altice labs

INNOVACTION

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INNOVATION STRATEGY

Dear Reader,

I am very pleased to be writing the first institutional message for 2016 edition of "InnovAction" publication, which also celebrates the legacy of "Saber e Fazer", ended in its 12th issue.

Telecommunication and Media Industries have been facing major disruptive and unpredictable forces for the last decade, having to rapidly adapt and rethink their strategies while still delivering top quality service to its clients and value to all stakeholders. Concerned with this scenario, and being included in a major international Telecom and Media Company, Altice Labs, an Altice Group company, is the responsible for coordinating all the Research, Development and Innovation activities within the worldwide Operations.

As largely spread by leading information technology research and advisory consultancies, by the year of 2020 mostly everybody and everything will be connected to the Internet and the number of "connected things" may reach 25 billions, including all kinds of vehicles and wearables. Most of the economic activities and interactions will be totally digital. The information generated from all those "things", wearables and digital economy interactions included, will fuel the rise of a new (and highly valuable) revenue stream: data, seen by many as the basis for a new economy.

For the Telecom and Media providers, foreseen challenges are huge: the more people connect to all kind of broadband access points, the more successful the alternative service providers (also called OTT providers) will be. Giant Internet companies will continue to drain a significant revenue stream from telcos, content and other utility providers.

On the other side, telcos will have to redirect their

investments according to a well defined technology strategic plan and focus on the constant pursue of competitive value propositions for their customers as otherwise they face the risk of losing a significant amount of communication and entertainment business or, in the worst scenario, becoming totally irrelevant.

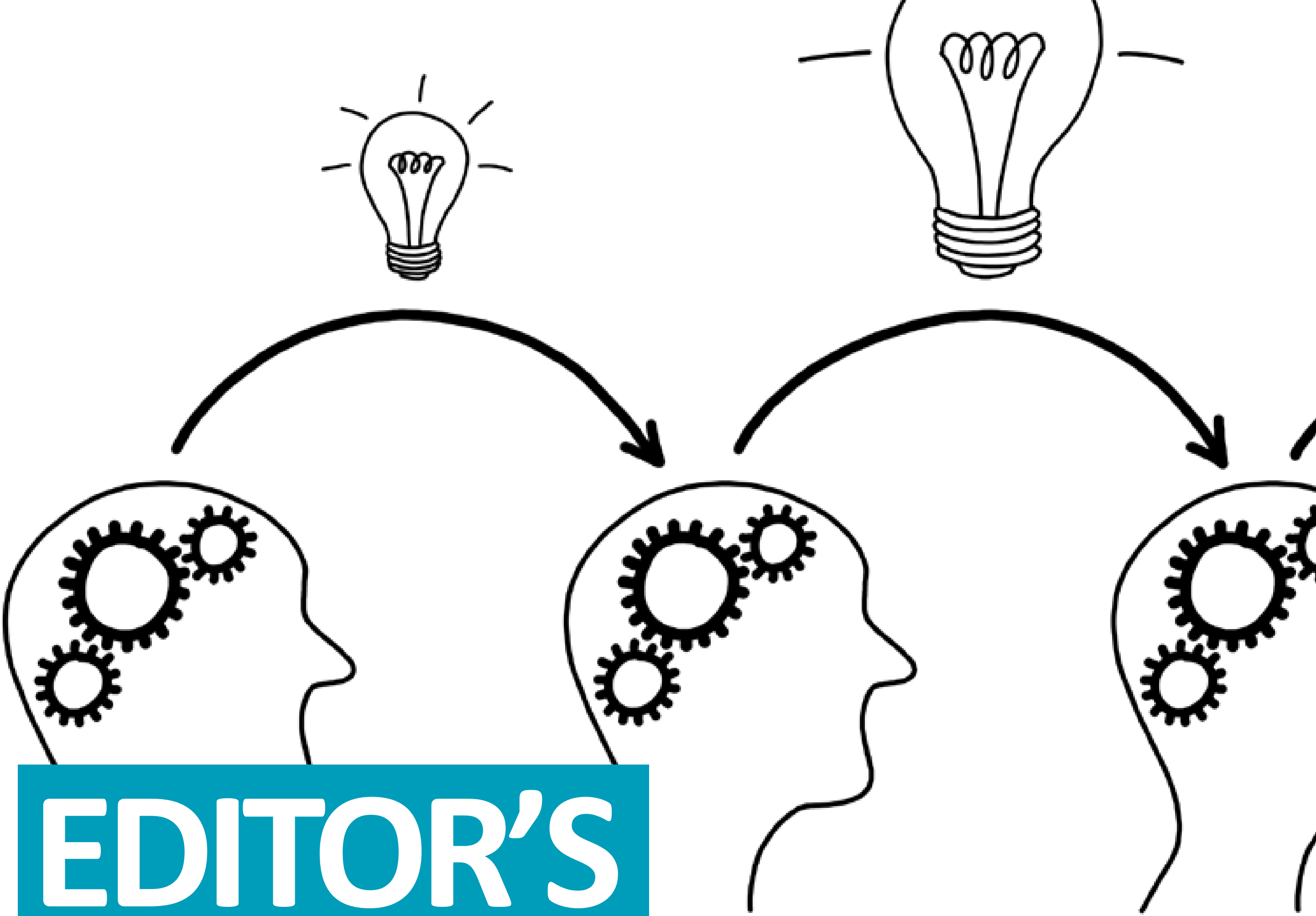
Having this in mind, in the end of 2015 and beginning of 2016, Altice Labs, along with Altice CTOs, redefined the group's technology strategic plan that includes the main trends on customer behaviour evolution, the vision of excellence the group wishes to attain, the key technological dimensions to reach this vision and, finally, a set of time-framed guidelines capable of future proofing the technology and business sustainability of the group's operations in a (more than ever before) uncertain world. The final result worked as background for this publication.

For a group like Altice, which has a very clear investment strategy in Telecom and Media, a technological publication such as the present one, is particularly relevant, firstly as a vehicle to share the most relevant technologic developments and knowledge throughout the group's operations all over the world and, secondly, as a way to reinforce Altice's firm commitment to technological innovation and the future.

I hope you enjoy reading it, as much as we, at Altice Labs, enjoyed writing it.

Alcino Lavrador

General Manager of Altice Labs



EDITOR'S NOTE

"InnovAction" is the first English edition of the publication previously named "Saber & Fazer", edited in Portuguese between 2003 and 2015 (12 editions) and under the responsibility of PT Inovação.

Due to the change in context, with PT Inovação now totally owned by the international group Altice and recently changing its name to "Altice Labs", we decided to publish the 2016 edition in English, under the name "InnovAction". Thus, this is Edition 1 of the "InnovAction" publication.

This publication has been positioned over time as a differentiating element of our company's activity, a pillar of R&D and Innovation capacity, representing our ability to understand technology and create solutions which add value to customers and business.

Presenting a total of seven articles, the 1st edition of "InnovAction" presents Altice Labs's (ALB) most relevant (for Communication Service Providers) approaches on technology, operations and business trends.

The first article presents our vision on a possible Technological Strategic Plan for a CSP and sets the scene for the remaining articles, focused on Big Data, Internet of Things, Optical Networks (NG-PON, NG-PON2), Virtualization (Cloud, SDN, NFV), '5G' evolution and Television:

- **Article 1 – A vision towards 2020:** Fierce competition and a world changing at a faster pace than ever before is what CSPs can expect from the forthcoming years. They definitively need a vision for the future;
- **Article 2 – NG-PON2:** NG-PON2 technology is a 40 Gigabit-capable passive optical network system in an optical access network for residential, business, mobile backhaul, and other applications;

- **Article 3 – Big data on media not just big, but smart:** Machine Learning targeting the Media;
- **Article 4 – NFV & SDN innovation strategy at Altice Labs:** Evolution of traditional communications networks to a new generation of programmable software based service infrastructure – The rise of the Digital Services Providers;
- **Article 5 – A "Startegy" for IoT:** Transforming the society through innovative services based on connected things;
- **Article 6 – 5G: a big step for technology, one giant leap for mankind:** What it is expected to be (and not to be);
- **Article 7 – Trends in TV: OTT, APPS, ADS:** Combining OTT, Apps & Ads, towards innovative functionality and added value.

A final word to the authors and technical reviewers who, with their dedication and knowledge, are the basis for the creativity and innovation that will ensure the present and future technological leadership of our organization. Also a special gratitude note to the editorial team for their commitment and hard work which made this publication possible, amidst deep enterprise changes.

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01

A VISION TOWARDS 2020

Fierce competition and a world changing at a faster pace than ever before is what Communications Service Providers can expect from the forthcoming years.

In fact, when looking ahead to the next five years – that is, until 2020 – mobile data traffic will nearly double each year, billions of devices will become connected, our homes will become networked device intensive spaces, digital content will play a central role in the society, while the so called digital economy will be a worldwide reality.

This evolution scenario, together with the ongoing demographic changes, a more demanding regulation, stronger peer competition and the OTT service providers pressure will force the traditional CSPs to rethink the way they will do business. Technology will be a strong asset and CSPs must be prepared to use it in its benefit by defining a clear vision, strategy and an execution path on how to leverage from existing and forthcoming technologies to build a winning value proposition for their customers.

This article summarizes the global contextual trends which all CSPs will have to address for the next five years, deriving from these trends a vision and a strategic positioning which should be adopted by a leading CSP.

Finally, some hints on a possible set of technological guidelines for a CSP running towards 2020 are suggested.

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Vision, 2020, Strategy, Technology

Setting the stage

The first thing anyone engaging on the elaboration of a Technological Strategic Plan thinks about is ... technology, of course!

As a matter of fact, this should be one of the last thoughts. Technology is no more than a mean to achieve a result. A very powerful one it is true, but still no more than that.

Well, if technology is not the starting point, one might be tempted to focus on business. Business is often seen as the ultimate goal of any successful player in almost every industry, so this seems as a very good starting point for defining a strategy, even if a technological one.

Wrong! Business is important of course (in the end, the figures will have to make sense) but for an industry that handles communication between people, focusing pretty much on how to deliver quality content to those people and trying to be part of their daily lifestyle, both personal and professional, or even of the surrounding ecosystem, everything is all about people.

In fact, our customers are the real reason of our existence, the keystone of any CSP (Communications Service Provider) success or failure, and the real ultimate goal of this industry.

Peter Drucker is often quoted on the ultimate objective of a Business: “The purpose of business is to create and keep a customer.” Please note the “keep” part, because it is often the most difficult one!

After they have their priorities set right, CSPs must proceed to understand what they need to provide to their customers in order to make them happy and successful during the target period and from that understanding derive a vision for the future.

Based on this vision, the technological strategic plan is prepared and the necessary tactical and operational guidelines leading to the fulfillment of this vision are built, and from then on the necessary technology investments can be timely executed.

Figure 1 illustrates the process of construction of a Technological Strategic Plan.

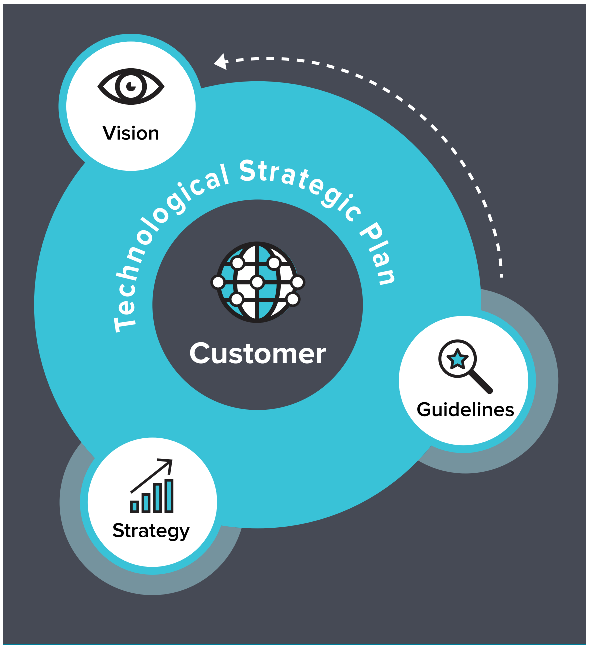

FIGURE 1 Key elements on a Technological Strategic Plan

The World in 2020

Analysing the customer of the future has a set of challenges that makes it a challenge by itself. First of all, customers behave quite differently depending on their socioeconomic surrounding, which by itself varies a lot all over the planet. Secondly, customers behave differently whether they are in their personal, family or professional lives. And finally new set of customers is arising: customers that are directly connected to the way humans will live their lives in times to come, even though these “customers” might be things.

Focusing on the geographical areas of the northern hemisphere, there are some key findings that are crucial to define our vision of who will be our customers in 2020.

Connectivity will increase its importance on citizen’s lives, with **ubiquitous mobile connectivity** becoming an even more important evaluation point when choosing the service provider. Both present strong two digits growth rates forecasted for the next five years, and this should be taken very seriously as a key point to consider.

Another relevant aspect is that customers are not only humans anymore. As a matter of fact, more and more "**things**" are getting connected as part of the overall ecosystem that a service provider needs to address. With a five fold increase forecasted up to 2020, and a 3 digit on the Billion dollars span, this is certainly an area to address.

Attached to these two (to-be) realities, other key points must be surveilled. **Wearable** technologies are growing fast, and the so-called **digital economy** is contributing strongly to G20 growth, with a 2 digit growth forecasted to next year. Of course, not only easy and appealing things are expecting a CSP. The remaining industries are becoming more and more aware of the power of information, and they make use of it to introduce **new revenue generation streams**, while the **OTT** (Over-the-Top) service providers consistently drain revenue from traditional SPs sources in the years to come.

When looking into **Individual Customers** perspective, there are two main conclusions:

- The numbers will continue to increase, with smartphones leading the way to even more subscriptions and especially much more traffic (particularly mobile);
- Content will be a key asset in the future, with customers willing to pay for tailored offers, and OTTs leading the way.

If you look into those customers as **Home and Family Customers**, you get a quite different perspective:

- Devices and connected things will proliferate inside the house, either because the number of personal connected devices will increase or because the number of the home connected things will raise exponentially;
- Generation gap increase brings a wide range of needs to be served, from the bandwidth starved connectivity needs of youngsters to the simpler, but critical, needs of surveillance and care of the eldery.

Another big challenge comes from the business world customers where **SMEs** are seen as a huge opportunity for CSPs. In fact, IP business traffic is expected to grow exponentially, specially driven by the forecasted increase on the usage of Cloud IT solutions and IT spending. With this type of customers steadily moving into the digital economic space, challenges on security and privacy will be key to keep them.

Finally, probably the trendiest of all findings: **Cities**. With population increasing its movement into cities, an ageing population and a need to manage all this with scarse resources, municipalities are increasing the technology investments applied to Smart City management solutions. The main goal being to increase citizen's well-being, constitutes a great opportunity for SPs to leverage from their credibility as technology players.

Main customer challenges to SPs

The 2020 customer will be a demanding one, introducing a very interesting set of challenges to Service Providers.

Standing on top of an implicit ubiquitous way of accessing services, customers expect top quality of experience when accessing the network or interacting with the CSP services for any reason (by

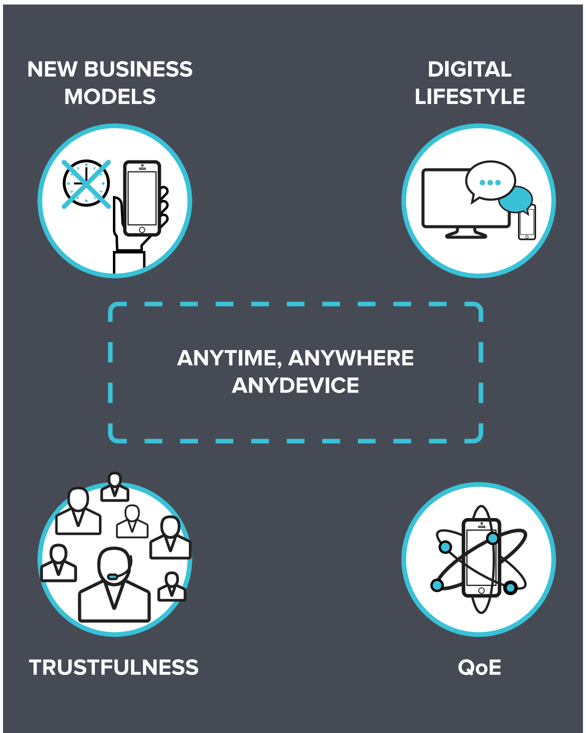

FIGURE 2 Main challenges to address

the way, the network, not a set of networks), with digital seen as the main path to achieve almost anything.

Being able to create new business models, capable of providing increased flexibility is also a required capability, while CSPs will probably be able to benefit from their credibility and strengthen their position on new revenue generation value-chains.

A Vision of Excellence

Based on a detailed understanding of the customer of the future, the CSP also needs to understand what it aspires to become in order to fulfill its customer's needs.

This "Vision of Excellence" is the basis for the construction of the Technological Strategy, presented afterwards. For ease of writing, we call this CSP the "CSP2020".

The CSP2020 will need to become an undisputed leader on its basic offers: connectivity, services and media. However, that will hardly be enough. Innovating on the way content and entertainment is produced and delivered is a must, since content will be one of the most valued assets of the future.

FIGURE 3 A vision for the CSP2020 Positioning

Furthermore, with increasing importance being devoted to wellbeing (both for the individual, family life and in the cities) and to the B2B market, the CSP2020 will have to work to become a reference in those areas or risks being replaced by more aggressive competitors.

Last but not the least, CSP2020 will have to be able to achieve what is stated above in a highly efficient and effective manner, while keeping the focus on providing a first class customer experience.

Not an easy task, but this is a highly competitive industry on a fast track to commoditization, where only the ones aiming high and executing well will be able to become a part of the future.

A Technological Strategy driven by Customer and Vision

At this stage, having set up a Vision for the CSP2020 positioning in the market and having understood how customers will behave and what they will be expecting from any Service Provider, its time to focus on technology.

In fact, being technology a (powerful) tool, it would only be natural that we centred our Technological Strategy on the Vision, and then defined the most relevant **technological dimensions** that will bring us into that Vision.

Those strategic key technological dimensions define, by themselves, a set of technologies that are relevant to achieve those goals as well as defining a set of initiatives whose role is to set the foundation for implementing the strategy.

Getting a deeper look into those dimensions, we can see that one of the most relevant to achieve our Vision is **Customer Experience**. Targeting on providing high satisfaction levels to customers using the CSP service offers, this technological dimension focus on empowering customers as well as on the

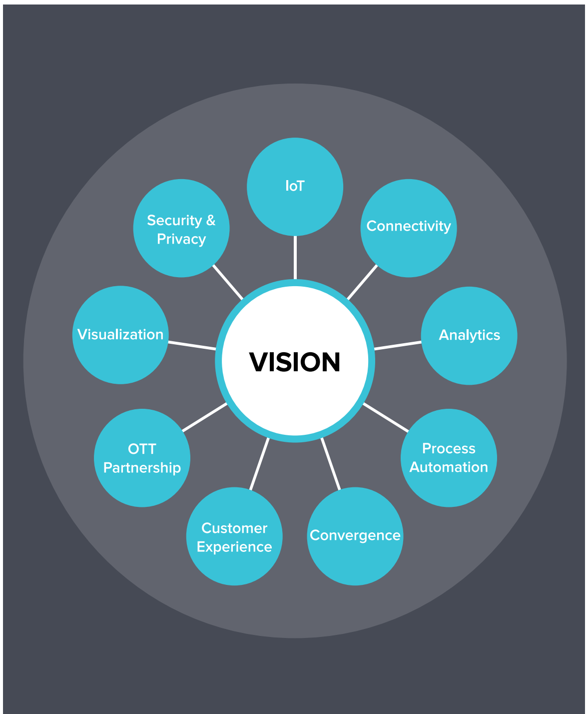

FIGURE 4 Strategic Technological Dimensions

network quality control. Those are strong enablers of experience for our customers, and a strong push must be made to achieve results in this area. We are not alone on this crusade, and being a mature concept on the industry, this is becoming a reality on most advanced Service Providers.

A key element on the experience equation, **Connectivity** solutions are the foundation of any CSP, and one cannot expect less than to excel in this matter. This area is currently under intense activity within standards fora, targeting how to increase networks capillarity by bringing fibre as close to the customers as possible. All this is accelerated by the huge traffic increase that is forecasted for the incoming years, as well as by the high number of connected devices. The key for succeeding on this dimension is to be able to perform this all-fibre approach in such a way that existing investments can be leveraged as strong contributers to it, while coexisting with new technologies.

Another key dimension contributing for the vision is **Process Automation**. Also being matured on the industry for some time, CSPs are starting to implement it, and there are good reasons for this. The definition of a common architecture for technology agnostic processes, which will be implemented both on business and operations, brings along high operational efficiency and agility when launching services. And with service lifecycle being ever and ever reduced, with customers willing to adopt and leave services at any time, this is a crucial contributor to success.

The customer studies also revealed that ubiquitous service **Convergence** is a must. Having the same experience when accessing the favourite service, regardless of the network required at that moment is something that will have to be simply natural in the future. Additionally, from the CSP point of view, having operational convergence is also quite desirable, since this will also contribute for a rationalized usage of CAPEX and OPEX.

Extending our strategy beyond the next two years, **Virtualization** is also an area to address. Moving into a cloud approach, both at the IT process level and at the network programmability will also become a key element for agility and rational use of resources (therefore increasing efficiency). There is still a lot to do in this dimension, with SDOs (Standards Definition Organizations) and open source communities still working hard to bring it to the light, while a strong industry movement is seen to contribute into it. Definitely a place to invest with hard work.

The dimensions addressing the new revenue streams that are expected to contribute to the raise of the bottom line in the future have another dimension in common. In fact, **Security and Privacy** perspective must be seen as a by-design characteristic of those platforms, and with customers increasingly becoming aware of it, and demanding it, a strong bet must be made in order to start having it present on everyone's mind.

With the number of devices expected to explode, defining a strategy to become part of the **IoT** movement is critical. In this particular dimension, the solution for that strategy is more than just technology! Technology is of course important, being mandatory to have an (also at this dimension) ubiquitous way of managing the devices, and also a way to deploy and manage new applications and services by enabling them to leverage from the assets any CSP has at its own service. It is also important the capacity of generating a partnership ecosystem including partners from several industries capable to bring along new service areas alongside the ones that are closer to the SP "traditional" business.

Finally, acknowledging that this industry has a lot more players that are moving into it from adjacent industries is a sign of intelligence. In reality, boarding an **OTT partnership** strategy is mandatory if CSPs intend to do the same they have been doing: leverage from existing capacities to become better. Also here this stretches way beyond technology alone, with openness being the key to get there. Openness in technology means being able to expose into APIs the access to existing and forecoming assets, so that others in the industry can be seen as partners from the customers point of view. This will mean an automatic uplift of the portfolio, where services can be monetized both by the partners themselves and by the customers as well.

Defining where to start

With a wide set of technological dimensions that must be addressed in order to walk towards the defined Vision, a key point on the Technological Strategy is setting priorities.

It will not be possible to address everything at once and at the same time, so focusing on getting into the dimensions that will be the foundation to a new level of technology involvement is what we have defined.

Despite addressing the immediate and short-term dimensions first, attention must be also focused in starting the work for the mid and long-term dimensions. Starting research and projects on those areas is also important, in order to evaluate solutions and build know-how alongside with the remaining of the industry (Figure 5).

Guidelines for getting things done

Once defined the technological dimensions that

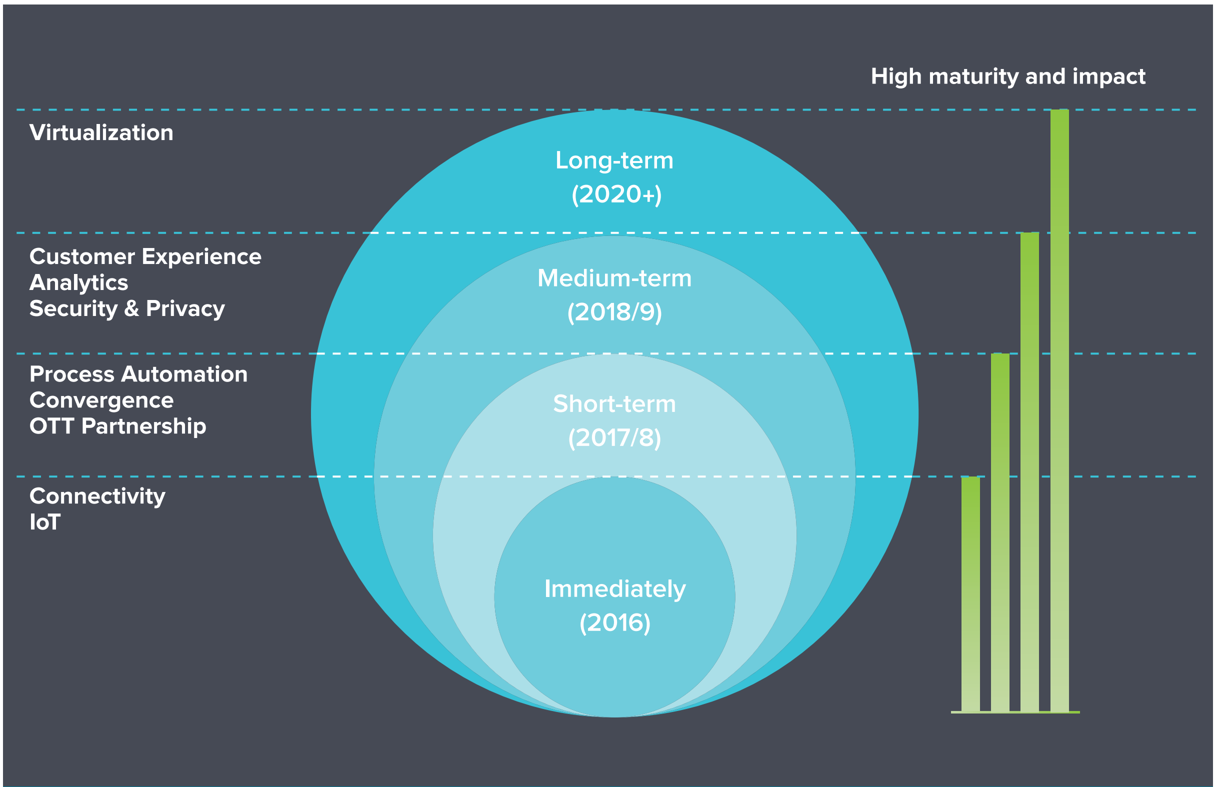

FIGURE 5 Impact on business and operations

need to be worked out and the priorities to achieve our Vision, the next phase is to define a set of initiatives that drive us into our goals.

Those initiatives will be the major guidelines to the CSP's operations, defining what aspects need to be addressed in order to achieve the relevant level of completeness on specific technological domains.

Depending on the urgency level of the technological dimension, the guidelines are more implementation project focused, when addressing immediate or short-term dimensions, or more research or experimentation oriented, when addressing medium to long-term dimensions.

Each guideline is defined as a set of features that will need to be implemented following a step-based roadmap, leading into a clearly defined value proposition. Blockers and enablers have been identified, so that it is clear what really has to be made available beforehand, and what could be considered as an ignition to each specific guideline.

From the immense variety of guidelines that could be implemented, the most relevant ones have been selected, having as criteria being as much effective as possible and producing results as fast as possible.

So, for the immediate initiatives, it is strongly believed that setting up what it takes to **bring fibre closer to the end-user** and at the same time **leverage existing, non-fibre, technologies** is the right path, while working on the **evolution of RAN** (Radio Access Networks) at the same time. Clear selection criteria has been defined in order to assist top management deciding on which technology to adopt in every situation.

Still on the immediate, addressing **IoT enablement** is an urgent need, especially if the group intends to benefit from the myriad Smart City opportunities arising everywhere.

Moving into the short-term, guidelines focus on achieving operational efficiency by implementing process automation protocols, with special focus on **business and operational process automation** and implementing afterwards a **Group-wide operations**

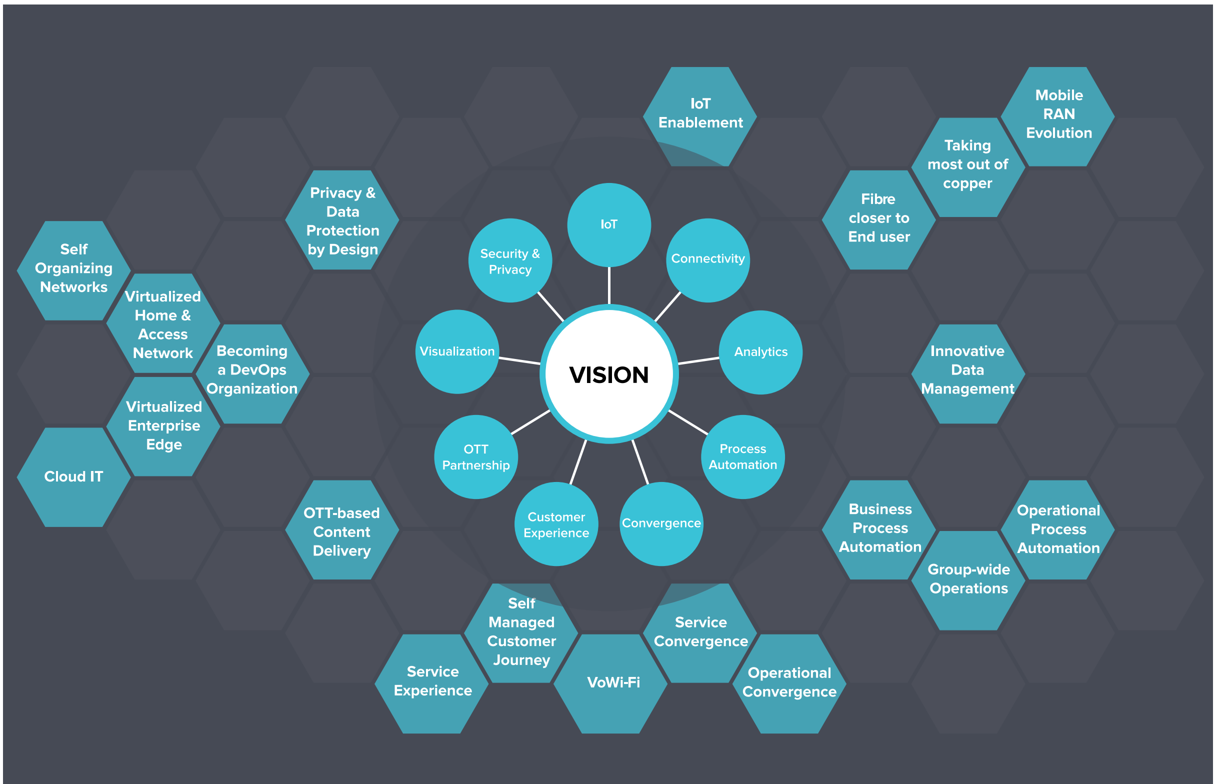

FIGURE 6 Guidelines per dimension

coordination centre. Another short-term guideline is to start moving into implementing what it takes to leverage OTT partnerships at its peak, focusing on **OTT-based content delivery** partnerships. To close the loop on the short-term guidelines, addressing convergence is also very important. That should be done by implementing **service and operational convergence**, as well as delivering **VoWi-Fi** as a quick service convergence example.

With those guidelines put into work, the baseline for getting real improvements in customer experience will be ready to use. Which means that implementing **Service Experience** and delivering a **self managed customer journey** experience is mandatory. Having this operationalized, Analytics and Security must also be assured, by implementing the **innovative data management** and **protection by design** guidelines.

Long-term guidelines will address Virtualization, covering **Cloud IT**, **self-organizing networks**, **DevOps** and **virtualizing** both on the **home** and **enterprise** environments, delivering results through proofs-of-concept and focused initiatives.

Now, what's next?

With the complete set of guidelines defined, there is also a roadmap proposal that closes up the Technological Strategic Plan [1]. The roadmap provides an indicative layout for achieving the goals defined by the strategy, while clearly defining the phases that should be pursued for each guideline.

Next steps would benefit from adjusting the plan to each group operation's local reality. There will be operations ready to start implementing some of the guidelines immediately, while others will take a while getting into a stage that allows starting implementing the Strategic Plan.

For some operations, the implementation of new technologies won't even be needed since they are not coherent investments. In other ones, a group-wide approach will bring huge benefits and economies of scale.

Summing up: the Technological Strategic Plan is not a recipe that applies to all, it is made of a set of guidelines that will now be worked in collaboration, always having customers as our main concern.

