FiberG: fiber everywhere, for 5G and beyond

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Dr. Konstantinos Stavropoulos develops and executes the marketing strategy for EXFO's mobile network (access, core, end-to-end) monitoring/optimization solutions, which include intelligent software platforms and expert professional services. His main areas of focus are 5G, 4G evolution, network virtualization/transformation, analytics, and automation. In addition to EXFO's 5G solutions and market positioning, he actively contributes to the promotion of EXFO's solutions for automated operations and fiber monitoring.

Konstantinos has been focusing on mobile networks for more than 20 years, through academic and professional roles. His experience covers diverse areas, from antenna array systems research and mobile network planning/optimization consultancy to the development/management/marketing of innovative software solutions. These solutions have supported automated planning/optimization, customer experience geolocation, device interoperability and acceptance testing, service assurance for physical/virtual networks, centralized and automated operations, and (big data) analytics. Konstantinos holds a PhD in electrical and electronic engineering from Imperial College London, has presented at dozens of conferences and webinars, and has authored several articles, blogs and white papers on mobile networks.

The dawn of FiberG[1]

Fiber to the premises/home (as part of FTTx initiatives[2]), fiber for small cells and distributed antenna systems (DAS), fiber for mobile transport, fiber for submarine cables, fiber for hyperscale data centers, fiber for network transformation[3]. Fiber everywhere.

Of course, the "fiber everywhere" reference is not new. Neither is it specific to 5G. If you check fiber-related news headlines, you will see that FTTx has been stealing the limelight. Depending on your location and broadband package, you may have also been receiving letters, emails or phone calls from your broadband provider urging you to upgrade to its latest and greatest offering. Yes, fiber.

It is true however that the fiber investment/rollout is often discussed together with the 5G investment/rollout, for example in operators' press releases or governments' infrastructure plans. This should not be surprising, considering the significance of (the broadband-enabled) internet access, which may even become a basic human right.

To extend the "fiber everywhere" definition, one could potentially claim that 5G promises to make mobile communications fiber-like ("wireless fiber") in terms of speed and reliability. More interestingly though, 5G and fiber should be seen in symbiotic/synergistic terms.

This article focuses on the rising importance of fiber networks, particularly in the context of 5G and future mobile/converged networks. To emphasize this importance and the relationship with 5G, the term FiberG (for "fiber generation") is proposed.

Note: *Similar to the "fiber everywhere" reference, FiberG does not imply that we should be deploying fiber where it makes little business sense. Of course, business cases may comprise criteria related to social/regional benefits that should be considered in the ROI (return on investment) assessment of fiber deployment.*

1. This article shares the same title with a presentation by Dr. Konstantinos Stavropoulos at EuCNC, European Conference on Networks and Communications, 2019. Also, an edited version of this article was published (as the cover article) on ICT Today January/February/March 2020, Volume 41, Number 1, https://www.e-digitaleditions.com/i/1192126-ict-today-january-february-march-2020/15?.
2. Related to the popular topic of FTTH or fiber-to-the-home (x = H), FTTx may also refer to FTTB or fiber-to-the-business/building (x = B). Both are part of FTTP or fiber-to-the-premises (x = P). FTTx encompasses notions–including FTTC or fiber-to-the-cabinet (x = C)–that will not be described in detail here.
3. Various network/digital transformation initiatives–from open network (see also later in this article) and IT architectures (e.g., CORD or central office re-architected as a data center) to automation and 5G–depend on a strong and well-performing fiber infrastructure.

