5G in Europe: More than a wireless upgrade

The wireline network evolution in preparation for 5G

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1. Introduction

5G is much more than a new access technology. Unlike previous mobile generations, which were defined by the air interface, 5G will change in fundamental ways how we build, operate, and use mobile networks end to end – from the core to the radio access network (RAN) to the users (people) and machines (things). These changes will be revolutionary, but they will be introduced gradually, to meet operator market requirements and satisfy return on investment (ROI) expectations. This process has started already: operators have embraced the 5G vision, even if many do not have a detailed roadmap, and they realize they need to get ready for 5G now.

Traditional dichotomies are fading away to create converged, virtualized 5G networks

- Distributed / Centralized
- Fixed / Mobile
- RAN / Core
- Backhaul / Fronthaul
- Wireline / Wireless

More than a technical specification, 5G is both a blueprint for technological innovation and a canvas inviting operators to experiment with new approaches to create a pervasive connectivity fabric that can reach everybody and everything, everywhere. The latency, throughput, reliability, and security requirements for 5G are extremely demanding, and will require more than a simple network expansion or update, especially when coupled with the escalating growth in traffic from users and the Internet of Things (IoT). Today's static, atomistic networks, where functions are fixed and tied to a location and an equipment element, will give way to dynamic networks that will be highly automated and optimized in near real-time. As we move toward this goal, many traditional dichotomies of the network environment have started to break down, giving operators unprecedented freedom and flexibility. This will bring innovation driven by densification, virtualization, edge computing, slicing, integration of multiple access technologies, and analytics to full fruition.

The network architectures that 5G enables will change how wireless and wireline networks work together. At the access end, wireless will become even more prevalent than it is already in connecting people and machines through IoT. Wireline plays a crucial role in transporting traffic from the edge to where content is hosted, manipulated, and streamed. With the increase in traffic loads, lower latency requirements, and denser infrastructure, the wireline transport infrastructure must evolve to avoid becoming the bottleneck in 5G networks. Adding more capacity is not enough. The wireline infrastructure will have to expand and move closer to the edge to serve new use cases, support new technologies, and meet end-user demand.

This paper looks at how the transition to 5G affects wireline backhaul, fronthaul, and the emerging converged-haul variations. We also consider the impact of those changes on how mobile operators transport traffic across their networks, and how they can plan for them as they transition to 5G. We specifically look at the implications for European mobile operators, with their more cautious approach to 5G compared to that of their Asian Pacific and North American counterparts.

2. The path towards 5G in Europe

The commitment to 5G is the same across the world. Operators have different deployment strategies – or may still be working on them – but the move to 5G is obligatory, and beneficial for both users and operators.

In Europe, however, 5G has received a cooler reception than in Asia Pacific or North America. European mobile operators plan to deploy 5G about a year after the first commercial deployments elsewhere, and possibly at a slower pace.

There are multiple reasons for the cautious approach in Europe.

First, many European operators are not convinced that 5G use cases are sufficiently compelling to justify the investment and upgrade effort, or that they will require 5G. But, as we will argue later in this paper, 5G use cases can run on 4G, but only if adoption is very limited. Although some will generate additional revenues (e.g., IoT applications), 5G is unlikely to dramatically raise subscriber revenues.

A better reason to deploy 5G is that it is a more efficient and hence a more cost-effective technology – i.e., the per-bit costs are lower than for 4G, and even more so for 3G. If this is true – and it is a widely accepted assessment – then the case for not deploying 5G is less persuasive than the case for deploying it. This holds especially if the deployment is gradual and done as needed, rather than a nationwide one at the onset.