References

[1] Proposal for a Technological Strategic Plan- Altice Labs, November 2015

02

NG-PON2

This paper presents an overview of the NG-PON2 Technology.

The requirements, the deployment and coexistence scenarios and the NG-PON2 optics innovations are presented, namely in tunable optics and photonic integrated circuits.

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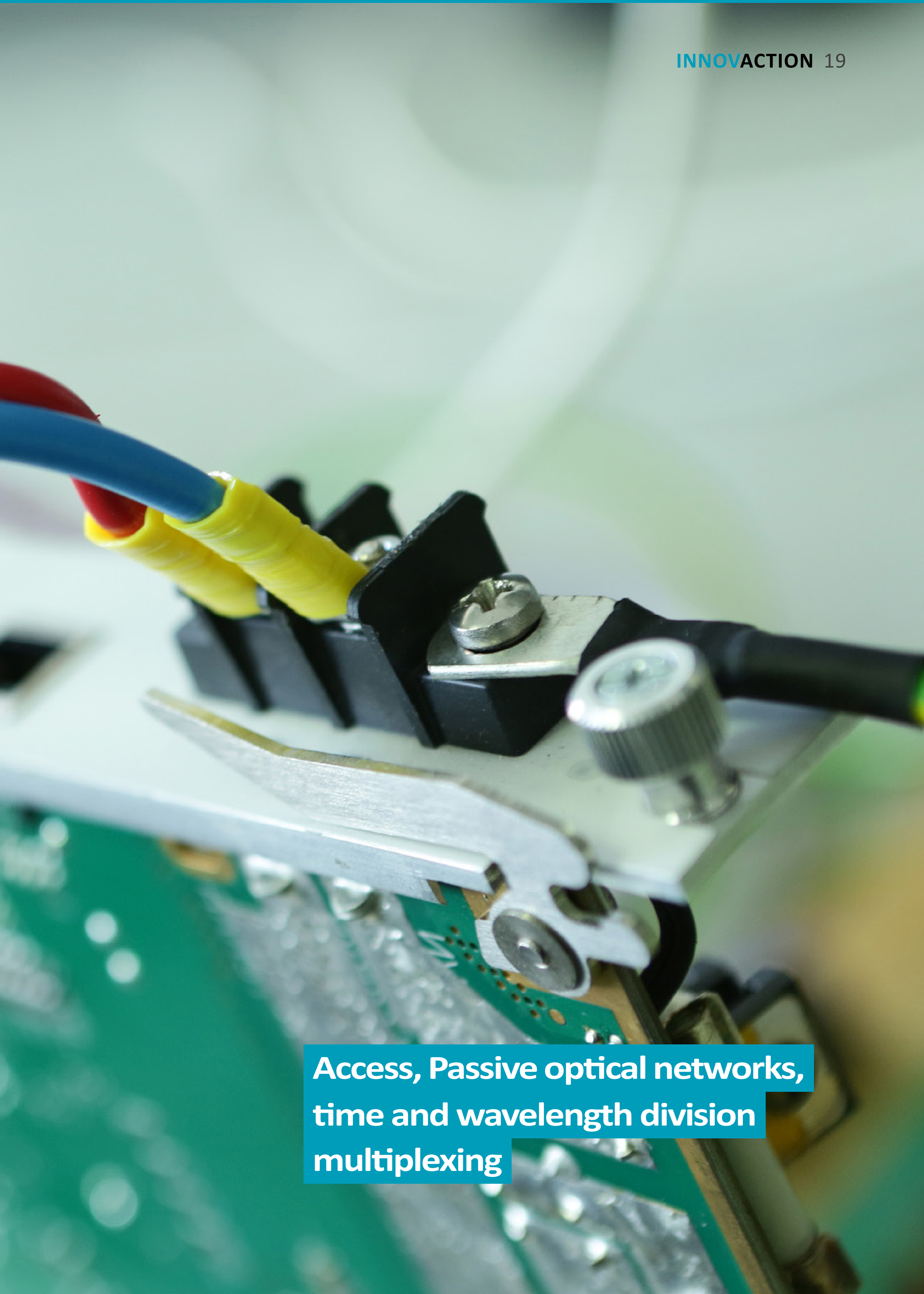

Access, Passive optical networks, time and wavelength division multiplexing

Introduction

Driven by the proliferation of heterogeneous bandwidth-consuming services, passive optical network (PON) architectures have been evolving in the last decade, providing enhanced availability, data rates and services. An evidence of this fast evolution is that both IEEE 802.3 and ITU-T together with the full services access network (FSAN) group are currently working towards the standardization of next-generation PON2 (NG-PON2) [1][2].

Several PON access technologies are currently deployed in the field, namely, EPON, 10G-EPON, BPON, GPON, XG-PON and the choices have been to evolve from the legacy systems without discontinuity of the previous technology, in other words maintaining coexistence over the same fibre span to further exploit the investment [3]. Additionally, as shown in Figure 1, spectral scarcity is now becoming a reality, since most of the low loss bands of the fibre are fully exploited. Gigabit PON technology, driven by the ITU-T, has conquered several markets and achieved high uptake rate. XG-PON was developed to try and improve the data rate, and due to the lack of component maturity together with tighter filtering and laser requirements, some risks were already taken. Starting from there, a new standard is now under finalization, the time and wavelength division multiplexing PON (TWDM PON) or NG-PON2 [2][4], representing a major change in the paradigm of previous technologies.

NG-PON2 is based on ITU-T G.989 series:

- ITU-T G.989.1 - 40-Gigabit-capable passive optical networks that contains the general requirements for the NG-PON2;
- ITU-T G.989.2 - 40-Gigabit-capable passive optical networks (NG-PON2): Physical media dependent (PMD) layer specification, that specifies parameters for the physical layer as wavelength plans, optical loss budgets, line rates, modulation format, wavelength channel parameters and ONU tuning time classes;
- ITU-T G.989.3 - 40-Gigabit-capable passive optical networks (NG-PON2): Transmission Convergence Layer Specification;

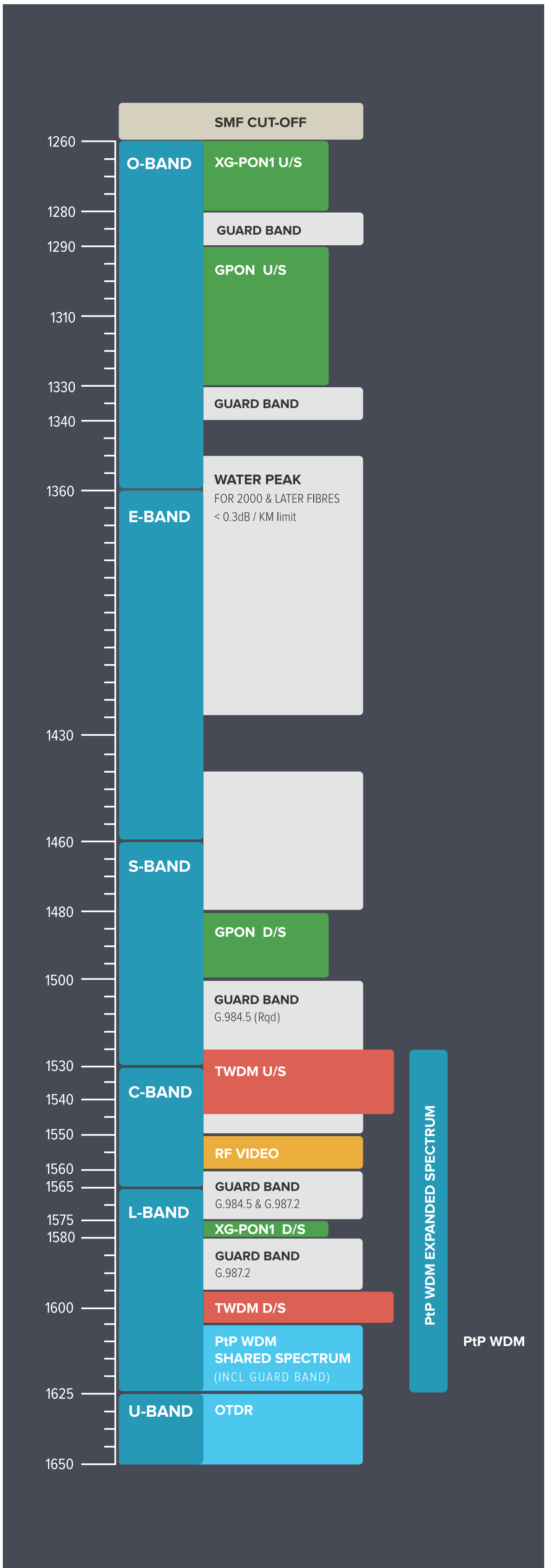

FIGURE 1 PON spectrum

- ITU-T G.989- contains the common definitions, acronyms, abbreviations and conventions of the G.989 series of Recommendations.

This paper is organized as follows: Section 2 presents the main requirements and drivers for NG-PON2. Section 3 explains the basic functionalities of NG-PON2 and continues into section 4, with TWDM PON main advantages. In Section 5 the TWDM PON development scenarios are discussed. In Section 6 and 7 the NG-PON2 optics are discussed. Section 8 concludes the paper.

Requirements and Drivers for NG-PON2

NG-PON2 main target requirements are the increase of aggregate capacity per Optical Line Terminal (OLT) PON port, a sustainable bandwidth on any Optical Network Unit (ONU) at downstream of 1Gbit/s and upstream of 0.5 to 1 Gbits, support of 64 or more ONUs per port, be compatible with legacy PON infrastructure, a 40 km differential reach and a smooth migration, i.e., legacy PON coexistence (GPON and/or XG-PON1), support for multiple applications on the same Optical Distribution Network (ODN) (residential, business, backhaul), embedded test and diagnostics capabilities and PON resilience, including dual parenting [18].

TWDM PON was selected as the primary technology solution for NG-PON2 (in April 2012). This decision was based on considerations of system cost, technology maturity, loss budget, complexity and power consumption.

There are several applications driving the demand for next generation PONs, namely:

- FTTB for multi-dwelling units;
- Enterprises;
- Mobile Backhaul;
- Fronthaul;
- Cloud-RAN.

Nowadays, content presents itself as the main driver for the high access bitrate requirements and it is more than the usual streaming to which we are used to, such as linear TV and video on demand.

Video content is also found in examples such as video surveillance, remote health care, video file transfer / data burst, etc.

Residential was the primary focus but mobile, business and M2M are demanding more and more content capacity.

As a consequence, CSPs need to prepare the access network for the future, which includes serving several segments and different backhaul features. It can thus be concluded that future access networks will be a truly multi-service solution.

The "cloud opportunity" is also a very important driver to evolve to NG-PON2 because:

- Software packages must be downloaded from data centres;
- Personal data is nowadays stored in data centres;
- Very high upload and download speeds are required as well as symmetry and low latencies.

Next Generation PONs will be a significant asset to promote successful cloud delivery.

What is NG-PON2

NG-PON2 is a 40 Gbit/s Capable Multi-Wavelength PON system that can grow up to 80 Gbit/s. It has 3 types of channel rates: basic rate 10/2.5 Gbit/s or optionally 10/10 Gbit/s and 2.5/2.5 Gbit/s. ONUs are colourless and can tune to any assigned channel [18 to 21].

In Figure 2 it is possible to find the basic NG-PON2 system.

The downstream TWDM channels, in L band, 1596-1603 nm, fit between XG-PON1 downstream and OTDR monitoring band. This enables simultaneous coexistence with legacy PON and 1550 nm RF video.

In upstream, the TWDM channels work in C band, 1524-1544 nm (wide band), 1528-1540 nm (reduced band), 1532-1540 nm (narrow band), above the WDM1r coexistence filter edge and below the 1550

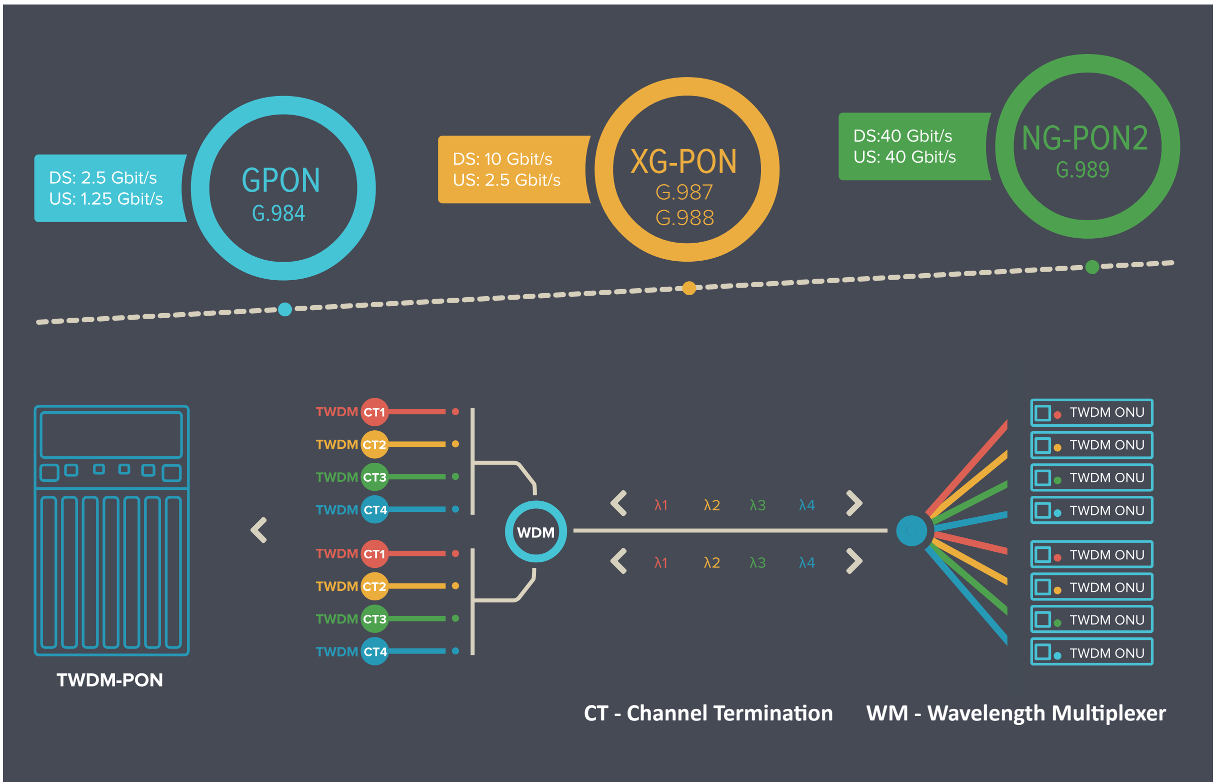

FIGURE 2 TWDM PON basic scenario

nm RF video band. The use of C-band allows lower cost ONUs [18 to 21].

Upstream wavelength options are driven by differing capabilities of the ONU transmitter to control its wavelength, i.e., wide band option is usable by wavelength set approach to channel control where a DFB laser may drift over a wide range, narrow band option may be most appropriate for temperature controlled lasers than can lock onto the assigned DWDM wavelength [18 to 21].

In Figure 3 is possible to see the wavelength tuning capabilities of the ONUs in the NG-PON2 system.

NG-PON2 is compatible with legacy loss budget classes, i.e., B+ and C+ of GPON and N1, N2, E1, E2 of XG-PON1.

It requires a minimum optical path loss of 14 dB and allows a differential reach of 40 km.

The optical path loss and fibre distance classes are presented in next tables [18 to 21].

class	N1	N2	E1	E2
Min loss (dB)	14 dB	16 dB	18 dB	20 dB
Max loss (dB)	29 dB	31 dB	33 dB	35 dB
Max. differential optical path loss	15 dB			

Fibre Distance Class	Minimum (km)	Maximum (km)
DD20	0	16 dB
DD40	0	31 dB

NG-PON2 has defined 3 classes of Tx/Rx wavelength channel tuning time and these classes were broadly defined based on known wavelength tunable technologies [18 to 21]:

- Class 1 components may include switched laser on arrays;
- Class 2 components could be based on electronically tuned lasers (DBR);
- Class 3 components could be thermally tuned DFBs.

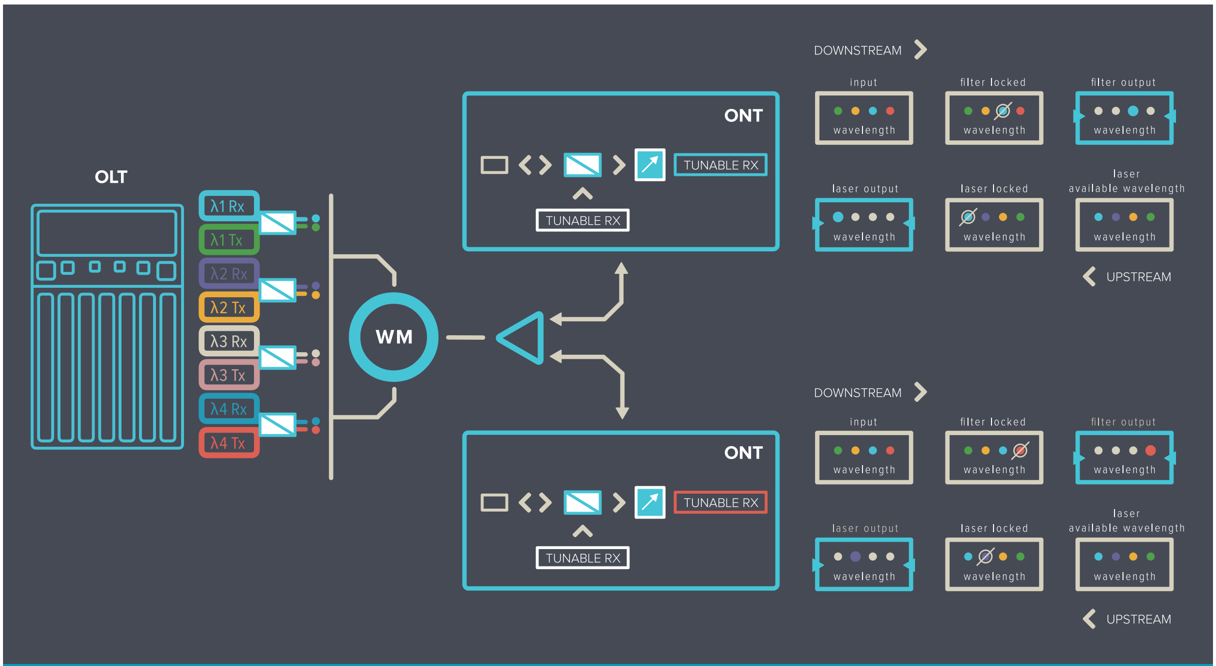

FIGURE 3 TWDM PON Wavelength tuning

Class 1	< 10 us
Class 2	10 us to 25 ms
Class 3	25 ms to 1 s

Through wavelength agility TWDM PON allows enhanced network functionalities unavailable in previous generations of pure TDM PONs, namely [18 to 21]:

- Incremental bandwidth upgrade (pay-as-you-grow);
- Selective OLT port sleep for power saving during low traffic periods, i.e., during times of low traffic load all ONUs can retune to a common wavelength and allow OLT ports to be powered down;
- Resilience against OLT transceiver failures through ONU retuning, i.e., all ONUs can retune to a common standby or working wavelength under a fault condition to maintain a basic service until the fault is cleared;
- Fast, dynamic wavelength and timeslot assignment using DWBA (extra degree of freedom c.f. DBA today) to improve bandwidth utilization efficiency.

NG-PON2 transmission convergence layer has new capabilities supported by the protocol, as multiple wavelengths, TWDM and point-to-point channels. Communication starts with a single channel adding more channels later and distributed OLT Channel Terminations (CTs) which can drive a single fibre [18 to 21].

These new protocol functions allow [18 to 21]:

- Multiple wavelengths so protocol supports tuning;
- New identities to distinguish system and wavelength channel;
- New management protocol for PtP WDM and TWDM activation;
- Dealing with ONUs with uncalibrated lasers that must not be allowed to transmit in the wrong wavelength channel;
- Inter-channel messaging for some procedures over distributed OLT channel terminations;
- New rogue scenarios that can be detected and mitigated.

Regarding the tuning support, the ONU state machine covers activation and channel management. PLOAM messages control tuning and new ONU parameters were added for tuning time.

Identities for multiple wavelengths and distributed OLT CTs are taking into account [18 to 21] that:

- Each downstream channel wavelength advertises channel information including channel number and an identity of the PON system that owns the channel;
- OLT CT can feed back upstream channel identity to ONU;
- ONU can feed back the downstream channel and system identity it is receiving to OLT CT;
- Distributed OLT controls ONU ID uniqueness across all channels, PtP WDM and TWDM;
- To not limit a potential future extension, the protocol has code space for 16 wavelengths even though the physical layer specifies up to 8.

NG-PON2 has an inter-channel termination protocol. The OLT CTs are distributed so that some procedures require messages to be passed between OLT CTs [18 to 21]:

- Synchronizing OLT CT Quiet Windows;
- ONU tuning;
- ONU activation;
- Parking orphaned ONUs;
- ONUs connected to the wrong ODN;
- Guided hand-off of ONUs between OLT CTs;
- Rogue ONU Isolation.

NG-PON2 covers different protection scenarios and rogue behaviours of the ONU [18 to 21]:

- ONU transmitter hops to wrong upstream channel;
- ONU transmitter starts transmitting at wrong upstream wavelength;
- OLT CT transmits in the wrong downstream wavelength channel;
- Interference from coexisting devices, either faulty ones or due to spectral flexibility;
- Distributed OLT channel terminations can be used for protection, requiring inter-channel termination coordination.

TWDM PON major advantages

FTTH for everything

A major advantage of TWDM PON is its ability to support different types of subscribers and applications by using different wavelengths and different bitrates on those wavelengths. It can assign a single wavelength to a particular customer, such as a business, or to a particular application, such as mobile backhaul.

Legacy investment preservation

TWDM PON coexists with legacy PON systems. No changes are required to the ODN, i.e., fibres, splitters and cabinets, as so, GPON network investments are preserved. TWDM PON can be added over an existing GPON or XG-PON network: an existing GPON network can be upgraded gradually over time (pay-as-you-grow). An operator could deploy TWDM PON where it has identified new market opportunities, such as enterprise subscribers. It could use TWDM PON for internal support of fronthaul and backhaul needs. The service provider could also take the option to upgrade existing high-end residential customers to TWDM PON where it faces significant competition from other service providers promoting 1Gbit/s and beyond.

Pay-as-you-grow

Wavelengths can be added one by one, as needed, to support customer growth and high-bandwidth applications.

TWDM PON deployment scenarios

In NG-PON2, different wavelengths are used.

The downstream wavelengths are multiplexed at the OLT using a WM1 device. This device multiplexes the downstream L band wavelengths into a single port and *demultiplexes* the C band upstream signals from the ONUs forwarding them to each OLT CTs.

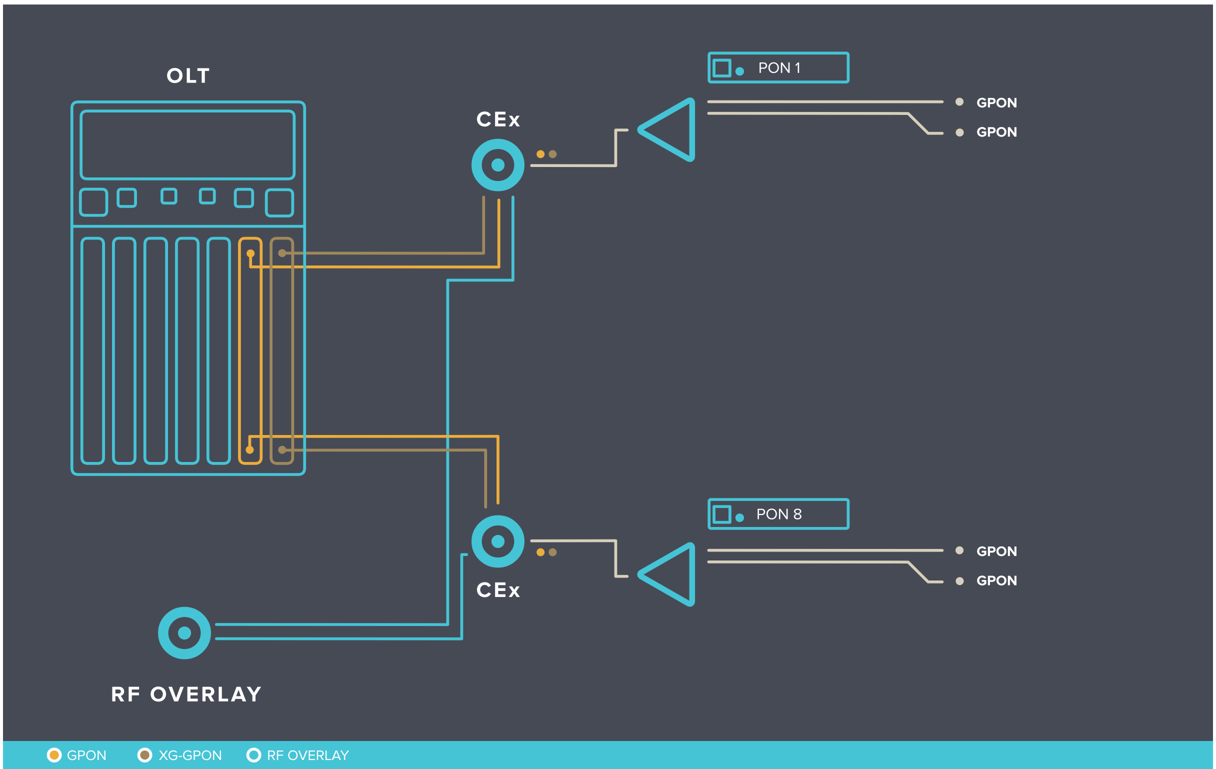

FIGURE 4 Coexistence scenario

In order to coexist with legacy PON networks a coexistence element is needed. This coexistence element can have different configurations depending on the technology that the service provider wants to deliver (Figure 4).

In the case of an existing GPON network, the most likely upgrade approach is to insert a TWDM card into the OLT platform. The TWDM PON line card can have the same wavelength on each port or different wavelengths on the various ports of the line card depending on subscriber, application and bandwidth projections. Several implementations of WM1 devices are possible, and they can be external to the TWDM card or integrated on it.

Three different arrangement options are possible:

- Option 1, one TWDM card per fibre with 4 wavelengths per PON card with WM1 integrated in a single output PON port;
- Option 2, one TWDM card per fibre with 4 wavelengths with external WM1 module;
- Option 3, based on the pay-as-you-grow approach, where the wavelengths are across TWDM cards with external WM1.

Next table provides a comparison from a service availability perspective of the different scenarios.

Scenario	Lambdas on a Single Card	Lambdas across cards
Wavelength Failure	Affected ONUs moved to other wavelength ports of the same card; All ONUs are down while the card is rebooting.	Affected ONUs moved to other linecards; Other ONUs on the card are tuned to other wavelength prior to card reboot.
Complete Line card Failure	Affected ONUs are down while card is not replaced.	Affected ONUs are moved to other linecards.
Software Upgrade	Affected ONUs are down during reboot and reactivation.	Affected ONUs are tuned in advance of upgrade.

The non-integrated modular approach provides several operational and economic advantages, such as:

- Straightforward support for pay-as-you-grow by addition of wavelengths;
- Easy bitrate configuration for each wavelength;
- Simple facilitation of wavelength unbundling per operator, which supports governmental requirements for fibre sharing or co-investment partnership business models.

From an operational perspective, to upgrade a network from the legacy GPON to NG-PON2, existing GPON subscribers that will remain on GPON must be briefly out of service during installation of the coexisting element (CEx), after which, the service is restored. Residential subscribers that will be remaining on GPON and not upgraded to TWDM PON will experience a brief service outage (which can be planned during low-usage hours), but only when the CEx is introduced. Wavelength additions or changes will not impact existing subscribers except those being upgraded to new wavelengths.

It should be noted that the same scenario described here would also apply in the case of XG-PON upgrades, since a CEx would also have to be introduced to enable the combination of GPON and XG-PON.

Figure 5 to Figure 8 present coexistence and pay-as-you-grow scenario.

