Briefing note – Future networks

Theme 1 –Telecoms with an IT core

4th October 2024

1 Introduction

The outlook for networks' technical development tends focus on the making them more agile and flexible, capable of meeting the need for high performance in terms of capacity, latency and resilience, and expanding the possibilities for "personalisation". Future services will be able to solicit these increasingly cutting edge features, provided they remain economically viable.

The digital transformation, or IT-isation, of telecoms – which consists, for instance, of replacing equipment dedicated to a certain network function by generic computer hardware that can run different software – is a trend that went from quiet beginnings in 2012 to a what today is a more and more widely adopted approach, and fully in line with that outlook. A transformation of electronic communication service providers is turning Telcos into Technos!

This briefing note follows through on the earlier ones that were published as part of the "Future networks"[1] cycle of inquiry, including "Network virtualisation: agile architectures" and the briefing note on "AI in telecommunications networks"[2]. Its aim is to deliver a snapshot of the current state of the art and explore what impacts these growing trends might have on markets and services.

The telecom industry's digital transformation is driving telecoms and IT sector players to invest outside their historic purview, and to interact with one another in various ways (client/supplier relationships, partnerships, competing in the same market, etc.). As a result, significant changes are appearing in network architectures and components, and in the ways to operate a network with new security imperatives, the need for new skills and increased competition. This aspect will be explored in the first part.

In addition, this digital transformation can act as a catalyst for networks' ability to foster the emergence of new applications and the development of new services for end users in the consumer market. The list of possible future use cases and potential new sources of revenue being identified by connectivity providers will be the focus of the second part.

Lastly telecoms' digital transformation is helping drive the emergence of new services, of dedicated solutions for businesses, but also of new market players in the areas of mobile connectivity and IT (notably cloud computing). The third part will look at the different players' possible positioning on these solutions being designed for businesses.

2 State of the art of the ecosystem for providing future networks' connectivity

2.1 Networks' digital transformation

2.1.1 Introduction to the concepts

Networks' digital transformation combines several technological developments from the world of IT.

The first trend that can be observed is **network function virtualisation (NFV)[3].** Virtualisation creates the ability to deploy these functions in the form of software that can be run on generic computer hardware which, in turn, means more flexible and agile network management.

A second trend is **the cloudification** of network functions, opening up the ability to provide unlimited access to resources virtually, making it easier to scale up and satisfy fluctuating capacity needs.

[1] Annex 1 – 2019 "Future Networks" brief on network virtualisation

[2] Annex 2 – 2019 "Future Networks brief on AI

[3] A network can be broken down into several elementary network functions. These functions can be virtualised and run on generic hardware.

Deploying network functions in the cloud thus endows telecoms operators with the same assets as digital service providers: instant and on-demand access to shared resources. These resources can rely:

- On a **public cloud**, i.e. which is shared with other applications inside the same data centre, but which are not necessarily supplied by the same operator and are not necessarily telecoms functions;
- And/or on a **private cloud**, i.e. a data centre that belongs to the network operator and is typically not shared with applications other than those used for the network's operation;
- On a **hybrid cloud**, i.e. the operator uses resources that are partially on a private cloud and partially on a public one. This configuration offers the advantages of having a private cloud to deliver certain functions and a public cloud for others;
- Or a **multicloud** approach, i.e. when an operator employs multiple public cloud services. This requires a certain degree of interoperability between the different clouds, particularly if the functions they are running need to talk to one another, or for functions that will run alternatively on the different cloud computing services.

Moreover, applying **artificial intelligence** to network operations could become increasingly commonplace. Network virtualisation increases the possibilities for incorporating AI building blocks to programme, optimise and automate certain tasks and functions, notably for load supervision and planning. The use of AI could even become critical to the next stage of networks' digital transformation.

Lastly, **Edge computing**, which consists of locating certain infrastructure at the "edge" of the network, closer to customers and closer to the data sources. They could also simplify data transmission by offloading the backhaul network to some degree.

These different technological development trends from the world of IT can foster more open network functions interfaces, and broader and more open design options for the network's different building blocks, such as source code sharing which is not uncommon in IT. Moreover, **open and interoperable interfaces** would enable the emergence of new types of third-party services, whose software building blocks would interconnect at different locations in the network. By the same token, open access to the design of network functions would open the doors to new functionalities within the network itself, as well as their ongoing improvement.