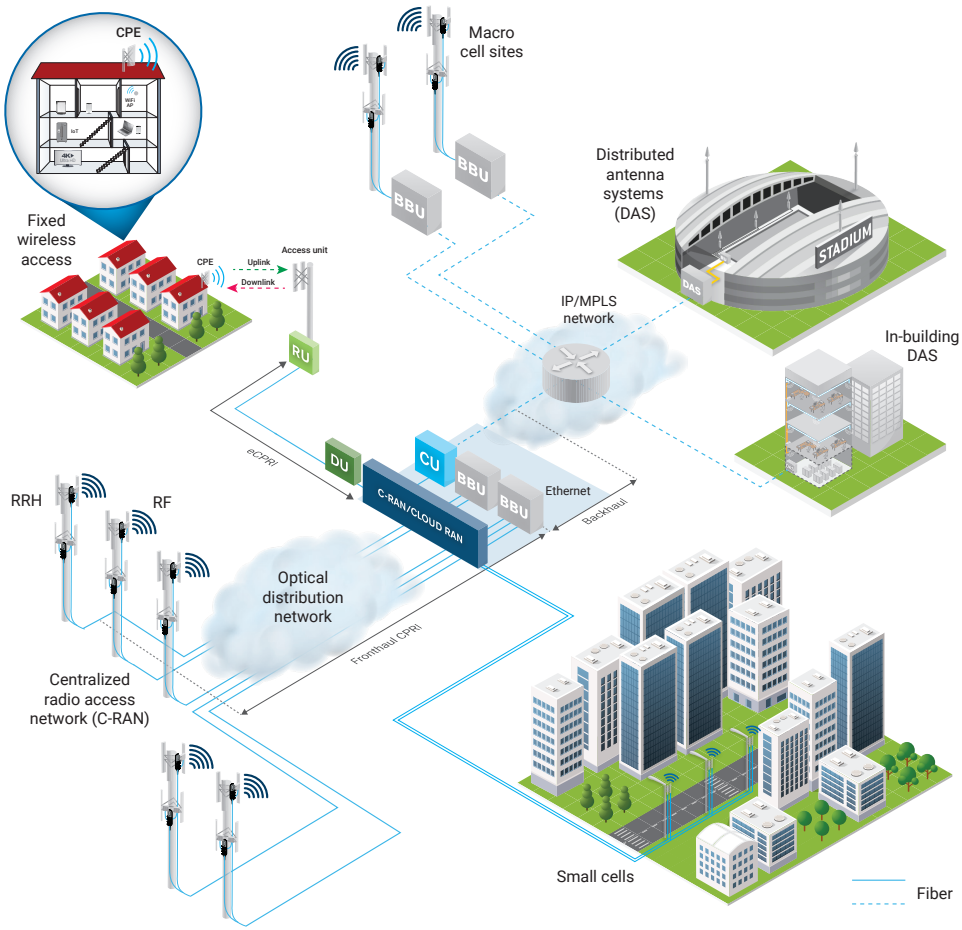

Figure 1: Fiber deployed to support different use cases, which will increasingly be 5G-related (note here the virtual/5G network architecture elements, such as remote unit (RU), distributed unit (DU) and central unit (CU)).

5G is here

Yes, 5G is here, now! Following launches by 56 network operators[4], the time has come for 5G to start delivering on its promises. But is 5G just another mobile network generation/standard?

5G can be seen as an end-to-end ecosystem[5] that will enable a number of interesting use cases across different consumer/enterprise verticals (see Figure 2). Undoubtedly, the specified 5G capabilities–in terms of ultra-high throughput/capacity, ultra-low latency, ultra-high reliability–are impressive.

It is however important to point out that the end-to-end ecosystem of 5G relies on existing and new infrastructure or concepts/technologies: from fiber and 4G (which is essential for 5G NSA, non-standalone) to C-RAN, NFV, SDN, MEC, SBA or cloud (and cloud-native). In fact, many of these concepts/technologies rely on fiber[6].

4. As per the GSA (global mobile suppliers association) "Evolution from LTE to 5G: Global Market Status" report, August 2019.
5. Based also on the 5G definition in the NGMN (next generation mobile networks) 5G White Paper, 2015.
6. In effect, fiber is needed to realize the benefits of concepts/technologies such as cloud and centralization (C-RAN, cloud/centralized - radio access network), virtualization (NFV, network function virtualization), softwarization (SDN, software-defined networking), edge computing (MEC, multi-access edge computing), service-centric operations (SBA, service-based architecture), etc. These concepts/technologies are critical pillars for 5G and future cloud-native networks.