NG-PON2 OLT and ONU optics

The current NG-PON2 OLT optics are based on Bi-directional Optical Subassemblies (BOSAs) integrated on XFP form factor. They are suitable for TWDM PON, 10Gbit/s downstream, 2.5 Gbit/s or 10 Gbit/s upstream. The XFP integrates an electro-absorption integrated laser diode with semiconductor optical amplifier (SOA) in order

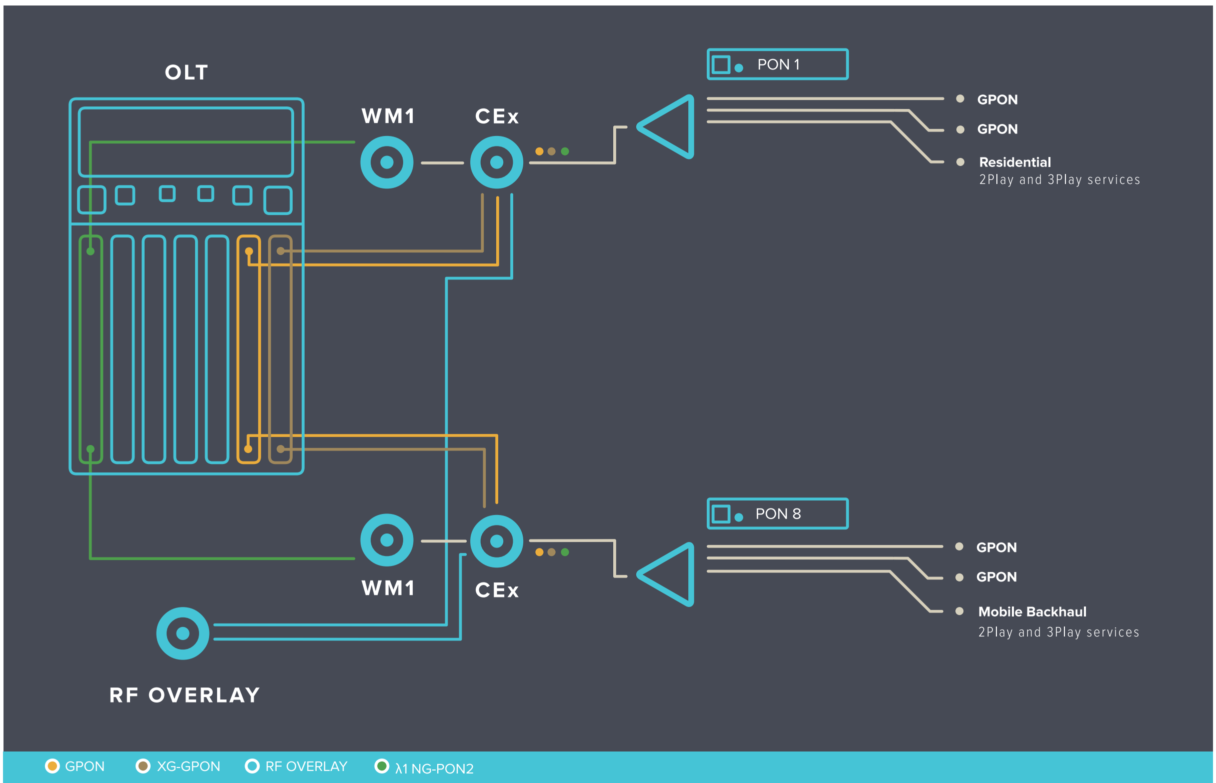

FIGURE 5 Pay-as-you-grow. 1st phase

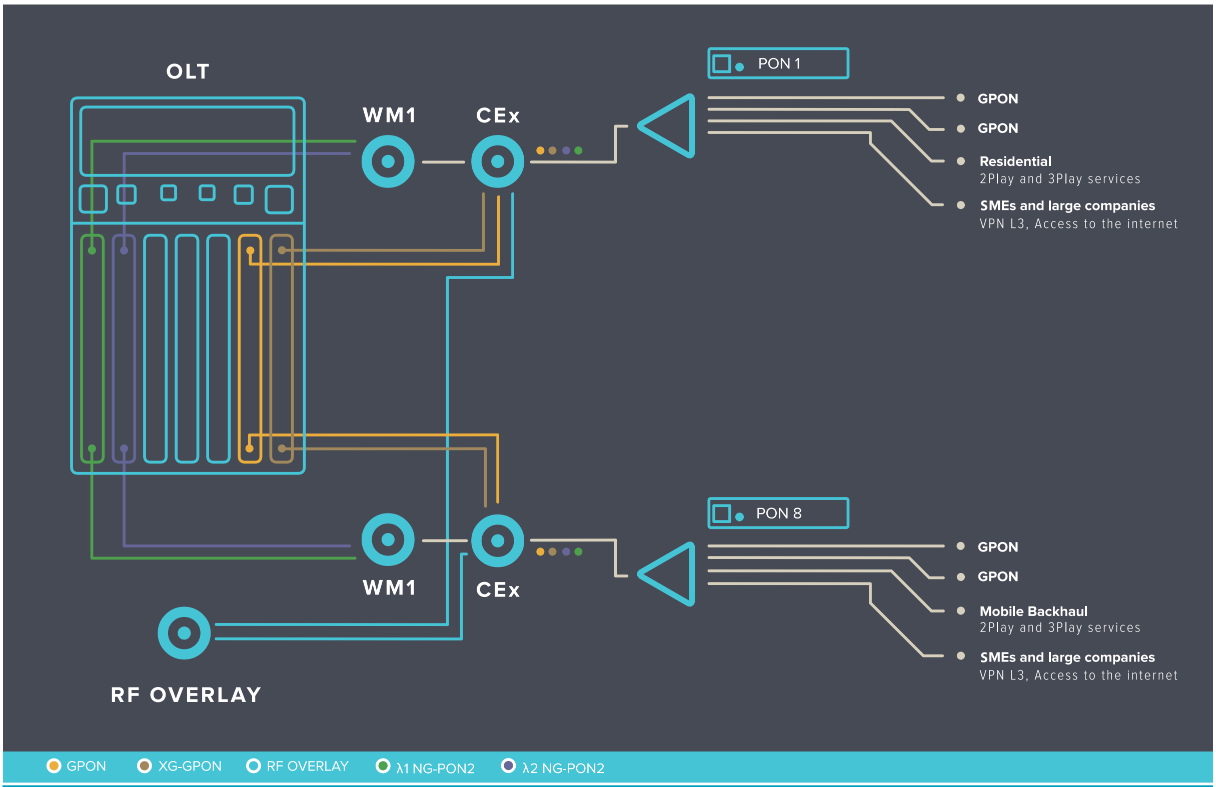

FIGURE 6 Pay-as-you-grow. 2nd phase

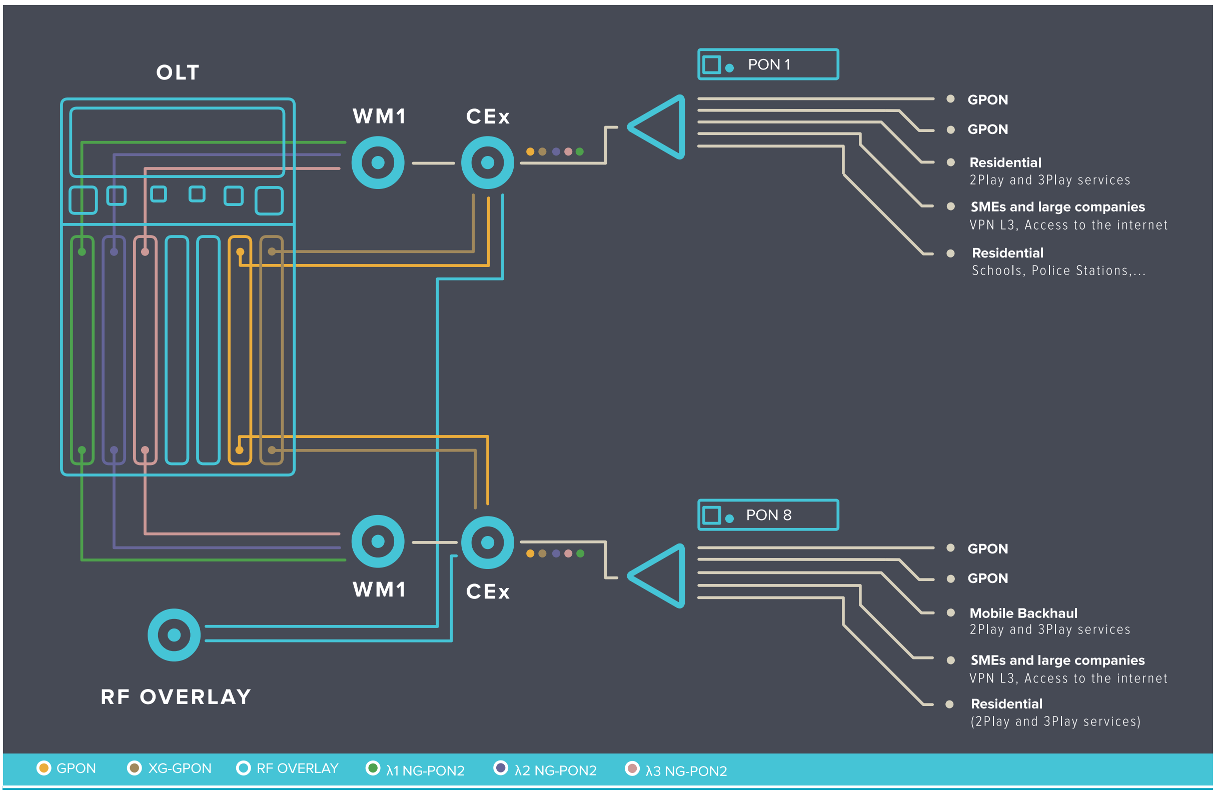

FIGURE 7 Pay-as-you-grow. 3rd phase

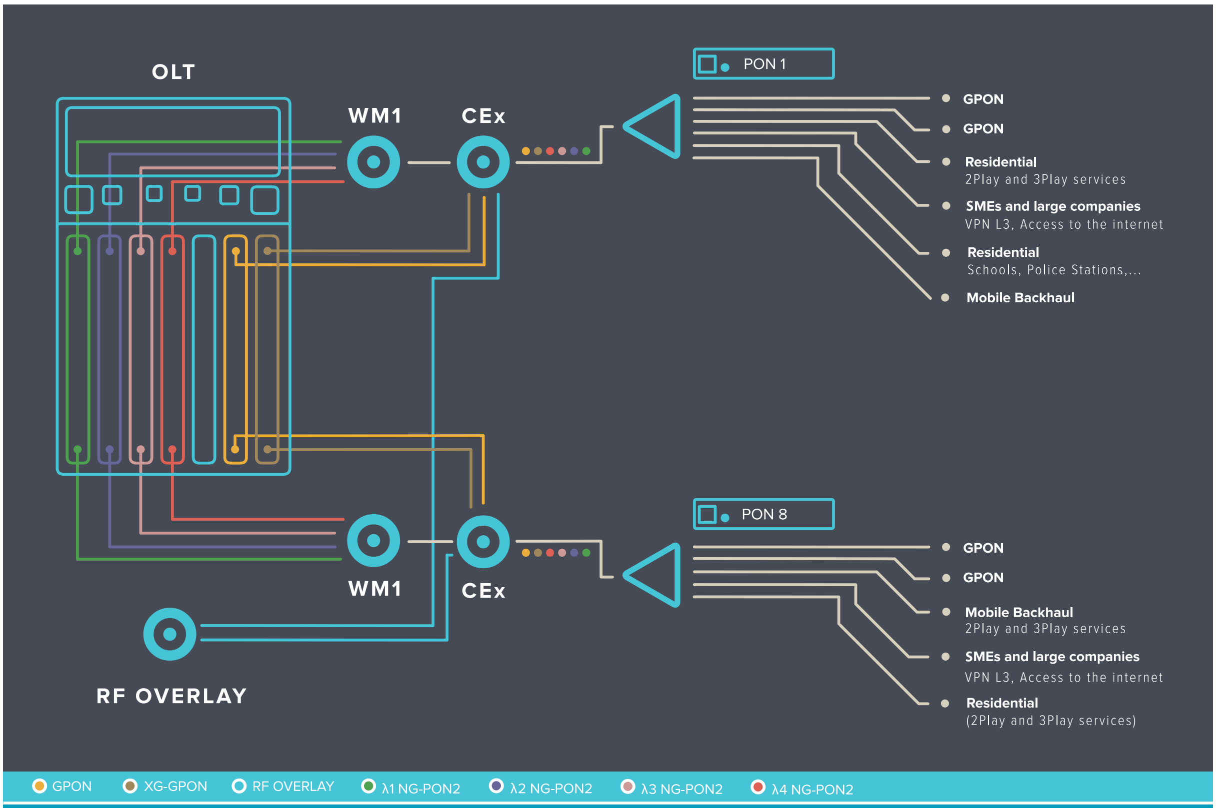

FIGURE 8 Pay-as-you-grow. 4th phase

to reach the type A N1 class NG-PON2 optical requirements (+5~+9 dBm at the output of the XFP). A high sensitivity burst mode avalanche photodiode (APD), a pre-Amplifier and a limiting amplifier as receiver components are mounted into a package integrated in single mode fibre-stub with a sensitivity equal to-28.5 dBm at 10 Gbit/s; and-32 dBm at 2.5 Gbit/s).

The NG-PON2 ONU optics are based on BOSA on board. The BOSA integrates a burst mode tunable distributed feedback lasers (DFB) at 10 Gbit/s or 2.5 Gbit/s emitting high optical power in a N1 type A link, +4~9 dBm capable of doing 4 upstream channels.

On the receiver side, a high sensitivity 4 channels tunable APD a pre-Amplifier and a limiting amplifier are able to operate at a sensitivity of-28 dBm at 10 Gbit/s.

Closing the gap between Photonic Integrated circuits and PONs

The road to commercial Photonic Integrated Circuits

It was back in 1965 that Gordon E. Moore predicted the number of transistors inside an electronic integrated circuit would double every year. Today, 50 years later, we face a technological revolution where electronic devices surround us and we cannot imagine our lives without them. Integration was the key to success and allowed mankind to develop computers, specific application hardware for numerous applications and small devices (yet very powerful) like our smartphones. Integration brought compactness, ease of fabrication and cost accessible technologies meaning success in the electronic industry. Affordable, efficient integration is now starting to occur in photonics. Photonic Integrated Circuits (PICs) are the dual of electronic integrated circuits in the optical domain, as they perform integrated computing and signal processing functions that are based on light. Their main application is in fibre-optic communications but they can also be used in biomedicine, photonic computing and sensing devices.

Photonic integration emerged at the end of the 1960s [5]. By that time, it was expected and believed that photonic integration would take a similar development path as electronic integration. However it took almost four decades until the first complex PIC (more than just a few components) entered the market [6]. This was due mainly to two reasons. In one hand in the 1990s a shift on technology focus from 'technology push' to 'market pull' delayed the funding for photonic integration. On the other hand there was a failure on the coordination of technology development which led to high costs and several different technologies developed [7]. An early example of a PIC circuit was reported in the Applied Physics Letter on WDM light sources [8] which integrated three lasers, a power combiner and a booster amplifier. In 1991, Duthie [9] reported a 4x4 cross-bar switch and in 1994 Kaiser [10] produced a polarization diversity heterodyne receiver. The era of high-complexity PICs started in 1988 when Smit published the invention of the Arrayed Waveguide Grating [11]. Almost 20 years after, Infinera launched the first truly complex PIC in a commercial telecommunications system [12].

Research context, objectives and work plan

PICs, as stated above, can be used in countless applications however their fast development was due to the systems based on fibre optics communications. In the telecommunications industry the goal is to reach as many clients as possible with the lowest cost while providing the best service. The demand for bandwidth and number of users has been increasing constantly and the only technology that can keep up with these demands is the fibre optic communication because it is the only technology that can supply high data rates and reach large distances. PONs are networks that do not need amplification or regeneration of the signal from the central office to the users, which due to fibre properties can extend up to 40 km. Although it was a success, the bitrates that are provided do not take full advantage of the fibre capabilities and thus new standards such as NG-PON2 are now ready to be deployed. It can quadruple the bandwidth and uses the spectrum more efficiently. With these improvements, the complexity of the networks and the components also increases, which translates in more difficulties controlling the components, more room needed and more power consumption. In order to tackle the problems that arise with this evolution, PICs are an inevitable evolution. With the integrated version of the discrete implementations, the control complexity, the floor space and power consumption will decrease. Integration also means the decrease of costs which will make these networks more affordable. However research still needs to take place to turn PICs competitive.

To increase competitiveness of PICs, several projects were developed so that generic foundry models were created and different users can contribute to the design of a single wafer in the same process, those are the so-called Multi Project Wafer (MPW) run [6] [7]. The cost of a MPW run when compared with a normal commercial run can be one to two orders of magnitude cheaper leveraging the increase of research in the field. To promote and streamline these processes, consortiums like Jeppix [13] were created. Jeppix offers contact with foundries and design houses of the different technologies as well as organizes the schedules of the different MPWs. The idea of generic integration is that the user is agnostic to the way the foundry implements the technology and sees the components as building blocks which means that if different foundries have the same building block (e.g. amplifier) it is very easy to translate from one foundry to another. Currently, there are three main platforms to develop PICs: Silicon (Si), Indium Phosphide (InP) and TriPleX (combination of Silicon Nitride – Si3N4 and Silicon Dioxide – SiO2). Each platform has different characteristics and main applications; the major difference is that with Indium Phosphide it is possible to have active elements (e.g. lasers) that are needed for the telecommunications applications.

Altice Labs and Instituto de Telecomunicações team started to work in the field of PICs two years ago within the scope of the NG-PON2 project. A complex PIC, able to transmit and receive NG-PON2 signals, with more than 40 components inside was designed, produced and tested [14] (see Figure 9 and Figure 10).

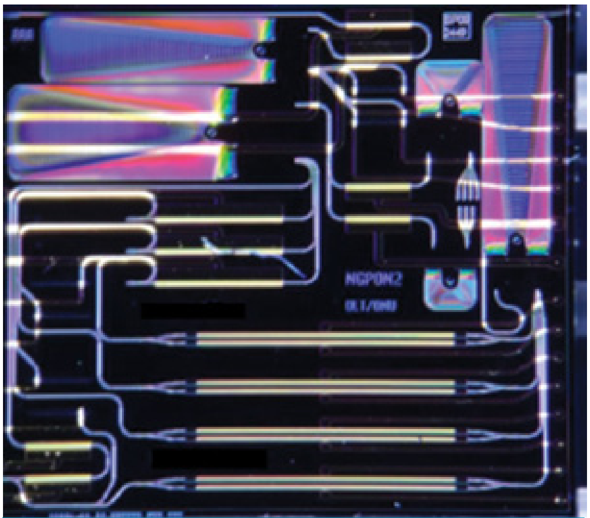

FIGURE 9 PIC for NG-PON2. Chip received from the foundry

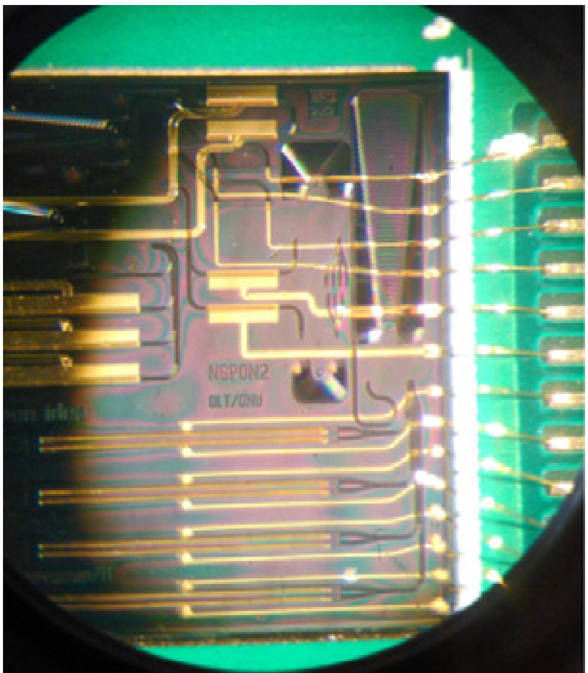

FIGURE 10 PIC for NG-PON2. Detail of packaging with wire bonding for the electronic circuit

For non-standardized networks that used advanced modulation formats and coherent detection an integrated circuit was also designed [15]. This last case was designed to operate in 100 Gigabit/s networks. Outside the scope of telecommunications, a PIC for optical signal processing was also designed and produced at Instituto de Telecomunicações and produced [16]. All this background gave the team experience with most of the foundries as well as an insight in the processes.

Despite the achievements that were obtained so far in the design and testing of PICs, there are still major difficulties in the process which are mainly due to the novelty of the technology. At this point in time, all the members of the consortiums like Jeppix are putting their effort to improve the platforms and links among them; this is also part of the research phase: providing feedback from the tests in order to help improving the results. One of the problems that the researchers currently face when designing for an MPW is the lack of information about the building blocks that the foundry provides. Despite the fact that there are design manuals with information about the process and building blocks, the information is not enough to perform the most accurate simulations before the design and production, which can lead to errors that only in a later stage will be found. To solve this, optical simulations software are starting to integrate the models from the foundries and the foundries encourage the users to develop their own blocks of simulations' [17].

With the first steps already taken towards a mature process on design and production of PICs this is an essential area to keep up with the evolutions that occur on the field and properly contribute to this topic. In 2016, the first commercial solutions of NG-PON2 are planned to be deployed and they will be based on discrete components. Their scalability depends on the appearance of integrated solutions and thus it is important that PIC research focus on this trend. As the demand for PIC production increases, foundries are also providing more options for MPW runs which will ease the whole process.

Optical communications and PIC are fields of science and technology under constant and fast development. New standards are created every year and the PIC technologies are still in development. In order to follow the trends, focus and investment must be conjugated in this field. This is the only way to guarantee growing and novelty in the fast changing world of innovation.

The first NG-PON2 photonic integrated circuit prototype totally compliant with ITU-T G.989 is expected in the 2nd quarter of 2016 and its mass production is foreseen for the 4th quarter of 2016.

Conclusions

TWDM PON will certainly become the network access technology that supports the widest range of subscribers and applications, leading to faster network monetization. The table below provides a summary of the advantages and disadvantages of TWDM PON versus GPON.

	GPON	TWDM PON
Flexible growth – pay-as-you-grow	+	+++
Ability to support MBH	+	+++
Ability to support mobile fronthaul	-	+++
Ability to support enterprise services	-	+++
Overall fixed–mobile convergence support	-	+++
Ecosystem status	+++	++
Commodity priced equipment	+++	++

TWDM PON's architecture enables the assignment of wavelengths to specific customers or applications. The wavelength design also enables a pay-as-you-grow development. While GPON can also support MBH, TWDM PON can provide more bandwidth, thereby supporting more MBH traffic. The assignment of wavelengths enables an easier support of enterprise services. In addition TWDM PON was designed to allow point-to-point overlays for the support of fronthaul.

In order to reach the full potential of the NG-PON2 in terms of density and capacity, technologic and industrial advances and innovations are undergoing, namely in the field of high integration PICs.

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03

NFV & SDN INNOVATION STRATEGY AT ALTICE LABS

The NFV and SDN concepts are here to stay and significantly impact the communications industry, both in the operational and business dimensions. The adoption of these concepts will provide a significant evolution of the network, bringing with it a set of innovation opportunities and challenges.

Altice Labs is fully aware of this network paradigm evolution in all its technical dimensions and has been exploring these topics mainly through international collaborative RDI projects since 2010. Furthermore, in order to apply the obtained knowledge in the company business units, a process based on short-term Proofs-of-Concept, internally named as planned innovation, has been running in parallel with the RDI projects to evolve our products and solutions towards this new network paradigm. This article focuses on the description of the planned innovation activities, which were recently completed, in particular the virtual Home Gateway PoC, closing the 2010 – 2015 cycle of exploratory innovation through RDI projects, as well as on the description of the recently launched exploratory and planned innovation activities in which Altice Labs is involved towards the challenging 2020: the '5G'.

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5G, IMT2020, LTE, NFV, SDN, RAT, LTE, 3GPP, ITU

Introduction

The urge to increase significantly the operational efficiency in service delivery and the agility to create and manage new services lead the traditional communication service providers to begin the adoption of the cloud computing paradigm as a foundation to its service infrastructure [1]. In this context, standardization bodies like ETSI (European Telecommunications Standards Institute) [2] and ONF (Open Networking Foundation) [3] started to define new network and service architectures, using cloud computing to promote the evolution from traditional networks (built over traditional network appliances providing network functions over dedicated specialized hardware – *network ossification*), to new generation networks where the trend is to decouple network functions (software) from the supporting infrastructure and to deploy those functions in geographically distributed telecom data centres (*living networks*). It is the rise of NFV (Network Functions Virtualization) and SDN (Software Defined Networks).

NFV Overview

NFV aims to transform network architectures by implementing network functions in software that can run on common purpose virtualized infrastructure built on top of industry standard hardware. Benefiting from IT Cloud Management evolution, especially the evolution in VIM (Virtual Infrastructure Management) platforms (e.g., OpenStack), the evolution towards an NFV enabled service architecture will lead to the creation of a new service environment, built over a mesh of micro data centres, the new service platforms. These platforms, including advanced virtual infrastructure management platforms, will provide enhanced agility for new services creation and management, being also a contributor for costs reduction due to use of common purpose hardware.

At present time, the creation of a new service requires the setup of an engineering project to coordinate and govern the configuration of several distinct network elements (appliances) and the creation of specific service logic in proprietary service delivery and control platforms. Additionaly, the management of this distributed service intelligence over several network appliances requires the setup of complex management processes. All this together compromises the agility to launch new services.

The migration of service logic to software functions hosted by data centres, the VNF's (Virtual Network Function), will allow the service provider to reduce significantly the operational impact of launching new services. At first, developing a set of software components is, in principle, much more agile and fast than to create new functions in several network appliances (or to deploy new appliances altogether) and additionally will bring much more flexibility to create new functions. Second, but not least important, the virtual infrastructure management capabilities provided by the new service platforms will support through API's (Application Programming Interface) full automated management of the VNFs. This will not only contribute to implement automated management processes (deployment, provisioning, supervision, etc.) but will provide new tools that will streamline the implementation of new service management scenarios like service personalization, service optimization (e.g., service load dynamic adaptation, dynamic QoS management) and service healing (e.g., service replacement and /or reconfiguration to bypass anomalies).

On the other hand, this evolution movement will impose new requirements on the traditional operations management processes, creating the need to explicitly manage new service elements like virtual compute, virtual networking and virtual network functions.

Architectural details about NFV are given in NFV/SDN Architecture Standard Foundations section.

SDN Overview

SDN is another key emerging concept for future networks. SDN assumes the segregation of the Network Functions (NFs) control and data planes, being NF data forwarding process fully commanded by control-level applications through programmatic means (high-level APIs) abstracting the specific network details [4]. This way, the control intelligence resides on upper layer applications, whereas the packet forwarding procedures are kept on the data plane network elements.

SDN stimulate the centralization of control functions in SDN Control Applications, creating a new paradigm for data plane control. Due to the holistic network view, this new paradigm enables the enforcement of control decisions considering the end-2-end state of the controlled network infrastructure. This approach will bring additional flexibility and agility in network control when compared to traditional networks. Centralized SDN Control Applications also act as a central point for the data plane functions configuration, exposing API's for northbound clients such as the operational management processes, contributing in this sense to facilitate end-2-end service management over the controlled domains.

Architectural details about SDN are given in NFV/SDN Architecture Standard Foundations section.

NFV + SDN Key Advantages

NFV and SDN are not dependent on each other and can exist separately. However, the evolution to a virtualized network architecture (NFV) and the implementation of new service scenarios (e.g., personalization, optimization, healing) make SDN an indispensable partner to NFV.

The new service scenarios rely on dynamic and automated virtual network functions reconfiguration, scalability, and even migration between several service provider data centres.

Being a major factor for service enhancement, the network functions lifecycle dynamicity requires the ability to automatically reconfigure the connectivity topology linking the network functions. SDN responds to this challenge.

Additionaly, service personalization, one of the major service enhancements tipically associated with NFV is in fact leveraged on the top of the capability to dynamically and automatically create specific chains of network functions to associate to a specific user service context, a capability powered by SDN.

Architectural details about the combination of NFV and SDN are given in NFV/SDN Architecture Standard Foundations section.

State of the Art on NFV and SDN adoption

This movement is still in its early stages. Network solution providers do not have mature NFV/SDN value propositions and service providers are conducting some "proof–of-concept" (POC) initiatives in order to evaluate NFV/SDN technology maturity and gain insight to define their own NFV/SDN strategy. Altice Labs has been participating in several international RDI (Research, Development and Innovation) projects in the NFV/SDN domains, commonly refered as exploratory innovation, as well as conducting internal PoCs, also known as planned innovation, aiming to evolve our products and solutions towards this new network paradigm and create the necessary knowledge and insight towards an NFV/SDN enabled Service Provider.

This article is organized as follows: NFV/SDN Architecture Standard Foundations section provides the NFV and SDN architectural details. Thereafter, NFV/SDN Innovation Background section provides a short summary about the exploratory innovation background and provides detailed information about the internal PoCs that have been recently completed – virtual Home Gateway (vHGW) PoC, closing the 2010 – 2015 cycle of RDI projects. NFV/SDN Innovation Foreground dives into the future and describes the recently launched exploratory innovation activities (i. Edge computing, ii. Autonomic network management and iii. Network service agility through DevOps), as well as the planned innovation activities in which Altice Labs is involved in the NFV/SDN domains towards 2020. The article closes with a set of conclusions.

NFV/SDN Architecture Foundations

NFV Architecture Basics

The first basic step towards NFV is the "cloudification" of Network Functions creating what is so called Virtualized Network Functions. For this, the NF has to be implemented apart from specialized hardware, and be able to run on top of a cloud platform, using

COTS (Commercial Off The Shelf) standard hardware, as shown in Figure 1.

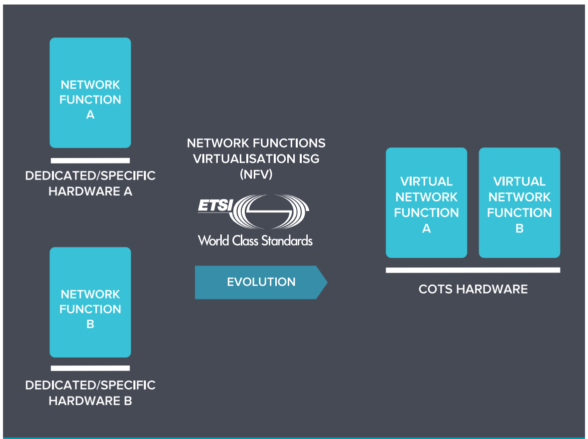

FIGURE 1 NF "Cloudification" Concept

Typical examples of VNFs are common routers or firewalls, but it can also be applied to mobile or fixed components, such as Packet Gateways (P-GWs), eNode-Bs (eNBs), Optical Line Terminators (OLTs) or even an entire architecture, like an Evolved Packet Core (EPC).

The "cloudification" of NFs can be further enhanced by using a complete management environment. In such case, the platform manages the entire lifecycle of VNFs, performing not just the deployment and disposal, but also managing the runtime operations, by migrating or scaling in/out VNFs, according to the function load requirements, leading to an efficient use of resources. Such platform is also able to orchestrate combinations of VNFs according to a given Forwarding Graph (FG), in order to create complex Network Services (NS).

Figure 2 depicts a simplified version of the full ETSI NFV architecture [2]. On the left side, it is shown the execution and control (runtime) operations, while the right side shows management and orchestration. The bottom left shows the "Virtual Infrastructure" (Network Functions Virtualization Infrastructure – NFVI), which comprises hardware resources (COTS), the virtualization layer, (e.g. KVM, VMware hypervisors) and the virtual resources (e.g. Virtual Machines - VMs, Virtual LANs - VLANs). VNFs run on top of one or multiple VMs and use network resources. On the top left, the "Management Support Services" (OSSs/BSSs) interact with the "Management and Orchestration" (right side) and with the VNFs. On the bottom right, the VIM (e.g. OpenStack) interacts with the "Virtualized Infrastructure" (hypervisor) to manage resources. On the top right, the "Orchestrator and VNF Management" module manages the complete lifecycle of VNFs and orchestrate NSs.

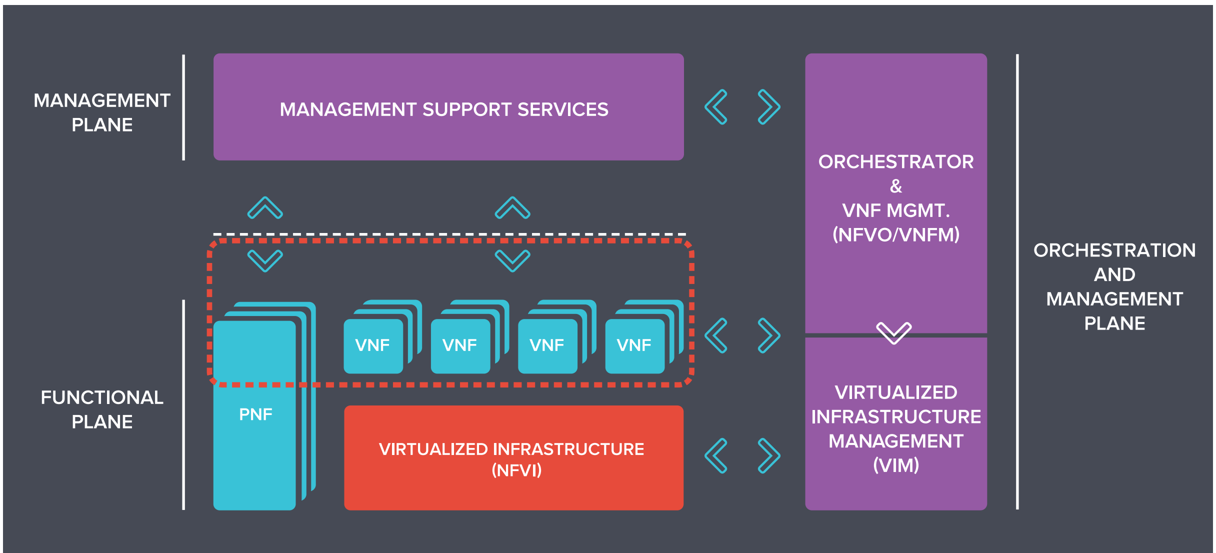

FIGURE 2 ETSI NFV Architecture

SDN Architecture Basics

The SDN concept, promoted by ONF [3], intends to clearly split the network into 3 parts: the user-data plane, the controller plane and the application plane. The user-data plane is composed by basic switching Network Elements (NEs), responsible to forward the user traffic according to basic commands received from the north (controller) interface. The controller plane is an intermediate layer composed by SDN controllers, which provide basic commands to the south (user-data) and high-level APIs to the north (application plane). The application plane use high-level APIs provided by the controller plane to programme the network, simplifying and speeding up the creation of new services.

Figure 3 depicts the basic SDN concept, assuming in this case as the starting point an already virtualized network. Overall, the NEs forwarding process is fully commanded by the applications, which use high-level APIs provided by the SDN controllers. In turn, the SDN controllers interact with the NEs through low-level southbound APIs to enforce basic forwarding rules, using tools like Command Line Interface (CLI), Netconf (Network Configuration) or the most recent OpenFlow. The SDN controllers provide APIs which abstract the programmer from the network details, making simpler the network service creation. This is one of the key advantages of the SDN model.