Network's digital transformation thus encompasses multiple trends that are not necessarily meant to be deployed simultaneously or in every component part of a telecommunications network. Section 2.1.2 sets out the overall digital transformation strategy observed amongst operators, and Section 2.1.3 explains in more detail how these trends are playing out in the different parts of the networks.

2.1.2 A "cautious" digital transformation

It emerges from discussions with industry players and existing analytical reports on the topic that operators are deploying these innovations gradually, and that they see no need to be the first in their national market to have a fully "IT-ised" network.

The cautious strategy of performing a gradual digital transformation of the networks, as much in terms of implementing all of the technologies borrowed from IT as the parts of the network involved, appears to be the path favoured by existing operators, even if several of the largest telcos are involved in projects aimed at accelerating their networks' transformation (Open-Ran Alliance[4], Sylva[5]) and in more

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[4] Open Ran Alliance: an initiative created in 2018 by AT&T, China Mobile, Deutsche Telekom, NTT Docomo and Orange to define an "Open, Intelligent, Virtualised and Fully Interoperable RAN" https://www.o-ran.org/

[5] Sylva: an association of telcos and infrastructure providers to define a virtualised network architecture, under the aegis of the Linux Foundation https://sylvaproject.org/

or less large-scale virtualised network trials. It must nevertheless be noted that some well-established major telcos, such as AT&T in the United States, Telus in Canada and NTT Docomo in Japan, are already deploying large-scale virtualisation and cloudification solutions on their commercial network.

On the flipside, some greenfield telcos such as Dish in the US, 1&1 in Germany and Rakuten in Japan have opted to deploy a fully virtualised network from the onset. These players are currently capitalising on their experience to offer consulting and integration services to other operators wanting to follow in their footsteps (e.g. Rakuten Symphony).

The most common **"cautious"** approach amongst established operators can be attributed in particular to:

- **preexisting hardware infrastructure inventory that cannot be virtualised or cloudified, and which is not obsolete,** which is an impediment to networks' digital transformation;
- a **still uncertain return on investment** given today's still relatively high integration costs, notably compared to already integrated and available solutions;
- the **methods for integrating and testing** virtualised solutions, and especially still nascent containerised solutions;
- the **maturity and efficiency** of these solutions are raising questions for certain telcos, who nevertheless identify the transition to those solutions as a potential long-term opportunity;
- the need to **build knowledge and mastery of these new concepts**.

It emerges from interviews with industry players that it is particularly by adapting to the solutions being offered by the market for the equipment that makes up telecom networks, which are increasingly virtualised and IT-ised by default, that operators are embracing this trend, rather than being driven by a real desire to earn a rapid return on these novel solutions. According to operators, there are still real gaps between the promises of these pioneer deployments with respect to the networks' digital transformation and the reality of the deployments (higher energy consumption, weaker performance in some respects, complicated integration process). The strategy of the informed follower, consisting of observing early adopters, could thus pay off in the long run.

Two forces driving an acceleration in networks' transformation can **nevertheless** be identified at this stage:

- first, **equipment suppliers** are offering more and more virtualised and cloud-based solutions rather than monolithic solutions relying on dedicated hardware which, according to telcos, nonetheless still carries certain advantages, not least the ease of integration with the rest of the network, their proven reliability and the small number of interlocutors needed to deploy a telecom network and ensure its operation;
- second, the **deployment of 5G *Standalone*,** whose standardisation in the core network borrows concepts from the world of IT, is contributing to an acceleration in mobile networks' transformation.

2.1.3 Incremental network virtualisation and cloudification?

Depending on their strategy, **not all telcos are at the same stage**[6] **in their adoption of these new network construction techniques, nor in the choice of the technologies to deploy in the different parts of the networks.**

[6] According to Capgemini, the overall level of network cloudification already stands at 31% worldwide, and could climb to 46% within four years: Capgemini Research Institute 2023: "Networks on cloud: a clear advantage" (https://prod.ucwe.capgemini.com/wp-content/uploads/2023/02/Final-Web-Version-Report-Cloudification-of-Networks.pdf)

If the different functions that make up telecommunications networks are already available at relatively advanced stages of virtualisation, porting these functions to the cloud is an additional step that opens onto other major strategic choices: private vs. public cloud. Networks' cloudification is thus currently at varying stages of progress depending on their different composite functions:

- **Support functions** (*OSS – Operation Support System and BSS – Business Support System*) that enable network supervision and customer management and billing, in particular, are the first building blocks to be carried to the cloud, whether public or private. Less critical to networks' operation, these functions are easier to upgrade to the cloud.
- **The backbone function**, for relaying data across the country, is composed of what is still primarily physical and dedicated equipment to guarantee better performance. The backbone function could also evolve through the use of Software Defined Networks or SDN. It is worth remembering here that quality of service issues (redundancy, traffic prioritisation) and the increased complexity of telcos' and businesses' largest networks spurred the development of software-driven networks. These developments tied to SDN are not necessarily synonymous with the virtualisation or cloudification of equipment which, for performance-related reasons, remain dedicated hardware, but it is the ways that SDN networks are operated that borrow from IT. Players such as hyperscalers could nevertheless invest in using some of their optical fibre infrastructure and data centres to roll out new backbone connectivity solutions based on increasingly virtualised network functions, as well as usage-based billing models employed by cloud computing companies.
- **Core network functions,** for managing fixed and mobile access networks, are being increasingly virtualised and cloudified by the different operators, not least to enable the deployment of 5G *Standalone*. For most operators, however – and this is true in France – the public cloud is not yet viewed as a solution for running a national core network. This is due to several factors:
  - The desire to **maintain direct control over infrastructures**, especially critical infrastructures, to maintain control over network quality (availability, performance, speed, restore and restart time…) and be able to continue to differentiate oneself from the competition.
  - At this stage, disaggregated solutions where the equipment supplier provides software building blocks that run on a public cloud, carry higher security risks given the demands that currently weigh on the networks. For a national network, these solutions require *ad hoc* testing from **a cybersecurity standpoint.**
  - **Operators do not view the capacity flexibility provided, in particular, by the public cloud as vital for the functions provided by a national network's core**, as a result of which the appeal of a public cloud remains limited (typically a handful of servers are enough to handle these functions).

  Some operators located in other countries, however, and new entrants in particular, have preferred to opt from the outset for core networks that are hosted on a public cloud. This is in line with their drive to achieve complete flexibility and a rapid scaling up of the networks. It is also part of a bid to share every network component on a single cloud. Provided security issues are properly addressed, it is not altogether out of the question that transitioning to a public cloud will become increasingly common if this trend catches on for the other network components.

- Prospects are opening up for pioneer deployments of virtualised **mobile access network** equipment, notably in Europe[7]. It emerged from discussions with industry players that the timeline for these deployments in France remains unclear, and may not be part of upcoming investment cycles for network upgrades. The advantages of virtualising radio access networks include flexibility and faster upgrades for operators: better management of cellular capacities (shared computing power between several radio cells), richer innovation within a more populated ecosystem, and expected gains in CAPEX and OPEX[8]. At this stage, the transition to the cloud remains a distant prospect and depends to some extent on the availability of the hosting solution close to towers (Edge computing).
- **The deployment of Edge servers integrating network functions (MEC: Multi-Access Edge Computing[9]).** These would be gradual deployments according to operators, starting on a regional scale, then steadily increasing in density. At this stage, there are still very few concrete examples of these solutions being used in France, and timetable for large-scale implementation have yet to be set. In future, networks and connectivity services could rely more and more on this type of Edge resources, and the availability of sufficient computing capacity on a local scale could become crucial to network performance. Under such a scenario, access to physical premises capable of hosting the required servers could become an additional issue in network deployments.
- **The fixed access network and enterprises' local Wi-Fi and wireline networks**. As with the backbone function, by their very nature access equipment continues to be dedicated and physical hardware, but the way the equipment is used to access businesses' fixed LANs could draw from virtualisation techniques, as with SD-WAN[10] architecture. This should not, however, undermine the technologies deployed to access the network. This topic will therefore not be examined here.

2.2 Changes in the connectivity infrastructure value chain

While only a handful of players are performing network rollouts today, with well-established customer/supplier relationships, **network virtualisation is creating a number of new player categories of various types and size.**

This plethora of players could foster more innovation, hence value-creation at different levels along the value chain – value that remains to be distributed amongst all of these players. On the other hand, the fragmentation of solutions and of the ecosystem only increases competition in each sub-section of the market. The ability to market complete solutions composed of elements provided by multiple suppliers would therefore require new partnerships to be formed within the ecosystem.

These partnerships would thus be especially necessary to ensure the interoperability of IT-ised/virtualised solutions' different components, and to guarantee the reliability of their performance and their security. Existing standards do not appear to be strong enough to guarantee these different performances without a considerable integration stage for the solutions deployed in the networks. These integration skills are new for the telecoms industry, but much less so for IT.

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[7] Deutsche Telecom is deploying these solutions in Germany, as are Vodafone and Orange in Romania.

