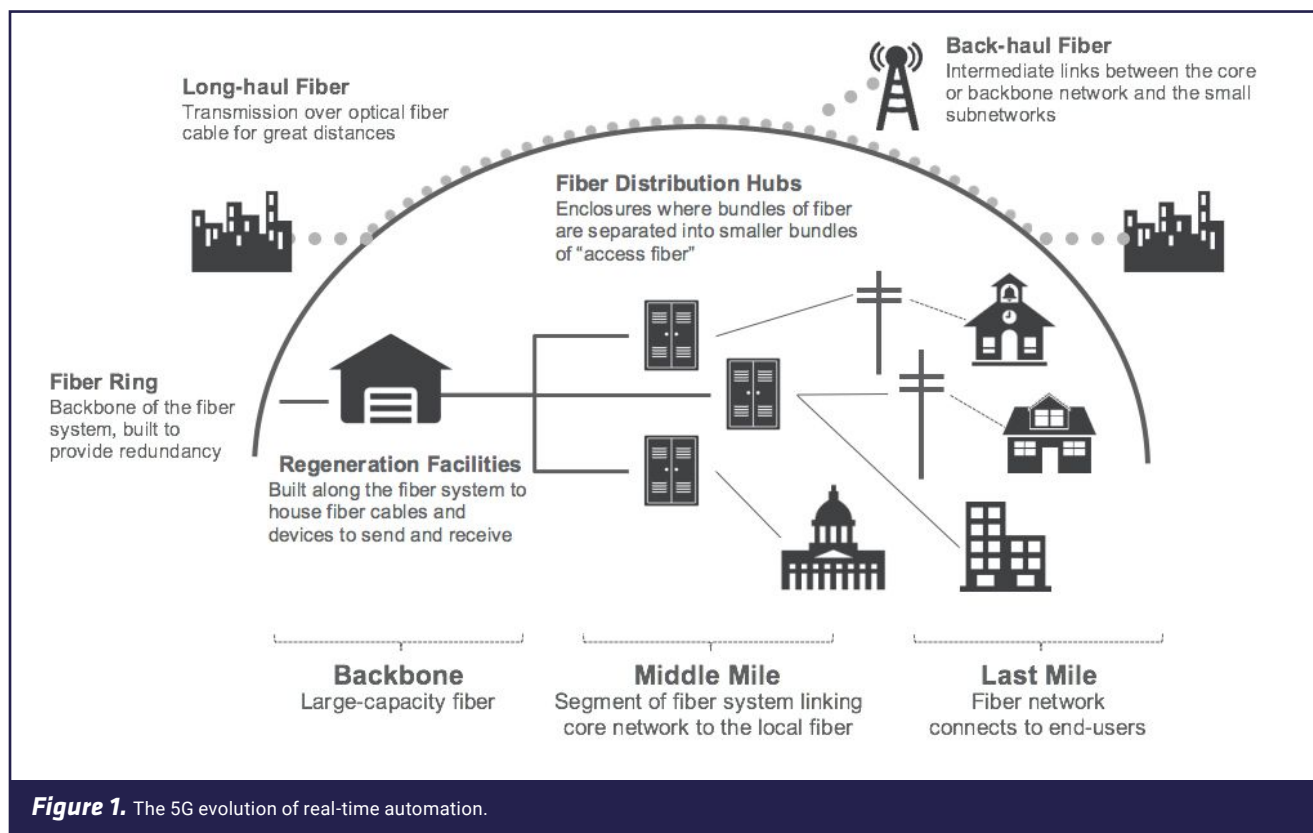
Overall, data connectivity is becoming the cities fourth utility – it is a must-have to do business, and cities are recognizing this. Connectivity in homes and businesses is a competitive advantage for cities, and they are rushing to implement it.

Creative Financing

Like water, gas and electricity, cities do not always deliver the service, but they enable construction of the basic infrastructure that delivers the service. We are starting to see more projects that combine government funding with public/private partnerships. In Europe and elsewhere around the world, many national governments are mandating and providing funding for large fiber build-outs. In North America, service providers, developers and local utilities are deploying parts of the civic connectivity infrastructure, while the city facilitates permitting and planning for construction.