NFV + SDN Architecture Combination

As NFV and SDN come from different standard organizations, at the time of writing this article, none of them had integrated the concepts into a single architecture. For this reason, herein we try

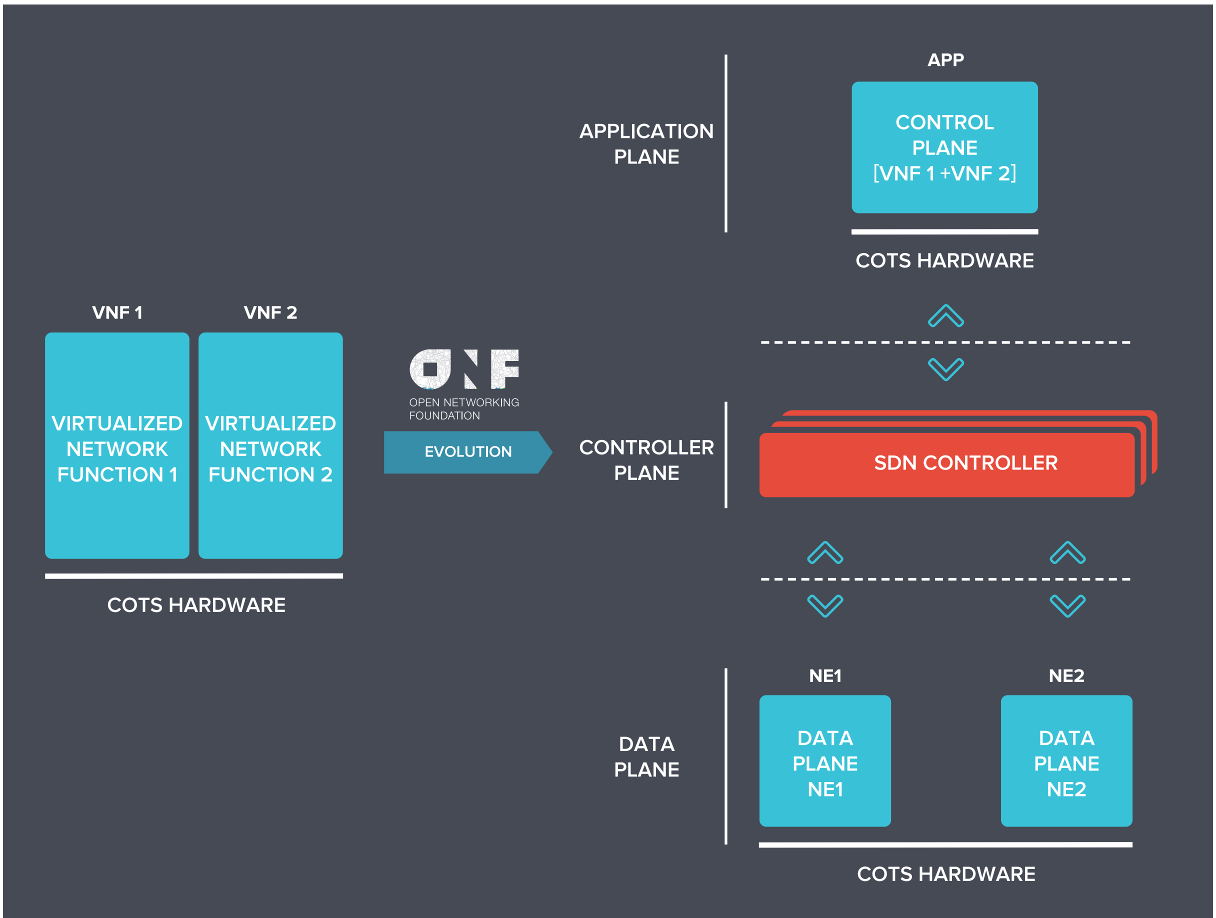

FIGURE 3 SDN concept

to provide our vision on a possible NFV and SDN integration, taking the ETSI NFV architecture as a starting point and introducing the SDN paradigm. Firstly, the NFV architecture, depicted in Figure 2, shows the VNFs (on the left part). Next, according to the SDN model, depicted in Figure 3, the monolithic VNF is separated into three parts (in this example a single control plane is used for both VNFs, whereas the data planes are kept separated). Finally, integrating both concepts, results in the architecture depicted in Figure 4 [5].

This integration is compliant with the architecture defined by the ETSI NFV. This integration requires a slightly different naming convention, as some pieces may have different names, depending on the (NFV or SDN) perspective. In order to consider "legacy" components (non-NFV, non-SDN), we kept the physical NFs in the leftmost side of the dashed red square of the architecture, meaning that we may have **Physical Network Functions** (PNF), which do not apply for the NFV and SDN models. In the same way, one may have VNFs, but with no SDN capabilities. For those, the **Virtual Network Functions** naming is kept, as shown in rightmost side of the dashed red square. In the middle, all NFV components are SDN-aware, meaning that they are split into three layers. In the bottom layer (user-data plane), one may have physical or virtualized Network Elements, which can be **Physical Network Elements** (PNEs) or **Virtual Network Elements** (VNEs), respectively. In this case, the names were chosen from the SDN world, since they describe the roles they are performing more clearly. On the controller layer there are the **SDN Controllers (SDN Ctrl)**, assuming here that we may have multiple controllers at different levels. Finally, for the upper part, the application layer, we used the naming **SDN Application** (SDN App). In this case, it is not specified whether it is virtual or physical, as it can be both. However, this layer will be mostly populated by virtual applications, considering that here there are no legacy boxes and hardware specific solutions will be declining.

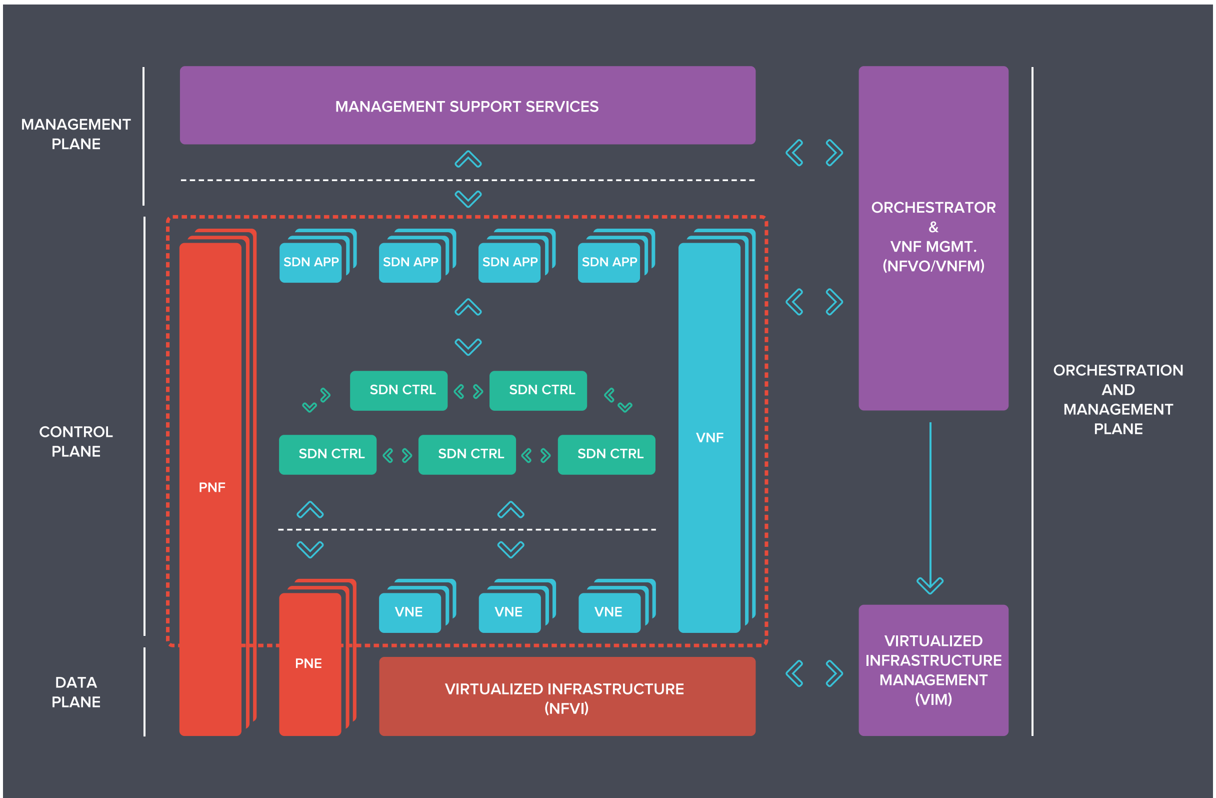

FIGURE 4 NFV and SDN combined architecture

NFV/SDN Innovation Background

This section will briefly outline the RDI activities carried out in the NFV/SDN domains in which Altice Labs has been involved in the last years, as well as describe the recently completed internal vHGW PoC.

Exploratory Innovation

Altice Labs has been studying the network virtualization concept since the end of last decade through international collaborative RDI projects, mostly funded by the European Comission (EC).

Around 2008 we started to study the network sharing concept, nowadays known as network slices, on top of a common infrastructure through network virtualization. Each network is tailored to a particular user or application requirements and takes into account the characteristics of the available networking resources. This work was mainly carried out in the EU-FP7 Programme 4WARD RDI project [6].

In 2010 we started studying and prototyping the coexistence of legacy and new networks via virtualization of resources and self-management, fully integrating networking with cloud computing to produce the "cloud networking" concept. This activity was achieved through the EU-FP7 SAIL RDI project [7].

In 2012, and still prior to the ETSI NFV movement, Altice Labs studied the migration from current mobile networks towards a fully cloud-based mobile communications system, extending the cloud computing concept to support on-demand and elastic provisioning of novel mobile services (e.g. vRAN, vEPC, vIMS). This work was mostly carried out in the EU-FP7 MCN RDI project [8].

Finally, in 2014, and fully aligned with the ETSI NFV evolution, Altice Labs started to design and implement an orchestration platform for the automated provision, configuration and monitoring of network functions (e.g. vHGW, vSBC, vDPI) over virtualized Network/IT infrastructures, as well as exploiting and extending SDN platforms for efficient management of the network infrastructure. This RDI activity is still running within the FP7 T-NOVA project [9].

Planned Innovation: the vHGW PoC

ETSI has identified a number of use cases that unveil the potential of NFV together with SDN [10] and has been supporting PoC proposed by the Industry [11]. The reasons for implementing our own PoC are explained below, but the choice of a specific scenario depended on:

- What use case can we explore in order to:

a) Learn as much as possible about SDN and NFV;

b) Involve as many Business Units as possible in the PoC;

c) Get the attention of the organization … while investing effort into something that is neither a product nor an research project?

- How can we actually do it?

Motivation

Figure 5 illustrates the rationale that led to the choice of a vHGW as the PoC scenario:

1. Former involvement in exploratory projects [8] [9] showed that NFV and SDN were promising technologies. Competences had been acquired and industry trends called for further trials and validation;
1. The acquired knowledge on SDN and NFV showed that it will bear strong impact to areas of interest to Altice Labs Business Units, namely on products and solutions in the areas of Network Systems, Services, Service Control and OSS;
1. Residential Business was identified as a particularly challenging (and visible) area:
    - High operational costs (e.g. truck rolls) can be cut if the complexity of the home scenario is reduced and if the operator gains more visibility into the home network;
    - The deployment of new, differentiating, services to the residential Internet access clients is strongly boosted by SDN and NFV;
    - High cost of the access network and

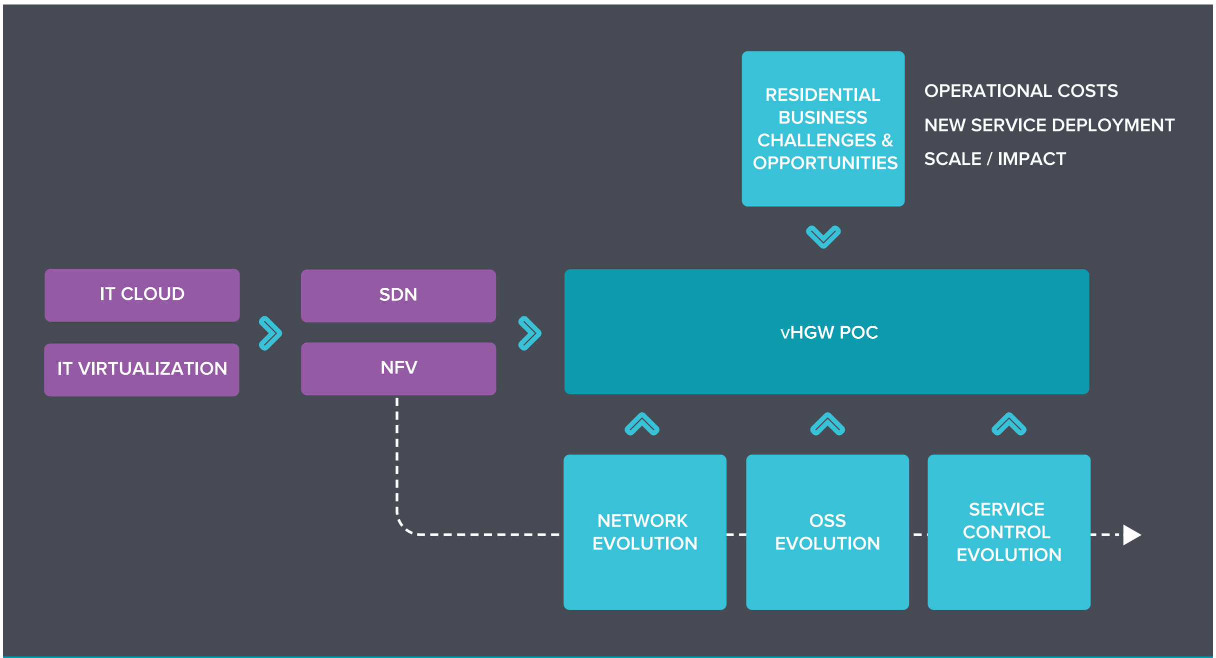

FIGURE 5 vHGW PoC rationale

home infrastructure guarantees that a PoC related to the possibility of saving money in this area gets the attention of the organization;

1. As a result of 1., 2., and 3., the idea of implementing a PoC that addressed the virtualization of the HGW came naturally, as a planned innovation project, building on the results of exploratory innovation projects and on the needs of the Business Units.

To keep the PoC within a feasible scope, the services evolution area has not been addressed at this stage. A particular service has been elected for the PoC: High Speed Internet (HSI).

As a result of all this, the PoC initial goal was fixed in setting up a scenario where specific HGW functions like Firewall or Parental Control could be run on a remote data centre and personalized using a common Self-Management Portal.

PoC Technical Goals

The overall scope of the PoC was limited, keeping a principle of short runs with visible results which were called “PoC Phases”, with limited and well defined scope:

Phase 1

- Extending the home network broadcast domain to the data centre;
- Implementing a virtual infrastructure in the data centre;
- Migrating HGW functions to the virtual infrastructure in the data centre;
- Implementing software defined service chains;
- Performing basic orchestration;
- Allowing basic self-management, with per device personalization (one device = one user);
- Implementing the mechanisms to support seamless session establishment and self-configuration activities.

Phase 2

- Enabling policy-driven service chaining;
- End-2-end service activation, encompassing integrated provisioning of physical network functions and of virtual network functions;
- Enhanced personalization. Per service per user configuration;
- A first approach to mobility across households.

Phase 3+

Further phases are described in the end of the next section.

PoC Technical Description

Herein the detailed technical aspects of each one of the PoC phases is described.

Phase 1

As a first approach to a PoC for a vHGW, a minimum scenario was established as illustrated in Figure 6.

Home Domain: To setup a home network domain, an Altice Labs ONT RGW (Optical Network Terminator Remote Gateway) was used. RGW functions like Routing, NAT (Network Address Translation) or Firewall were stripped out, and the equipment was left with a minimal set of capabilities, those related to the local Wi-Fi AP and the L3 functions needed to establish and keep a GRE (Generic Routing Encapsulation) tunnel to the data centre.

Data Centre PoP: A virtual infrastructure was built, relying on COTS Hardware and open-source software, namely:

- Hypervisor: Linux KVM (Kernel-based Virtual Machine);
- Switching: OVS (Open V Switch);
- SDN Controller: ODL (Open Day Light);
- Virtual Infrastructure Manager: OpenStack.

Adjustments were made to ODL to support the chaining of functions that were required.

A homebrew orchestrator with the NFVO role was adopted.

Two open-source, off the shelf functions were “elected” to be run on the PoP, on a per-household virtual environment, as VNFs:

- Firewall (Alpine Linux);
- Parental Control (DAN’s Guardian).

NAT and DHCP (Dynamic Host Configuration Protocol) for the home network were ran from OpenStack.

A self-management portal was built to support the demonstration of the PoC, featuring the personalization aspects that highlight the possibilities of the scenario.

Access Network and Transport: In a first approach, access network features were left out of the PoC. ONT/OLT/BNG configuration was statically prepared to setup a tunnel between the home domain and the data centre.

Service Control: Altice Labs AAA product was used as a combined DHCP+AAA server for authenticating, authorizing and managing IP addresses for the ONTs. Another instance of Altice Labs’ AAA was used as a

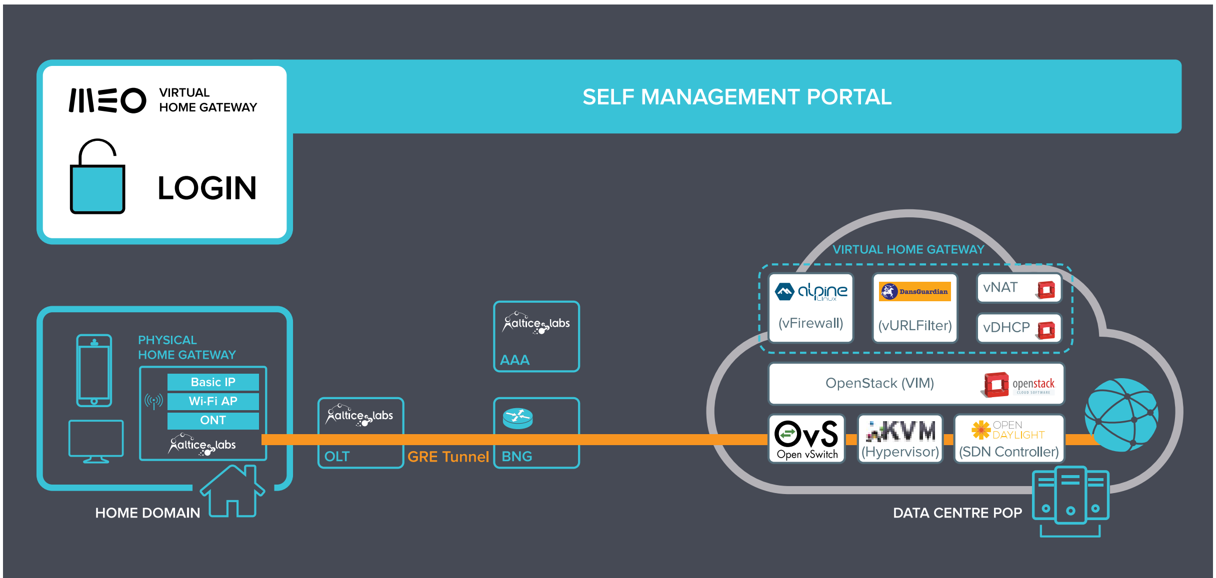

FIGURE 6 PoC phase 1

centralized transparent authorization endpoint for user sessions, keeping the chain configuration and attachment status of devices, to be read/written by the portal and queried by the DHCP server. Both AAA servers generate notifications to the orchestrator.

Management: In phase 1, a strictly functional approach was tried. No managerial issues were involved, apart from the user's self-management of the Internet access service.

For the phase 1 demonstrator, an authenticated home network user was able to:

- View the attached devices;
- Block access to a particular device (MAC);
- Characterize a device and assign it to a user;
- Configure functionalities for the user/ device (different service chains were chosen according to the selected functionalities – URL filtering for Parent Control, service blocking using Firewall).

Phase 2

Figure 7 illustrates the PoC phase 2.

For phase 2, two major developments took place:

- **Service Control:** A policy-driven approach to service chaining was developed, including:
  - **Subscriber and Policy Repository:** to keep the information that is needed for policy enforcement;
  - **Policy Server:** to determine what policies to apply based on context and subscription information. Controls a Classifier, a Traffic Accounter and a Traffic Shaper to enforce policies regarding service chain selection, gating and QoS control;
  - **Classifier:** Deep packet inspection of traffic allows the classification of service flows;
  - **Traffic Accounter and Traffic Shaper:** VNFs that are controlled by the Policy Server, to count traffic and to enforce QoS rules;
- **Management:**
  - **Service Activation:** NFV orchestration and the "traditional" fulfillment activities were combined into a "Multidomain Service Activator" in charge of coordinating configuration across all platform;

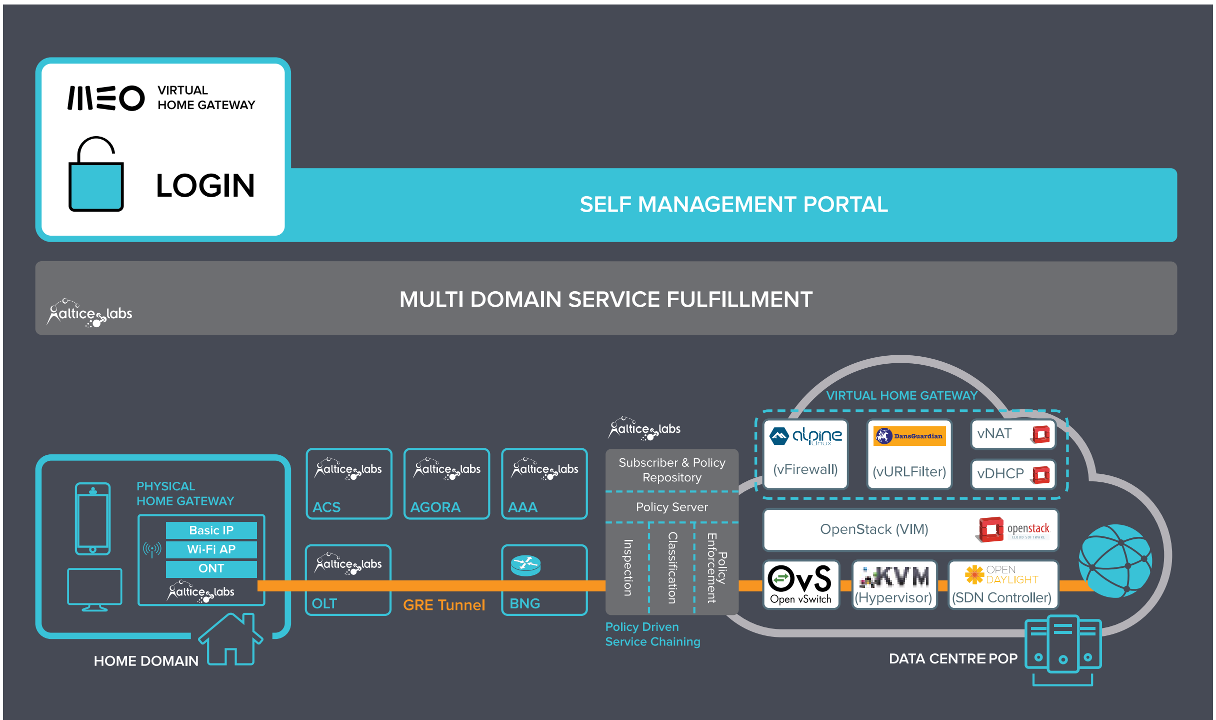

FIGURE 7 PoC phase 2

- **Self-Management** portal was enhanced with per user configuration capabilities and session context awareness.

NFV/SDN Innovation Foreground

This section describes the NFV/SDN domain innovation activities for the upcoming years. In detail, the major NFV/SDN related RDI activities are highlighted in the next section, whereas the subsequent section depicts the NFV/SDN related planned innovation roadmap.

Exploratory Innovation

This section describes three major RDI areas that will be impacted and significantly evolved due to the adoption of the NFV/SDN networking paradigm. These areas are: i. autonomic network management, ii. network services agility through DevOps and iii. edge computing. Altice Labs is actively working on these areas under the scope of the Horizon 2020 programme RDI collaborative projects.

Autonomic Network Management

The current networking paradigm, illustrated in Figure 8, poses a number of challenges to network operators, in particular, the management of anomalies and upgrades in the regular behaviour of the network are one of the main sources of increasing both capital and operational expenditures. Nowadays, operators have to do their best to detect and mitigate all sorts of problems in the networks, such as link failures, performance bottlenecks, security attacks, QoS degradation, software bugs, and hardware faults, among others. Existing solutions typically require manual re-configuration of the equipment, and in some cases, the only solution is the installation of new equipment and functionalities such as routers, NATs, firewalls, intrusion detection systems, load balancers, probes, etc. These tasks cannot be performed without affecting even for limited time the normal operation of the network. This causes disruptions in the services and violations in SLAs (Service Level Agreement), thereby incurring in increased operational and capital costs and compromised end users' QoE (Quality of Experience).

Research in recent years in the area of SDN and NFV has resulted in the emergence of new capabilities

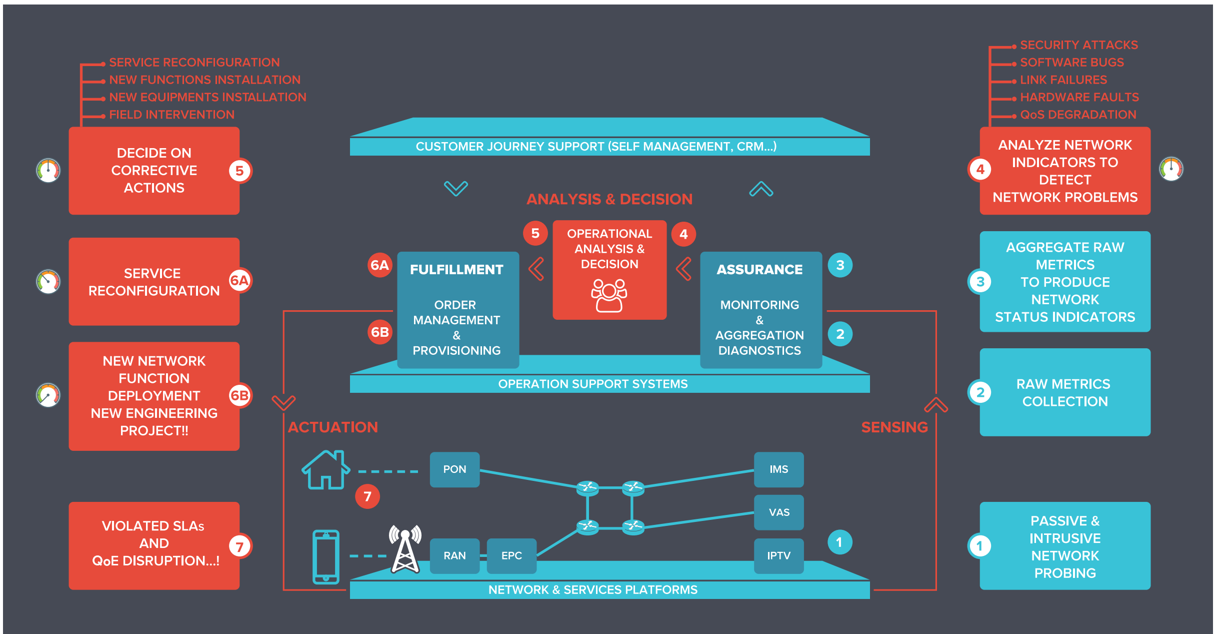

FIGURE 8 As-Is Network Management Paradigm – Human-based, Machine-assisted

that significantly improve the agility, flexibility and cost efficiency to manage network functions. These capabilities are the foundations to trigger a paradigm shift in the way network operations are planned and deployed, called autonomic management – Figure 9.

This new management approach will explore SDN, NFV and cloud computing technologies, together with innovative algorithms, to achieve a highly intelligent paradigm for smart self-management of complex networking scenarios.

One of the main impacts of introducing autonomic capabilities is to significantly reduce the operational costs directly related to the management of the network. Essential network management tasks are automated, which will enable remarkable reduction in the complexity of the network management, currently being manually conducted. Proactive and reactive actions are automated in order to resolve/ mitigate networking problems, thereby minimizing the current labour-intensive maintenance and troubleshooting tasks for network operators, leading to more significant decrease in OPEX.

In order to provide a fully-automated and highly intelligent autonomic management system, three key properties must be addressed by the architecture. The first one is related with **automated network monitoring**. The architecture should enable the automatic deployment of NFV applications, typically known as probes or sensors, in the network infrastructure to facilitate system-wide distributed monitoring. These virtual applications are spread across the access and backbone network infrastructures to enable end-2-end user, service and network awareness through the collection of metrics from all required elements in the network architecture. The collected information must feed data analysis algorithms (e.g., data analytics, data mining, machine learning) in order to create key indicators that may translate to (1) service affecting conditions (network failures, performance bottlenecks, security braches, intrusions, etc.),

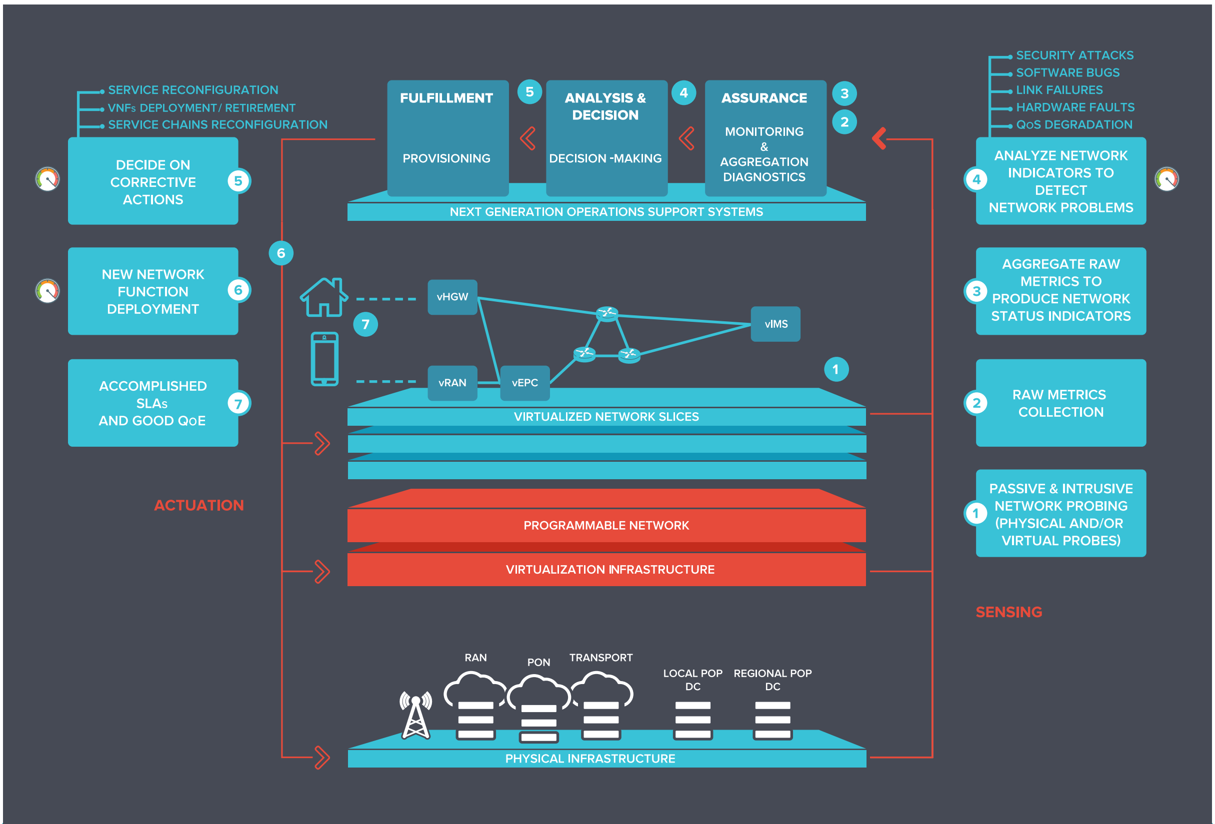

FIGURE 9 NFV/SDN-ready Network Management Paradigm – Machine-based, Human-assisted

(2) conditions thay may evolve to service affecting conditions in the future, (3) non optimal service delivery to specific users, i.e., detection of situations where the service topology being used to deliver a service to end users can be optimized in order to minimize the resources being used or the service QoS. Packet inspection tools such as intrusion detection systems, selective packet processing tools, user profiling tools and network monitoring tools are some examples of software used to gather measurements to derive these high-level metrics.

The second key aspect that must be fulfilled by the new management architecture is the **autonomic network maintenance**, i.e., the ability to define high-level tactical corrective and preventive measures to respond to the diagnosed conditions. These tactical measures may correspond to reactive actions of the network in response to fix/mitigate existing network issues of various kinds, or may correspond to proactive actions to prevent the evolution of the diagnosed condition to an effective anomaly affecting services. These actions may be mapped to request for automated configuration, scalability, migration of existing VNF's, the deployment of new VNF's or the reconfiguration of services' connectivity logical topology.

The combination of automated network monitoring with the automated network maintenance is the backbone of the autonomic service management, contributing to maximize the chances of sustaining the healthy operation of the network (and services) enabling intelligence-driven responses even in scenarios unknown *a priori* and without requiring human decisioning and intervention.

