Our 5G world in 2025: what to expect, how to make it happen

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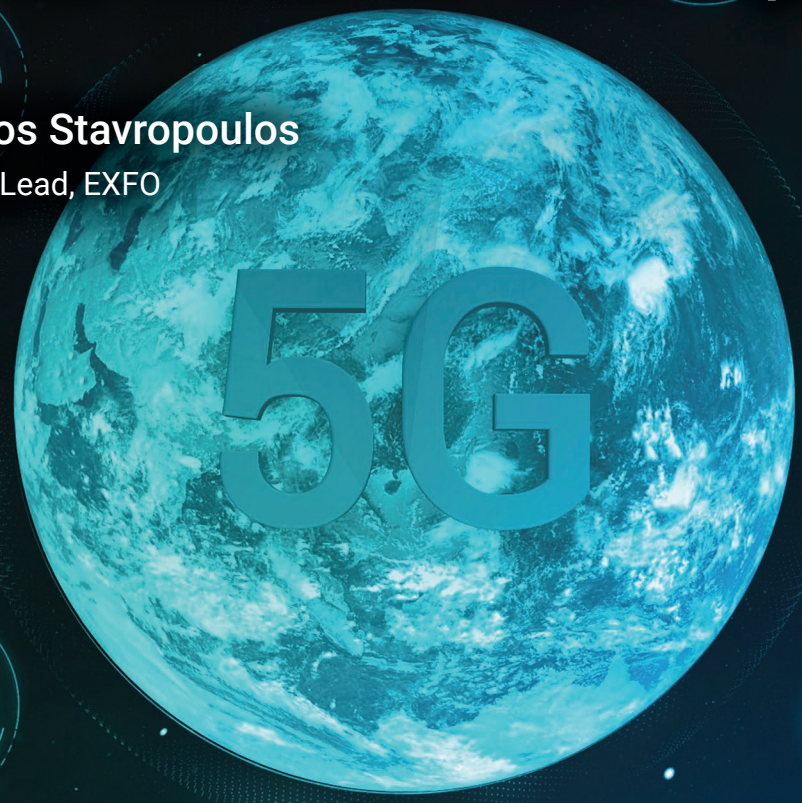

white paper

EXFO

Executive summary

There has been a lot of noise around 5G recently. But what about the future? What about the 5G use cases realistically expected, say, by 2025? And what about the approach necessary for 5G to deliver on its promise by then? This white paper tries to address the above questions.

What 5G is, what 5G will be

5G should be seen as an end-to-end ecosystem that will enable exciting use cases across multiple consumer and enterprise verticals. Interestingly, 5G builds upon the fiber and 4G infrastructure as well as IT concepts, from network cloud/virtualization to service-based architecture. More importantly, 5G is a catalyst for change, not just for the mobile/telecoms industry but (potentially) for our world in general.

5G: Five years from now. . .

We expect: one network, many service providers (including new entrants, using a common "infinite" infrastructure); the smart interconnected world (with devices becoming active "living" parts); the rise of robots (not limited to Industry 4.0); the next step (or leap) in personalization (and our "me"-centric experience); a new reality (in our experience of the virtual and real worlds). How 5G deals with energy efficiency will remain an open topic, while some exciting use cases may just about start changing our world (e.g., autonomous vehicles, internet of senses, remote surgery).

Challenges for 5G

Complexity, investment and regulation are the key high-level challenges for 5G to deliver on its promise by 2025. Complexity wise, new (mainly IT) concepts, the fiber infrastructure, 4G, and 5G-specific features have created a challenging multi-layer puzzle for 5G and for its defining concept of end-to-end network slicing.

AIM for 5G success

On top of the high-level—verify, deploy, operate—network lifecycle approach, the 5G success depends on three interrelated key themes: automation, a multi-faceted concept relevant to simpler tasks and more intricate or ad-hoc activities; intelligence, including the "right" data and insights (e.g., in understanding the network and service topology) as well as AI; mindset, required by the B2B (and B2B2C) nature of 5G and by the fading demarcation lines between telecoms and IT or between wireless and wireline communications.