Electric utilities are in a unique position to deploy fiber infrastructure because they already own rights-of-way and have existing overhead poles or underground conduits that can accommodate new fiber, so they can deploy fiber more quickly and at a lower cost. In some cases, cities in North America are funding or partnering with local power companies to build out the “middle mile” of the fiber network – the part from central offices or other distribution hubs to neighborhoods or business parks (see Figure 1). Middle-mile networks are the most common municipal model due to less risk, decreased cost of deployment and the ability to lease excess conduit/fiber to private providers. Cities and municipal organizations building middle-mile networks include Centennial, Colorado and Howard County, Maryland to name just a few.

In many other cases, cities are also building the “last mile” that connects customers, often in partnership with local municipal electric companies. Ammon, Idaho; Hudson Oaks, Texas; and Fairlawn, Ohio; all are deploying last mile connectivity on their own, while Chattanooga, Tennessee; Lafayette, Louisiana; and Longmont, Colorado are partnering with local electric utilities to reach end customers. We see similar trends internationally in Stockholm (Stokab), Netherlands (Reggefiber, Citynet Amsterdam), and Singapore (OpenNet) just to name a few. Carriers are also building their own last-mile networks, and 5G access will play



an increasing role in delivering this connectivity, either through the densification of mobile networks or deployment of new fixed access solutions. Verizon has already launched 5G wireless access trials in several cities in 2018.

Network Convergence

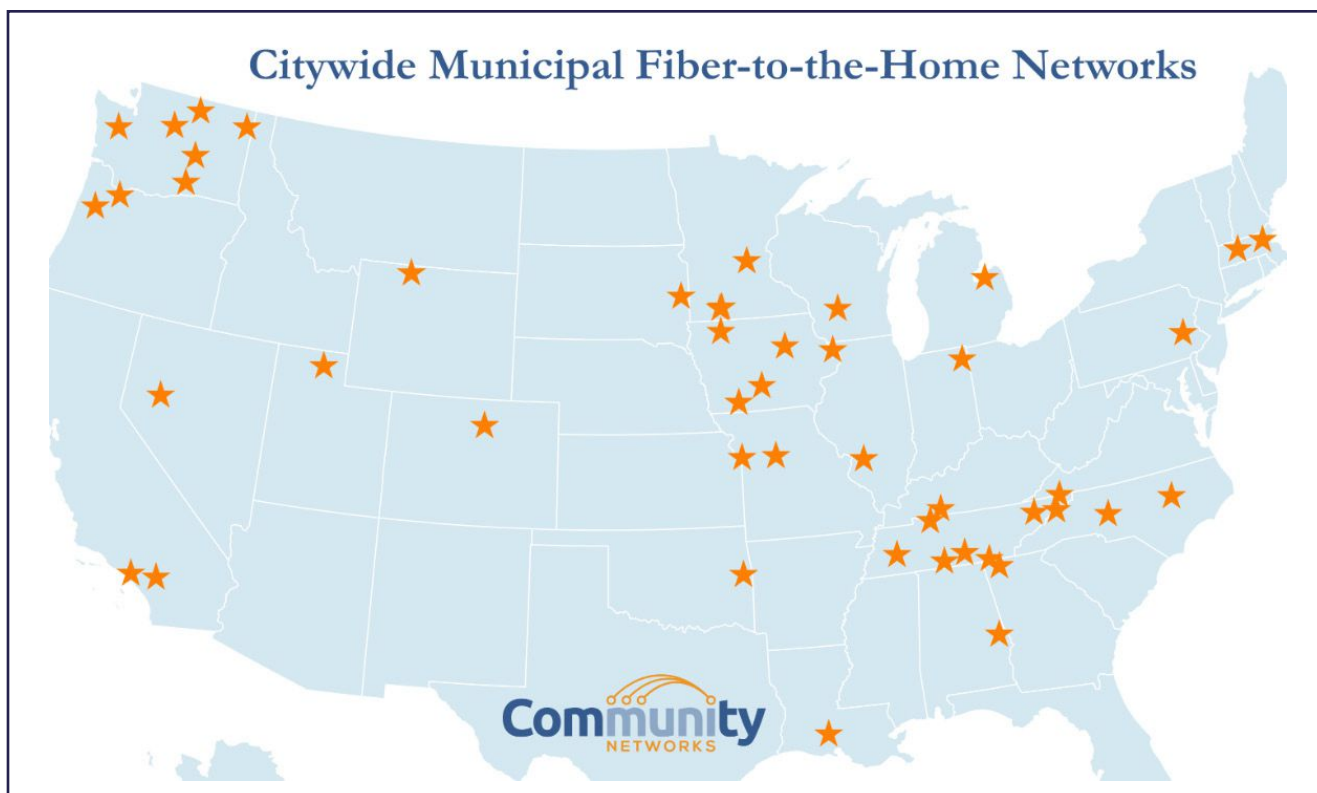
In the past, service providers built separate wireless and wireline networks. Wireless infrastructure is becoming more centralized. Therefore, it makes more sense to converge all the wireless backhaul traffic onto the same fiber used by wireline services. The process of fiber network convergence is primarily driven by the development of enabling technologies, user demand, and service providers' capabilities. Large, incumbent service providers have both wireline and wireless operations. Therefore, converging onto a single network and maximizing asset utilization makes excellent business sense and will be a push for 2019.