Finally, the third key feature is the **automated and dynamic service provisioning** taking into account not only the service type characteristics but also the status of the network architecture. This comprises dynamic smart selection of the best locations where the services should be deployed (or migrated to) considering the requirements associated with the specific service instance being provisioned (for instance the contracted QoS) but also the key indicators produced by the automated network monitoring applications that translate the network health (anomalies, performance), in order to guarantee that the provisioning of new services also contributes to maintan the required levels of network performance, health and security.

This research activity is currently being addressed in the EU-H2020 SELFNET RDI project [12].

Network Services Agility using DevOps

Nowadays, deploying a Network Service may imply lengthy hardware procurement processes, as well as usually complex 'hand-over' of the newly developed service to the operations team and acceptance tests that depend also on the knowledge handed over from development teams and the hardware availability. This is even worse when further activities like training affects many employees, for which training environments have to be put in place, increasing even more the network services' time-to-market.

Two recent trends dramatically change this: on one side, the above mentioned NFV/SDN, which enables the quick (re-)configuration of the network, to accommodate new services, and a merge of the software development and operations teams, known as DevOps, which eliminates the hand over time gap mentioned above.

Furthermore, a collection of objectives implying improvements in Telecommunications set for 2020, known collectively as '5G', also address this, namely to dramatically reduce the time-to-market of new services ('from 90 days to 90 minutes'). Telecom operations must thoroughly review its processes in order to be in line with this objective. '5G' also strongly pushes into significantly lowering barriers to entry of service developers/providers, not necessarily coming from infrastructure providers, which means that Telecoms will probably have to open their infrastructures to these new service providers, without negatively affecting services already deployed.

These '5G' drivers, together with the NFV and SDN trends, lead Altice Labs to rethink development and operations internal processes, namely with the objective of making them more agile.

DevOps is a set of procedures, tools and techniques that allow organizations to dramatically streamline software development and operations (hence the name) processes, by bridging the gap that usually exists between those two groups. The whole idea is to accelerate the delivery of value, minimizing waste - of time, of software that is built, tested, delivered and only partially used and of software that is delivered with errors and has to be corrected.

Adopting DevOps implies a series of techniques and procedures already used in Agile development, applying them to the deployment of software, taking advantage of the virtualization of resources. These techniques and procedures are:

- **Automated tests:** to increase the quality of the delivered software, tests have to be executed very often (for each change in software), which is impossible to do with the traditional manual testing procedures. Therefore, code is written to test code, making it possible to execute those tests without human intervention and as often as needed. These tests should consider a layered approach, in which lower level tests are run more often (often using techniques that fake dependencies, specially if those are slow, like databases, network, file systems, etc.) and are faster to run, while higher layer tests are slower (because no fakes are used) and consequently ran less often;
- **Continuous integration:** reduce risks by integrating often, and therefore a smaller number of changes on each integration: if the integration breaks, it is a lot easier to spot the offending change or code. Depending on the technology stack used (programming language, frameworks, etc.), a **continuous build** process that compiles and links dependencies may also be needed;
- **Continuous delivery:** having a continuously integrated system is only a small step from having it delivered also continuously. Some kinds of systems and some kinds of changes to those systems must have human intervention for the delivery to effectively take place. Sometimes continuous delivery is also called **continuous deployment**;
- **Infrastructure as code:** when the infrastructure is virtualized, it is common to be able to define it through code. When this happens, a completely new dimension is opened, since techniques that are more usually used in software development, like version control, automated tests, etc., can also be used in defining the infrastructure. This activity then becomes a **repeatable** process, through which hundreds or even thousands of servers can be provisioned in a consistent way and in relatively short times;
- **Configuration management:** manages systems' configuration lifecycle, including dependencies between different **configuration items**. In its broadest sense, configuration management also covers functions like **root cause analysis** (of a detected problem), **impact analysis** (of a planned change), etc., making it a crucial asset in today's IT infrastructure.

The most common metaphor to DevOps is a 'pipeline' that is fed by development, passes all the planned phases of that pipe without human intervention (unless a problem is detected), and delivers the value added by the developed software to the 'customer'. Each stage of this pipeline applies quality control measures before any change proceeds to the next stage.

The main impact for Altice Labs of such an approach for developing software is much beyond a mere **change of culture**. Agile Methodologies, to which a DevOps approach is very closely connected to, are supported in many principles (see 'The Agile Manifesto', http://www.agilemanifesto.org/) that somehow are still strange and difficult to accept by many developers, as leaving them the responsibility to define the infrastructure on which the developed software will run seems really strange for more traditional organizations.

Nevertheless, Altice Labs and Altice Group operations will surely benefit from adopting such processes, since those are the most efficient known at the time of writing, delivering value to the 'customer', whoever he/she is. DevOps forces the organization to streamline and automate software development and delivery processes wherever possible, even in scenarios where the Ops are from an external entity. Activities like **test automation**, which have already started in Altice Labs, will be of great advantage, but also evolve a lot as well, when used in a DevOps process.

One of the approved EU-H2020 projects under the ‘5G’ call, SONATA (Service Programming and Orchestration for Virtualized Software Networks) [13] addresses precisely the issue of applying DevOps in NFV and SDN environments. What has been known as ‘5G’ pushed down barriers to market entry, delivery times (services), etc., so organizations really have to change if they want to keep doing business successfully in this market. Lowering barriers to market entry means that telcos will have to host services that have been brought up by other players, in a much faster way than what is still the todays’ current practice. This significant increase in delivery speeds implies much more Agile cultures, and new processes and tools that are not easily adopted or adapted to the organizations. This explains the importance of such projects, in which experimentation e.g. trial and failure are relatively inexpensive, while allowing for on job training.

(Mobile) Edge Computing

The emerging cloud paradigm is increasingly replacing IT servers traditionally located on enterprise premises, and moving them to centralized clouds. Big data centres (DC) are able to hold a large amount of COTS resources at a very low cost, taking advantage of economies of scale. With the NFV advent, the same paradigm can be applied to network functions, which can be virtualized and moved to a data centre. However, because of its nature, not all VNFs can be centralized. For this reason, the deployment of local/regional micro-DCs is under discussion and becoming a consensual belief in the telecom community.

Today, many services are able to run efficiently from centralized DCs, taking advantage of high data rates provided by modern broadband technologies. However, some other services would benefit if placed on the edge of the network, closer to clients. Edge computing provides four main advantages:

- **Ultra-low latencies:** many applications, such as augmented reality or gaming, benefit from very low latencies, which can be obtained by placing services closer to clients, fostering new services;
- **Backhaul bandwidth efficiency:** edge computing can promote an efficient use of local communication, minimizing backhaul capacity when local/regional communication is kept on the edge, not requiring to be forwarded outside (core), which is especially relevant for data intensive services. Examples are the delivery of video streaming on sport events to spectators on the stadium, or video analysis of surveillance cameras (IoT), which can be performed locally on the edge, sending outside only notifications of relevant events (e.g. car accident detection) or small video chunks;
- **Location awareness:** the information about client’s location can be used to customize the delivery of certain services - location based services;
- **Network context information:** network context information can be used to leverage the user experience, e.g. by adapting the quality of the content (video) according to the actual network conditions.

In this context, by the end of 2014, ETSI has created the MEC (Mobile Edge Computing) ISG (Industry Specification Group) [14], which intends to standardize a service execution framework, capable of offering to developers and service providers an IT service environment on the edge of mobile networks.

Although the focus of ETSI MEC is the mobile environment, this concept can be applied to any non-3GPP network, like Wi-Fi or even wired technologies such as DSL, Fibre, Cable, etc. The rationale is the same: to take advantage of the unique environment that only operators can offer and to provide better and new services. Candidate services can be provided by the operator, but mainly come from OTTs, from which operators expect a significant interest, trying to recover some revenues recently taken away.

Figure 10 shows the basic components of the MEC architecture, that are being developed under MEC ISG.

Although the MEC environment can be anywhere between the client and the core, eNBs seems the

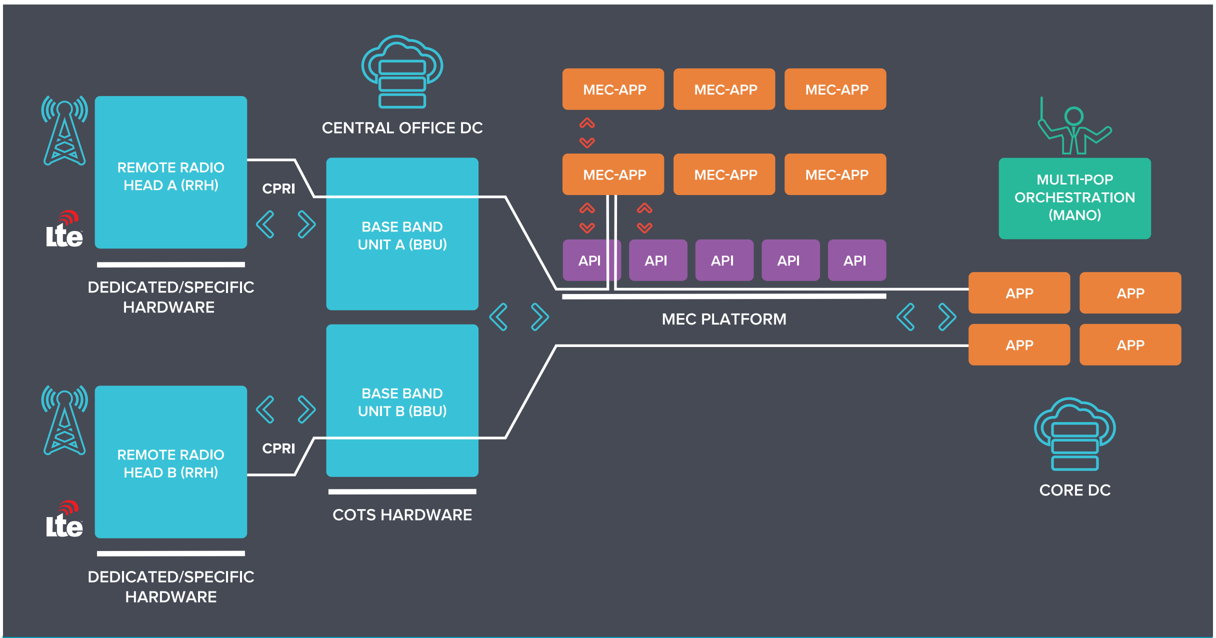

FIGURE 10 MEC basic architecture

most suitable target. MEC environment is composed by a main entity, the **MEC Platform**, which is responsible for the integration with the mobile network and provides APIs to allow applications to interact with the network. Examples of APIs are:

- User-data plane traffic uplink/downlink traffic interception (breakout);
- Access to network information (NSIS);
- Access to client's location.

MEC Applications run on top of an IT infrastructure, likely to be virtualized, and use APIs to programme services to clients. On top of this, there is a **Management and Orchestration** layer, responsible to manage the Apps lifecycle and orchestrate the placement of the different application on multiple edges.

The MEC concept imposes significant requirements to operators, especially regarding the creation of small IT/cloud infrastructures on the edges, which is quite more expensive when compared to the same capacity in a single central DC. However, some other trends may act as enablers for the edge computing success. The ongoing process of virtualization of access network functions on mobile networks (C-RAN) will impose the separation of the eNBs into RRHs (antennas) and BBUs (signal processing), deploying the BBU components into small local micro-DCs. In the same way, with the evolution of wired networks, some equipment is expected to face similar evolution (OLT, CMTS, etc.), ending up by converging wired and wireless access functions into common micro-DCs. In such an environment, where operators are already spreading IT resources along the edge for NFV purposes, MEC solutions become affordable, as edge computing environments can share resources with NFV. Figure 11 depicts this convergence and evolutionary view of MEC environment.

Altice Labs is part of the H2020 RDI Superfluidity project [15], which intends to develop the MEC concept, among other research subjects.

Planned Innovation: Upcoming PoCs

After the implementation and demonstration of the vHGW POC, Altice Labs is currently working in the analysis of new problem spaces relevant to be addressed regarding the services and network evolution using NFV and SDN, and on the specification of new solution prototypes, namely:

- New generation of enterprise services: evolution of the current generation of

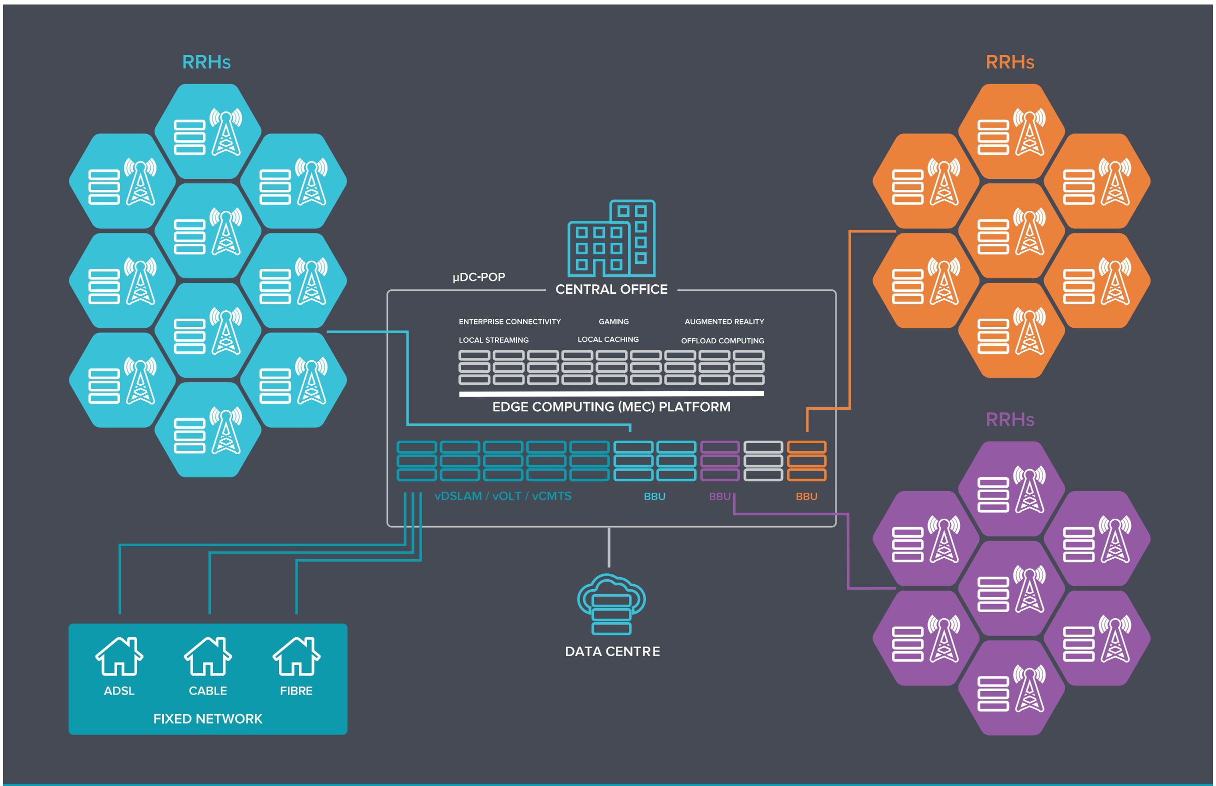

FIGURE 11 MEC evolutionary context

enterprise services to provide self managed programmable VPN services to enterprises, complemented by virtualized CPE services and virtualized IT services;

- Convergent central office architecture: full virtualization of fixed access PON network and mobile 4G network, convergent policy driven network control architecture, convergent policy driven service chaining. This PoC, aside from network virtualization, intends to addresses the current Gi-LAN network evolution and goes beyond promoting fixed mobile convergence through a unified control and service chaining;
- Assurance architecture for NFV and SDN network: definition of the architecture basis for end-2-end assurance over new NFV and SDN networks architectures.

Other PoCs, covering a wider scope than the vHGW will extend to other areas, such as the corporate vCPE.

Also planned, as the PoCs matures, is the set up of joint field trials envolving Service Providers network operational teams, addressing field requirements which will be a further step towards the validation of the chosen approaches.

Conclusions

More than a trend or hype, NFV and SDN paradigms will for sure be adopted by the telecommunications industry. We can go further and say that NFV and SDN adoption will be major transformation forces, driving the evolution of traditional Communication Service Providers to a new generation of Digital Service Providers, emerging over a new generation of Service Platforms.

The new generation Service Platforms will have in its core a “network of data centres”, where the vast majority of service funcionalities will reside. Being the access networks a valuable asset inherited by the telco operators, this new generation Service Platform will be complemented with managed access connectivity which is a considerable differentiating factor as compared to Internet players.

The new generation Service Platforms will boost the speed, agility and flexibility for new digital services creation and, at the same time, will furnish the means to dynamically control, in near real time, the configuration and topology of the service functions, managing effectively service loads, service quality levels and anomalies affecting services. In the end, the ultimate purpose is to achieve unmatched levels of operational efficiency and improve significantly the customer experience.

Altice Labs has been following and contributing to the most relevant SDO's and industry organizations that have been specifying and implementing NFV and SDN architectures and technologies since the early stages of this technology. Due to this, Altice Labs has developed internal critical skills and reached a maturity level that supports the current engagement in the most relevant international exploratory innovation projects, the capability to implement internal Proofs-of-Concept and to feed the Altice Labs' product business units with the knowledge and experience required to evolve its product roadmap, thus future-proofing the company's portfolio by adapting it to new technological frameworks, like SDN and NFV.

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04

A “STARTEGY” FOR IOT

IoT is an opportunity for the foundation of new businesses in the future connected society.

In just a few years, tens of billions of devices will be spread around the world, demanding ubiquitous network access, IoT specific functionalities, data management enablers and monetization services, in order to make the IoT vision real and sustainable. Operators have a huge opportunity to move up in the value chain by becoming key technological partners in the IoT market thus promoting the creation of useful services to verticals, enterprises and end-users. But the time to act is now.

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IoT, Vision, Strategy, Application Enablement, Things, Data, Monetization, Framework, Business

Introduction

We are facing a new digital revolution that will have remarkable impacts on future societies. The gap between the virtual and the physical world is thinning. A massive spread of small 'intelligent' objects with communication capabilities is starting to bring into reality the Internet of Things (IoT) vision, impacting the citizens daily lives in an outstanding way.

IoT is the base for the 4th Industrial Revolution by permitting the optimization of the manufacturing processes through an intelligent control of industrial machinery. Moreover new services are arising in the health domain allowing for effective remote care of patients and elderly people. Transports will also be deeply affected: the trend of connected cars will foster the creation of new services making the mobility much easier, faster and safer. IoT will also extend the domotic concept towards a complete and efficient house automation. Within cities there will be also major improvements in order to promote a sustainable usage of its resources and infrastructures.

There are some key market drivers for the IoT growth: devices are cheaper, network access is becoming ubiquitous and new vertical services emerge everyday, creating disruptive business streams. Forecasts are impressive: "The worldwide market for IoT solutions [is forecasted] to grow from $1.9 trillion in 2013 to $7.1 trillion in 2020" [1]; "IoT hardware and connectivity revenues are growing at about 10-20% annually, while apps, analytics and services are growing even more rapidly at 40-50% per year" [2].

In this new digital era, devices will require not only convergent connectivity, but also intelligent IoT functionalities, data management enablers and monetization capabilities to facilitate the creation of smarter and innovative services. Communications Service Providers (CSPs) are in a privileged position to become key players in the IoT sphere. They can provide the core infrastructural components required to support the new business opportunities. Additionally, CSPs can use IoT to enter in vertical domains that have been traditionally out of their scope of business thus opening the doors to a huge market. Now is the time to act.

Main Trends

Several trends are emerging in the IoT arena, with high potential to facilitate and accelerate its adoption. From the perspective of CSPs, three of them must be highlighted: **Smart Cities, Low Power Wide Area Networks (LPWANs) and Embedded SIM Card (eSIM)**.

According to the United Nations, by 2050, 66% of the world population is expected to live in cities [3]. IoT has the potential to revolutionize several activities within city planning and control. Additionally, it promises to increase sustainability, safety and to make the cities more *liveable* places, through a countless set of new services (e.g. street lighting management, waste management, intelligent road monitoring, traffic congestion monitoring and management, etc.). Smart Cities are characterized by the application of information and communication technologies in the management of the urban spaces providing enhanced quality of citizens daily lives. The advent of IoT makes it possible to have a much more dynamic control of the city, based on information gathered from sensors spread all over the neighbourhoods and also the ones carried on personal devices, in particularly, those embedded in mobile phones or wearables. This new source of information will feed the "city data lake" allowing to infer the user and environmental situation thus enabling the full real time control of cities, making them smarter. For instance, it will be possible to adapt the infrastructures of urban spaces to cope with the daily growing movement of people and cars: sidewalks will enlarge during rush hours (e.g. entry and exit of schools); the road will adapt the direction of lanes according to the peak hours; traffic lights will set its own state to respond to the city dynamics; and public lighting will react based on the environmental context.

The Internet of Things requires wide area data connectivity for its deployment and, in specific scenarios, it also mandates low cost and long battery life in order to allow for the effective implementation of services. LPWANs technologies are a possible answer, since they enable a cost effective deployment and maintenance of services requiring large coverage and long battery duration. Currently, several technologies compete in this emerging space, some proprietary (e.g. SIGFOX, OnRamp/RPMA) and other open or partially open (e.g. LoRa, Weightless, DASH7). Traditional telco standardization bodies are also working to have available standards for this specific IoT connectivity segment, namely 3GPP (EC-GSM, LTE-M, NB-CIoT) and ETSI (LTN). Different technologies are already there but the market is still unclear in respect to specific adoption.

GSMA eSIM specification (Embedded UICC- eUICC) is a standard for the “over the air” remote provisioning and management of operator subscriptions. Although the final technical specifications have not yet been concluded, it is expected that in the next years eSIMs will gradually replace the traditional SIMs. The eSIM brings key benefits to stakeholders in the M2M (Machine-To-Machine) and consumer electronics space. It is not coincidence that both Apple and Samsung are engaged in talks with GSMA to adopt eSIM standards. eSIMs solve the challenge of managing devices in the field (remotely located, geographically spread, often hermetically sealed and hard to reach) and simplifies the manufacturing processes related with equipment requiring SIMs. eSIMs will be major achievements, for instance, for the automotive industry where future cars will be connected regardless of its manufacturing region. The eUICC specification will for sure accelerate the development of M2M and IoT markets.

Market

CSPs have a strong opportunity to shape the IoT reality by becoming key technological partners, supported by trustful customer relationship and typical connectivity offers. IoT enablement and vertical value-added services bring new opportunities for telcos to create value and generate higher revenues, moving up in the value chain. However, new over-the-top (OTT) **competitors are arriving at the market**. Bosch, Amazon, and many other players are running for the IoT business. Figure 1 presents a small sample of IoT Application Enablement players.

FIGURE 1 IoT enablement platforms market

As in other areas of the competitive CSP landscape, imagination has to be used in order to create a collaborative competition approach, instead of a pure competition strategy.

IoT Enablement

Vision and Positioning

The leading CSPs are **key players in the IoT domain** making possible the **Smart Cities materialization and the operational optimization across all industrial domains (verticals), materializing a connected society**. To make this vision happen, it is crucial to assume a long-term strategy to successfully address the IoT opportunity.

From the CSP perspective, the technological value chain of IoT encompasses 5 key layers, as shown in Figure 2:

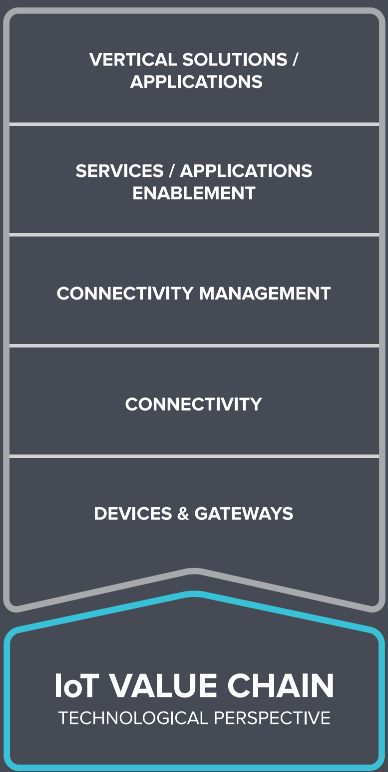

FIGURE 2 IoT Technological Value Chain

Devices and Gateways layer refers to all equipment required to collect sensor information, actuate in the environment and link with the wired or wireless telco-based network. The Connectivity layer deals with all communication infrastructures regarding its specificities (fixed, mobile, LPWAN, etc.). The Connectivity Management allows for the management, monitoring, troubleshooting and support to the M2M connectivity over multi-technology networks (traditional landline and cellular and also new IoT low power WANs).

The next layer is the core of IoT: Services and Applications Enablement offers solutions by providing a layer of API offer allowing the abstraction of the device specificities from the applications. This typically includes capabilities for data gathering, mediation, transformation, storage, monetization and other telco-based functionalities.

Finally, Vertical Solutions and Applications provides specific service logic, making available useful IoT solutions to the market.

In the IoT playfield, CSPs are typically involved in the connectivity layers, but to increase their business margins from IoT they need to move up in the value chain. For that they must create an **Application Enablement ecosystem**.

Strategy

The strategy to achieve the CSPs vision passes by moving forward the typical telco-based connectivity offering towards **the creation of a carrier-grade IoT Enablement Framework** tailored to stimulate the creation of new businesses transversal to all domains of activity. It typically includes core services to manage devices and applications allowing secure data exchange, functionalities to process, store and analyze data from devices and, finally, services to monetize IoT events and services.

Moreover, it is mandatory to promote **an ecosystem of technological partners, fostering the creation of innovative services** in order to rapidly answer to future society demands. The promotion of a creative environment where different knowledge areas intersect is crucial to create new business opportunities and bring up innovative business models in the connected society.

The strategy rollout shall follow an evolutionary approach, with well-defined steps, making it possible to evolve the framework and ecosystem, while always considering realistic timeframes and agendas. The materialization of these key vectors can run in parallel but always ensuring a gradual progression.

Carrier-grade IoT Enablement Framework

Figure 3 presents a high level view of the carrier-grade IoT framework.

The rationale behind this framework is to answer

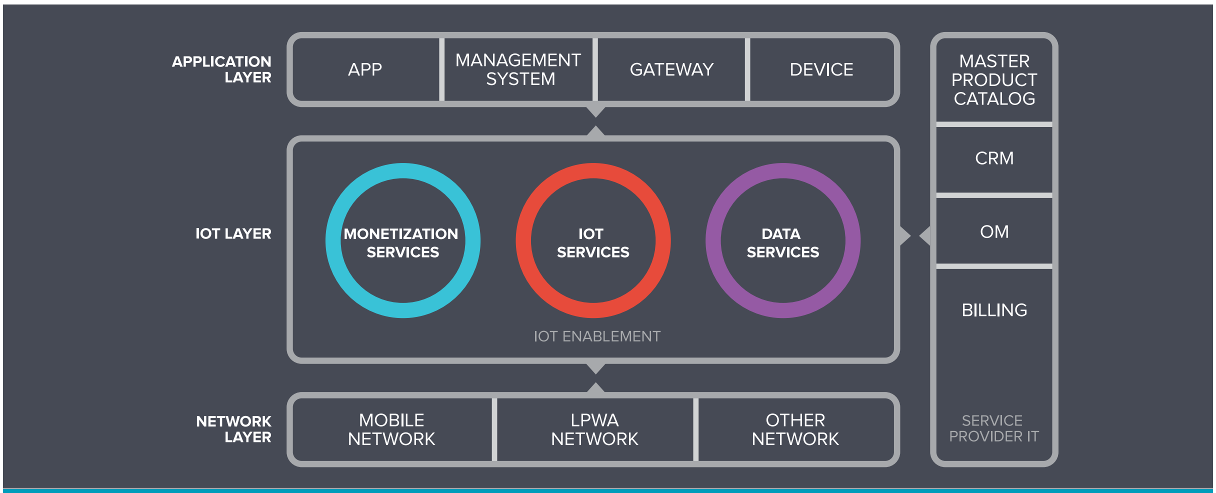

FIGURE 3 Carrier-grade IoT Enablement Framework

the typical telco-based requirements in terms of business and operational perspectives, by providing cloud-based open APIs that support different technologies and protocols easing the end-to-end system integration. Moreover, it shall have a cost effective horizontally scalable architecture. It shall also provide elastic data storage capacity with enhanced security and access rights management mechanisms. By design, the solution must provide a set of transversal services to ensure its efficient operation, administration and maintenance. Moreover, it must be built to allow the integration with the existing operators' ecosystem.

This infrastructural framework must cope with all related IoT, Data and Monetization services that are key enablers to support the implementation of the different verticals, and which constitute one of the major differentiation points a CSP can present to the market.

IoT Services

IoT Services (Figure 4) are the foundation of the IoT Application Enablement Ecosystem. They provide the main capabilities required to deal with devices and IoT applications.

The Device and the App Inventory components include functionalities to control their full lifecycle process. The Device Management component provides mechanisms to carry out device configurations, firmware updates, fault and performance monitoring. The Register and Discovery component capabilities are mandatory to let devices and applications become known by the system during runtime phase. The Rules Engine must provide the required skills to allow subscriptions to rules-based metadata events and respective notifications. Finally, the Device Interaction component gives support to synchronous and asynchronous communications, making possible the exchange of information between devices and applications.

FIGURE 4 IoT Services

Data Services

Data related services (e.g. big data) have the potential to generate a significant part of the revenues in the IoT, and CSPs should start seeing it as a competitive asset which can be enriched with other data sources of the existing ecosystem, contributing to its positioning as an innovator (Figure 5). There are several examples where IoT links to big data. For instance, UPS, a major logistics company, uses sensor information and big data analytics to reduce idling times, fuel consumption, and harmful emissions. It continuously processes data gathered from more than 200 data points for each vehicle in a fleet of more than 80.000 vehicles, leading to major efficiency achievements [4].

Data services components provide a set of functionalities required to extract useful information from the data gathered or received from devices. Following the TM Forum Big Data Analytics Reference Model [5], the ecosystem shall support near real time event processing and data analytics for information extraction. But for that a set of specialized capabilities are required.

The Data Ingestion component ensures formatting and normalization of data and its integration with heterogeneous data sources. The Data Management capabilities deal with the enrichment of the data collected in order to make it more powerful. There is of course the need to store not only IoT data but also data from other sources of information. This is the core task of the Data Storage capability. The Near RT Event Processing component allows for the processing of streaming data in near real time. Finally, the Data Analysis component makes it possible to compute batch data allowing the extraction of metrics and automatic report generation. Figure 5 presents the core Data Services module.

Monetization Services

Increased complexity in service offerings and innovative business models progressively require advanced monetization capabilities. CSPs are recognized as strong implementers of those business models, whilst benefiting from a strong trust relationship with customers.

The Monetization Services module (Figure 6) aims at providing capabilities to support scalable and event-agnostic charging of IoT services, enabling different business models in a multi-industry environment. It makes possible, for instance, charging the service based on the devices connected, on the number

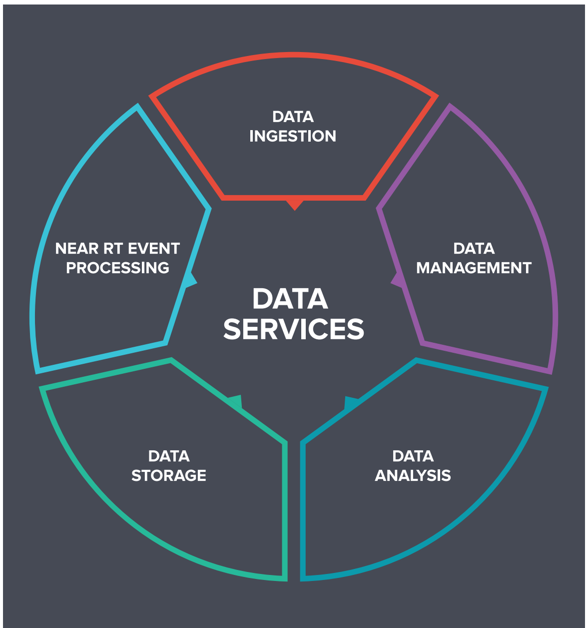

FIGURE 5 Data Services

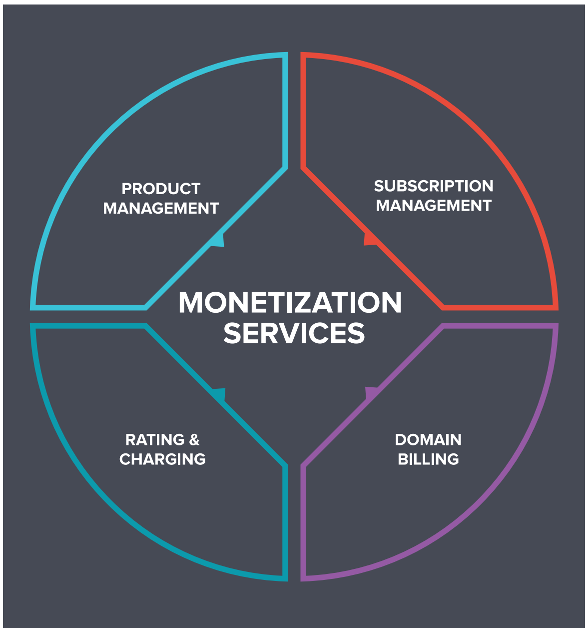

FIGURE 6 Monetization Services

of messages exchanged or on the space used for storage. To this end, it is mandatory to build a product ecosystem to integrate the monetization of IoT services with business and operational processes of the Service Provider.