Another concern that European operators have is about the ability of their backhaul networks to scale to 5G throughput and latency requirements. Compared with the US and top Asia Pacific markets, European operators rely more on wireless backhaul which is more constrained than fiber in performance. To move to 5G, and especially to standalone 5G, operators will have to upgrade both the RAN and the backhaul network, and support fronthaul more extensively as they move to a virtualized RAN. This means expanding fiber connectivity to reach a higher number of sites and, depending on the competitive environment, it can be a difficult and expensive process, although one that will be eventually necessary. In the meantime, a slower pace in the transition to 5G, may reduce the pressure to upgrade to wireline, but does not erase the need to move forward with it.

Regulation also plays a role. Operators are uncertain whether sufficient 5G licensed spectrum will be available, and they worry about the license costs.

"We will need to transport much more traffic across our networks compared to what we have today. Consider that today, a base station is connected with a 10G interface. With 5G, we are aiming to provide gigabit speeds to each and every user. It means that the base station should be served by 100G interfaces, which is really challenging.

We need more than just fiber connectivity. We need to change the architecture, the topology, even the media that we are using for our transport network today. Both fronthauling and backhauling have huge challenges on both throughput and latency."

Kostas Chalkiotis, Vice President Mobile Access – Technology & Innovation, Deutsche Telekom

Furthermore, European operators face a tougher competitive market and lower per-subscriber revenues compared to North America, leaving them with less financial ability to invest in a new network migration strategy.

This is not the first time European operators have moved more slowly than those in Asia Pacific and North America. Despite the European commitment to LTE when LTE was new, commercial launch was later, and adoption slower, in Europe than in the other two regions.

With slower, more gradual 5G deployments, European operators avoid a large initial investment at what might not be the right time in terms of financial availability, market growth, or technology cycle.

5G specifications allow for gradual deployments – for instance, by allowing operators to roll out 5G as a non-standalone access technology that uses the LTE core.

The transition from 4G to 5G in the RAN can also be gradual – as well as driven by demand and device adoption, and limited to specific technologies or options. Operators can deploy equipment today that supports 4G, and when necessary, they can upgrade it to 5G.

Some of the early deployments in the US have kept a tight rein on 5G investment another way, largely confining them to fixed services over millimeter wave (mmW), which is a very selective part of 5G.

Even if European 5G deployments are not as aggressive as those in China, South Korea, or the US, operators still have to pave the way for 5G. They can benefit from the advantage of having more time to get their networks ready for it, and this will enable them to be better prepared for the disruption that 5G as a major technology advance will bring.

5G affects the RAN but also the rest of the network. This includes transport, and wireline transport is a crucial part of end-to-end wireless network performance. It must become 5G-ready before deployment starts – ready to manage the massive amounts of traffic that 5G will generate. European mobile operators are concerned that 5G may unleash so much capacity in the RAN that their wireline network will not be able to cope with it, thus undermining their 5G RAN investment.

The wireline network must also evolve and be ready to manage the massive amounts of traffic that 5G will generate. The success of 5G is predicated on the ability of RAN and transport to support each other. A weak wireline transport network will drastically reduce quality of experience (QoE), even if the RAN works flawlessly. Operators should take action ahead of their 5G launch to ensure their transport network is ready to meet the challenges of 5G.

"We will be replacing a lot of microwave radio systems, a lot of macro-cell wireless backhaul, with fiber. Where we still have to use wireless in urban areas, we will increasingly be moving to E band for capacity reasons. Macro-cell wireless backhaul will mainly reside in locations that require lower capacity.

We're going to be capacity constrained if we're not using fiber in the network. Conventional microwave will give way to fiber."

Andy Sutton, Principal Network Architect, Architecture & Strategy, TSO, BT.

3. Optimization of user experience and application performance

Moving to 5G is not optional. Many operators may not have announced plans for 5G, but they do agree that the transition will eventually happen, because 4G networks simply cannot support the increased traffic loads from users and IoT in a way that is cost-effective and meets the stringent performance requirements.