Real-life examples have occurred where a fiber-to-the-home (FTTH) network was built and several months later, the same construction crew dug up the same street to lay fiber for a cell

site, which is wasteful and disruptive. Network convergence would mean one build-out that could be used for multiple service delivery platforms including FTTH.

That said, most cities will incorporate different providers' networks in their overall infrastructure. How should they tie all these networks together? The first step is to put all this fiber, from different vendors, in the same trench and in the same conduit. Some networks need to be private (public safety, for example), but cities can, at least, ensure that all networks use the same conduit and, perhaps, even the same fiber bundle. After all, when the U.S. Interstate Highway system was built, there were not separate roads for trucks, cars and motorcycles—a shared infrastructure was built. It makes sense to do the same with fiber networks.

Applications drive the need for more bandwidth: parking, smart meters, public safety (surveillance cameras), traffic management, 5G small cell densification, waste management, and coordination of departments for emergency services are just a few examples. It is easy to see that a single converged network would be the most cost-effective way to support these



applications. When a city builds out a fiber network to its light poles, for example, those poles can support smart lighting, surveillance cameras, and small cells for 5G network densification.

In fact, the emergence of 5G networks, over the next couple of years, is a major driver for fiber deployments. 5G will not only bring faster speeds, but also much denser small cell deployments due to distance limitations with millimeter wave technology and ultra-low latency applications at the edge. By providing the pole infrastructure and facilitating permitting, a city can speed the build-out of fiber-to-the-pole networks by utility companies or service providers.

By meeting these expectations, 5G will foster new applications. Large companies like Netflix and Uber were built because fiber and 4G mobile wireless infrastructure were there to support their services. With its increases in bandwidth and coverage ubiquity, 5G will drive similar innovations, but it will rely on fiber for transport to and from the rest of the city's network.

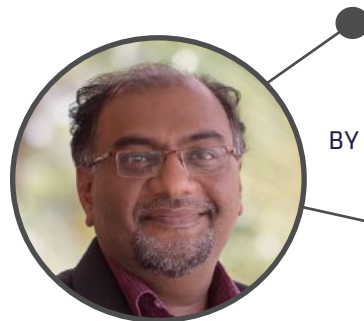
Cities are implementing smart city applications because they improve efficiency, reduce costs, generate new sources of revenue, and most importantly, improve the lives of their citizens. By planning ahead, using creative funding approaches, and

converging networks around citywide fiber rollouts, cities will move forward on the path to becoming smarter in 2019.