[8] CAPEX = capital expenditure; OPEX = operational expenditure

[9] Multi-Access Edge Computing is a concept that has been standardised by ETSI, whose purpose is to share IT services and cloud computing capacities (notably network functions) within the same infrastructures located on Edge servers close to users, via well-defined interfaces and protocols.

[10] Software Defined Wide Area Network

The market for virtualised telecoms solutions integration is beginning to develop, and operators are taking on some of these new methods internally. Veteran suppliers and IT companies, notably hyperscalers, are at the forefront here as they have been accumulating know-how for years, the former with skills from the world of telecoms, and the latter with cloud computing expertise.

This vertical disaggregation trend could create issues at several levels in terms measuring the QoS of the infrastructures and virtualised solutions being accessed by downstream players.

According to several of the players queried, in addition to integration issues, newfound dependence on specific hardware (processors, a particular server motherboard, hardware acceleration chips) could occur, which means that certain performance levels required by the networks could not be met with generic and multivendor hardware. This becomes increasingly true as network density (especially mobile) increases. RAN virtualisation – where performance requirements (in terms of speed and latency) are more demanding – is a good illustration of this problem: several base station virtualisation solutions are run on hardware outfitted with customised accelerator boards that handle very specific computing operations that classic processors[11] are not designed for; switching to generic hardware leads to excess consumption and weaker performances.

Fuelled by potentially different geopolitical interests, different industrial strategies in different parts of the world are likely to lead to differences in the design and choice of the technological standards used for network deployments[12], particularly those pertaining to network virtualisation (such as the Open RAN specification). This could have repercussions on the timeline for the large-scale availability of equipment, hardware compatibility and even network interoperability.

2.3 Issues and challenges surrounding this transformation

2.3.1 New skillsets required

The structural changes to networks described here above require suppliers of connectivity, and telcos in particular, to undertake organisational changes at multiple levels. This is the main issue to emerge from the interviews that were conducted. Skillsets need to be developed to choose connectivity provision solutions, negotiate partnerships (which building blocks to develop in-house, which ones to contract from partners, which partners to use), building block integration, and possibly building block development. Changes also need to be made to trial and maintenance methods, and to operational methods for networks which become infrastructure as code (IaC) that is deployed automatically, and employs methodologies borrowed from the IT universe: DevSecOps, CI/CD[13]. These operational shifts are being implemented especially as part of software-defined networks.

Working methods created jointly by telcos, cloud computing service providers and integrators make it easier to choose network architectures and configurations. Mastery of the integration and operation of virtualised telecoms building blocks requires a high level of expertise in each IT and telecoms sector. This creates the need for cross-sector hiring and training between the players.

Depending on their choice of positioning (development, integration, operations, etc.) and their core businesses, future connectivity providers will need to implement upskilling strategies in-house and/or in concert with other players in the ecosystem. Moreover, although they are experts in their traditional field, existing teams will need to increase their skills and knowledge of the new techniques borrowed

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[11] Classic or General Purpose Processors (GPP) outfitting generic servers could support some of the virtualised RAN's less demanding functionalities.

[12] This type of phenomenon was already seen with 3G, which was developed using different standards (CDMA in the United States, UMTS in Europe and TD-SCDMA in China).

[13] DevSecOps and CI/CD (Continuous Integration/ Continuous Delivery) are software development and agile change implementation principles, which also ensure a high level of cybersecurity for applications.

from IT, which means: in-house training, the merging of IT and telecoms teams, and external recruitment.

The agility that the different players display in developing and maintaining top flight mastery of these technologies, particularly by adopting the right hiring and training strategies, appears to be a crucial issue here, and the failure to do so could prove an impediment to more rapid adoption of these technologies.

2.3.2 Sizeable investments in new infrastructures

Virtualisation, particularly of the kind that will reach beyond the core network, requires a transformation of operators that could mean substantial investments.

Network virtualisation is synonymous with sizeable investments in infrastructures (cloud infrastructures, servers and virtualisation hardware) but also with migration costs for operators, along with staff training costs. Added to which, pioneer deployments of fully virtualised solutions reveal a significant increase in energy consumption, and so in resulting operating costs.

This virtualisation could nevertheless be facilitated by companies providing pre-integrated NaaS[14] solutions that employ a pay-as-you-use model. This means that integration costs become variable costs, which enable players to lower their CAPEX by aligning spending with their needs. Changes in the cost of licences for usage-based pricing could, however, offset any savings. A European Commission report[15] assessed the decrease in CAPEX and OPEX tied to core network virtualisation at between 3.7% and 5%.