5G use cases
Real-time: voice, video streaming, conversational video
Real-time, location-based: AR, VR, tactile internet
Extreme mobility: connected cars, high-speed trains and other public transportation, fleet management
Ultra-reliable communications: remote healthcare, autonomous driving, critical lifeline services
IoT: video surveillance, other video-based services
Automation: manufacturing, warehousing
Fixed broadband: replacement of residential broadband connection

The main drivers for 5G adoption are the increased reliance on wireless networks for connectivity for both users and IoT devices, the widening range of activities and applications that require connectivity, and the need for high-capacity, low-latency access.

The box on the right shows use cases that 5G will enable or support more efficiently than existing networks do. An argument frequently made is that none of these use cases strictly requires 5G. While this is true, 5G is necessary to support these use cases in commercial deployments with the reliable scalability required by wide-scale adoption. An augmented reality (AR) or virtual reality (VR) demo can work on a 4G network in a carefully controlled setting, but a commercial 4G network would not be able to support a dense uptake of AR, such as in a stadium or a shopping mall.

Furthermore, all of these use cases will coexist on the same network infrastructure, and 5G will be required to support them all. It will do so not only by providing more capacity and lower latency, but by optimizing user experience and application performance by allocating the appropriate network resources to each use case. 5G real-time traffic management tools such as network slicing can accomplish that by horizontally segregating traffic flows with different requirements and managing them separately.

Impact on the transport infrastructure

- ▲ Capacity
- ▼ Latency
- ▲ Scalability
- ▲ Reliability
- ▲ Security
- ▲ Network slicing support

The wireline infrastructure must evolve to support such tools as part of the optimization and automation of the end-to-end network. Only by doing so will it be able to support not only the increase in traffic volume, but the requirements that the new use cases have in terms of latency, reliability, security, and cost efficiency. To ensure an optimized utilization of network assets, the wireline infrastructure must support network slicing and other traffic management tools as part of the optimization and automation of the end-to-end network.

4. RAN densification

Usage will continue to grow faster than technology innovation can improve spectral efficiency. As impressive as 5G RAN performance will be, it will not eliminate the need for densification or, specifically, the expansion of indoor infrastructure.

On the contrary, 5G will facilitate densification and make it more cost effective, with its support for mmW, unlicensed access, integration with Wi-Fi, and RAN virtualization.

Beyond the impact of these technology changes on the wireline infrastructure, densification creates specific challenges for transport.

The primary one is the need to reach a higher number of locations, with more diversity across them than would be common in a macro network. In many of these locations, equipment is not mounted on telecom assets; it may have to be operated in concert with the venue or real estate owner. In these locations, fiber and electrical power connectivity might not be readily available, or leasing it might be expensive, and access to the equipment might be gated by venue owners. Increasingly, the wireline infrastructure has to reach these locations, too, as the need for fiber connectivity moves closer to the edge and the RAN, as capacity density grows.

As operators gradually move to a virtualized RAN, they will need a fronthaul connection from the remote radio unit (RRU) to the remote baseband unit (BBU). Fronthaul requires higher capacity and tighter latency, and the transport infrastructure must also support that.

5G-driven densification will also encourage new business models. Some of these will involve enterprise private networks. Some will be neutral-host, small-cell deployments in which multiple operators share the network access infrastructure or, more commonly, the backhaul. The transport network has to be able to manage backhaul sharing and provide the relevant parties – enterprise, neutral hosts, operators, service providers – visibility into the backhaul's performance.

Impact on the transport infrastructure

- ▲ Number of locations
- ▲ Non-telecom assets
- ▲ Capacity density
- ▲ Indoor reach
- ▲ Move towards the edge
- ▲ Support for fronthaul
- ▲ Backhaul sharing

5. Virtualization and edge computing

Virtualization and edge computing may be the factors that will have the largest impact on the transport infrastructure as we move to 5G. Not only do they alter how networks work, they disruptively change where and how network functions and content are physically located. This is a game changer for transport, because it alters *what* is being transported across various parts of the network, not just how much traffic or with how much latency. Furthermore, this is not a one-time, steplike change, but a deeper change, from a fixed, deterministic transport infrastructure to a flexible infrastructure that can reconfigure itself in real time in response to traffic fluctuations.