Morné Erasmus is the director of Smart Cities at CommScope. He is responsible for leading the company's global smart city program and is a regular presenter at industry conferences. Since joining CommScope in 2012, Morné has held senior roles in Technical Sales and Segment Strategy. He has more than 20 years of experience in the technology industry, spanning five continents. Morné holds a degree in electrical engineering from the Cape Peninsula University of Technology in Cape Town and is currently based in Dallas, Texas.

Happiest Minds

SDN is Here to Stay – Do You Have an SDN Validation Strategy in Place?



BY JASON CHANDRALAL

Software-Defined Networking (SDN) offers the promise of increased agility, programmability, and revenue services opportunities. While SDN has been widely deployed in the data center and enterprise environments, and many service provider deployments are underway, I think the best is yet to come. According to IHS research, SDN deployments are expected to grow exponentially, reaching an \$18 billion addressable market by the end of 2019.

SDN is centered around the idea of providing a centralized view of the network along with ensuring optimized management by creating distance between two crucial elements – the controlling plane and the forwarding plane.

As per the Open Network Foundation (ONF), SDN is the physical separation of the network control plane from the forwarding plane, where a control plane controls several devices. The SDN architecture, basically, has five key attributes; direct programmability, control layer abstraction, programmatic configuration, open standards design and vendor-neutrality. Abstracting control from the forwarding plane enables network administrators to, dynamically, adjust network-wide traffic flow and thereby bring in a lot more agility into the network.

With major adoption of network function virtualization and deployments of software-defined networking, the average network architecture has started to look drastically different today. This as AT&T drives its Network 2020 vision and similar global communication service providers increasingly transforming their networks and adding new virtualized services and revenue streams. Within this architectural evolution, software-defined networking has the potential to transform the way networks are designed, implemented, and managed. It is important to understand some of the typical SDN based Network Virtualization

designs that are being rolled out that necessitate an SDN validation strategy.

- » **Underlay Networks** — This includes leaf and spine physical switches that are deployed and controlled by the SDN controller through exposed open APIs such as Openflow and NetConf. The controller integrates with the VIM manager to obtain all the relevant data to create virtual networks.
- » **Overlay Networks** — Programmable virtual data plane elements (vDPs) are inserted into common off the shelf (COTS) servers and controlled by the SDN controller. They form overlay networks using tunnels that are routed over the legacy network fabric (like VxLAN). Usually a gateway is present and participates in the overlay networking.
- » **Integrated Overlay Underlay Networks** — This architecture is where overlay and underlay networks work together to provide both flexibility and performance. This approach has been gaining acceptance due to the benefits of end-to-end visibility and seamless control.

Hence, testing these solutions makes it crucial to adopt a holistic testing approach that brings together white box, grey and black-box testing methodology that integrates the complete technology stack.

SDN Validation Approach

After laying down the various network viewpoints of how SDN is implemented, integrated validation focuses on two main approaches; vertical layer testing approach and horizontal layer testing approach.

The vertical layer approach covers applications, the network, and the Security Layer.



Some of the focus areas in a vertical approach are mentioned below:

1. **Network applications** – onboarding, topology, services and deployment.
2. **Network infrastructure** – OF protocol conformance, SDN controller functionality, south bound and north bound API Tests, scale and performance, Interoperability.
3. **Security** – secure control channel, NBI authorization/authentication and SDN controller security.

The horizontal layer approach focuses on the data plane, control plane and management application plane much like the layers of the OSI stack.

Some of the functional tests in a horizontal approach include:

4. **Data plane tests** – validate the throughput, latency, scalability and other parameters like flow latency, TCP flows between hosts, UDP parallel sessions, etc.
5. **Control plane tests** – validate and measure the SDN controller, CPU utilization, response time and flow drop rates through traffic injection. Here the SDN controller is connected to several virtual data plane elements.
6. **Management plane tests** – onboarding time for REST API, GUI based provisioning, CLI based provisioning and stress tests on management plane processing.

Conclusion

SDN is here to stay and will rapidly gain acceptance with most service providers, and enterprises, in the coming years. Therefore, a well thought out, proven approach that is based on industry best practices, leveraging community support, and proven domain expertise, provides the much-needed predictability and assurance required for a successful SDN rollout.