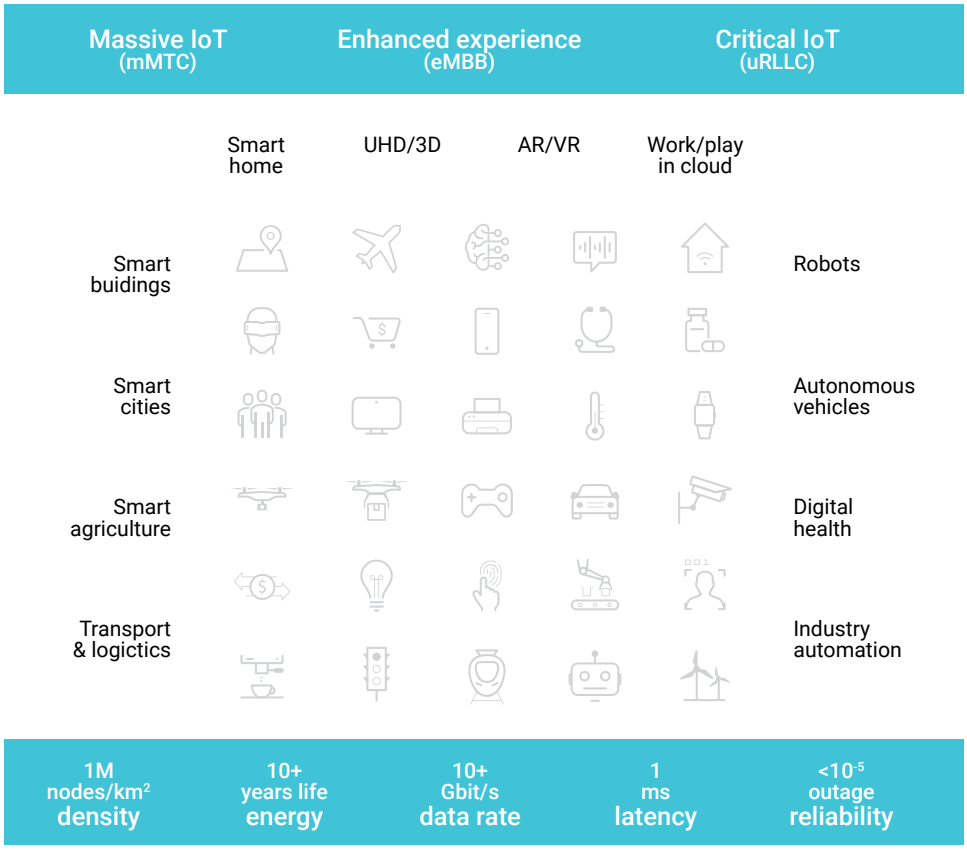

Figure 2: 5G boasts impressive capabilities and will enable interesting use cases across verticals.

FiberG significance

Fiber is important for 5G, because fiber can support the demanding "ultra" requirements of 5G with regard to throughput/capacity, latency, and reliability. In fact, fiber can meet the requirements of concepts/technologies that are essential 5G pillars.

As a proven and trusted enabler of past mobile network generations/standards (focusing on the transport domain, including backhaul), fiber has already been considered a key factor in deploying small cells (as part of 3G/4G network densification) and 5G fixed wireless access networks.

All in all, rather than competitors (for the fixed wireless access or home broadband market), 5G and fiber should be seen as complementary, if not in an inevitable state of synergy and eventual fusion. As an essential part of the 5G architecture, the performance of the underlying fiber infrastructure will directly affect the experience of 5G. In other words, any fiber issues will be interpreted as 5G issues. Fiber will be a key enabler for 5G end-to-end network slicing too.

End-to-end network slicing

End-to-end network slicing is arguably the defining feature of 5G. In fact, network domain-specific (e.g. core) slicing is not a new concept. New is the ability to split network resources into virtual network slices with distinct characteristics and SLA (service level agreement) requirements, and to provide users/devices with the relevant service and (truly) end-to-end network performance.

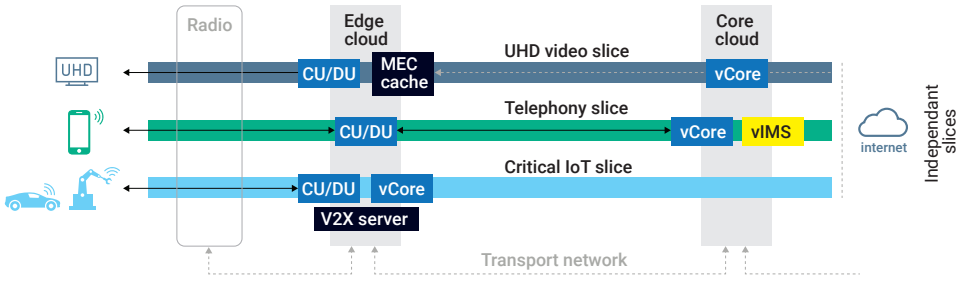

Figure 3: End-to-end network slicing relies on optimal domain-specific and cross-domain performance from the device to external servers.

It should be evident from Figure 3 that the transport layer has a crucial role to play in network slicing. And this is where fiber would come to the fore.