Generally speaking, in light of the investments it requires, **network virtualisation appears bound to be assigned to investment cycles for deploying new technologies or upgrading/replacing equipment.**

2.3.3 Security and resilience issues

Discussions with industry stakeholders helped to highlight newfound network security, resilience and data management issues tied to virtualisation and moving operations to the cloud:

- **Criticality of the telecom service**: national network service restoration time requirements are not currently guaranteed on a public cloud (notably when this cloudification goes hand in hand with pooling resources and centralising network functions);
- **Data privacy**: some of the data are relayed over the network without an encryption protocol (notably at the access network level). Without additional protections, users' data could be accessed by stakeholders involved in this level of the network;
- **Open interfaces**: the increased number of functional building blocks supplied by different players, interfaces open to app developers will invariably increase the number of vulnerabilities on networks and require stepped up efforts to validate the security of these interfaces and the building blocks that connect to them.

The stakeholder ecosystem as well as regulatory bodies are working to tackle these issues. One example is the SecNumCloud[16] standard that sets forth data isolation rules between two customers,

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[14] Network As A Service

[15] Implications of the emerging technologies Software-Defined Networking and Network Function Virtualisation on the future Telecommunications Landscape (https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=44563)

[16] SecNumCloud: Designed by France's National Agency for Information System Security (ANSSI), the SecNumCloud label proposes a set of security standards to guarantee compliance with high level technical, operational and legal requirements. Vendors marketing cloud computing services must demonstrate that they adhere to the highest security standards and comply with European data protection regulations.

but these rules do not prejudge the hosting company's access to the data; they could therefore not suffice to guarantee compliance with security standards.

On the matter of resilience, if a major incident occurs on the network, having an end-to-end view is made more challenging by the addition of the different layers of virtualisation, which complicates the ability to analyse the malfunctions and repair them.

Lastly, the cloudification of network functions is likely to raise sovereignty issues to the extent that they could fall under the purview of foreign regulations. These issues are not explored in detail in this briefing note.

2.3.4 Environmental issues to consider

This digital transformation also raises environmental impact issues for players deploying these solutions. Added to which, energy consumption could be a cost issue for operators in light of fluctuating electricity costs. This is also a source of concern for end users.

It emerged from the discussions with stakeholders that the impact of networks' transformation is an issue being investigated by connectivity providers, but no clear trend has emerged:

- First, the public cloud could help significantly decrease networks' energy consumption[17] thanks to the of sharing network functions;
- Second, early deployments of telecoms solutions running on generic hardware (notably open RAN) are currently proving more energy-hungry than their dedicated and optimised counterparts.

This is therefore a problem that could be further investigated as the solutions become more mature.

[17] Study on the trends and cloudification, virtualisation, and softwarisation in telecommunications, report prepared by PLUM Consulting and Stratix for BEREC, December 2023 (https://www.berec.europa.eu/system/files/2023-12/BoR%20%2823%29%20208_%20Study_claudification%20virtualisation%20and%20softwarisation.pdf)

3 New consumers services provided by future networks

Discussions with stakeholders revealed that the flexibility created by virtualisation and cloudification developments seek above all to decrease network operating costs over the long term.

In particular, they underscored how difficult it is at the stage to make any predictions about the supply of new innovative services to consumers, particularly based only on the best performances and greatest flexibility ushered in by the networks' virtualisation and cloudification.

Opening the networks to app developers was, however, held up as an opportunity to bolster innovation if not to design new applications that capitalise on network functions.

3.1 Will the networks' digital transformation enable the emergence of new services?

Regarding future services: the stakeholders queried are currently planning on only a small number of concrete use cases – such as providing even more video content with higher quality and, to some degree, thinking about cloud gaming opportunities.

This does not mean that, in future, the networks' digital transformation will not bring greater agility to their developments (more rapid scaling up, new functionalities, standards tested more rapidly in situ, then deployed on a large scale, etc.). The development of networks' virtualisation, cloudification and softwarisation is, for instance, likely to spur an acceleration in innovation cycles, and potentially the increasingly rapid emergence of new use cases and new markets.