Adopting a layered and test-centric focused approach provides benefits related to the early detection of bugs, improved test cycles through automation, an increase in confidence levels, identifying non-functional benchmarks, interoperability, improved security guidelines, and most importantly the adequate testing required to ensure smooth delivery.

Jason Chandralal is general manager of Product Engineering Services at Happiest Minds Technologies. He is responsible for defining and leading Test Engineering solutions in the area of Datacenter Technologies specially focused on SDN and NFV technologies. Jason is also responsible for embedded and Systems and device related technologies associated with Internet of Things and Industrial Automation. He has over 24 years of experience in Telecom, Datacom, Networking and IoT product development and testing working across Network Equipment Provider, Telecom Service Provider, Hi-Tech and Manufacturing customers with specialization Networking and Testing, QA.

IDF

Let the Market Bridge the Broadband Divide



BY WAYNE BROUGH

Fixed wireless is the best way to reach 24 million Americans currently beyond the reach of high-speed Internet.



Today, in the United States, there are 287 million Internet users. The online world has changed how we live, prompting a burst of innovation that reaches every aspect of our lives. How we shop, how we keep in touch with friends and family, how we watch television and movies and how we work — all of these things have been changed by the Internet.

In addition, it is not just the simple things in life that the Internet has changed. With enhanced access to vital services, such as telemedicine and online education, most Americans have access to services unimagined just a decade ago.

However, not every American enjoys these benefits. According to the FCC's 2018 broadband deployment report, 24 million Americans have little or no access to high-speed Internet. Broadband deployment in rural America lags the rest of the

nation due to the prohibitive infrastructure costs of serving small and isolated communities.

Fortunately, however, the FCC has a chance to correct this disparity by reconsidering the way spectrum is allocated and, if done properly, that change could open the door for companies to quickly ramp up service to these underserved communities.

More specifically, the FCC is developing a proposal that would make room for new players in a part of the spectrum that is known as the C-band. One of the most innovative proposals out there would allow fixed wireless service providers the opportunity to enter the market rapidly in these underserved regions, delivering quality, affordable high-speed Internet access to those previously unable to obtain it.

The proposal would ensure that those currently using the spectrum — fixed satellite service and other fixed services — would not be harmed by any potential interference from the new spectrum users. The FCC would coordinate between existing and new users to ensure everyone can coexist. Basically, the proposal would empower the FCC to arrange current users more efficiently while ensuring that no spectrum needlessly lies fallow when it could be put to use serving rural customers.

Fixed wireless service is a localized form of Internet access, ideally suited for serving rural communities. In fact, the average fixed wireless service provider has only about 1,200 customers. Fixed wireless Internet providers set up an Internet-connected base station that wirelessly transmits Internet access to their local customers. It is easy to deploy, and the capital costs of setting up a fixed wireless network is, roughly, one-sixth the cost of laying cable, making it truly affordable for most rural Americans.

While the digital divide has long been a concern of the FCC and the federal government, the solutions floating around Washington often focus on government programs and subsidies, such as the costly and inefficient universal service fund for telephone service. This approach is a burden on taxpayers and is politically contentious, which means it often takes years to implement. Fixed wireless, on the other hand, is capable of being deployed the minute the light turns green.

Why is the light not yet green? As is often the case with innovation, regulatory barriers are making it difficult to deploy fixed wireless service. Much of it has to do with the current rules on spectrum allocation, which are outdated and can actually deter broadband deployment.

One of the FCC's primary responsibilities is, efficiently, allocating spectrum to various providers — from mobile phones to radio and television. Spectrum is scarce and will be getting scarcer as 5G and the Internet of Things place more demands on the public airwaves, so the FCC needs to reevaluate how the spectrum is currently managed.

Providing reliable, high-speed broadband access to rural communities has significant economic benefits. Take, for instance, agriculture, which has always relied on evolutionary technology to thrive. Fixed wireless service can bring the high-speed Internet

where the local telephone and cell companies will not go, enabling high-tech farming to increase crop-yields and quality; robotics and drones for herd and crop management; and sensors to over-see soil conditions. Similarly, access to telemedicine and other essential online services can provide important quality-of-life improvements for rural communities, as well.