In a non-virtualized network, functions are tied to a physical element. Transport is planned around the location of such elements and expected traffic characteristics. In a virtualized network, functions can be moved across the network for many reasons – e.g., to improve QoE, lower latency, optimize resource utilization – and these changes in location can be made dynamically, rapidly, and in response to variation in demand and network conditions. The transport network has to have the flexibility to detect and adapt to these changes, and to do so within the required timeframe and in an automated, eventually autonomous, way. The wireline network must also embrace the increased level of openness that virtualization encourages and enables, by seamlessly supporting a broad, multi-vendor environment. No one vendor offers a best-in-breed end-to-end solution.

RAN virtualization pushes the evolution of the wireline network further. In today's networks, the legacy infrastructure has restrained the push to RAN virtualization and edge computing. 5G will accelerate this evolution. The newly deployed networks will be virtualized all the way to the RAN, and edge computing will be necessary to keep latency low to meet the 5G requirements.

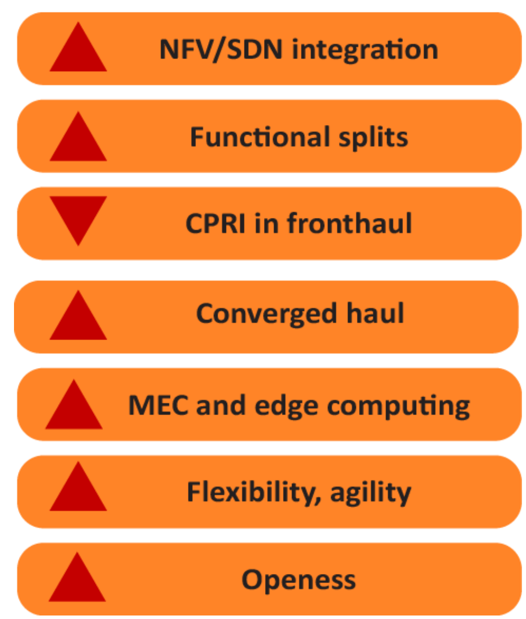
There are multiple virtualized RAN architectures, but they all require at least some of the RAN functionality to be located away from the cell site where the RRU is, in a remote location with pooled BBUs. A virtualized RAN requires an additional fronthaul connection to carry the analog signal from the RRU to the BBU. The distributed architecture that dominates today requires only a backhaul link to connect RAN and core.

The need for fronthaul has been another factor in slowing down RAN virtualization. Operators need a fiber connection to the cell site; that limits RAN virtualization to areas where fiber is available. This is most often a problem in small-cell deployments, because small-cell locations are less likely to have fiber than macro-cell locations are.

That is unfortunate because a virtualized RAN architecture is even more valuable in co-channel small-cell deployments, because it allows for better-coordinated transmission between macro- and small-cell layers, and operators lacking fiber cannot benefit from it.

To get better value from the 5G virtualization of the RAN, operators need to bring fiber transport to both the macro-cell and small-cell layers, wherever possible.

Impact on the transport infrastructure



Today's fronthaul links typically use the Common Public Radio Interface (CPRI). Originally developed for very short fronthaul links (from the top of a cell tower to the base), CPRI is ill suited to the longer distances needed to connect the RRU and the BBU, because it needs extremely high bandwidth, low latency, and dedicated resources. Also, CPRI implementations are proprietary, thus limiting the flexibility and openness of the fronthaul link. CPRI, already struggling in a 4G environment, will simply not scale to support the higher 5G RAN throughput requirements.

Moving beyond the CPRI interface has become an urgent priority as we approach 5G, and much work is devoted to CPRI alternatives. Emerging as the most likely to succeed are Ethernet-based solutions that are standards-based, need less capacity, and scale to meet 5G fronthaul traffic loads.