3.2 Open networks, a new source of value for the networks?

According to the stakeholders who were queried, networks' digital transformation could help make networks more open – a concept that appears to appeal to a growing number of operators. Launched roughly one year ago, notably by Telefonica and Orange, the Open Gateway Project seeks to define and standardise APIs (Application Programming Interfaces) for partner operators by drawing on the CAMARA[18] initiative. Today, 47 of the largest telcos which account for 65% of mobile connections worldwide have joined the project. Some operators are already offering developers access to certain APIs, including:

- Device location verification/retrieval
- Authentication at the network level (SIM SWAP)
- Carrier billing
- Multi-access Edge computing

These newly available functions will pave the way for new value-added services such as secured authentication to a banking app from the network.

Developers will benefit substantially from having access to open interfaces from every operator in a given national market[19], and even more so from multiple countries. The standardisation of these interfaces gives app developers the ability to create solutions that can be ported to different operators' networks, and so bolster the profitability of their applications development business.

Particular attention needs to be paid to the conditions for implementing the interfaces themselves, along with common software development kits (SDK) that are known to developers in standardised

[18] Camara: an open API development project under the aegis of the Linux Foundation, created on the initiative of major telcos and telecom infrastructure suppliers https://camaraproject.org/

[19] In February, Spain's top three mobile operators simultaneously launched an offer for app development based on Open Gateway APIs.

environments. The aim would be to ensure the ability to develop these applications in open and varied environments, based on independent hardware and software solutions implemented in virtualised networks, and to avoid closed and proprietary solutions.

It is worth nothing that efforts to monetise access to these interfaces are taking various avenues, including:

- The creation of an API access marketplace by one or several cooperating operators;
- API aggregation by an intermediary that purchases access to APIs in a wholesale market then resells it to developers via its own platform.

According to some analysts, these different market schemes are expected to represent up to several billion euros by 2030.

The feedback from stakeholders on the creation of new services concentrated chiefly on the opportunities being opened up in the business market. This will be the focus of the next part of this briefing note.

4 Developments in connectivity solutions for businesses

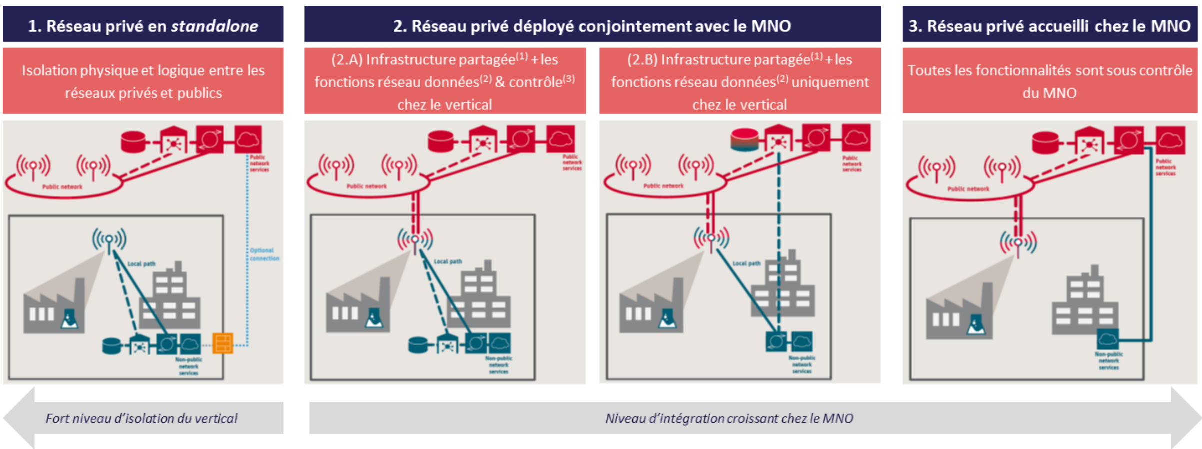
The digital transformation of telecoms is driving several major development trends in connectivity solutions for businesses:

- Public, private and hybrid mobile networks, notably 5G, could provide back-up to industrial and logistical infrastructures;
- The fact that IT services are replacing certain longstanding telecoms services (such as landline calling) is driving operators to bundle connectivity and IT services.

4.1 Mobile connectivity solutions for businesses

The digital transformation of the industrial fabric and different "verticals'[20]" communication needs could rely increasingly on private or professional mobile radio networks. Some private networks have already been deployed in different sectors. They enable more efficient productions chains in factories, for instance, relay more and better quality audiovisual traffic during sporting or cultural events, and improve logistical processes in ports.

Networks' digital transformation can facilitate the deployment of a wide range of mobile network rollouts for businesses, which would help meet the needs of verticals:



The network on the left is fully autonomous and aimed chiefly at businesses with high-level performance, resilience and security needs. The network on the far right has a slice[21] that is made available to the vertical that requests it, and capitalises on existing national networks.