High-level opportunities

Figure 4 depicts the opportunities that 5G brings to network operators[7]. Of particular significance is the adoption of new business models, for example network as a service (NaaS). Based on end-to-end network slicing, 5G can facilitate the provision of distinct slices for different service providers or enterprise/private networks, as/when needed (i.e., in a more flexible manner than the model currently followed for MVNOs, mobile virtual network operators).

These opportunities also highlight the importance of the underlying fiber infrastructure, and the need to address all FiberG-related challenges.

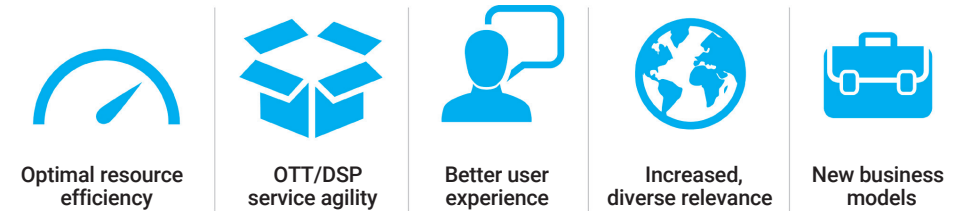

Figure 4: High-level opportunities for 5G network operators.

7. 5G promises optimal efficiency in the use of network resources, improved agility in introducing new services so as to follow the over-the-top (OTT) and digital service provider (DSP) paradigm, enhanced and more reliable mobile user experience, increased relevance to a number of consumer/enterprise verticals as an enabler of exciting and mission-critical use cases, and a solid foundation for business transformation.

Challenges for FiberG

FiberG is not challenge free. High- and low-level, new and old, global and regional, commercial and technical, there are a number of challenges to address. And the advent of 5G has not made things easier.

Investment focus

Practical challenges (such as digging) when rolling out fiber contribute to its overall rollout cost. In addition, the versatile nature of 5G further complicates the relevant decision-making and dimensioning process. Put another way, operators must identify the use cases to potentially target in the future, how much additional fiber they should lay (perhaps, to support other operators as part of infrastructure sharing), who they should be partnering with (including industry or local government), etc.

Note: *As part of their ROI focus, network operators should also be open to alternative options whenever fiber rollout appears to be challenging or altogether prohibitive.*

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Regulation

Regulation covers a variety of areas, from the need to obtain permission for fiber installation/upgrades, to the crucial role of fiber in 5G end-to end network slicing. With regard to the latter, it will be interesting to see how SLAs for 5G services are monitored and–in the case of degradation/outage and consequent penalties–paid for, if network slice performance is affected by fiber issues. Also, how fiber network operators will be regulated when dark fiber is used or when critical (e.g., health) services mandate the highest level of reliability.

Standardization

The number of optical transport options[8]–and suitability for specific use cases, considering 5G (e.g., for fixed wireless access) too–is an interesting topic of discussion. If we focus on the mobile transport domain, the push for open network architectures[9] (and moving away from non-proprietary standards) to simplify and optimize the use of fiber infrastructure is driving the requirements for next-generation transport. Similar to other industry areas, the sooner the relevant standards become finalized and mature, the better.

Performance

How can we ensure that the existing fiber infrastructure is 5G-ready? This is a particular concern, and not just for ageing fiber networks that will have to be upgraded. In addition, how can we then ensure that fiber performance is not compromised? Any issues would also compromise the performance of 5G. If such issues occur at launch, the negative impact on the success of 5G would be immeasurable. But even after the 5G launch, it is vital to monitor the performance of fiber, take swift action when issues occur, and–if possible–predict and prevent such issues from even occurring.

Note: *The next section (on automation) comments further on the topic of fiber network performance. The following subsection is relevant too.*

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8. Options include P2P (point to point), WDM (wavelength division multiplexing) and TWDM (time and wavelength division multiplexed) PON (passive optical network), and P2P WDM overlay. Factors such as capacity and latency support, cost, and reuse of the existing fiber infrastructure, are key in assessing the relevance of these options to 5G. NG-PON2 (next-generation PON 2, TWDM-enabled) is already being discussed in the context of 5G. Note also that the need for guaranteed throughput, latency and reliability has led to the development of standards such as TSN (time-sensitive networking) and FlexE (or FlexEthernet) for 5G transport. The fronthaul-related specification of eCPRI (enhanced common public radio interface) or the requirement for scalable and higher-bandwidth front/mid/back/cross-haul support (with 100G and 400G Ethernet data rates being considered, as applicable) are some of the multiple facets of this interesting topic.
9. As also manifested by the emergence of industry organizations/workgroups such as O-RAN Alliance and OpenRAN (part of TIP, Telecom Infra Project), which are promoting open architectures and interfaces for virtualized radio access networks.