Another shift crucial to adoption of a virtualized RAN is a move to functional splits, which allow for some baseband processing to remain at the cell site. The more baseband processing is done at the cell site, the lower the throughput requirements, but also the more limited the benefits from RAN virtualization.

Operators will have to find the best tradeoff for the functional split and ensure that their transport network can handle the performance requirements of the split.

Functional splits erase the sharp differentiation between traditional backhaul and fronthaul, occupying an intermediate position between the two. To manage the set of link types that can connect the RRU to the BBU and to the core, operators increasingly think about the connection from the cell site to the core as converged haul, rather than as backhaul or fronthaul.

Edge computing is the final driver in the evolution of the transport network. While RAN virtualization pushes signal processing to a centralized location, edge computing heads in the opposite direction, moving processing that has typically been done in the core – content storage and services – toward the edge. The edge location may be the RAN or, more likely, an intermediate aggregation point, which may be co-located with the BBUs in a virtualized RAN.

By storing content and running services locally, edge computing lowers the latency and improves the utilization of RAN network resources. To do so, the transport network has to be designed to support edge-computing traffic, and to accommodate the coexistence of traffic from converged haul and edge computing within the same network infrastructure.

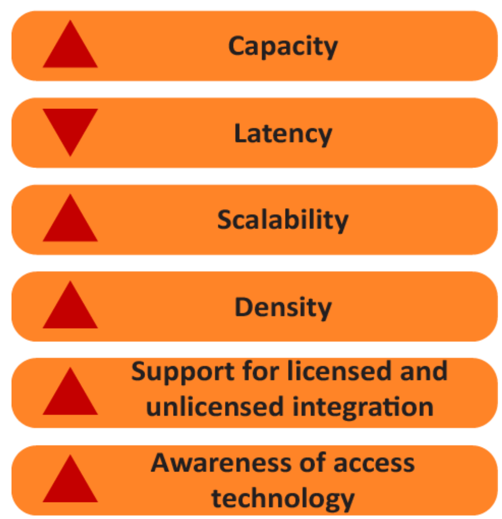
6. Air interface evolution

While virtualization and edge computing will change the wireline infrastructure, the 5G air interface will change its scale. The 5G RAN will carry impressive amounts of traffic across the network, and will concentrate this traffic very tightly in dense hotspots. The transport network must find a way to accommodate this traffic to avoid becoming a bottleneck that constrains 5G RAN access.

Multiple drivers will jointly enable the higher capacity of the 5G RAN:

- Antenna technologies, such as massive multiple-input multiple-output (MIMO) or beamforming, improve spectral efficiency, so they will increase the traffic load that can be delivered over the same amount of spectrum that is used today.
- Sub-6 GHz unlicensed spectrum, used opportunistically, will complement licensed spectrum, with a combination of 5G New Radio (NR), LTE, or Wi-Fi for the air interface. Unlicensed spectrum is already used widely and accounts for most of the traffic to mobile devices, but in 5G it will be more tightly integrated with other interfaces. As a result, the unlicensed traffic integrated with the mobile network will in most cases be transported alongside 5G's traffic, creating an additional traffic source for the transport network.
- Integration across interfaces and bands includes sub-6 GHz unlicensed bands, but it extends to licensed bands and mmW spectrum as well. Operators get a powerful framework to manage traffic across bands and technologies to optimize the allocation of network resources.
- More advanced carrier aggregation and dual connectivity will further improve the allocation of network resources.
- The use of mmW for access has the potential to radically expand network capacity in hotspots. In these locations, mmW may be deployed as an access technology, because it makes many gigahertz of spectrum available to operators and service providers. In areas with a high density of demand, mmW can resolve congestion, but at the cost of adding high traffic volumes to the wireline network's existing load.

Impact on the transport infrastructure



8. Analytics, artificial intelligence, and automation

As we move to 5G, wireless networks become more powerful, pervasive, dynamic, and flexible. They also become more complex and require more effort and more sophisticated tools to optimize the use of network resources. And wireline networks must adapt in order to work in this new environment.