The networks' digital transformation (and particularly the virtualised nature of 5G architectures) enables the emergence of new configurations: core networks switched to on-premise servers [22], an access network based on Open RAN building blocks, support functions (such as OSS and BSS) that can be run on these same servers. Finally, these solutions are modular: they can therefore be assembled using different building blocks from potentially different vendors[23]. In other words, new architectures, new players and new business models designed specifically for verticals are expected to be emerge.

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[20] Verticals refer to all private sector enterprises, regardless of their area of activity, and public sector structures.

[21] i.e. making use of network slicing, which was ushered in by 5G: a "slice" of the network whose QoS is managed end to end, is provided to meet the particular needs of a service or use case.

[22] Servers located on the vertical's own premises.

[23] Worth noting is the emergence of suppliers such as Casa System, Amarisoft, Mavenir.

The diversity of business use cases and their associated requirements could lead to a greater segmentation of connectivity solutions, right up to bespoke deployments. As a result, a larger number of players could position themselves in the market for business solutions, compared to consumer market solutions. Several of them are already forging a foothold to market their products: operators, public cloud providers, integrators, consulting firms, equipment suppliers, etc. Competition over PMR network provision appears to already be relatively strong, but this is still a fledgling market, and solutions are only gradually taking shape, although it is still too early to say with certainty how the market will eventually be structured.

If the revenue generated by the supply of private or professional mobile connectivity were to grow, it seems only logical that the market would attract a growing number of vendors.

4.2 Emergence of "bundled" solutions: IT services being paired with connectivity

4.2.1 Value shifting to bundled solutions

Businesses' needs are evolving, and connectivity is now viewed as a means for accessing IT solutions hosted in data centres in different locations, both on businesses' premises and on public clouds.

Telecoms operators are marketing a growing number of solutions that bundle telecom and cloud services (SaaS, e.g. Microsoft 365, online storage, etc.). For the largest corporations, these solutions are typically customised according to their needs. Close to 50% of enterprises (of all sizes) subscribe to a solution that bundles telecom services and other collaborative/cloud solutions, and around 30% of them consider that they did not have a choice, i.e. that only a bundled solution was capable of satisfying their needs.

4.2.2 Who is marketing these bundled solutions?

Telcos

First, because certain IT services are coming to replace veteran connectivity services (e.g. unified communication services vs. classic fixed telephony services), telcos are adapting to their customers' needs, and being driven to bundle connectivity solutions with IT services.

If these solutions seem less profitable than their veteran telecom services, especially for integrated operators, all telcos now market bundled solutions. All of the telcos interviewed thus offer online storage services, often coupled with other cloud services (applications layer). The operators nevertheless stressed that certain conditions attached to these bundled solutions are determined by the cloud computing service provider. For instance: Microsoft 365 is supplied by default with Azure storage (which is also owned by Microsoft): operators that own data centres do not appear able to sell their own storage services or to market multicloud solutions.

Operators have certain assets in the connectivity market that can be a gateway to the applications market:

- If an enterprise wants to switch to a dedicated mobile network to satisfy its needs, the expertise that telcos have developed over the years requires time, and remains a core part of operators' business, which make them top choice IT and telecom service providers;
- From a more general perspective, telcos have developed a degree of trust with both consumers and businesses. This brand reputation built in supplying connectivity, combined with their proximity to customers, makes them a natural choice for end users.

The networks' increasing move to virtual and cloud-based operations could, however, render these assets more marginal in the eyes of businesses shopping for a vendor further down the road. This relationship could be particularly undermined by the growing prominence of IT systems integrators that are positioning themselves as businesses' strategic partners for all of their IT and telecoms infrastructure, thus relegating telcos to the rank of a sub-contractor, providing connectivity.

Cloud computing companies

Cloud computing companies, and hyperscalers in particular, are already preferred partners for enterprises, whether for the supply of IaaS[24] or SaaS[25] solutions. These are well-known companies which in some cases also sell Edge computing solutions for businesses.

In the same way that telcos are expanding their product line to include cloud services, some hyperscalers are developing network solutions geared to enterprises' business applications. Here, hyperscalers could position themselves as businesses' main interlocutors, and provide infrastructure to operators that can support both networks and applications, which would bolster sharing solutions. Using the infrastructure supplied by the hyperscaler, telcos would become mere subcontractors, supplying the connectivity portion of the solution.