Cost-effectively expanding the reach of high-speed broadband to rural America will bring real economic and social benefits to communities that have not enjoyed the same benefits available in most American cities. Better spectrum management will allow market-driven solutions for broadband deployment, rather than bureaucratic subsidy programs that cost taxpayers money and take years to produce results.

Rearranging the C-band to utilize bandwidth more efficiently will attract innovators and entrepreneurs who are willing to make the necessary investments to bridge the broadband divide. The only thing standing in their way is outdated regulatory impediments, which the FCC can reform in its review of the C-band spectrum. Unleash the fixed wireless service providers! Millions of Americans are waiting for the green light.

Wayne T. Brough is currently president of the Innovation Defense Foundation (IDF). He received his Ph.D. in economics from George Mason University, with fields in industrial organization and public choice. Prior to cofounding the IDF, Dr. Brough was the chief economist and vice president for research at FreedomWorks. Previously, he worked at the Office of Management and Budget, focusing on transportation regulations; the United States Agency for International Development, focusing on market reforms in Africa; and in the research branch of an investment bank, where he covered U.S. domestic policies. Dr. Brough's analysis examines the importance of competition and open markets for the evolution of the internet as well as addressing the impact of specific regulations. His work has appeared in newspapers, books, and on television; he has testified before Congress and state legislatures, and filed comments in numerous regulatory proceedings. He has publicly championed the importance of an unfettered internet through his writings as well as a wide array of public speaking engagements.

Sicap

A Three-point Best Smart-Watch Strategy Approach for Mobile Operators



BY OLIVIER ENGEL

Smartphones are so last season – the way forward is smartwatches and other wearables. These are touted to be the next consumer obsession and are estimated to create a global \$40 billion business by 2020. Mobile service providers will get a 25 percent slice of these revenues, but need the right business model, value chain positioning, and technology enablers to do this.

Wearables will help mobile service providers to drive more than \$12 billion (€10.07 billion) in service revenue by the end of 2021, following a CAGR of 36 percent. This corresponds to approximately 25 percent of the total wearables revenues for mobile



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service providers. According to research conducted by analyst house, SNS Telecom, **(Wearable Technology Ecosystem: 2016-2030 ▶)** wearable devices are expected to generate a global market worth \$40 billion with over 240 million annual unit shipments by 2020.

Can Smartwatches Revive the Flattening Smartphone Market?

Smartwatches are the single biggest product category in the wearables segment. According to technology analysts at IDC, **smartwatches will account for 44.6 percent of all wearables ▶** estimated to ship by the end of 2022.



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Due to relatively high price points, smartwatches have yet to reach true mass-market appeal. This is, however, expected to change in 2019. According to Alan Antin, the Senior Director at Gartner, the overall, average, selling price of **smartwatches will decline ▶** from \$221.99 to \$210 in 2022. This will be because of lower-priced competitors and higher volumes, which will lead to reductions in manufacturing and component costs.

As smartwatch prices drop, the market will segment into smaller sub-categories, including the health and sport sectors, payment market, fashion scene, for small children, and the elderly. Shipping volumes will continue to grow, due to more use cases and price points meeting the demand.

Global smartphone shipments have flattened out, and even decreased in 2018. The strong growth trend in smartwatch segment could benefit the mobile service providers' business. However, compared to smartphones, a fundamentally different business approach is required.

What is the Optimal Smartwatch Business Model for Mobile Operators?

A successful smartwatch business model is critical for an operator's success in wearables. The commonly used transaction-based product business model, in which physical smartwatches are sold to consumers, is the worst-case scenario for operators – as they could be left without any recurring service revenues. From the operator's perspective, wearable device sales should always be a combination of a product, services and a subscription.

Smartwatches have a tiny screen, and the applications consume small amounts of data. Periodic location tracking, health checks or calendar updates are typical data transactions. Even if mobile operators are sitting in the bit-pipe service provider role on the wearables value chain, the connectivity-only business model will

not become a gold mine for them and the lucrative 30 percent share of the \$40-billion in revenue will remain a distant dream.