Beware of tradition/basics

While 5G brings new challenges for fiber networks, "traditional" fiber issues should not be ignored. Such issues include dirty connectors, macro-bends, bad splicing, and cuts/breaks. Interestingly, the number of fiber network failures attributed to the "humble" connectors (due to manufacturing defects, inappropriate handling, and environmental factors) can be significant.

In these terms, standard practices–inspection, (link) characterization, (protocol) validation–will remain key in ensuring that the fiber infrastructure is strong enough and ready to support 5G.

Automation is crucial for fiber networks too, both in testing and in monitoring. As a matter of fact, automation is essential for FiberG, today.

FiberG automation

5G accentuates the need for automation in network/service deployment and operations. A multitude of automation use cases, from simpler (e.g., repetitive process automation) to more complex ones (e.g., dynamic network slice orchestration), have been discussed in the context of 5G. As manifested in news headlines and articles, machine learning (ML) and artificial intelligence (AI) have been dominating this discussion.

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Testing

Network operators can no longer rely just on a handful of highly experienced engineers to support extensive fiber network upgrades/rollouts. To ensure that engineering teams (often, contractors with little experience) consistently follow best practices and correctly test the deployed fiber, major operators have been increasing the degree of automation in their deployment process.

The ability to automate the fiber testing workflow drastically reduces the time required for manual setup and reporting. Workflow automation also helps increase the level of compliance to operators' test methodologies that are frequently overlooked in practice, leading to test repetition and fiber performance issues that could have been avoided. On the other hand, intelligent test automation enables engineers to quickly and successfully perform tasks that would require advanced expertise and a significant amount of time.

Monitoring

The concept of remote, typically 24x7, centralized monitoring is far from new. In fact, it is standard practice in most fiber networks. What has become more pronounced is the need for granular visibility. This means that the fiber infrastructure should be monitored in real time. Furthermore, it means that the location of fiber issues should be identified with high accuracy, to minimize unnecessary engineering team trips and to accelerate issue resolution.

Automated, granular fiber network monitoring is mandatory in the context of end-to-end network slicing, particularly for SLA-sensitive services. As an essential part of the 5G architecture, any issues affecting the fiber infrastructure would also impact on the performance and end-user/device experience of 5G. The ability to proactively monitor the fiber network and correctly quantify (ideally, pre-empt) the impact of issues on relevant 5G services and customers is going to be key.

The end of silos

In reality, FiberG automation should be part of the 5G automation discussion, and not treated as a separate topic. The divide-and-conquer approach followed in the past, which has led to the creation of operational silos that has tormented network operators for years, is unlikely to be followed in the automation-driven DevOps age of 5G.

Even references to "testing" and "monitoring" as distinct areas of interest for network operators are likely to be revised. For example, which of these areas would be more relevant for the centralized monitoring (to check and ensure compliance) of field test activities? The demarcation lines, which may have simplified team organization in the past, are now under attack.

The 5G concept of end-to-end network slicing emphasizes the need for a better, end-to-end approach to deploying and operating networks. This end-to-end approach will inevitably incorporate the–crucial for 5G–fiber infrastructure.

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Beyond 5G

5G may or may not be the ultimate mobile network generation/standard. Similar to 4G and 4G evolution[10], the standardization of 5G and its evolution are likely to span more than 2 3GPP releases (Release 15 and Release 16, currently). And what about 6G?

For many, 6G will not remain confined to research labs, and a commercial launch should be expected in a decade or so. There are a few reasons/signs[11] why we may need 6G:

- The curse of odd numbers[12] – Like its odd-numbered predecessors (1G and 3G), 5G will not be able to fully deliver on its promises
- The 5G hubris[13] – The all-encompassing, highly ambitious vision of 5G reflects an industry overconfidence that will be difficult to realize
- We cannot predict the future[14] – New use cases and enhanced capabilities, following research breakthroughs (often in adjacent areas), typically arise

So, what would 6G look like?