All the areas of evolution discussed in the previous pages contribute to this increase in network complexity.

New, demanding 5G use cases require end-to-end network optimization to maximize QoE for each application and to allocate network resources efficiently. This is required not only to keep subscribers and IoT customers happy, but to implement the operator's strategy for service and traffic management.

For instance, a network may support extremely low latency, but it would be wasteful to require that all traffic be delivered with low latency. The operator has to decide which applications and users have priority, and manage the network accordingly. This has to be done in real time (or at least in near-real-time) and tied to location to gain full benefits. The network has to have the flexibility and agility to do that, and, because of the granularity of the intervention in time and space, the process has to be fully automated.

RAN densification causes an increase in the number of cells; it also creates a multi-layer architecture. This means a more complex network that requires carefully coordinated transmission to avoid interference and maximize throughput.

Virtualization and edge computing create a dynamic environment in which functions can be moved to and instantiated in multiple locations, and the networks have to be able to seamlessly accommodate these changes, because they happen on a real-time basis.

Along with being denser and multi-layered, the new RAN integrates multiple access technologies (from 2G to 5G, plus Wi-Fi), as well as licensed and unlicensed access. To take advantage of this integration of multiple access channels, operators have to manage traffic carefully at the application level or using tools such as network slicing to allocate the right type of traffic to each interface.

This is where analytics, artificial intelligence, and automation come into play. They give operators tools to manage complexity, and to benefit from the new capabilities and opportunities for differentiation and new revenue streams that this complexity brings.

In this context, automation becomes the necessary foundation for the massive data processing that analytics and artificial intelligence require, and for fine-tuning the network that they prescribe.

With its central location within wireless networks, the transport network is a key element in operators' efforts to tame the complexity and to benefit from it. As such, it has to support the analytics and artificial intelligence tools the operator uses, within its automation framework.

9. Recommendations for mobile operators

- Access is increasingly wireless, and transport increasingly wireline. Operators must ensure the two networks converge for optimized support of each other. Both wireless and wireline are crucial to fulfilling the International Telecommunication Union's IMT-2020 5G vision.
- To support pervasive connectivity, massive traffic loads, and new use cases, wireline networks must move closer to the edge, requiring fiber connectivity to reach further out, to more locations, and – with densification – to non-telecom assets and indoor locations. Mobile operators need to move towards a converged haul approach in which the wireline infrastructure can reach the end points of a multi-access and multi-layer RAN.
- The transport network must support the same 5G RAN performance requirements in terms of capacity, capacity density, latency, reliability, security, and other metrics. If the transport network does not evolve along with the 5G RAN, it will become the bottleneck of 5G performance and constrain the value of the 5G investment.
- Virtualization, densification, edge computing, network slicing, analytics, artificial intelligence, and automation change the way operators will build and run mobile networks. The transport network needs to have the flexibility and agility to automatically optimize network performance and resource allocation. This is both a technological and a cultural change that requires operators to fundamentally change how they build and operate wireless networks, and the transport infrastructure will have a prominent role in this transformation.
- Operators stand to benefit if they start preparing the transport network ahead of their 5G deployments. The changes needed are beneficial to 4G networks, as well, and do not derive directly from 5G specifications, some of which may still need to be defined. A strong transport network will let them hit the ground running when they are ready for 5G.

Glossary

AR	Augmented reality
BBU	Baseband unit
CPRI	Common Public Radio Interface
IoT	Internet of Things
MEC	Multiple-access Edge Computing
MIMO	Multiple-input multiple-output
mmW	Millimeter wave
NFV	Network Functions Virtualization
NR	New Radio
QoE	Quality of experience
RAN	Radio access network
ROI	Return on investment
RRU	Remote radio unit
VR	Virtual reality

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About Senza Fili

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

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