The Product Management component includes the tools for designing business offers, controlling the product lifecycle and that allows for product catalog management. Subscription Management functionalities support the management of the customer subscription lifecycle, the adherence to concrete offers and the configuration and execution of all related provisioning flows. The Rating and Charging component provides functionalities that configure charging and rating rules and allow for account charges both in online and offline modes. Moreover, it can provide Top Up Management, enabling the advanced payment of IoT services. Finally, the Domain Billing component allows the generation of billing items related with IoT services usage.

IoT Ecosystem Environment

The IoT Ecosystem Environment encompasses the means and initiatives to boost the IoT landscape through the creation of key partnerships with stakeholders from all the value chain in order to create a fast response capability for Smart Cities and other vertical sectors opportunities (Figure 7).

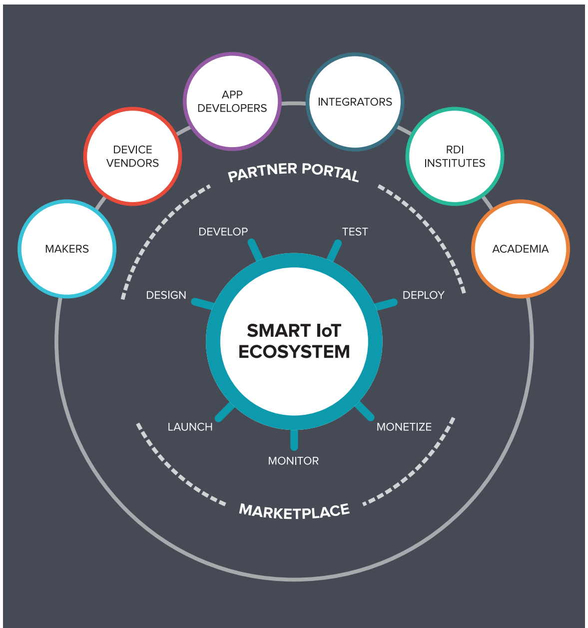

FIGURE 7 IoT Ecosystem

The concept of an IoT Ecosystem also intends to encourage the creation of a makers' community by linking with academia and RDI institutions in order to foster the emergence of new businesses and revenue streams. Moreover, the IoT environment shall include the tools for easing the development, making available documentation and handbooks, SDKs (Service Development Kits) for devices and applications integration, developer tools (e.g. Sandboxes) and support for creators. For the Application Enablement expansion, it is also crucial the creation of a device certification programme to support plug and play equipment.

Altice Labs' Role

Leveraging its experience and know-how in the area of M2M communications, monetization platforms and IoT RDI Projects, Altice Labs has a **strong opportunity to become a key IoT player on any CSP ecosystem**, enabling the emergence of a connected society and smart world.

To achieve this ambitious objective, the strategy encompasses the coherent combination of the following three key vectors: the evolution of the existing M2M managed connectivity solutions, integration with IoT LPWANs and the integration of IoT App Enablement components. The main goal is to build and integrate platforms and tools giving the CSP a complete experience of the IoT business, supporting monetization of convergent offers while combining different types of IoT connectivity and services.

Closing Remarks

In only a few years, tens of billions of devices with communication capabilities will be spread all over the world leading to an amazing transformation in the society. IoT connects the physical world to the Internet making possible the creation of revolutionary services across all domains of activity.

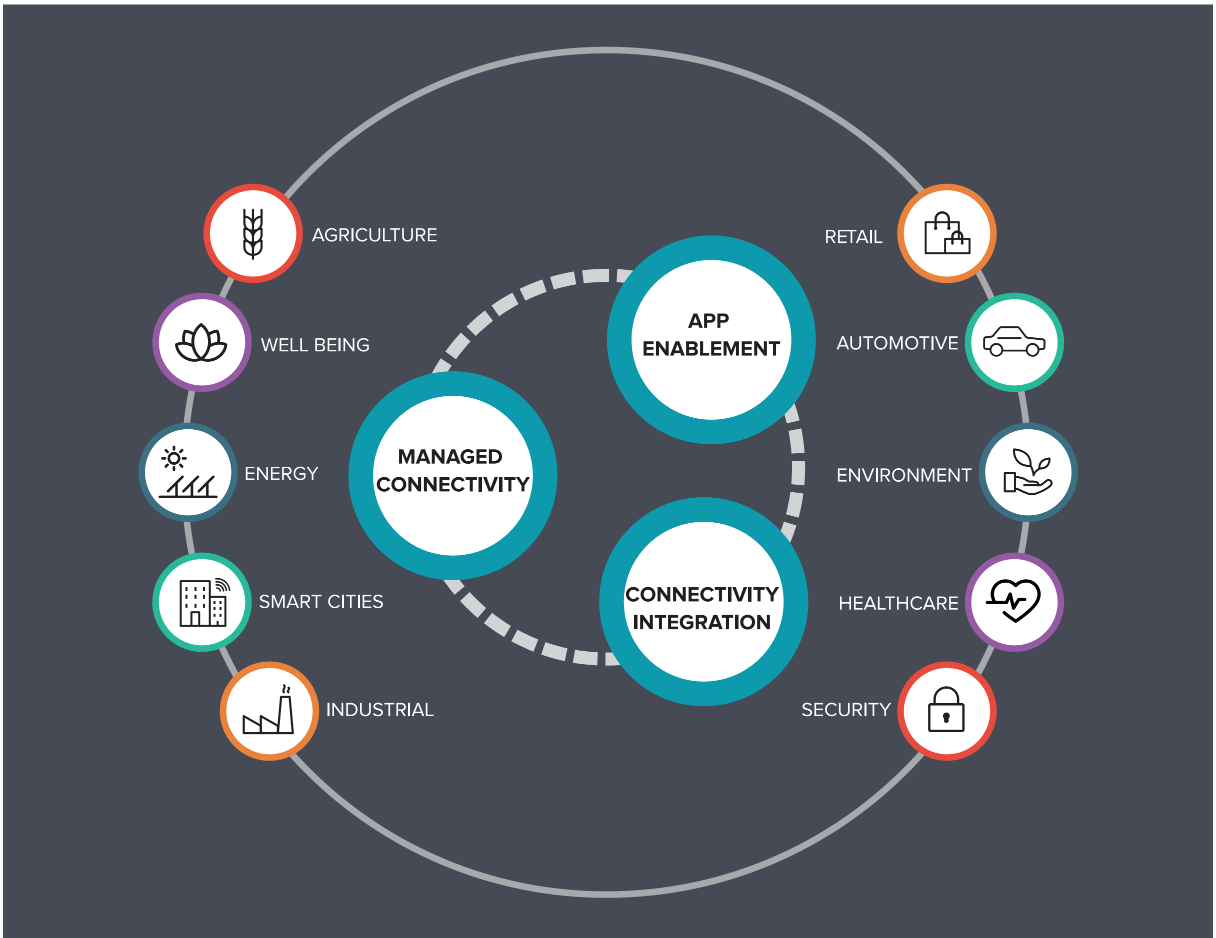

FIGURE 8 Altice Labs' strategy IoT key vectors

IoT will affect our everyday life by bringing new value to the digital age; it will enable the foundation of a new society where things will be used to improve people's quality of life.

CSPs must become key players in the IoT revolution. They need to lead this transformation by promoting the definition of an appropriate ecosystem skilled enough to answer future society needs. Moreover, they are in the best position to provide the required infrastructure to support new business opportunities. IoT capabilities, data management enablers and monetization assets are key components of an IoT framework, regardless the domain of activity.

IoT is happening now. There is a new and huge market out there. Operators need to move forward and seize this gigantic opportunity.

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05

BIG DATA ON MEDIA: NOT JUST BIG, BUT SMART

This article explores big data strategies in media industries and its users, suggesting that data, particularly news, is not only growing at a fast pace, but also getting smarter.

This article presents an innovative big data media project, “Máquina do Tempo”, a joint collaboration between SAPO and University of Porto, that led to an interactive online tool for navigation and exploration of 25 years of news articles, supported on automatically generated entities’ co-occurrences networks and rich profiles.

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Big Data, Media, News, Machine Learning, Natural Language Processing, Information Extraction, Named Entity Recognition, Information Visualization, Text Mining, Computational Journalism

Introduction

The big data hype is said to present huge opportunities for CSPs. Most trends – in technology development, consumer behaviour, regulation and RDI investments forecasts – seem to corroborate that big data will play an important role in future revenue streams.

The advent of IoT, the "massification" of connected device ownership (either smartphones, tablets or other wearable devices), investments in ultra-fast networks and cloud enablement infrastructures put CSPs in a privileged position to lead this hype and start innovating with data. Having been transforming its business to adapt to the digital economy needs and to the virtualization and automation trends, CSPs do have the resources – Human and data sources- available to engage in this new knowledge field, though investment in developing and acquiring specific skills is obviously needed.

Big data *per se* has little value… but data processing applied to societal, business or organizational challenges can open a whole new business stream for CSPs: in business predictive analysis (advanced business intelligence); e-health (pandemic pattern detection); civil protection (early detection mechanisms); context aware marketing; available media information processing (extract the coherence and correlations among the amounts of media information available) or even typical CSP product enhancement (TV recommendations based on previous video consumption). Although having access to a huge amount of near real-time data, CSPs must comply with strict regulatory standards of privacy and security, legislation that is not applicable to OTTs, who use their client's data more or less freely, being able to deliver value added and tailored offerings to its clients. Besides this, legislation is being reshaped to include the new content delivery trends, which is good news for CSPs, who have the most to gain in this big (data) game.

CSPs have constant access to network traffic data, client consumption of data, a huge network of sensors and connected things and, now, how do

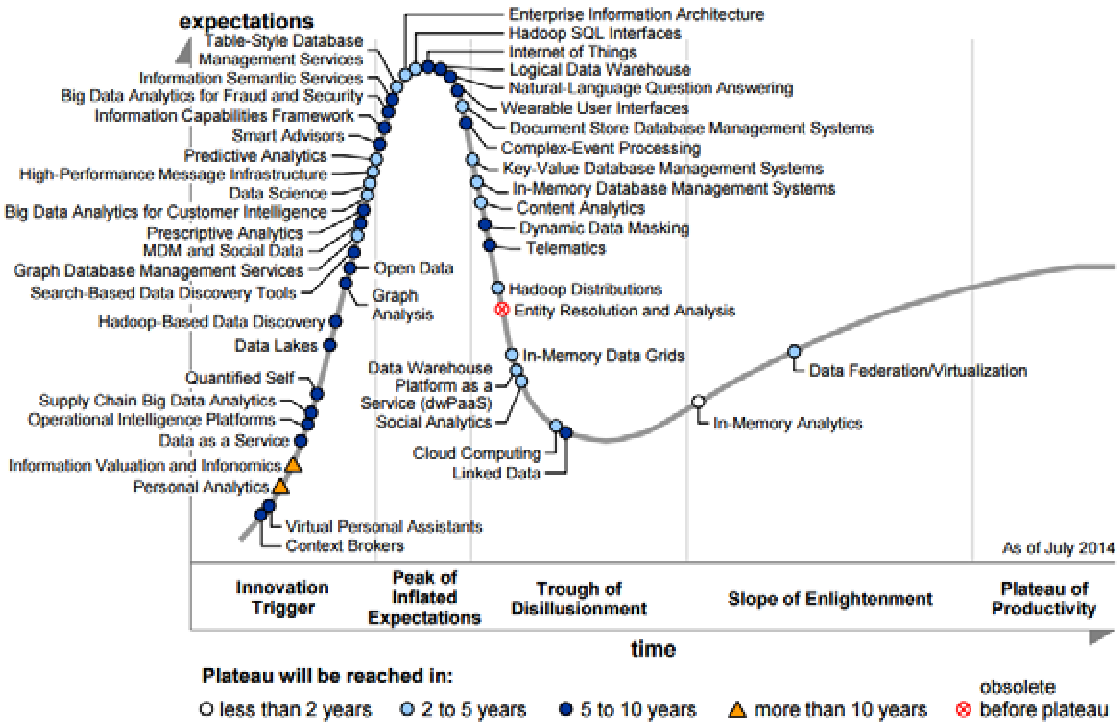

FIGURE 1 Hype Cycle for Big Data, 2014 [2]

they monetize this? Is the market ready for the big data-based offering? Are CSPs ready to deliver it?

In order to understand how CSPs will play a strategic role in this subject, it is essential to first acknowledge that – due to the already mentioned "minor" obstacles - the current moment is still an early stage in the big data hype: companies are still experimenting innovative big data based solutions, testing market acceptance. It is estimated that in the near year of 2017, "60% of big data projects will fail to go beyond piloting and experimentation and will be abandoned" [1] (refer to Figure 1).

So, it is time to test, experiment and gain critical knowledge in big data.

According to a study held by The Economist Intelligence Unit [3], the top two key data challenges in businesses are the quality, reliability or comprehensiveness of data and the lack of effective systems to gather and analyze data. Additionally, the same study results show that in the top three data insights critical to decision-making, two include "current status" (e.g. quality) and "qualitative" (e.g. customer experience). Quality of Service and user experience are, in fact, two of the most important aspects that need to be carefully evaluated in order to maximize the probability of success and revenue of a media product nowadays.

To look at the information available and understand the potential of a particular mix and match / combination of data sets is almost a transcendent art. So one shall start by using data that already grasps very well: SAPO made the PoC (the subject of this paper) using a star solution "SAPO news", a newsfeed tool built entirely in-house.

From the PoC materialized in the launch of "Máquina do Tempo" [4], SAPO climbed to a new era. It may seem innocent to correlate news, but a whole new world of possibilities was open by this research and testing: you can correlate people with less positive attitude towards society (terrorist associations), correlate news about brands or trendy goods / behaviours, correlate stock exchange information with political news in real time and trace information valuable to the society. It is truly information innovation.

The solution proposed in this article tackles both aspects by bringing new, innovative and high quality information to the end user (B2B or B2C), keeping and even improving the high standards of quality of service for SAPO/PT media news room, and at the same time providing such information through intuitive interfaces to engage the users at their maximum potential. As stated by Matthew Keylock [3], "If you don't engage with your best customers, they won't want to engage with you. Every decision either grows or erodes loyalty." Such engagement can be driven in many different ways, but with the advent of mobile and high-definition devices, data visualization is drastically increasing its importance in this field. The BBC media company is just one of many examples, where their mission for data journalism is to become visual journalism [3].

"Wikibon expects the Big Data market to top $84 billion in 2026, which represents a 17% compound annual growth rate" [5], and the CSPs are very well positioned to capture part of this value.

Related projects and State of the Art

Related work on big data, with special focus on media, may be divided into two major categories: products and projects from large media producers, typically news agencies and news editors; and smaller industrial and scientific projects focused on enriching media content available online.

Large industry related projects

Such industries envision retrieving to their customers the most informative and high-quality content and, therefore, the focus is on the data itself (e.g: news articles). Additionally, most of the effort is for the last minute news and for the "real-time" events, inevitably leaving aside rich stories told through the news, where the actual big data is.

New York Times [6] is one of the most important and long-lasting media producers, publishing news, and consequently generating data since 1851, with more than 13 million news articles available. TimesMachine [6] is a repository of "129 years of New York Times journalism, as it originally appeared" and brings to the end user access to the digitized content of such data in a time-centric approach. Although this represents an unique and valuable resource, no further analysis and mining are performed on the top of this data. Coming from its RDI group, NYTLabs [7], Delta (a visualizing reader activity in real time), StreamTools (a graphical toolkit for data streams) or Kepler (semantic network visualization of topics) are examples of new and differentiated approaches for Big Data analysis on media. BBC Research & Development started a project [8] in 2011 focused on NLP (Natural Language Processing) and ML (Machine Learning) techniques used to spot connections, improve understanding and avoid information overload. Nevertheless, such data analysis dies at RDI Labs and never achieves its final destination, news readers, journalists or merely curious people.

The Guardian data blog [9] is considered to be one of the first systematic efforts to incorporate publicly available data sources into news reports. These reports are typically the result of large journalistic investigations of public data (news included) and have an important impact on the big data area. Nevertheless, Guardian's approach is not able to provide to the user freedom of choice, analysis and data exploration. Data analysis and results are subject to the media producer interests.

Exploratory related projects

Besides, smaller industrial and scientific projects from organizations that typically aspire to higher risk strategies, have enough space to explore and develop intelligent systems, supported on new approaches from big data and machine learning, aiming for an improved media content and user experience.

"News Explorer" [7], by IBM Watson, aims at extracting entities (persons, organizations and events) from online news and subsequently connect such entities based on their presence on news articles. Some user experience decisions on the web application disable the possibility of a richer exploration of information, diminishing the capabilities of exploring such a big data repository of knowledge.

"Libero 24x7" [10] aims to bring to its customer better and differentiated knowledge, by means of two interactive online tools: "timeline" and "grafo", a network of entities mentioned on news. Even though it allows free navigation through the news, its user interface is very poor and constrains the analysis of the data.

Recently there has been an increase of new companies, particular startups, targeting for ML and NLP as a service. AlchemyAPI [11], Luminoso [12] or Aylien [13] are examples of such boom in Software as a Service (SaaS) industries, where one of the application domains is media. Nevertheless, these industrial and scientific projects, smaller in scale and yet in an immature state, frequently fail on two essential aspects: (i) the quality and user experience regarding the interfaces with the users, ranging from web and mobile applications to infographics and interactive applications and (ii) the lack of information and extracted knowledge from data which is actually new.

State of the art

Although in different stages of maturity and complexity, many of these products and projects share similar scientific approaches to achieve their means.

Named Entity Recognition (NER) is a broad area of study that aims to identify and extract entities (person's names, organizations, etc.) from text. NER supported on machine learning is being studied by the research community for a long time [14] [15] [16] and most recent results point out to more accurate and language-independent methods [17], generic enough to be applied on agrammatical language such that from social media [18] [19]. Linguistic patterns are rule-based approaches for NER tasks [20] [21] [22], supported on dictionaries definitions and synonyms, among others. Although language (and domain) dependent, accuracy is most of the times higher when comparing with machine learning approaches.

Entity Disambiguation (NERD) is another problem yet to be fully solved. For example, "Costa" may both refer to "António Costa" or "Marco António Costa", Portuguese politicians, but also to "Costa Coffee", a coffee shop chain in the UK. This task's major goal is to identify the true entity for each mention, based, for instance, on the information extracted from large encyclopedic collections [23] [24] or by its context [25] [26] [27].

News Media is an interesting market where quotations are highly relevant [28]. Quotations, with particular emphasis on those from public personalities, convey rich and important information, and most studies focus on direct quotations [29] [30]. Quotations identification is executed at the sentence level, both with hand-crafted rules and lexica [31] [32] [33] or machine learning approaches [28] [34]. Indirect quotations are clearly the most challenging ones, and besides that, they contain richer information, including for example, temporal and spatial modifiers.

Challenges for Smart Big Data on Media

Smart big data on media content embraces important challenges for both large media industries and smaller exploratory ones. First, working on big data environments, applying machine learning and artificial intelligence techniques and exploring their results in appropriate ways, involves complex, time-consuming and risky strategies that only smaller industry player or RDI Labs are able to tackle. Second, assuring high quality and innovative information and user experience are key aspects for larger media industry player but at the cost of less engaging and less intelligent outcomes.

The solution presented in the following section aims to fulfill this gap and improve user experience and B2B and B2C QoS, while enhancing journalist's tools for higher quality news and novel information, without neglecting the economic viability of the outcome.

Proposed Solution

The proposed solution comprehends three main pillars, as depicted in Figure 2:

- Machine learning for media;
- Big data infrastructure;
- User interface, all with common ground knowledge: news media.

This solution aims to give a contribution to the current state of the art on media projects dealing with big data scenarios, with a special focus on news. It aims to build ML models capable of extracting, classifying and correlating information available on news. To build such models, this solution uses ML algorithms that can learn from real data and predict on unseen data, using big data cloud-based infrastructures, capable of operating very large amounts of data, both historical (batch processing) and stream. Lastly, special attention is also given to the user interface and user experience, as this is the privileged mean of communication and knowledge sharing between end users and media producers.

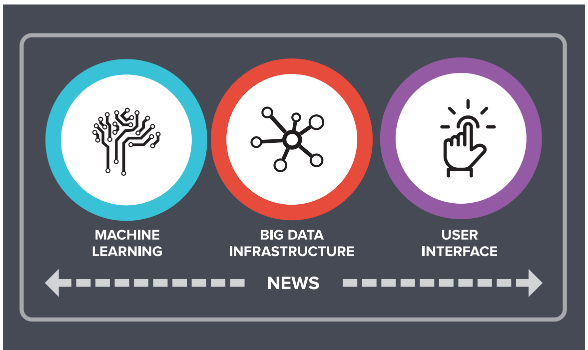

FIGURE 2 High-level domain solution

Machine Learning for Data Analysis

The architecture for the first pillar of the proposed solution is presented in Figure 3.

This workflow interconnects news articles, in its raw format, to the user interface where the final solution is available. For the sake of simplicity, news articles are assumed to be already stored in a database, although such process includes RSS feeds crawling and scraping, among other data cleaning and indexing techniques. NERD is the first step of the data processing pipeline, and this solution focuses on persons only. Although Wikipedia and Freebase [35] knowledge bases cover a large set of entities, namely persons, such sets are restricted to mediatic

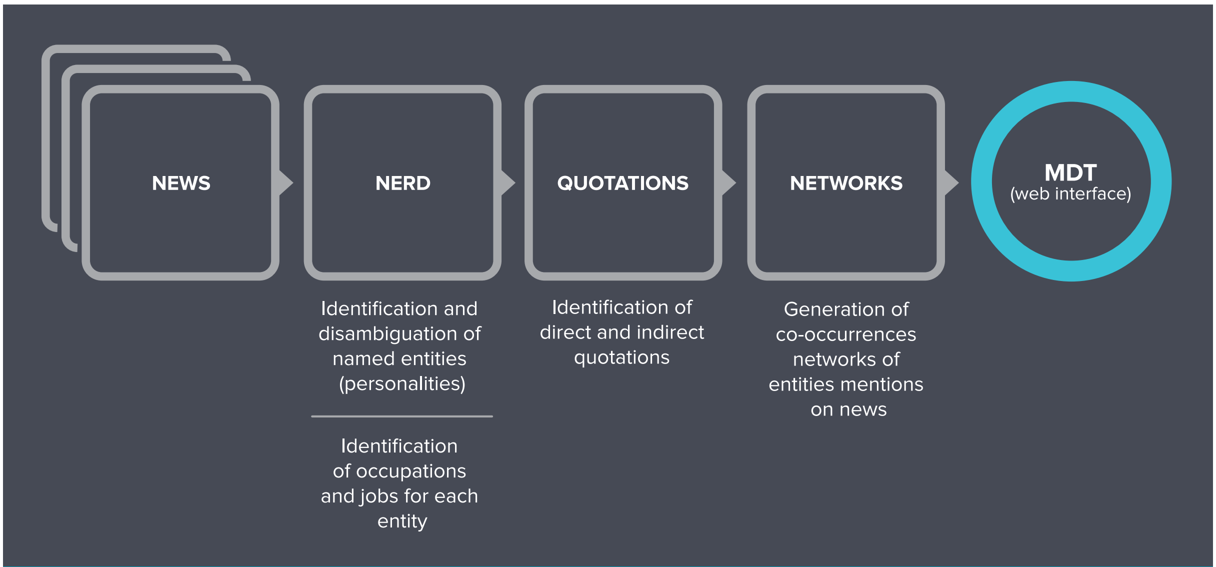

FIGURE 3 Pillar I - Machine Learning architecture

entities, are barely updated and do not include most of the persons mentioned on national scope news articles, such as Mayors, deputies, soccer coaches or CEOs of smaller companies. Moreover, manual based lists of entities do not satisfy our needs. The proposed solution for NERD is supported on ML, in particular in Conditional Random Fields (CRF) algorithm. CRFs are undirected statistical graphic models [36], and have shown that these models are well suited for sequence analysis, particularly on named entity recognition on newswire data. Our method is based on a bootstrapping approach for training a NER classifier with CRFs [37] and led to high-quality results (83% for precision and 68% for recall). Additionally, news articles convey excellent information regarding current and past jobs and roles of public personalities. Such information can be used to automatically generate micro-biographies with the support of apposition structures. For instance, "Barack Obama, president of USA, (...)" or "The Russian leader, Vladimir Putin, (...)" are examples of this linguistic structure. This property was explored such that, by using linguistic patterns, is it possible to build a high quality and specialized knowledge base [38]. Results achieved also point to a high-quality resource, with 97% precision and 59% recall values.

Automatic identification and extraction of quotations (refer to the second block in Figure 3) is a complex task due to a large number of linguistic variations that may exist at the language level. First, a non-neglectable amount of quotations omit the speaker, frequently being replaced by pronouns (e.g.: "He said..."). This process is referred as co-reference. Second, the speaker can be replaced by a different entity type, frequently an organization (e.g.: "Microsoft declared that..."), thus diverging from the true meaning of quotation. Also, speakers name can have different variations, such as short versions of the name (e.g.: "Barack Obama" and "Obama") or a job descriptor (e.g.: "The President of USA said that..."). Lastly, quotations are not necessarily bounded by single sentences and can occur in multiple sentences. Because of all these unsolved challenges on the quotations extraction topic, using a fully automatic machine learning approach for this problem would not retrieve high-quality results. Quotations' extraction is thus based on a set of linguistic patterns matched against news articles sentences. Results show higher precision values for direct quotations, as expected, but also considerably high (approximately 80%) precision values for indirect quotations extracted from single sentences.

The last core block from the architecture presented in Figure 3 refers to networks. Networks, also known as Graphs, allow the visual representation of relations, without losing important characteristics of networks such as the strength of connections, centrality or clicks. For news media, networks of entities are clearly a meaningful approach to visualize and analyze information reported on news articles. This solution is based on networks of co-occurrences of persons on news. For each news article, if two or more persons are mentioned in that particular text, a co-occurrence relation is created. Nodes represent persons while edges represent co-occurrences. The size of each node is directly connected with the number of mentions of the person of news articles, and the thickness of the edges matches the number of news articles which both persons co-occur. Apart from node size and edge thickness, yet another variable can be introduced on the network, namely entity types or categories of documents, to name a few.

Although graphs may seem to be a good solution to visualize relationships between entities extracted from news, this approach quickly becomes non-informative as soon as the amount of data drastically increases – a big data scenario. The number of nodes and edges become so high that no visual patterns are possible to obtain from such networks, if no additional steps are taken into account. The proposed solution uses a two-folded approach to deal with this challenge. The first feature to highlight is the Force Atlas algorithm, used on networks. This algorithm [39] is supported on the physical behaviour of electrical charges and springs and aims to spatially distribute nodes and edges of the network based on the strength of the connections. It naturally enhances the creation of clusters (groups of connected nodes), which points to a particularly relevant aspect of such data visualization.

Second, both egocentric and global networks have a depth of 1.5, instead of typical unitary depth networks (star networks). Examples of both networks depths are presented in Figure 4.

Depth networks are a common measure of distance on graphs and represent the number of edges that needs to be transversed between any two nodes. This solution is based on 1.5 networks (right example in Figure 4), a balanced solution between unitary depth networks (left example in Figure 4), which are low informative networks, and networks with depth equal or higher than 2, which can easily saturate.

The third and last important feature included in this proposed solution relates to the classification of news articles. Classification refers to the process of automatically assigning one or more classes to a particular document (e.g.: sports, Europe or

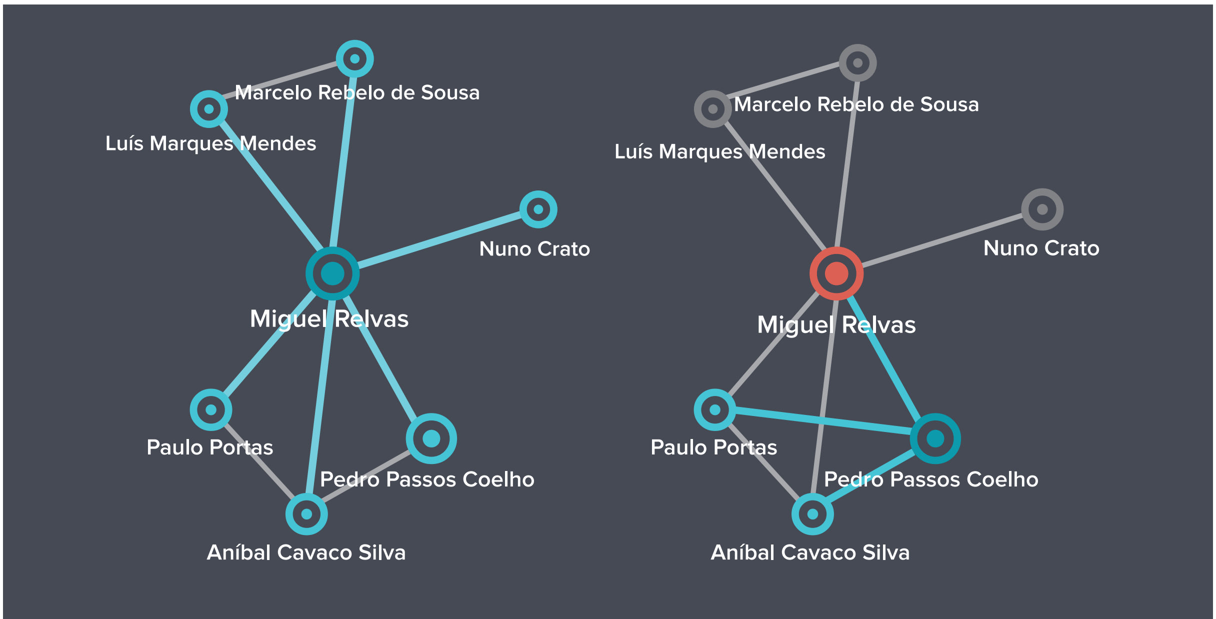

FIGURE 4 Egocentric networks with depth 1 (left side) and depth 1.5 (right side)

migrants). To tackle this classification problem, a multi-classifier approach was implemented: Support Vector Machines (SVM) and Nearest Neighbour (NN) classification models were built to deal with different specificities of this task [40] [41]. Much of the classification process is commonly performed by journalists and editors at the time of writing a news article. Such information is typically delivered to end-users through metadata (e.g.: tags associated with news articles). Machine learning is one of the approaches used to expand such list of metadata classes and thus enrich news articles with additional information. With an expanded list of classes for each news articles, it becomes possible to correlate entities with classes (e.g.: "António Costa" is frequently mentioned on politics news) and, ultimately, filter networks of entities based on news classes, allowing more detailed search and analysis of data.

An Infrastructure for Big Data on Media

The second large contributor for the proposed solution is the architecture, depicted in Figure 5. It represents the logical infrastructure of the proposed solution, from an engineering point-of-view.