Will the AIM approach suffice for 5G to deliver by 2025? Will challenges we have not foreseen arise on the way? Que sera sera (whatever will be, will be). . .

Note: For a more detailed discussion on 5G—from its challenges to relevant solutions and lessons learned from deployments—please contact EXFO.

Introduction

There has been a lot of noise around 5G recently, with many network operators launching (or about to launch) 5G, prioritizing services for their initial 5G rollout, sharing the 5G challenges they have been facing, etc.

But what about the future? What about the use cases that 5G is realistically expected to support, say by 2025? And what about the actions and approach necessary for 5G to deliver on its multifaceted promise by then?

This white paper tries to address the above questions. We start by looking into the perception and definition of 5G, followed by the 5G use cases likely to change our world by 2025. Next, we discuss the 5G challenges (focusing on complexity) that worry network operators. Last but not least, we look at what is required to ensure that 5G fully delivers by 2025, if not earlier.

If in the future we stop a 5G network, we will be stopping society.

Telefonica CTIO Enrique Blanco (October 2019)

What 5G is, what 5G will be

2019 was a great year for 5G with 50 service launches by network operators in 27 countries worldwide[a]. But how is 5G perceived after this pivotal year?

Following its non-standalone (NSA) launches, 5G may be regarded today as the latest mobile network standard/generation, a high-band wireless technology for ultra-high throughput focusing on fixed wireless access (as an alternative to fiber/cable), and/or a hotspot technology (to ease the data demand/pressure on 4G).

In reality, 5G is much more than any of the above. 5G should be seen as an end-to-end ecosystem[b] that will enable exciting use cases across multiple consumer and enterprise verticals. The "ultra" 5G—throughput/capacity, latency and reliability—capabilities are indeed impressive. And it is these capabilities, together with network slicing, that are expected to make 5G standalone (SA) a critical part of the world's connectivity backbone. So critical that, as stated by the CTIO of a leading service provider (see quote), 5G performance issues will affect the "hospitals, cars and industry", not just mobile users.

a. Based on the GSA (Global mobile Suppliers Association) "5G Market Snapshot" (October 2019). The number of launches refers to commercially available, 3GPP-compliant 5G services.

b. As per the NGMN (Next Generation Mobile Networks) 5G White Paper (2015) definition of 5G.

In effect, 5G is a catalyst for change, not just for the mobile/telecoms industry but (potentially) for the way we live, for our world in general.