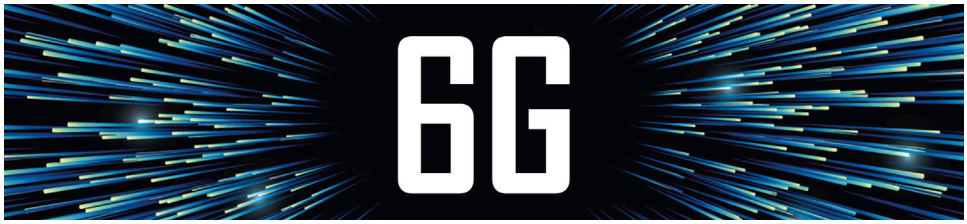

Figure 5: Will 6G be launched in 2029-2030? (note: the 6G "logo" in the figure is fictitious)

10. In total, there were 7 (2 + 3 + 2) 3GPP releases related to 4G and 4G evolution, from Release 8 to Release 14. These were grouped as LTE (Long Term Evolution), LTE-Advanced, and LTE-Advanced Pro.
11. Cynics claim that the 6G introduction will be dictated by commercial/marketing needs. In other words, even if the underlying requirements do not justify the emergence of a new standard, 6G will become an industry term in one way or another.
12. According to this "curse", odd-numbered mobile generations are not as complete or successful as the (subsequent) even-numbered ones. 1G could not take the world by storm like 2G did, while–the hugely problematic–3G pales in comparison to 4G.
13. A favorite topic in ancient Greek tragedies, "hubris"–excessive pride or self-confidence, and defiance of gods–led to punishment. For 5G, the need to address a variety of use cases and the complexity inherent in end-to-end network slicing have raised (some) eyebrows.
14. A typical use case example would be the impact of the iPhone launch, which few had foreseen. On the capability/infrastructure side, the IT and network/telecoms convergence would be a relevant example.

6G capabilities

6G is expected to deliver even better throughput/capacity, latency, and reliability. Enhancements to privacy and security are also expected. Interestingly, many discussions around 6G focus on the topic of energy efficiency. Indeed, the advent and success of the energy-hungry virtual/cloud networks is likely to require additional action on top of what has been envisaged as part of 5G. Considering also its environmental impact, energy efficiency may well become the headline 6G capability.

6G enablers

Unsurprisingly, 6G will require more spectrum, and the THz (above 300GHz) territory is currently under investigation. Promising new technologies such as LiFi ("light fidelity", based on the WiFi acronym, or visible light communications) are being discussed as potential 6G candidates. These discussions effectively form part of "convergence" efforts to bring different networks (i.e., mobile, Wi-Fi, satellite, and fiber/cable/copper) closer together. 6G could well be the fixed-mobile convergence standard. On the other hand, despite the huge interest in AI, 6G (rather than 5G) standardization may incorporate AI. A similar point holds true for other "hot" concepts (e.g., Blockchain), which could become 6G pillars.

6G applications

Is 6G the network generation/standard to fully support tactile internet (which has already been described as a 5G application)? Is 6G the technology that will successfully merge communications with biology? Perhaps. At the same time, requirements for applications of less intriguing albeit still challenging nature–for example, addressing use cases related to rural communities or supporting 8K video–are also being discussed in the context of 6G.

And what about FiberG? Is the 6G discussion relevant? Well, yes and no. If 6G represents a radical step change from 5G and its evolution, the requirements on the underlying fiber infrastructure will be radically different too. In this case, upgrades would not only be necessary, but mandatory. If 6G turns out to be a 5G+ standard (or if 6G is never launched), the required fiber network enhancements may only be incremental and, therefore, more manageable.

Either way, fiber should be regarded as a vital part of the 5G/6G/otherwise-labeled future mobile/converged network infrastructure. Fiber has an essential role to play, for 5G and beyond.

Conclusion

Fiber can support the 5G requirements for ultra-high throughput/capacity, ultra-low latency, and ultra-high reliability. In fact, fiber is needed to realize the benefits of concepts/technologies that are key 5G pillars, including C-RAN, NFV, SDN, MEC, SBA, cloud, etc.

As an indispensable part of the 5G architecture, the performance of the underlying fiber infrastructure will directly affect the experience of 5G. In other words, any fiber issues will be interpreted as 5G issues, and impact on interesting–and even mission-critical–use cases. It is therefore crucial to address the (investment focus, regulation, standardization, and performance related) fiber challenges, and to increase automation in fiber network deployment and operation.

On top of its rising importance for services/applications that are not 5G-specific, fiber has an essential role for 5G and future mobile/converged networks. This is indeed the dawn of the "fiber generation". It is the dawn of FiberG.