Hyperscalers would thus play a pivotal role in the supply of connectivity to businesses, even if for fixed access the last-mile connection would still belong to operators, added to which, for mobile access, telcos will continue to be able to leverage their wireless network expertise.

Cloud computing companies have several positioning options in these markets:

- concentrate on their core business, position themselves as service providers to telcos for the network's IT-isation.
- market solutions that incorporate certain telecom building blocks, underpinned by an IaaS infrastructure without going so far as marketing a complete telecom solution;
- position themselves as providers of direct, end-to-end connectivity to enterprises taking an NaaS[26] approach.

All of these strategies are currently being employed or tested in the marketplace.

5 Conclusion

Telecom networks' digital transformation appears to be part of a natural progression: 5G architectures are increasingly virtualised, the range of players positioned to supply connectivity is growing, and including more and more IT companies, and telcos are acquiring new IT systems integration expertise.

The fragmentation of network architectures, and the growing number of players involved in the supply of connectivity, creates network security and resilience issues and challenges. These aspects were investigated as part of the "Arcep and future networks" cycle of inquiry, and are summarised in the "Network resilience" briefing note.

Discussions with the sector's stakeholders revealed three core trends which could require regulatory action:

- **Networks' digital transformation appears to be advancing in stages, with already several major issues tied to that transformation, notably concerning the use of public cloud solutions to operate networks and supply connectivity to consumers. Some of these issues could raise regulatory questions, notably the market for integrating network functionalities.**

[24] Infrastructure As a Service

[25] Software As a Service

[26] Network As a Service

- **It is still too early to identify future consumer services: use cases are not yet clearly defined. Opening access to network APIs could, however, pave the way to new uses and new services. Careful oversight of how future API access markets operate could thus prove necessary.**
- **Connectivity solutions for businesses could, however, benefit directly from the spillover effects of networks' digital transformation. This market could undergo profound changes. On the one hand, some IT services will replace veteran telecom services, leading to the combination of software and connectivity solutions (facilitated by the cloud and virtualisation). On the other hand, bespoke wireless connectivity solutions are likely to emerge in response to verticals' needs. The networks' IT-isation could unleash innovation from a host of players, with a range of assets, with no clear evidence at this stage of the market's resulting structure.**

In addition to AI-based innovations that could make their way into network management (by improving predictive maintenance, radio resource allocation between the different users, improved traffic routing, etc.) – as referred to in the January 2020 "AI in telecoms networks" briefing note – artificial intelligence could fuel the creation of new services. The contribution of generative AI, especially those systems dedicated to the developer community, has rapidly become a tool for accelerating app developers' adoption of development tools, which are capable of answering specific requests about how development environments function, right up to being able to automatically generate functional lines of code (a generative AI prompt can provide access to functions that have already been coded by the developer community).

The innovations that will be enabled by AI and the possible synergies with future networks have the potential to radically transform the connectivity sector:

- by making operators' organisation more agile (notably by facilitating staff members' upskilling thanks to the implementation of AI-based conversational tools, which makes teams more agile) for more efficient integration of the expected gains from the network's IT-isation;
- by improving how the networks' function and optimising their architecture;
- by making much greater use of connectivity to access different types of AI that are positioned more or less deeply in the networks and beyond (this increased use derives from the load that AI inference model inputs (prompts, images, etc.) can put on the network, and from the particular network performance requirements of this connectivity: low latency, high resilience (e.g. Edge computing);
- by enabling a more rapid expansion of new services.

Network security issues also move to the different layers powered by AI. The application layers powered by AI will potentially need to take on the security requirements that networks today must already satisfy. Moreover, the AI building blocks that will be in the network will also be subject to these same security imperatives.

These aspects will be examined in more detail in a future briefing note. The question is whether the conjunction of the ongoing digital transformation of the networks and the advent of more precise and more affordable AI has the ability to redraw the applications landscape that relies on connectivity and, beyond that, "future networks" themselves.

Annex

Interviews

A series of interviews helped to inform our thinking about network virtualisation. The positions taken in this briefing note do not, however, necessarily reflect the views of the people interviewed nor of the institutions or companies to which they belong.

Those we interviewed included

- Association Française du Jeu Vidéo
- Airspan
- ANSSI
- AWS
- Bouygues Telecom
- Cap Gemini
- CEA Leti
- Cellnex
- CNRS
- Dell
- DGNUM
- Ericsson
- Google
- Huawei
- Iliad
- Mavenir
- Nokia
- Orange
- SFR
- VMWare
- Vonage

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