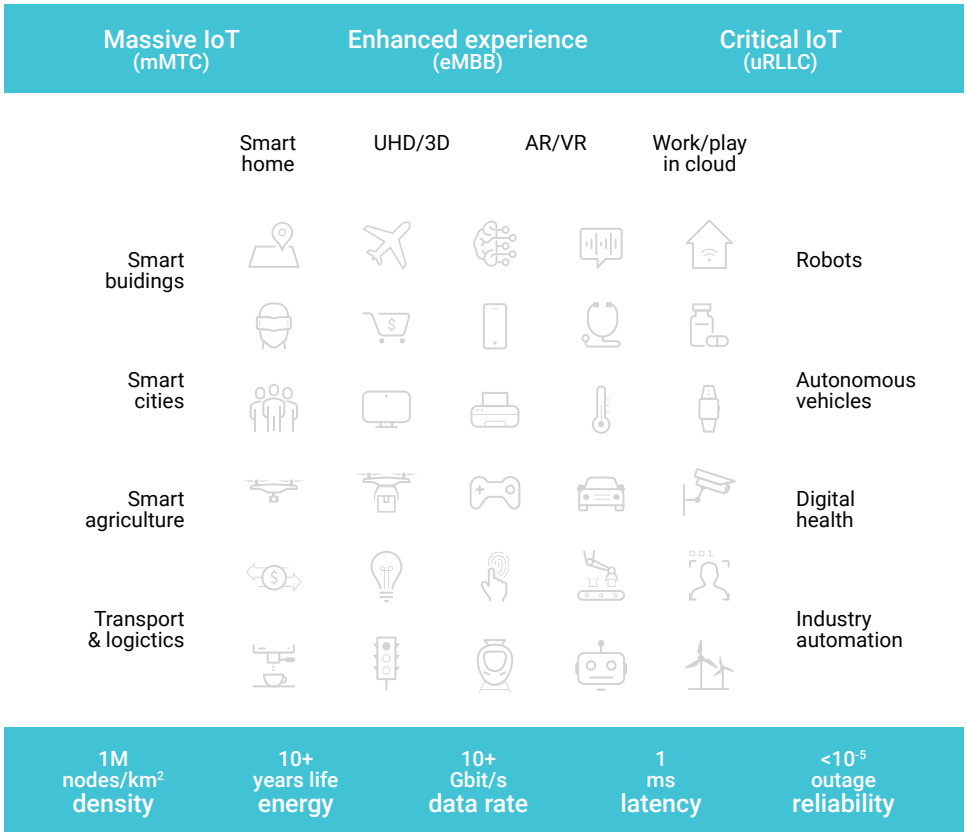

Figure 1. 5G will enable exciting use cases and support diverse verticals with its impressive capabilities [c]

Interestingly, the 5G "ecosystem" builds upon a variety of existing and new concepts/technologies as well as infrastructure. In addition to fiber and 4G (the foundation for 5G NSA), concepts from network cloud/virtualization to service-based architecture are relevant [d] to 5G. Even WiFi (including its latest version of WiFi 6) and satellite networks could be seen as belonging to this wide "ecosystem" of 5G.

In effect, 5G is a catalyst for change, not just for the mobile/telecoms industry but (potentially) for the way we live, for our world in general. 5G promises optimal network resource efficiency, service agility, and better user experience as well as increased relevance to new verticals (manufacturing, media and entertainment, health, automotive, transport, logistics, utilities, etc.) and new business models for network operators.

On top of these high-level promises, 5G is expected to accelerate consolidation in the telecoms space while helping render the distinction between mobile and fixed-line communications even less pronounced. Many telecoms industry observers also expect the introduction of 5G to coincide with, if not facilitate, the emergence of a global telecoms landscape with a few prominent global players but a myriad of local, use-case/country focused companies.

c. 3D: 3-dimensional. eMBB: enhanced mobile broadband. mMTC: massive machine-type communication. UHD: ultra-high definition. uRLLC: ultra-reliable low latency communication.

d. Relevant mobile network and IT concepts/technologies include: cloud (and cloud-native) and resource centralization (e.g., C-RAN, cloud/centralized radio access network), service-centric operations (e.g., SBA, service-based architecture), virtualization (e.g., NFV, network function virtualization), softwarization (e.g., SDN, software-defined networking), edge computing (e.g., MEC, multi-access/mobile edge computing), etc.

The mobile/telecoms world—now embracing transformation and adopting the IT vocabulary and architectures of open, intent- and service-focused, data abstraction and reusable module-based networks—will evolve.

How much of that will happen by 2025? The period of five years from now is neither very long nor short. It allows us to expect certain trends, such as the rise of mega cities or the growth in video consumption, which may still be reversible. 2025 is also a landmark year, for which estimates abound. For example, there will be 1.2 billion 5G connections worldwide according to GSMA[e], while the planet's population will reach 8.1 billion. But estimates are just that: estimates. And as seen with IoT in recent years, numbers will have to be revised, more often than not.

So, what do we expect 5G—following also its SA launch enabling end-to-end network slicing—to bring by 2025? Will it be the "infinite-capacity" network or the network that "never" fails? Will it pave the way for the Amazon or Apple network to be launched, following upon the steps of Rakuten? Will it help radically transform workplaces and jobs?

Well, wild guesses aside, we can still discuss what we realistically expect—rather than prophesize about—will happen by 2025. Or how the mobile/telecoms world—which is now embracing transformation and adopting the IT vocabulary and architectures of open, intent- and service-focused, data abstraction and reusable module-based networks—will evolve. And how the mobile/telecoms world will impact our world in general.