In a subscription business model, the wearable device, either a smartwatch or another connected gadget, is sold “as-a-service,” customers can subscribe with a standard recurring fee on a weekly, monthly or annual basis. Alternatively, they can pay fees based on their usage or other relevant key performance indicators. In either scenario, the fees will cover the costs of the device itself, and the costs of using it — including wireless data transmissions.

The subscription business model will generate, for operators, a continuous stream of service revenues. Additionally, it will provide operators with additional possibilities for bundling smartwatches as companion devices for smartphones. This increases device sales and improves relationships with customers.

Bundling devices and services through a subscription model can allow the device to be sold at a discount. The real goal will be to drive revenue from the allied services.

How Should Operators be Positioned on the Wearables Value Chain?

The wearables value chain is essentially composed of four components — devices, applications, platforms, and connectivity. To achieve a profitable subscription-based business model, operators need to take up the role of both platform and connectivity provider on this value chain.

This will allow tight bundling of multiple devices, services, and connectivity into a single subscription. In telecom standards, a mobile subscription always includes a primary device, which is typically a smartphone, and multiple secondary devices, such as smartwatches. With the right network enablers in place, all these can be bundled into the same subscription and phone number.

Which Network Enablers do you Need for a Smartwatch Business?

To achieve a sound and sustainable wearables business, mobile operators will need several technology enablers on their network. This starts from a flexible billing and subscription management platform that supports the bundling of devices, to services, subscriptions, and companion devices.

Subscription Manager Data Preparation (SM-DP+) is Needed for eSIM provisioning

Smartwatches are increasingly based on an Embedded SIM (eSIM), especially the latest high-end products. eSIMs, found in the non-removable and non-accessible software and hardware units inside smartwatches, require the standard functionalities on the mobile network.



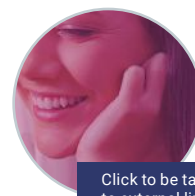
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Through the **Subscription Manager Data Preparation (SM-DP+)** functionality, operators can, securely, encrypt their network credentials to be ready for over-the-air (OTA) provisioning on the eSIM. Subscription manager

secure routing (SM-SR) can deliver the encrypted credentials to the eSIM, securely. Once the credentials are installed, it can remotely manage the eSIM. Thereafter, all the services can be managed, including enabling, disabling, and deleting the credentials, as necessary, during the lifetime of the watch.

Does the Device Entitlement Server Make Smartwatch Activation Easier?

Device entitlement is a standard device authentication and service activation procedure and one of the enablers needed for the subscription-based business model for smartwatches. The device entitlement server (DES) is the centerpiece component of the mobile device entitlement. It authenticates mobile devices, including smartwatches for the network and makes sure the devices can access only the allowed services — Voice over Wi-Fi (VoWi-fi) and LTE (VoLTE), for instance.



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Google Android and Microsoft Windows Mobile are examples of operating systems that are based on a standard device entitlement procedure described in the GSMA's specifications. Some device operating systems, such as Apple iOS have opted for a proprietary device entitlement process.

Key Component: Websheet Server

A websheet server is one of the key components needed by operators to activate smartwatches and other secondary devices. A websheet server provides the authentication login dialog between



the device, or the user of the device, and the network. It can be used to present the terms and conditions and pricing plan information to be accepted by the users.

In Conclusion...

The \$40 Billion wearables market is a lucrative business opportunity for mobile operators and MVNOs. However, in order to capture the anticipated 30 percent revenue slice, a prompt implementation of the three-step wearables strategy is crucial.

Operators must master the right technology enablers on their networks, position themselves strategically on the wearables value chain, and embrace the subscription-based business model — otherwise they will lose out!

Olivier Engel, EVP Research and Development at Sicap has more than 14 years of engineering experience, with more than 10 years within the telecoms industry. Prior to joining Sicap, Olivier worked at Unilog IT Services and Logica. His responsibility at Sicap is to ensure high-quality software development and delivery to all customers globally. Olivier has a degree in Information Technology Engineering from Ecole Centrale de Lyon in France.



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