From the flow of information represented in Figure 5, on the most left side of the architecture, news articles are consumed from a distributed messaging framework, SAPO Broker [42]. This framework, among other features, provide Publish-Subscribe and Point-to-Point messaging, guaranteed delivery and wildcard subscriptions. From the scalability perspective, there can be as many consumers as necessary, according to the throughput of data. Data is then routed to the Information Extraction Engine, where most of the information extraction, processing and classification takes place, as described in this section. IE engine is modular, such that information is extracted and processed in logically independent blocks. With this approach, in the event of an increase of the throughput of data, this represents an increase on the number of blocks of data to process, which, ultimately, means more computational power need (e.g.: additional server or virtual machine, more CPUs or an increase of

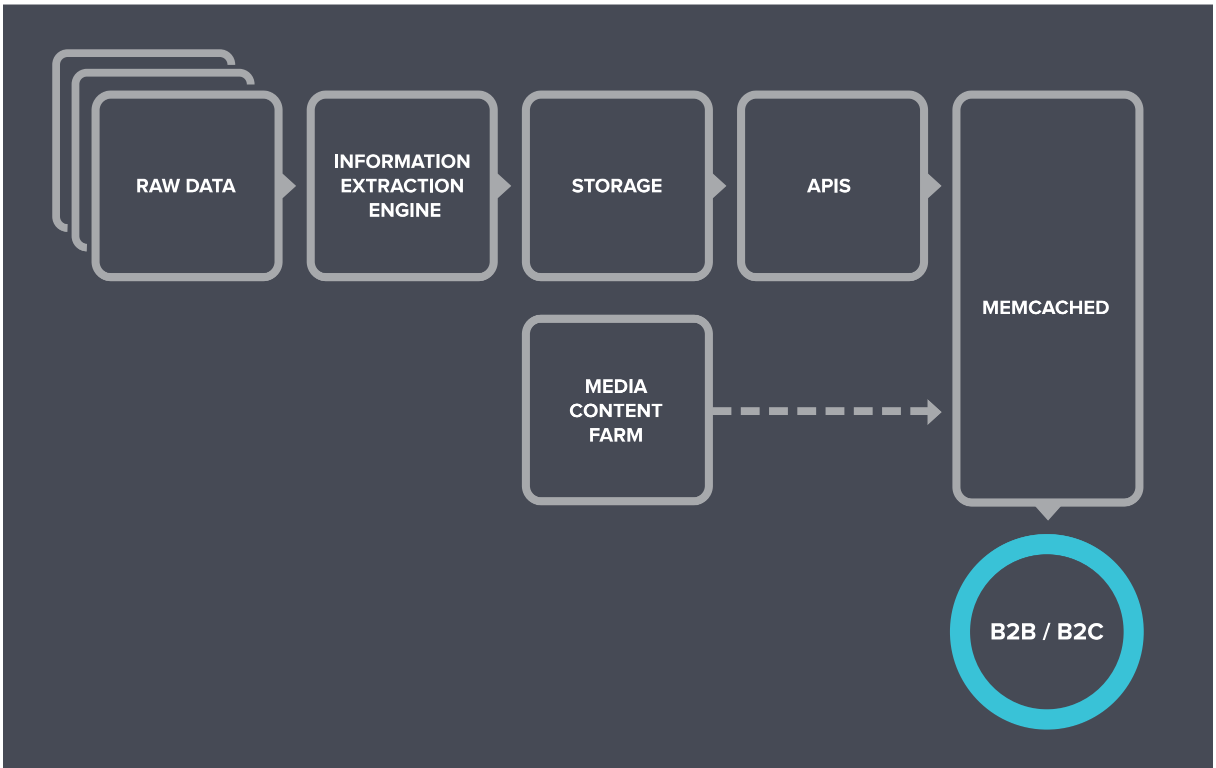

FIGURE 5 Pillar II - Big Data infrastructure

memory). Such information is subsequently stored and indexed in high performance and low latency systems such as SOLR. Additionally, these indexing systems are redundantly spread in the backend network for both performance and resilience issues. Moreover, nontextual data (typically images and videos) is stored in a separate key/value database for improved performance responses.

APIs account for the interface between storage and indexing systems, with fully processed data, and final user applications and services, for both B2B and B2C scenarios. Such APIs are specifically designed and optimized for pre-established usages to guarantee standardization of responses and sub-second responses. A further cache mechanism is the last building block of this architecture, positioned to ensure that repeated requests are quickly and seamlessly retrieved.

User Interface for Media

The last main pillar referred in the high-level domain solution from Figure 2 is the user interface. From a user-centric perspective, the user interface is the second biggest challenge for big data on media, and successful products and services in this field are still scarce (refer to section 2). There are two important aspects that impact on the quality of the user interface and consequently on the user satisfaction: (i) how the information is organized and (ii) how the user can interact with such information. Both aspects are crucial to engaging end-users and turn this approach into a successful product thus creating new opportunities for business.

In the following section will be presented "Máquina do Tempo", a media product, developed by SAPO and maintained by Altice Labs in collaboration with the University of Porto. This product is the face of a big data and ML infrastructures with a user interface carefully designed to fulfill both user and business needs.

"Máquina do Tempo"

"Máquina do Tempo" (MdT) [4] is the completion of the solution presented in the previous chapter. It is an interactive online tool which allows users to navigate and explore news published during the last 25 years. Such large repository comprehends news from LUSA, a major Portuguese news agency, together with news published online by the main Portuguese news stream. With MdT users can analyze personalities and events from from historic records as reported on the news.

This project was developed within the scope of a collaboration between the SAPO R&D Laboratories at the University of Porto and SAPO Notícias and is the culmination of five years of research and development from both institutions.

MdT comprehends a set of approximately 8 million Portuguese news articles written between 1987 and today, representing around 160 million distinct sentences and more than one thousand million words.

MdT has more than 200 thousand distinct personalities and 5 million relationships, and about half a million direct and indirect quotations stated by these entities. On average, each entity has 4 different identified occupations during the 25 years' timeframe of MdT. All this information is automatically extracted and indexed with ML and natural language approaches (refer to section 4).

MdT has essentially two means of interaction: a personality based and a timeline selection. Exploring MdT from personalities point of view allows users to access an automatically generated profile page for each entity, thus enabling user access to a wealth of information ranging from the entity photo and occupation to quotations extracted from news, most relevant news mentioning such personality as well as the deeply most connected entities on a specific timeframe. Figure 6 depicts the profile page from Marcelo Rebelo de Sousa, a Portuguese public personality frequently mentioned on news and with a long political record.

The header of each profile page includes, apart from name and occupation, statistics regarding the entity's presence on news, such as the total number of mentions, quotations or relationships and a distribution over news categories/themes (e.g.: politics or sports). Additionally, users can explore the presence of each personality on news since 1990 at

FIGURE 6 MdT profile page

the distance of a click: using the timeline view, the date and time intervals can be changed according to user's needs and all information presented on each page is updated accordingly. By exploring the networks of personalities, users are able to navigate on egocentric co-occurrences networks for each specific profile page selection.

Moreover, global networks, as depicted in Figure 7, allow users to explore co-occurrences networks without any particular egocentric entity. This is particularly interesting to explore clusters of entities and their most relevance presence on different topics of news, which can be obtained with the support of different color nodes for each topic.

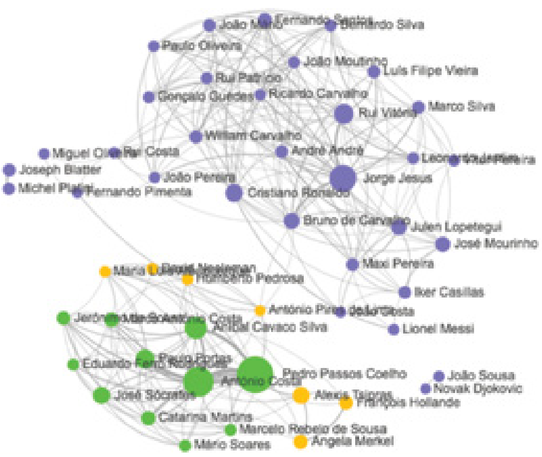

FIGURE 7 MdT co-occurrences network

As previously discussed (refer to sections 2 and 3), user engagement is one of the key data challenges in business. SAPO web portal, with approximately 30 million daily visits, is constantly pursuing innovative and positive experiences to improve and impact on its user engagement. Considering this as an opportunity for SAPO news services, SAPO developed a widget at SAPO web portal (its homepage), which is an entry point for MdT. The widget is presented as shown in Figure 8.

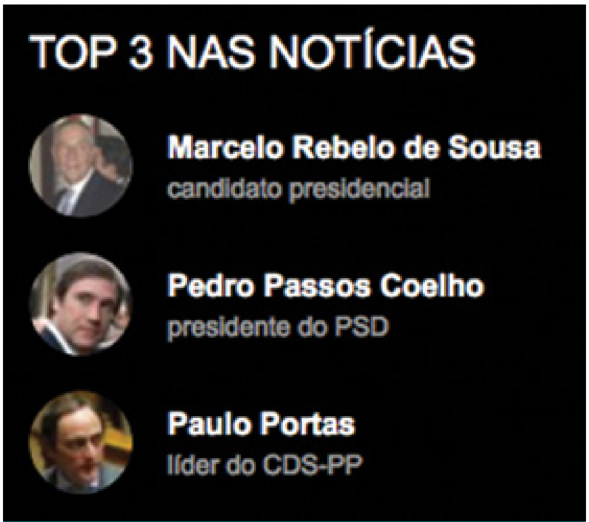

FIGURE 8 MdT widget at SAPO homepage

The idea behind this widget is simple: give clear and updated information to SAPO users about who is getting more attention on news. The result is a top three list with the persons most mentioned on news during the past three days. For each person, the user has a photo, to immediately associate the name with the person, as well as the current job/occupation most frequently referred by media. With this approach, we believe two goals were achieved: first, and based on users' feedback, we identify an improvement of user engagement by adding new approaches on top of traditional online news services; second, there was a significant increase on web traffic, as a consequence of the redirection of traffic from SAPO homepage to MdT, impacting directly on ads revenue, among other KPIs.

Conclusion and future outlook

Is data big? Yes. Big data has already arrived and media is well part of it. There are definitely no doubts concerning that. Is data getting smarter? The amount of data produced on a daily basis by media industries is too high, so that the benefits the society can take from it are still scarce. What to do with so much data is what actually bothers all, from scientists and journalists to entrepreneurs and business people.

The society and the industry are both still far from having intelligent news media software. The size of data is not, at this time, the greatest challenge. Such challenge is related with the language analysis and processing, as well as to prepare machines to actually extract novel and usefull knowledge from data. At the current stage, machine learning and artificial intelligence are able to enhance content and support humans on decision making. That seems to be all.

New York Times states that "The future of news is not an article" [43], and pinpoints some future directions such as enhanced tools for journalists and adaptive content, referring that the future of news is much more than a stream of articles and highlights the distinction between ephemeral content and evergreen content. The journalism business needs to create and deliver more high-quality information, instead of, for instance, publishing hundreds of articles a day, then starting all over the next day, recreating any redundant content each time.

SAPO's "Máquina do Tempo" is an approach to support journalists on their investigation, to give readers the opportunity to explore news without any barriers and to eventually support the society with new and richer information along time. Next developments on MdT will include additional entities types (organizations, locations and events), also more complex relations between entities [44], and an innovative approach to automatically build stories from news [45].

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06

‘5G’: A BIG STEP FOR TECHNOLOGY, ONE GIANT LEAP FOR MANKIND

‘5G’ is the next big milestone in wireless communications. Expected to start being commercially exploited around 2020, it will represent a new stage in wireless communications, answering the identified requirements that will enable new ways of doing business and establishing societal relationships.

‘5G’ will reflect the already observed trend of an increasingly more ‘wireless’ world, for humans and machines. Thus, even if ‘5G’ must be implemented by technology, supported by significant future improvements, current ‘5G’ discussions are focused in the expected impacts it will have in the way we will communicate, do business, interact with the surrounding world and also foster interactions with and between artefacts. This is why, currently, ‘5G’ represents much more than a pure technological evolutionary aspect, in fact encompassing all the expected evolutions and transformations to be observed in our future communication immersive experience.

As it can be expected, ‘5G’ is flourishing in activity being the focus of all telecommunication’s actors. From researchers to businessmen, ‘5G’ is being worked in many dimensions.

This article aims at explaining what ‘5G’ means, taking a pragmatic approach with an emphasis in standardization, focusing on the technological basis of the fifth generation of wireless communications and in what is expected to be enabled by it.

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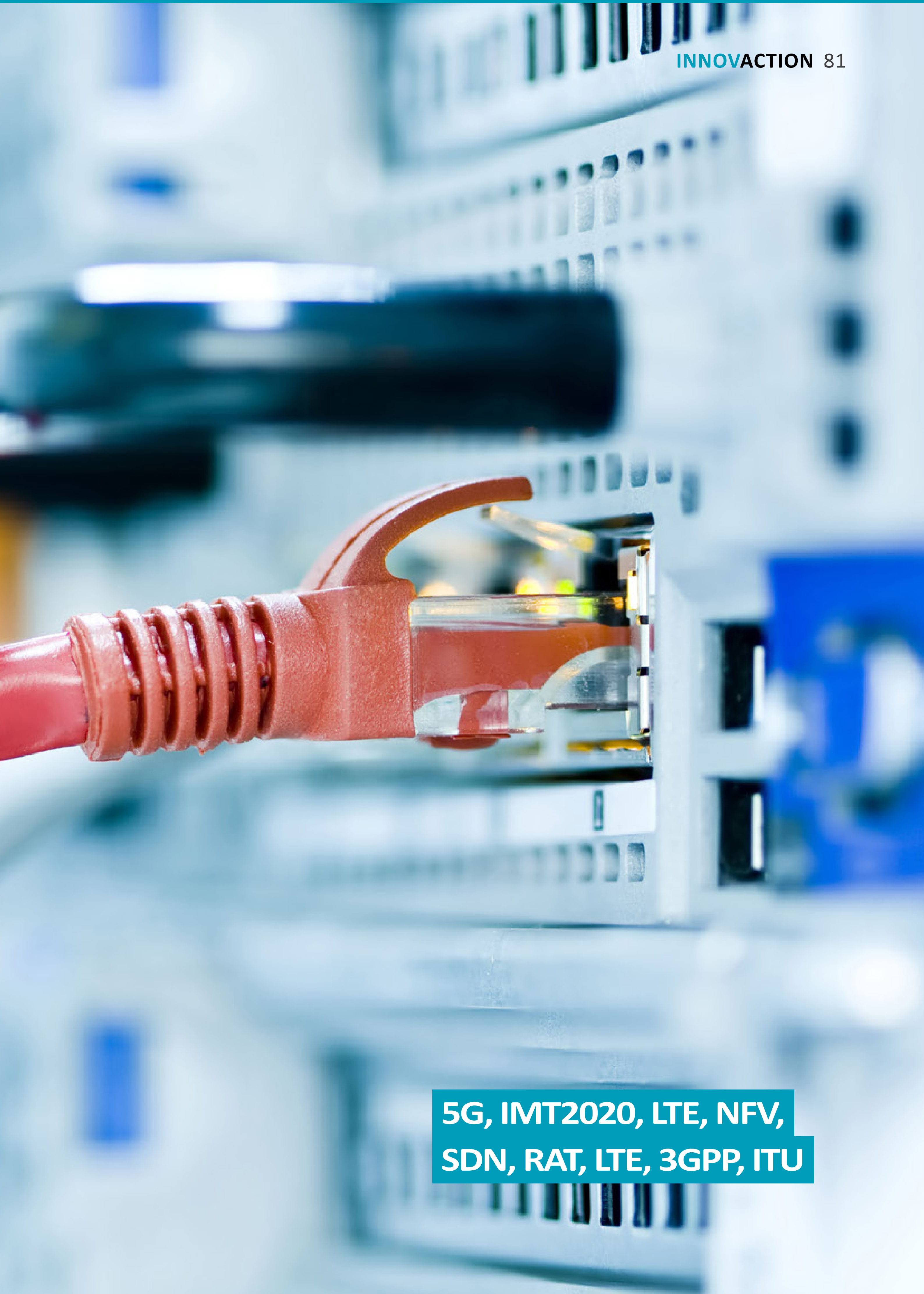

5G, IMT2020, LTE, NFV, SDN, RAT, LTE, 3GPP, ITU

Introduction

The following are citations from '5G' (5th Generation) related documents, produced by the identified organizations:

- ITU-R [1]: "enabling a **seamlessly connected society** in the 2020 timeframe and beyond that brings together people along with things, data, applications, transport systems and cities in a **smart networked communications environment**";
- NGMN [2]: "5G is an **end-to-end ecosystem to enable a fully mobile and connected society**. It empowers value creation towards customers and partners, through existing and emerging use cases, delivered with consistent experience, and enabled by sustainable business models";
- 5G-PPP [3]: "5G is more than an evolution of mobile broadband. It will be a **key enabler of the future digital world**, the next generation of **ubiquitous ultra-high broadband infrastructure** that will support the transformation of processes in all economic sectors and the growing consumer market demand."

As can be seen, the term '5G' has assumed a quite broad meaning, concentrating on it many different aspects, clearly going beyond previous technical scope of a mobile 'generation' definition. Today, more than technology, '5G' means all the societal and business relationships changes, expected to be observed around 2020 and beyond, supported by telecommunications. This next 'generation' is expected, according to Ericsson's forecast [4], to have 150 million subscriptions, by 2021.

Approximately every ten years a new 'generation' has emerged from 3GPP, marking important milestones in wireless communications, clearly reflecting different communication needs: from first mobile, analogue communications (1G) in the 1980s, to permanently connected and consuming broadband Internet services (4G) (Figure 1). This reflects the fact that the world and the society is increasingly becoming more 'wireless', with expect huge advances in the area, fostered by the '5G' current big excitement.

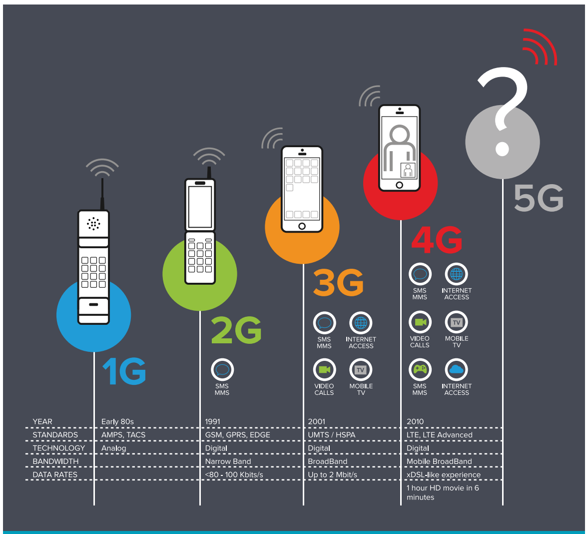

FIGURE 1 Mobile wireless network generations [6]

Currently, '5G' is in the 'wish list elaboration' phase, with many use-cases being elaborated, with the purpose of requirements extraction to, later, be reflected in supporting technological developments and standardization. As an example, the four white papers [5] on vertical sectors (eHealth, Factories-of-the-Future, Energy and Automotive), recently released by the 5G-PPP, can be taken, documenting '5G' expectations and identifying requirements.

While there is much debate related to the definition of '5G', it is widely agreed that this new network must provide improvements in capacity, deployment and operational costs, as well as ecological impact. Technically, in a few words, '5G' will bring significantly improvements on bandwidth and reduce latency, will be ubiquitous, improving geographical coverage and connecting everything, being more energy efficient and reliable, and allowing much more simultaneous connections. '5G' will be leveraged by emerging technologies, like virtualization, cloud and software defined networks, besides all current radio developments.

Recently (October 29th, 2015), ITU endorsed a resolution [7] that establishes the roadmap for the development of '5G' mobile and the term that will apply to it: "IMT-2020", under the motto "IMT-2020 to provide lightning speed, omnipresent, ultra-reliable mobile communications." More information

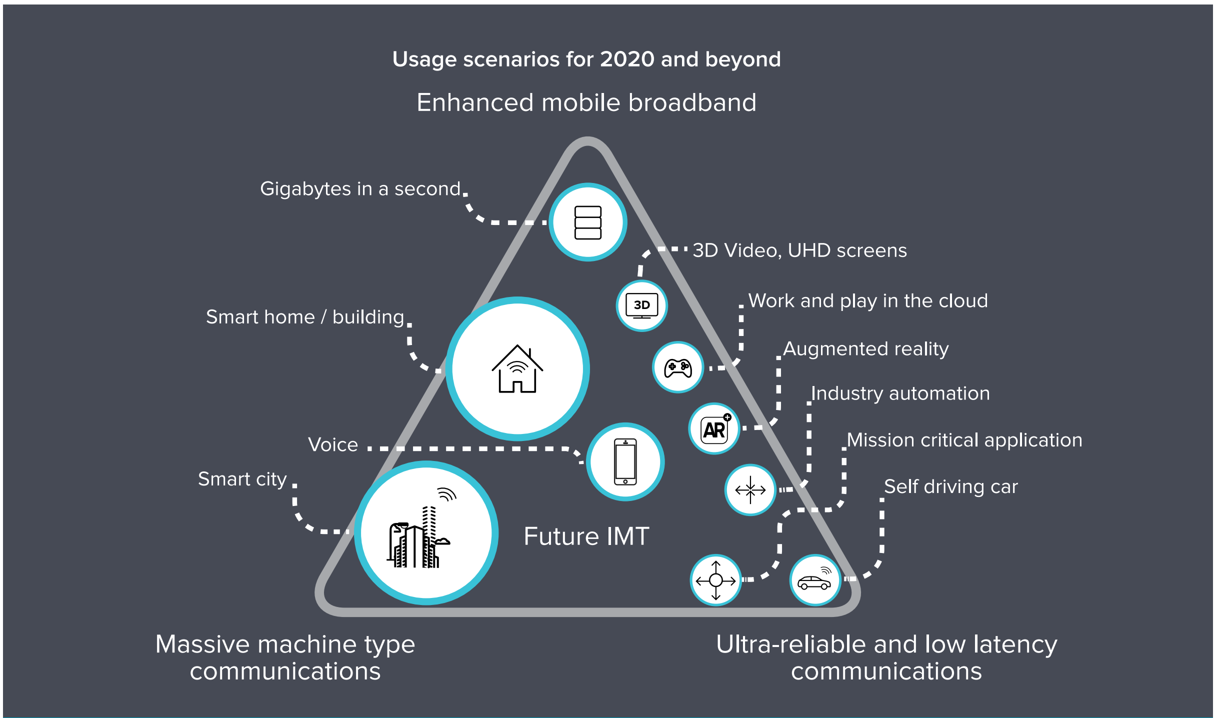

FIGURE 2 IMT 2020 and beyond usage scenarios [8]

about IMT [1] and IMT-2020 can be found at a specific ITU-R web page [9].

‘5G’ use cases and requirements

ITU-R has identified a set of ‘usage scenarios’ for ‘IMT for 2020 and beyond’ [8]. These were organized along three use case categories, as shown in Figure 2.

3GPP, via its SMARTER Study Item (Study on New Services and Markets Technology Enablers) is elaborating TR 22.891 [10], currently encompassing fifty-nine ‘use cases’, extracting requirements to be met in future 3GPP Releases’ features. This is work in progress, being complemented by results from the *NexGen* (SA2 Architecture) and RAN (Radio Access Network) activity.

The target performance enhancements required to address scenarios demands, are summarized by ITU-R in [8] in eight ‘key capabilities’, as shown in Figure 3.

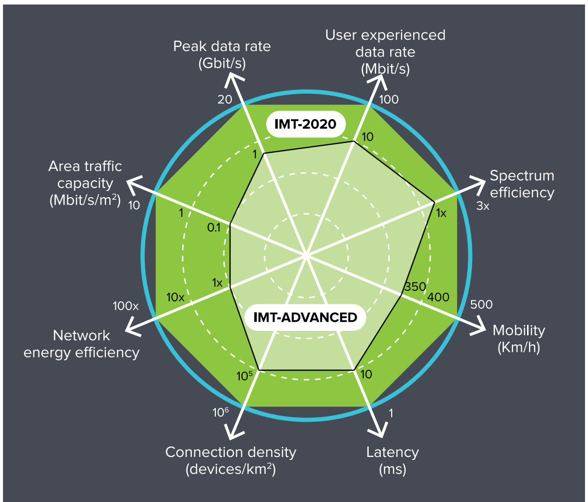

FIGURE 3 Enhancement of key capabilities from IMT-Advanced to IMT-2020 [8]

1 IMT, International Mobile Telecommunications, are standards and systems created by the International Telecommunication Union (ITU), for the creation, operation and management of mobile networks and Internet communications

These can be grouped as follows:

1. Capacity (global area traffic and connections);
1. Throughput (peak and experienced data rates);
1. Latency;
1. Mobility;
1. Efficiency (spectrum and energy).

As can be seen, the challenges are significant, with some parameters requiring enhancements with factors of 100x.

Next figure (Figure 4), also from ITU-R, maps those key capabilities into the identified usage scenarios.

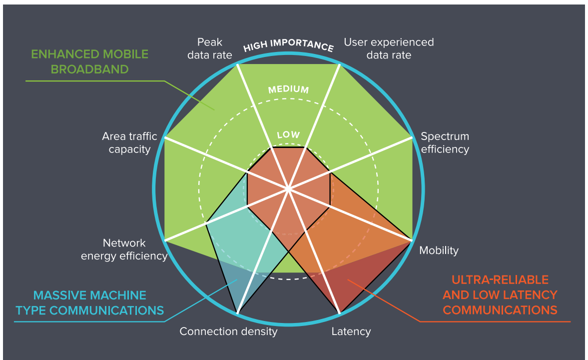

FIGURE 4 Importance of key capabilities in different usage scenarios [8]

It can be seen that eMBB (enhanced Mobile Broadband) presents the wider range of requirements, while mMTC (massive Machine Type Communications) and ultra-reliable and low latency communications have very specific requirements.

Other organizations and vendors present slightly different numbers and also add other parameters, like:

- Reduction to 20% in network management OPEX (5G-PPP);
- Services' deployment time below 90 minutes (5G-PPP);
- Cell spectral efficiency of 30 bps/Hz (Samsung);
- Cell edge data rate of 1 Gbps (Samsung).

Another relevant figure (Figure 5), from GSMA Intelligence [11], goes into more detail and shows the dependency between some identified use cases and delay *versus* bandwidth parameters.

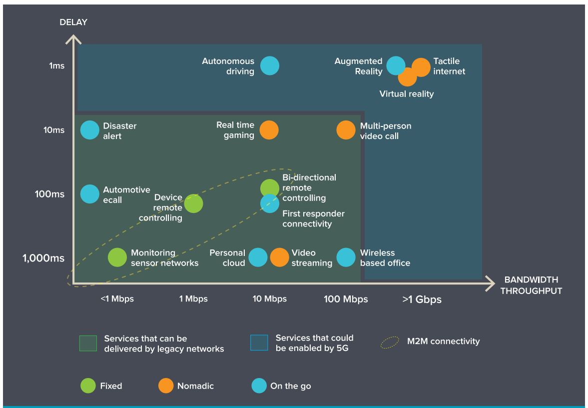

FIGURE 5 Bandwidth and latency requirements of potential '5G' use cases [12]

Based on that required improvements, 3GPP recently held the RAN '5G' workshop [13], concluding on the need for a new radio interface as the only way to answer those. This new RAT (Radio Access Technology) will not be backward compatible with previous radio interfaces (as for previous generations), but must be forward compatible, allowing an easier evolution, although it is stated that "strong LTE evolution continues in parallel."

Evolution at 3GPP towards '5G'

As shown at the introductory section, mobile wireless communications have evolved going through several 'generations' (1G/2G/3G/4G). However these designations, even if sometimes used, most of them as a marketing aspect, are not officially adopted by standardization bodies, like ITU-R and 3GPP. This will become noticeable in the next paragraphs, being referred only to establish the commonly accepted correspondence.

Even if the "original scope of 3GPP was to produce globally applicable reports and specifications for a third generation mobile system, today the project provides complete system specifications for cellular telecommunications network technologies" [14]. With this role, 3GPP is a fundamental SDO in the standardization process related to wireless communications, which "produces Technical

Specifications, to be transposed by relevant Standardization Bodies (Organizational Partners) into appropriate deliverables (e.g., standards)" [15].

LTE was firstly introduced in 3GPP Release 8, representing a significant change from previous mobile network generations: only packet switching ('All-IP') is supported, more intelligence is pushed into network edges and support for non-3GPP RATs. Still, even if branded by many as '4G', Release 8 does not fulfil '4G' requirements (being considered as '3.9G'). Those are expected to be fulfilled by 3GPP Release 10 compliant systems.

LTE-A (LTE Advanced) is the next big step in the 3GPP mobile networks, standardized in Release 10, being the first to fulfil (even to surpass) IMT-Advanced requirements for '4G', providing:

- Increased peak data rate: 3/1.5 Gbps (downlink/uplink);
- Higher spectral efficiency: 30 bps/Hz;
- Increased number of simultaneously active subscribers;
- Improved performance at cell edges: e.g. for downlink 2x2 MIMO at least 2.40 bps/Hz/cell.

The main new functionalities introduced in LTE-A are:

- Heterogeneous Networks (macro/small cells);
- Carrier Aggregation (CA);
- Enhanced use of multi-antenna techniques (MIMO, Multiple Input Multiple Output, or spatial multiplexing);
- Support for Relay Nodes (RN).

Following 3GPP Releases (11 and 12) will further improve LTE-A. These will contribute with, for instance, Coordinated MultiPoint (CoMP) in Release 11, while Release 12 introduces features to accommodate LTE-M (or 'LTE for IoT') requirements, in addition to the introduction of a new UE (User Equipment) category (LTE Category 0). Release 13 and following Releases will advance on these.

LTE-A Pro will be the next major milestone from 3GPP, to be ready in March 2016, with Release 13 freeze. For some, this is '4.5G'. It provides significant improvements, in the path towards '5G': MTC enhancements, D2D (Device-to-Device), CA enhancements, interworking with Wi-Fi, licensed assisted access (at 5 GHz), 3D/FD-MIMO, indoor positioning, single cell-point to multi-point and work on latency reduction.

From Release 13 onwards, 3GPP decided that future LTE releases will adopt the name LTE Advanced Pro (LTE-A Pro). Future Releases (14, 15 and 16) will incrementally standardize '5G', introducing features to be referred in next sections. 3GPP approaches this topic by phases:

- **Phase 1:** to be completed by second half 2018 (end of 3GPP Release 15);
- **Phase 2:** to be completed by December 2019 for the IMT-2020 submission and to address all identified use cases and requirements (end of 3GPP Release 16).

This is summarized here [16] and depicted in Figure 6:

- Release 8, December 2008: LTE is introduced;
- Release 9, December 2009: Enhancements to LTE;
- Release 10, March 2011: LTE Advanced;
- Release 11, September 2012: Enhancements to LTE Advanced;
- Release 12, June 2014: Further enhancement to LTE Advanced;

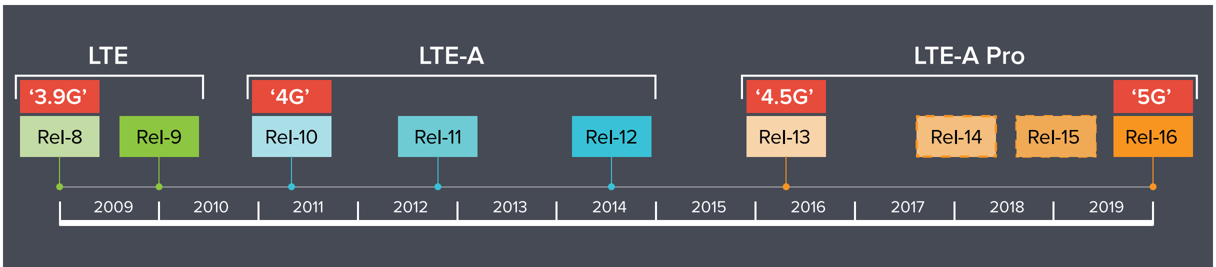

FIGURE 6 3GPP Releases calendar

- Release 13, March 2016 (expected): LTE-A Pro;
- Releases 14, 15 and 16, targeting completion on December 2019: '5G'.

For more detail on the current and future events, a 3GPP '5G timeline' [17] is presented below (Figure 7), focusing in the RAN and showing the dependencies with ITU-R.

The defined ITU-R '5G' calendar, under IMT-2020 scope, is depicted in more detail in Figure 8 [18], which shows two important events (WRC [19] 15, which already took place, and WRC 19) and several milestones.