Important note

As per the 5G "ecosystem" definition, it is essential to point out that many 5G use cases will be supported by a dynamic mix of enabling technologies that includes, but is not limited to 5G. Take the example of the new era of industry or latest industrial revolution—denoted as Industry 4.0. In addition to 5G, non-public or private networks, the industry-related discussion revolves around advances in sensors (including wearables), actuators, robotics, machine learning, deep learning, and artificial intelligence (AI) as well as advances in gesture, voice and eventually brain control of machines.

So, let's travel in time to 2025 and see how 5G will change our world. Are you ready?

e. GSMA (GSM Association) is a trade body that represents the interests of mobile network operators. Note that, 5G connections wise, other estimates anticipate higher numbers of connections by 2025.

Prediction is very difficult, especially about the future.

Niels Bohr

5G: Five years from now. . .

Which 5G use cases are likely to change our world by 2025? Instead of far-fetched predictions, the following subsections cover what is likely to happen in the next five years. While still prone to error due to human subjectivity and inability to foresee what is coming [f], these subsections should depict at least some aspects of our future, including the role of 5G. The section also comprises a few 5G-related comments on what is less likely to happen by 2025.

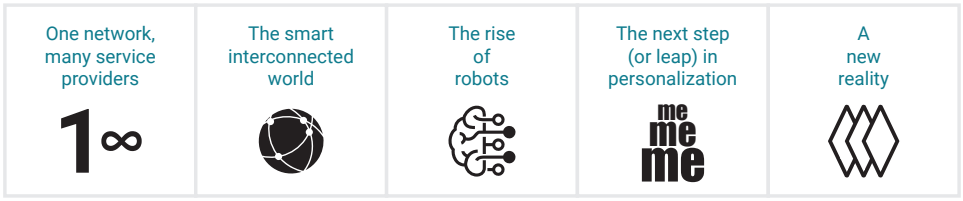

Figure 2. What 5G is expected to enable by 2025

One network, many service providers

The traditional notion of network operators who build and operate their own network infrastructure to provide service offerings is already under attack. By 2025, the move away from network centricity to service focus, based on features such as network slicing, will have transformed the mobile industry. In practice, this should mean more service providers—including new entrants, potentially even well-known names in the IT or retail space—making use of a common "infinite" network infrastructure. This should also, hopefully, mean more choice for consumers and enterprises.

The smart interconnected world

Smart wearables, smart appliances, smart home, smart office, smart city, smart world. . . 5G will strengthen the fabric of connectivity to enable people and devices to communicate better. For devices in particular, the ability to share not just gathered data but also AI-generated insights (e.g., predictions) and even to act will transform isolated passive modules into active "living" parts of a truly interconnected world. By 2025, the long-awaited IoT—and IoE—impact is likely to have started materializing.

The rise of robots

5G has been linked with the proliferation of automation, for example in industrial applications. Discussions around Industry 4.0 typically highlight 5G as a critical requirement for the factory of the future. Indeed, the ability to support ultra-low latency and ultra-high numbers of devices (e.g., factory robots) as well as private networks make 5G a key enabler for Industry 4.0. By 2025, we are likely to see robots elsewhere too, from parking valets to home companions to delivery drones.

f. Our "bets" on future developments would be safer if we focused on what is already being considered in one way or another. For example, based on the 5G support for enhanced mobile broadband in conjunction with the expected further increase in video and data consumption, "standard" use cases such as better video and internet or app experience would constitute such a "bet". Private networks have also become a hot topic of discussion (not limited to 5G), especially in the context of factory automation. That said, even popular 5G use cases such as autonomous vehicles may be further away than many of us think today.

The next step (or leap) in personalization

Today, we are more-or-less accustomed to our handsets and apps providing relevant data based on our interests, prior internet searches, etc. Privacy issues—a hot topic in itself—aside, 5G is expected to help make our experience even more personalized. In addition to routine daily activities, such as contextual information received in real time as we walk in a commercial district, 5G may enable a shift in data utilization, for example in how we monitor our health and how we confirm health issues.

A new reality

5G promises to transform our experience of the virtual and real worlds. Cloud gaming and UHD (4K, 8K) video are expected to become commonplace by 2025. On the other hand, virtual reality (VR) and augmented reality (AR) are likely to change the way we watch sports (including our stadium experience), visit historical sites or travel as tourists, shop, learn, work and live. To a different extent, the 5G promise for a new "extended" reality should be more than just a promise by 2025.

A note on the energy efficiency paradox of 5G

The energy efficiency profile of 5G has a "Janus[g]" quality. On the one hand, 5G is more (radio and network) resource-efficient than 4G. It also enables applications that should make us all more productive, for example in using energy (due to less time driving around to find a parking space, smarter use of lighting, etc.). On the other hand, and without counting the environmental cost of deployment and operation, the 5G reliance on cloud (data centers) means that energy consumption is certain to go up. This is why energy efficiency has become a key topic in the evolution of 5G, and even 6G, and is expected to remain so by 2025.

The previous subsections describe use cases that we are likely to see 5G enable by 2025. So what about those that are less likely to occur?

g. The (ancient Roman) god of duality, beginnings and endings, usually depicted as having two faces (one looking left, and one right). Expression also used to denote contradiction (and duplicity).

What may not happen by 2025

There are a number of exciting 5G use cases that may just about start changing our world by 2025, for example:

- **Autonomous vehicles**
  While self-driving (free-moving) vehicles are expected to show up on some roads, five years may not suffice for wide adoption and acceptance by skeptics and authorities. Even more time is likely to be required for self-flying vehicles, including taxi drones.

- **Internet of senses**
  Tactile internet is an "ambitious" 5G use case. Although progress will be made by 2025, we may have to wait for 5G evolution (or 6G) to reliably support the virtual experience of touch. Taste and smell will probably take longer too.

- **Remote surgery**
  Full implementation (i.e., not limited to video-based remote assistance) heavily depends on the regulatory framework and not just the performance of the 5G infrastructure. This is another use case that may need more time to convince its doubters and opponents.

The above 5G use cases only form a small representative list. Who knows, an accelerated pace of implementing and accepting such use cases may prove expectations wrong. It will not be the first time!

However the future may pan out, one thing is certain: there are a few 5G-related network challenges to address first. These are discussed in the next section.

Any issues with 5G NSA could affect the 5G deployment plan, the launch of 5G SA, and the overall success of 5G.

Challenging network domains, concepts, infrastructure

What is the biggest challenge for 5G? For some, it is to get 5G right the first time. Any issues with 5G NSA could affect the 5G deployment plan, the launch of 5G SA, and the overall success of 5G. Others are concerned that extremely high expectations set for 5G may be hard to meet.

On a high level, the 5G challenges can be categorized as follows:

- **Complexity**
  Albeit promising, 5G is inherently complex. As per the subsections that follow, 5G entails technical challenges of a different nature or similar but accentuated-complexity challenges as compared with say, 4G.

- **Investment**
  5G calls for significant investment in new resources—from (licensed) radio spectrum to network equipment and sites, and from technical expertise to advanced software solutions.

- **Regulation**
  In addition to standard network operation concerns (from spectrum availability and harmonization to site application and construction), regulation is needed for the new verticals and use cases that 5G will address[h].

Next, let's take a closer look at the 5G complexity and some of its main aspects. As briefly commented in the "What 5G is, what 5G will be" section, whenever we talk about 5G, we should think of distinct but inextricably linked building blocks as well as the end-to-end picture.

h. The versatile nature of 5G and its dependence on the underlying network infrastructure will lead to interesting discussions here (e.g., regulation of mission-critical applications and SLA responsibility of each involved party). Meanwhile, in the more traditional spectrum regulation space, licensed spectrum sharing—such as or simpler than Citizens Broadband Radio Service (CBRS) in the US—is likely to become commonplace.

New concepts: the IT “invasion”

It all (arguably) started with NFV. But there are a large number of IT-originated concepts that have been discussed for a while, and have now made their way into mobile/telecoms. Interestingly, even the notion of “open” network architectures, which would have been dismissed as irrelevant if not totally out of the question in the past, is now being considered by Tier 1 operators. Of course, the popularity and industry acceptance of open RAN initiatives and solutions does not mean that the consideration of such—new for mobile/telecoms—concepts will be challenge-free.

Fiber infrastructure: the “fiber” of 5G

Similar to 4G, the performance of 5G depends on the transport network, which in turn relies on the underlying fiber infrastructure (not everywhere, but to a very large extent). Despite wireless alternatives, fiber has a fundamental role to play in 5G. And as FTTx[i] initiatives intensify worldwide, and novel optical fiber/transport options appear as candidates for specific use cases, the question is how best to make use of both the existing and soon-to-be-deployed fiber infrastructure to support 5G.

In addition to its essential role in 5G NSA, 4G will remain a key part of the network infrastructure for many years.

4G: live “forever”. . .

Due to the 5G NSA dependence on 4G, any 5G-impacting 4G network degradation will be seen as a 5G issue. In addition to its essential role in 5G NSA though, 4G will remain a key part of the network infrastructure for many years. Indeed, similar to 3G or even 2G today, 4G will continue to support many use cases in 2025. Its optimization, densification and evolution should therefore be seen as important pieces of the wireless and overall telecoms puzzle.

“Strictly” 5G: new features

Although 5G relies on existing network infrastructure and concepts, there are a number of features new[j] to 5G. Such features—new radio (NR) and new core (5GC) or operation in high spectrum bands (mmWave) with massive MIMO antenna systems—require careful consideration, testing and monitoring. The defining 5G feature or concept of end-to-end network slicing could be part of the same discussion, although it merits a subsection of its own.

i. Refers mainly to FTTH or fiber-to-the-home (x = H). Also, to FTTB or fiber-to-the-business/building (x = B), FTTP or fiber-to-the-premises (x = P), FTTC or fiber-to-the-cabinet (x = C), etc.

j. For simplification, any 5G features based on incremental changes and the evolution of network features/capabilities are treated here as “new”. Similarly, mobile network capabilities that may have existed for a while but have not been deployed before (e.g., massive MIMO) would also be seen as “new”.

The end-to-end picture

Network slicing in 5G emphasizes the need for domain-specific as well as end-to-end network and service visibility. While this visibility is not a new requirement, 5G elevates it to a higher level. Without such visibility, network slicing would fail to maximize network efficiency or satisfy SLAs including SLAs for mission-critical applications. And the impact, as commented earlier in this document, would be that "society stops".

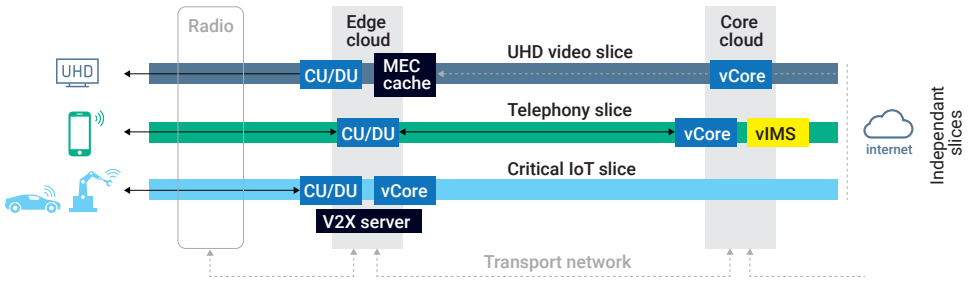

Figure 3. 5G network slicing relies on optimal domain-specific and end-to-end (device to external servers) performance[k]

The complexity of 5G exacerbates known challenges and introduces challenges of a different nature to the network lifecycle approach.

So, as we move towards 2025, how can we successfully deal with the complexity of 5G while also taking investment and regulation challenges into account? The next section tries to tackle this question.

How to aim for 5G success by 2025

What do we need to ensure that 5G fully delivers by 2025? Well, the high-level network lifecycle approach is largely known:

- Verify features/capabilities and relevant equipment/software as early as possible
- Deploy infrastructure and services based on ROI-driven planning and comprehensive testing
- Operate network and services focusing on user/device experience and monetization criteria

As commented in the previous section, the complexity of 5G exacerbates known challenges and introduces challenges of a different nature to the network lifecycle approach, while the significance of investment and regulation should not be overlooked either[l]. In light of these challenges, the success of 5G depends on three interrelated key themes.

k. CU/DU: centralized/distributed unit. IMS: IP multimedia subsystem. V2X: vehicle to anything. vCore: virtual core. vIMS: virtual IMS.

l. For simplicity, other factors—from 5G device (not just handset) availability to standardization—or the different challenges posed by greenfield (i.e., new) deployments versus rollouts of 5G on top of legacy (e.g., 4G) infrastructure are not considered in the how-to discussion here. For more information, you can contact EXFO.

The success of 5G depends on the successful, broader and deeper adoption of automation.

Automation

A popular topic for many years, automation is not limited to 5G. In practice, the 5G discussion mainly focuses on network complexity to highlight the need for advanced or intelligent automation. But automation is a multi-faceted concept relevant to simpler or repetitive tasks (e.g., automated workflows) as well as more intricate or even ad-hoc activities (e.g., orchestration).

Interestingly, skepticism around the scope and impact of automation persists. In some cases, this is due to fear that automation will put jobs at risk. In other cases, automation has not yet proven its potential, especially with regard to complex tasks and activities. Whichever the reason, the success of 5G depends on the successful, broader and deeper adoption of automation.

This adoption should be seen in the context of headline telecoms themes such as transformation. Indeed, the radical change that 5G necessitates in the way that networks are planned, deployed and operated—to address and monetize new use cases—should abide by the same "rules". For example, sensitivity to the current organizational culture inside service providers is of paramount importance, and linked to the 5G need for a different mindset. At the same time, automation has a key prerequisite.

Intelligence

For 5G to fully deliver on its promise, intelligence is fundamental. Intelligence (or analytics) can be seen as a multilayer term. It implies a smarter approach to 5G deployment, which prioritizes network areas based on identified (e.g., geolocated) customer needs and selected use cases. It also refers to insights related to end-to-end 5G network and service visibility, which can be used for troubleshooting and optimization purposes.

5G emphasizes the need for data and insights of finer detail/resolution, for example provided in real time so as to react to issues in seconds if not milliseconds. In addition, to utilize data in a faster and more cost-effective manner (e.g., in terms of equipment footprint), there is now a need not for "big" but for "right" data. The 5G "right" data reference encompasses requirements for better accuracy (e.g., in our knowledge of the network infrastructure) and better understanding of the topology or links connecting network elements, services and devices/users/customers.

Yes, machine/deep learning and AI[m] will also play an essential role intelligence wise. By integrating predictive and, for automation purposes, prescriptive capabilities, 5G will go beyond proactive troubleshooting and powerful diagnostics to move to a preemptive mode of network/service operations. But automation and intelligence will not suffice for 5G to succeed by 2025.

m. The introduction of AI and its impact on not just telecoms but employment and our life in general has a number of practical and philosophical/ethical connotations. While interesting and relevant to our world in 2025, AI and its implications are not the focus of this document.

Mindset

5G may drive the wave of change in the mobile/telecoms industry, but it will also be affected if that change does not happen as needed. Yes, a bit of a chicken-and-egg situation. Take for example the operational silos created by the divide-and-conquer approach to dealing with network complexity. For 5G to deliver on its promise, inefficiencies in network/service operations must be addressed.

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Such considerations underpin the requirement for a new mindset. The B2B (and B2B2C) nature of 5G is one of the main reasons why this different mindset is required. The fading demarcation lines between telecoms and IT or between wireless and wireline communications make for another one. And more than ever before, complexity and cost pressures accentuate the need to collaborate (in some cases even partner with competitors) and to truly embrace innovation.

The seismic change caused by open network architectures—including the most complex domain of radio access (RAN) and the ability to work with a multitude of vendors and not just well-known NEMs—is a concrete manifestation of a dramatically changing landscape. And the gradual transformation of network operators into service providers who no longer own their network infrastructure should not be overlooked either. For 5G to be successful, the mobile/telecoms industry must be—literally and metaphorically—open.

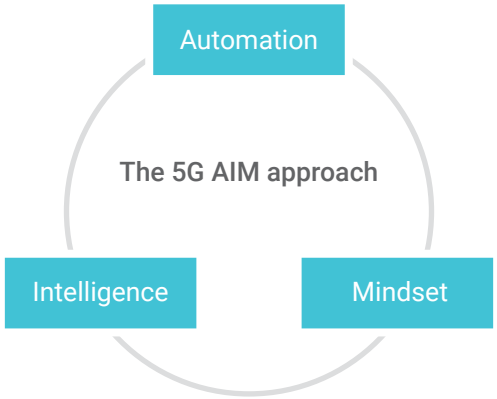

Figure 4: The AIM (Automation, Intelligence, Mindset) approach for 5G success by 2025

Automation. Intelligence. Mindset. These three high-level prerequisites combined are going to be key for the success of 5G. And by taking the first letter of each word, the easy-to-remember AIM acronym is created[n].

Whatever we call this high-level approach, it is required to ensure that 5G delivers on its promise by 2025, if not earlier. Will such a 5G approach suffice? Will challenges we have not foreseen arise on the way? Que sera sera[o]. . .

n. Of course, no term can fully represent the diverse challenges encountered in practice. Furthermore, Tier 1 operators have already started following such an approach, by gradually increasing their reliance on automation and analytics, and by starting to introduce a different, more dynamic (DevOps or "try and fail fast"), IT-like mindset in their organization.

o. Meaning "Whatever will be, will be", this phrase became popular following the success of a 1950s hit song of the same title.

For a more detailed discussion on 5G–from its challenges to relevant solutions and lessons learned from deployments–please contact EXFO.

Conclusion

5G is monopolizing headlines, typically with stories about the status of deployments or the next-year plans of network operators and other companies interested in 5G. But how much can 5G actually change our world, not in a year but after a longer time period? Only time will tell.

This white paper is a high-level attempt to discuss what the future holds with and for 5G. The document has looked into the use cases that 5G is realistically expected to support by 2025, including industrial and extended-reality applications. The white paper has also focused on key 5G network domain/concept challenges, and has outlined a high-level—AIM or automation, intelligence and mindset centric—approach to address them.

Acronyms

2G/3G/4G/5G	2nd/3rd/4th/5th generation
3D	3-dimensional
3GPP	3rd generation partnership project standards organization
4K/8K	UHD-resolution video
5GC	5G core
AI	artificial intelligence
AIM	automation, intelligence, mindset
AR	augmented reality
B2B	business to business
B2B2C	B2B to consumer
CBRS	citizens broadband radio service
C-RAN	cloud/centralized RAN
CTIO	chief technology and information officer
CU	centralized unit
DevOps	"try and fail fast" IT operations model
DU	distributed unit
eMBB	enhanced mobile broadband
FTTx	fiber to the x
GSA	global mobile suppliers association
GSM	global system for mobile communications (2G standard)
GSMA	GSM association
IoE	internet of everything
IoT	internet of things
IMS	IP multimedia subsystem
IT	information technology
MEC	multi-access/mobile edge computing
MIMO	multiple input multiple output
mMTC	massive machine-type communication
NEM	network equipment manufacturer
NFV	network function virtualization
NGMN	next generation mobile networks
NR	new radio
NSA	non-standalone (5G mode)
RAN	radio access network
ROI	return on investment
SA	standalone (5G mode)
SBA	service-based architecture
SDN	software-defined networking
SLA	service level agreement
UHD	ultra-high definition
uRLLC	ultra-reliable low latency communication
V2X	vehicle to anything
vCore	virtual core
vIMS	virtual IMS
VR	virtual reality
WiFi	"wireless fidelity"