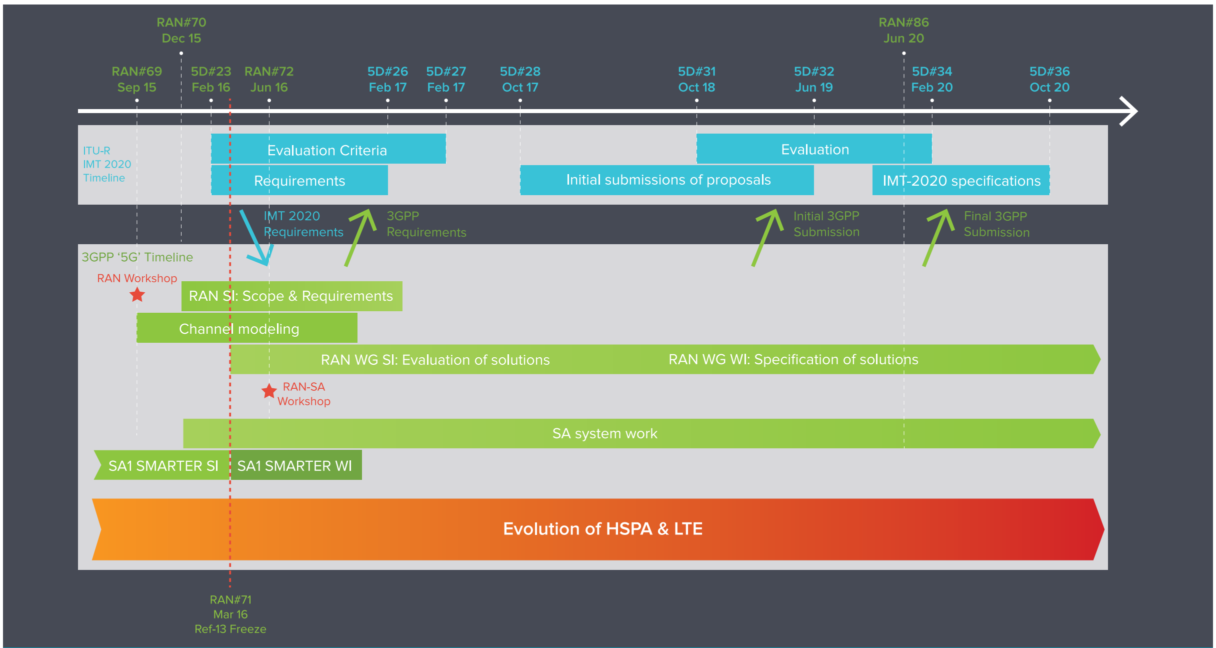

FIGURE 7 3GPP timeline for '5G' [17]

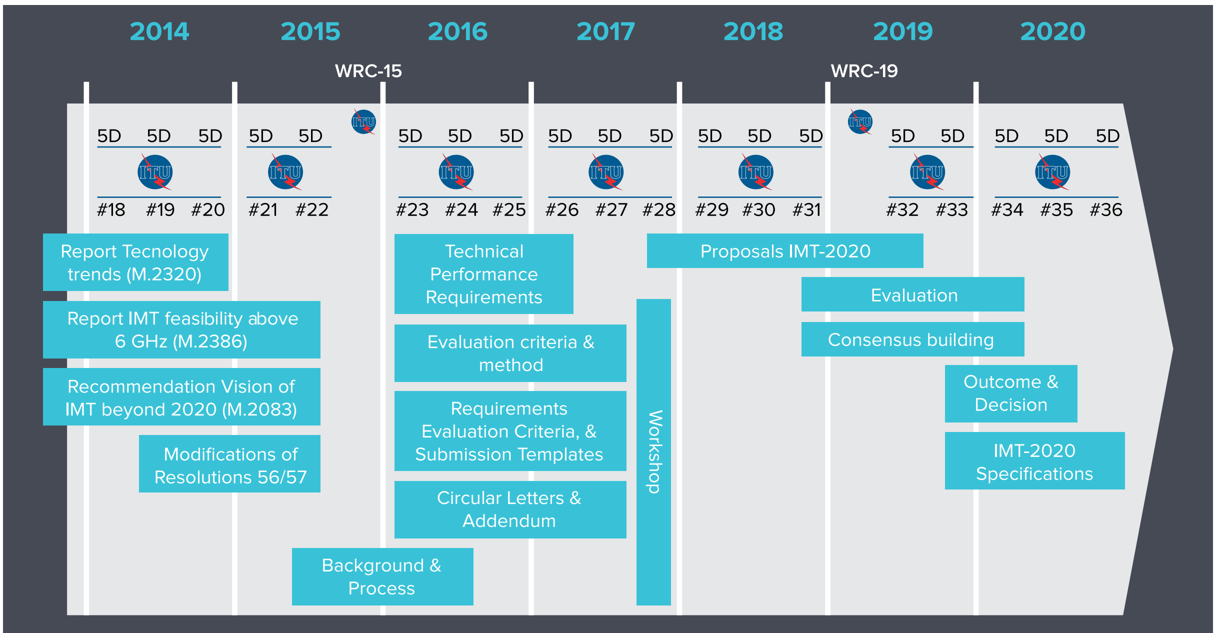

FIGURE 8 Detailed timeline & process for IMT-2020 in ITU-R [18]

IMT-2020 submission deadlines are as follows and must be accomplished by 3GPP:

- Initial technology submission: June 2019;
  - High level description of the technology;
- Detailed specification submission: October 2020;
  - Stage-3 specifications (3GPP plans to do final submission in February 2020, based on specifications functionally frozen by December 2019).

Further information on Releases' features can be found at the 3GPP web page, dedicated to Features and Study Items [20].

'5G' technological definition

The 3GPP target is to find a "highly **flexible** and **capable** '5G' system to meet **diverse requirements** for the three usage scenarios envisaged for 2020 and beyond" [21]. Besides impacting the radio interface, a modular architecture is required in order to avoid having to answer to all required features in all the future deployments. In addition, 'Network slicing', from terminals to service platforms, heavily based on NFV/SDN, will allow building virtual networks, with specific characteristics, answering to explicit communities requirements (e.g. more data or control intensive data, priority to robustness or high bandwidth).

A large number of technologies and concepts are expected to be part of '5G', progressively evolving and being incorporated into successive Releases, as demonstrated in the previous section. Nevertheless, a revolutionary approach is expected in some areas, since pure evolution and optimization of current solutions is not enough, considering the challenging defined '5G' requirements (see section 2, on identified requirements).

In short, '5G' will need a **new radio interface**, without backward compatibility, and a **new core network architecture** (CN), to be able to provide the expected performance and functionalities for the new digital society of 2020 and beyond. This is particularly true to achieve the sub-1ms latency and the >1 Gbps bandwidth.

These two aspects, new RAT and architecture, will be the major revolutionary milestones of '5G', while other features will be appearing as evolutions from today's situation, as future 3GPP Releases will pop-up, contributing in general to achieve overall '5G' goals.

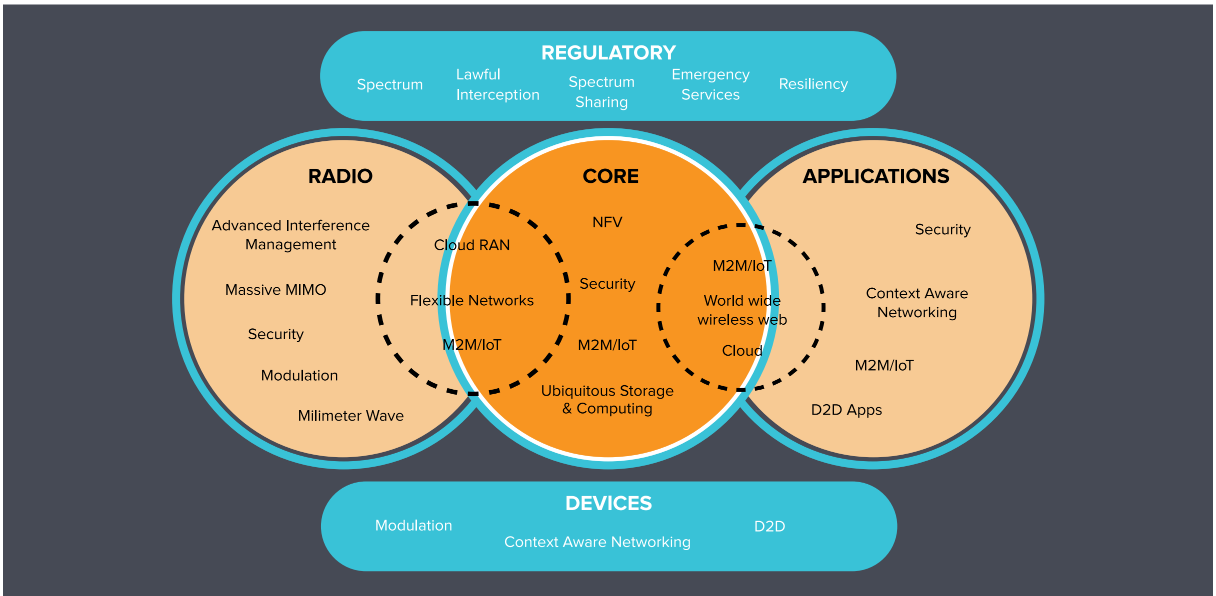

FIGURE 9 4G Americas preliminary view of the end-to-end '5G' ecosystem [22]
(Source: 4G Americas)

The next two sub-sections go into more detail about the core and access evolution. Figure 9, taken from 4G Americas [22], summarizes it, providing a holistic view on what '5G' can be.

Core Network

3GPP is addressing the definition of a new architecture via a new group called "Next Generation" (NexGen). Results are targeting 3GPP Release 14 with the objective to "design a system architecture for the next generation mobile networks" [23].

As stated by 3GPP, "Earlier 3GPP system architectures focused on the 3GPP access part. The just starting work on the next generation system architecture has a wider scope, including also considerations on non-3GPP accesses, certain access independence and convergence aspects." In fact "One of the architectural characteristic of '5G' CN is to minimize access dependencies and to allow its evolution independent of RAN; this '5G' characteristic will be viewed as one of the key requirements."

A number of goals have been identified for the new architecture (modified extract from 3GPP feasibility studies [10]):

- Allow for an independent evolution of core and radio networks;
  - Core and RAN network domains shall be functionally decoupled;
- Support multiple types of access, including new radio, LTE evolutions and non-3GPP accesses;
  - The new architecture shall minimize access dependencies;
- Allow a simultaneous use of multiple access technologies by the UE;
- Have a clear separation between Control and User plane functions (SDN principles);
- Support generic exposure of services and functions by functional elements to enable reuse by other entities (SOA principles);
- Support enhanced MBB, critical communication (CC), massive M2M use cases;
- Support network slicing, with resources isolation between slices;
- Minimize the signalling (and delay) required to start the traffic exchange between the UE and the PDN;
- Support a structural reduction of the round-trip delay to 1ms between UE and the PDN (in active state);
- Support native IP and non IP connectivity services;
- Support broadcast services;
- Support different levels of mobility, service continuity, network resilience and UE power consumption.

In order to achieve that, the new architecture, still to be defined, will integrate and be based in a number of technological components, being the generalized adoption of virtualization the main building block. Based on that, SDR and SDN (Software Defined Radio/Network), MEC (Mobile Edge Computing) and SOA (Service Oriented Architecture) shall be deployed.

Optical technologies (e.g. PON based) will also play an important role, in both backhaul and fronthaul, in order to achieve the required transport capacity, in a very dense radio access network.

Access

As stated before, the '5G' architecture will clearly integrate other access technologies, besides 3GPP defined RATs, including wired ones. Still, a new RAT is required. According to 3GPP, there is a "general consensus that the next generation RAT will be defined by RAN groups in two phases (Phase 1 and Phase 2) in two consecutive 3GPP releases (Release-15 and Release-16)."

Besides required performance, the new radio access will incorporate functionalities for emerging areas as:

- Device-to-device communication (D2D);
- Moving networks (e.g. V2x).

As with the Core Network, virtualization will also make its appearance in '5G'. In addition, several specific radio technologies will evolve and be part of the new RAT. This will include:

- Utilization of centimetre and millimetre wave bands;

- Up to 6 GHz (Phase 1 – year 2020);
- Up to 60/100 GHz (Phase 2 – year 2025);

- New radio access modulations, as Universal Filter Orthogonal Division Frequency Multiplexing (UF-ODFM);
- Downlink multi-user transmission using superposition coding;
- Massive/Distributed Multiple Input Multiple Output (MIMO) antenna schemes;
- 3D/FD (Full Dimension) MIMO schemes;
- Advanced inter-node coordination to minimise interference; Interference cancelation/ utilization (ICIC);
- Spectrum sensing and dynamic shared spectrum access;
- Cooperative usage of licensed and unlicensed spectrum;
- Multi-cell cooperation (CoMP);
- Massive carrier aggregation;
- New MAC (Medium Access Control) for light communications;
- Virtualized cloud based radio access (C-RAN) network control and processing;
- SON techniques, for opportunistic and adaptative use of resources;
- Cognitive radio and network;
- Multi radio access technology integration and management, including small cells and HetNets;
- Evolved satellite communications;
- Wired and wireless backhaul integration.

Other standardization bodies work

Besides ITU-R and 3GPP, other SDO are directly or indirectly contributing to '5G' definition and specification. These are a few examples, not being exhaustive in the analysis.

ETSI – European Telecommunications Standards Institute [24]

NFV and MEC are being standardized in the scope of ETSI, and are expected to be part of '5G'. While NFV is a more generic development, MEC is targeting mobile network but in its specification it is stated that no 3GPP standards' changes will occur. In this scope, 3GPP has to look into ETSI NFV work, while ETSI has to look into 3GPP work on LTE standards.

In addition, ETSI is also working in machine type communications, from where requirements are expected to extract from 3GPP in future evolution of LTE.

3GPP work in millimetre communications as to collaborate with ETSI work in mWT (millimetre Wave Transmission), since this is also under ETSI scope.

IEEE – Institute of Electrical and Electronics Engineers [25]

IEEE is further progressing the 802.11 technology: 802.11ac (Wi-Fi)/ad (WiGig)/ax. These technologies may complement or be an alternative to 3GPP developments. Considering the 3GPP architecture aim of being access independent, close work with IEEE must exist in order to integrate IEEE defined access technologies in 3GPP core. Current E-UTRAN already as support for WLAN integration.

In addition, having 3GPP looking into unlicensed spectrum for LTE operation will also need coordination with IEEE.

MEF – Metro Ethernet Forum [26]

ITU and MEF established a Memorandum of Understanding (MoU), in order to align strategies in this emerging area. '5G Cloud Access', 'integrated fixed-mobile hybrid '5G' networks' and 'virtualization' are some of the identified areas benefiting from this MoU.

'5G' research in Europe

The European Commission is heavily promoting '5G' development, funding a large number of projects and initiatives, via the Horizon 2020 (H2020) Programme [27]. H2020 is "the largest-ever European Union (EU) research and innovation programme" [28].

One of the adopted mechanisms to foster '5G' development and put the European industry in the ‘5G’ lead, is via the creation of a Public-Private Partnerships for ‘5G’ (5G-PPP [29]), one of the H2020 instruments. The private part is represented by the ‘5G’ Industry Association, encompassing almost fifty entities from the European industry and academia. The 5G-PPP contractual arrangement was signed in December 2013 between the EU Commission, representing the public stakeholder/s and the ‘5G’ Association representig the private entities.

Information about the main H2020 ‘5G’ funded projects (‘5G’ first call [30]) can be found at the 5G-PPP brochure, recently released [31]. Altice Labs is participating in four of those 18 approved projects (*Charisma*, *Selfnet*, *Sonata* and *Superfluidity*).

‘5G’ European funding already started in the 7th Framework Programme (FP7), with the funding of several relevant projects, addressing directly ‘5G’ or supporting technologies. Examples of success projects from FP7 calls on ‘5G’ are: ADEL, MCN and T-NOVA, some of these with active participation from Altice Labs.

‘5G’ experimentation and promotion

A significant number of initiatives have started for experimenting/trialling ‘5G’, outside major manufacturers’ laboratories. The most significant ones are:

- ‘5G’ Innovation Centre, hosted at the University of Surrey (http://www.surrey.ac.uk/5gic):
    - Supported by Huawei, Fujitsu, Samsung, Telefónica, Rhode&Shwarz and Aircom, among others;
- 5TONIC, hosted at IMDEA (http://www.5tonic.org/);
- 5GLab, hosted at Technische Universität Dresden (http://5glab.de/):
    - Supported by Alcatel-Lucent and Vodafone, among others;
- ‘5G’ Berlin (http://www.5g-berlin.de/) and Open ‘5G’ Core (http://www.open5gcore.org/), both hosted by Fraunhofer FOKUS.

All relevant vendors have announcements related to ‘5G’ experimentation. As an example there is the Munich ‘5G’ VIA (Vertical Industry Accelerator) testbed, launched by Huawei.

‘5G’ is also the subject of several other organizations, intending to promote the ‘5G’ development, experimentation and standardization. Three of these are the Korean ‘5G’ Forum [32], the Chinese IMT-2020 (‘5G’) Promotion Group [33] and the Japanese Fifth Generation Mobile Communications Promotion Forum (5GMF) [34]. Agreements and collaborations between them and with the European 5G-PPP have been established. Besides promoting ‘5G’, these organizations conduct research and development activities, aiming at standards contributions.

Additionally a significant number of partnerships and collaborations are continuously being announced, especially between operators and manufacturers, reflecting the global interest in ‘5G’ and the required collaboration among several entities to faster prepare for the ‘5G’ arrival.

Conclusions

Undoubtedly, humans and machines electronic communications’ trend is to increasingly become more wireless. Requirements and expectations related to a new generation of mobile communications are identified via a large number of scenarios and use cases, being elaborated by several fora, including standardization bodies.

The perception of no delay (‘tactile Internet’) and unlimited bandwidth are at the top requirements. Other significant demands include more reliable communications and higher and denser number of connections/devices (IoT). The emphasis is also on energy and spectral efficiency, to reduce energy consumption and increase capacity.

Even if a large community is addressing ‘5G’ and lots of investments are taking placed in technological areas related to it, there is not yet a clear ‘5G’ definition. Standardization activities are evolving, backed by strong investments in research, development and innovation, and the European Commission, via its H2020 programme, is a good example of this effort.

IMT-2020 is the reference for that new 'generation'. From LTE, defined in Release 8, to LTE Advanced Pro, based in Release 13, soon in production, Releases 14 to 16 shall progressively address those IMT-2020 requirements.

From 3GPP point of view, a new RAT is required. However, '5G' must go well beyond that, requiring a new architecture, which shall be access network independent, flexible and service oriented. Thus, '5G' architecture is expected to emerge out of technologies like virtualization, cloud and SDN.

Defined use cases and scenarios clearly demand for a new approach, which must focus on common solutions instead of specific, dedicated solutions for each challenge, simplifying network architecture.

A final word to 'beyond 5G': even not knowing today exactly what '5G' will be, work on what 'Beyond 5G' (B5G) might be has already started [35]. Considering that '5G' will be developed in two phases, 'B5G' intends to provide inputs to '5G' Phase 2' and what will come after this, leading to 6G:

- Phase 1: technically introduced by 2018/20 using spectrum allocated in WRC-15 [36] below 6GHz. This is what is referred in this document as '5G';
- Phase 2: technically introduced by 2025 and maybe lasting to 2030, adding spectrum allocated in WRC-19 above 6GHz.

As it could be expected, inputs at this time are very vague, confirming some of the expected '5G' enhancements and further extending some of those. Extensive 'softwarization' and more 'intelligence' are referred, as well as extending MIMO and a detailed look into optical wireless.

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07

TRENDS IN TV: OTT, APPS, ADS

This article addresses three apparently disjoint major trends in TV: OTT, Applications and Advertising.

Along the references and examples discussed throughout the text, we show how they are being combined towards increasingly innovative functionality and added value to our offers for the TV ecosystem.

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OTT, TVOD, SVOD, AVOD, QoS, ABR, HLS, HSS, MPEG-DASH, TV Apps, AAL, TV Ads, CTR

Introduction

Like many other established technologies, TV has been sentenced to death too many times, but paraphrasing Mark Twain, we can say that “the reports of its death have been greatly exaggerated.”

In this article we will address three hot topics in the TV ecosystem. These are not precisely technical concerns, neither exactly business issues but linger in the fringe between these two connected areas.

The first topic is the OTT entrance in this market, originally fully owned by operators, and the effects this will have on them. We also see that technology pioneered by OTT players will be put to good use by traditional operators.

In that sequence we will analyze the concept of *appification*. It attained major relevance on the mobile world but is increasingly extending to other areas including the TV environment. In this case perhaps the technologies are not there yet, but we may anticipate that it can be a source of anxiety for the TV channel concept.

Lastly, since there is no such thing as TV without advertising, we will explore some new ideas that bring a refreshed relevance to the TV advertising business and will present our recent work in this area, which has the potential to tie up all these trends, adding value to our offers.

OTT

With the recent expansion to more and more geographies, including small markets like the Nordic countries, Netherlands and Portugal, Netflix is trying to achieve critical mass and world dominance, and people wonder how its introduction will affect the currently established pay TV market dynamics. Our understanding is that it will make a difference, but not the same in every market and it will depend a lot on the existing offerings.

In the USA, operators are afraid of the so called cord cutting, where existing cable customers will drop their subscription to go for an antenna plus online SVOD subscription. Indeed, in recent years the pay TV market has been shrinking in the USA, with cable estimates for 3rd Quarter 2015 going for about 300.000 less subscribers, and this is actually an improvement from previous quarters, which presented bigger losses. At the same time Netflix subscriptions reached more than 43 million USA customers [1].

There is undeniably a trend there, pushed by millennials and by the worse than normal economic climate. But in the USA case there was also a trend of ever growing TV channels lineup with a corresponding price increase. An average cable subscription is around $87, where services like Hulu and Netflix are priced under $10. However, they still need a good Internet connection and those are on the higher tide. If it can be seen as a sign, the biggest USA cable operator, Comcast, has now more internet customers than pay TV subscribers.

In addition, the idea that getting TV from the Internet was actually viable was reinforced by the TV channels themselves by allowing TV viewers to catch-up full episodes of their popular series directly from the broadcaster website or through Hulu.

In contrast, with the recent successful push for bundled services in Portugal, there is very little to save by dropping the TV service, since a plain internet connection needed for OTT services is almost the same price as a triple play offer. In addition, over the air TV is still limited to the four national channels. There is a very limited form of catch-up TV through the broadcasters’ websites. More important than that, all operators offer an all encompassing 7 days, 80 channels full catch-up directly on their services and STBs, for free.

To further reduce the demand for cord cutting, the most watched TV events are (like in USA) appointment television in the form of sports events, that have little value in on-demand setups like SVOD [2].

Even more appalling is the Netflix’s current catalog in Portugal (and other countries outside the USA). A slow start is understandable, but a newer trend is that the content rights owners are restricting the licensing to OTT services because of the risk they represent to broadcasters: drain their main revenue stream.

All of this combined suggests that, in Portugal, Netflix and alike OTT SVOD offerings will predictively have a small impact in the overall pay TV ecosystem.

VOD business models

There will be some effect though, and in our view the most affected players will be the premium movies and series channels like TV Cine. In reality Netflix and other similar offerings will be like any other premium channel in the operator lineup.

The most important difference is that unlike the premium movie channels that are still linear in nature, an SVOD-like premium channel will be fully interactive and on-demand, allowing the viewer to actually select what movie to watch and when, without having to rely upon the broadcaster schedule. This is essentially the biggest feature of a SVOD service and, for example, MEO's catch-up service "Gravações Automáticas". The real power for the customers is the possibility of watching any asset from a huge catalog, at any time.

However, these OTT services pioneered or made relevant a couple of concepts and technologies that traditional operators are now starting to leverage for their own benefit. The first concept is similar to what happened in the music industry: there is more market in a subscription service than in selling content by the piece. In the music world it was the difference between digital downloads, like iTunes and music streaming, like Spotify.

In the VOD industry this piece by piece service is the traditional VOD renting, also called transactional VOD or TVOD, where you pay a one-time fee for watching a movie during a limited timeframe (commonly 1 or 2 days). This is the standard business model promoted by traditional operators in their digital offerings.

By contrast, the subscription VOD or SVOD is a service where you pay a monthly fee for accessing the whole movie and series catalogue. For the subscription period, usually 1 month, you can watch as many movies or episodes you want. It is like comparing a normal a la carte restaurant (TVOD) with a buffet restaurant (SVOD). One result of a buffet meal is that we normally eat too much, succumbing to what is called the binge eating attitude. Similarly, in the SVOD world we are observing customers really getting into an approach of binging their watching, burning through stacks of episodes from a series. Catering to that kind of usage, SVOD services that started with a big movies catalogue mutated to having a much bigger number of assets from serialized shows that they brought from TV producers. Some services even started to produce their own series with some degree of success, being Netflix's House of Cards the poster child of this kind of strategy.

There is also a third business model for VOD that is advertising VOD or AVOD, the most prominent operator on this model being YouTube, although in reality, with the recent launch of Red, they are supporting all business models.

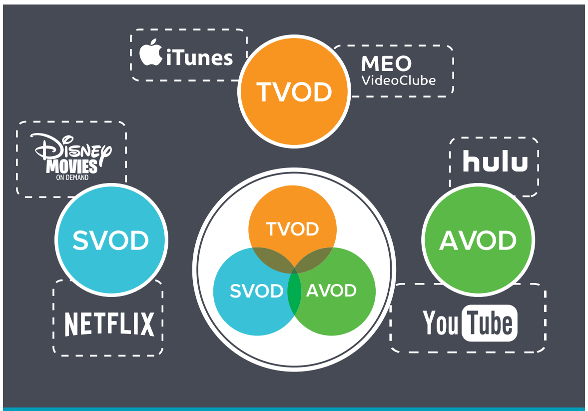

FIGURE 1 Video on Demand revenue models

Beyond business models and the attitude towards content consumption, the new online services pushed the boundaries also on the technical arena.

Adaptive Bitrate Streaming

Traditionally, operator based VOD services use some kind of bandwidth management to guarantee a consistent user experience. In IPTV this is achieved with QoS controls and a managed network. In cable solutions this is accomplished with fixed allocations at the edge QAM level. These are good solutions for completely managed networks, but they are neither cheap nor very flexible. However they provide a very good user experience with very low buffering times and a good response to user interaction, the so called trick modes (play, pause, fast forward, rewind and skip forward and backward).

Everyone who has watched video off the Internet is very akin of the dread "Buffering, please wait..." that plagued any YouTube watching.

Being completely over-the-top, these new video services operators did not get the luxury to pre-allocate bandwidth or to manage end-to-end QoS. What they did was to encode the videos in various quality levels and let the end user select what kind of quality he wanted to watch.

In the YouTube case, it started with buttons on the interface to allow the user to select SD, HQ or HD streams. Normally the user will select a level appropriated to his network conditions. Those that have a good connection will select an HD stream and those in a public Wi-Fi will select a lower quality stream to avoid buffering pauses in the watching experience.

This was not an ideal solution and had an additional problem that if the user selected a streaming level and then the network conditions changed, because the Wi-Fi link improved, or some other user started also streaming a movie effectively halving the available bandwidth, the user would have to make manual stream quality adjustments or cope with a subpar experience.

Today most OTT services and a growing number of IPTV operators have moved to a newer streaming methodology called adaptive bitrate streaming (or ABR streaming). What this technique does is basically automate the stream quality selection for the users. Instead of the user having to select the best stream quality for the current networking conditions, the player does it automatically.

Reality is a little more complicated than that and, for this to work, the video file must be encoded in various quality and definition levels. A manifest file is also produced to signal the various profiles and that allow for the stream to be switched without this change being perceived by the user. It is almost as if the video file is split in small snippets of video, each 2 to 10 seconds long and stitched in a play list.

All the intelligence is then transferred to the player. Let's say the player starts playing file SD-001, and detects that the network allows for a better bitrate (based on last time to download a video snippet and the buffer fullness), it will next play HQ-002. If it is still possible to go higher it will then play HD-003 and will stay in the highest quality until the network conditions deteriorate, when the player will decrease the quality asking the server for HQ-004.

With this technique the player will be adaptive to the changing network conditions, but also to the terminal capabilities. For example, if the player is not powerful enough for a HD stream the player will never ask for it.

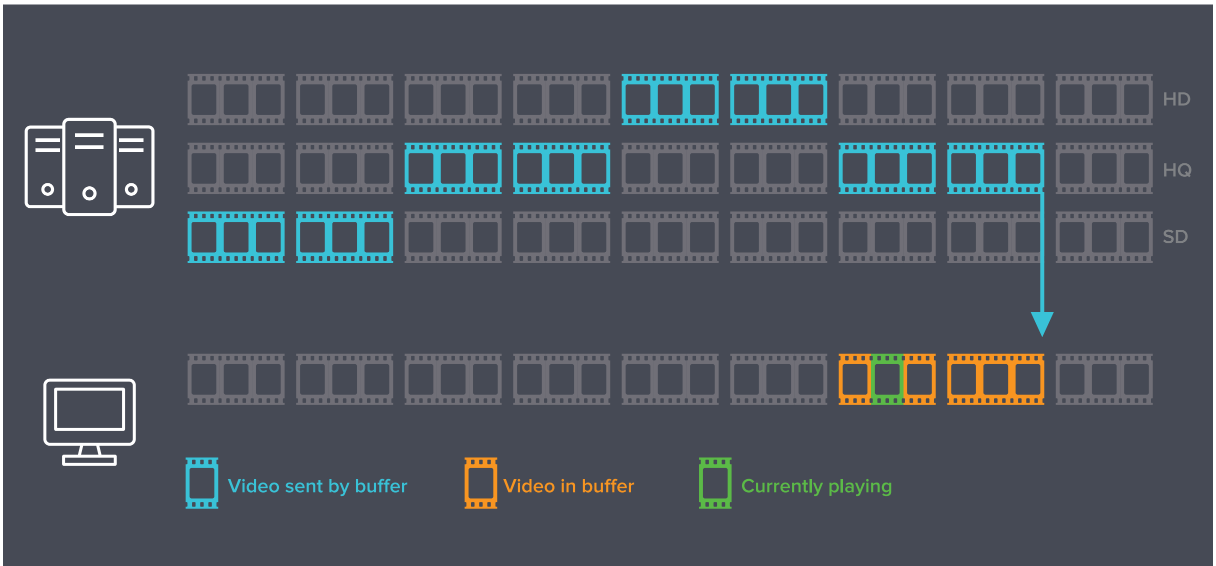

FIGURE 2 Adaptive HTTP Streaming

This technique minimizes the perceived buffering time solving one of the biggest hurdles in a pay online video service. Of course this is done by lowering the video quality level but for most users this is a fair trade-off.

Besides these technical achievements there are additional benefits for the service operators, being the most important that **this new way of streaming does not require any special software or hardware like the specialized RTSP streamers or the one used in cable operations. In most cases, it just needs a standard HTTP server, really lowering the barrier to entry. And as it uses HTTP it is very cache and firewall systems friendly**, since in reality the player is just downloading static files. These advantages are so compelling that not only OTT services are using them, but also operators are heavily investing in that kind of streaming deprecating old solutions, because they are cheaper, more scalable and easier to maintain and operate.

Yet, there is still one hurdle with ABR. Right now there are still too many protocols. Apple ecosystem uses HLS, Microsoft uses Smooth Streaming (HSS), Adobe relies on Dynamic Streaming and there are a couple of others.

For example, to support a wider variety of devices, Altice Labs uses simultaneously HLS and HSS for MEO Go service [3]. The more devices we can support the better, but having to support two streaming technologies (and still support RTSP for older devices) represents doubling the work most of the times.

However a new solution is emerging: in 2012 the MPEG-DASH was published as ISO standard and both

FIGURE 3 MEO Go service

OTT and managed networks operators are pushing to migrate their clients to comply with this new standard [4]. There are still issues to solve, related to DRM normalization, but that is a completely different subject.

Apps

In recent years there was a seismic shift in the mobile world that will, in time, also transform the digital world into an App-o-verse (an universe of Apps). This process of *appification*, that some users take for granted, with mind-sets that make them search first for an app in their smartphone, before even looking for a website, is already stretching its arms towards the web. The websites of before, mostly just data repositories with little interaction, are being replaced by authentic web apps as the way to attract users. Sites like Google Maps are way more than a website and are built with the purpose of performing an action or task. And that is the biggest difference: the sense of purpose attached to the new websites, which is also transforming the web into a set of apps.

This *appification* of the digital world will not stop in the mobile and web worlds, it will reach way further [5].

It is no surprise for us to hear Tim Cook, Apple's CEO, stating that they believe **"the future of TV is apps"** [6]. We also trust it is. In fact, we have been believing it for some years: in the last 8 years, **since MEO service was launched, we developed more than 100 apps for TV** [7].

Some of those apps worked well, some not so much. However, we saw the Portuguese customers using more and more of the interactivity provided. From the younger ones using MEO Kids, to the huge usage we always had in the Secret Story app, season in, season out. And the apps usage was always going up all over the wide spectrum. This obviously paved the way for the most used app we have right now, our all encompassing 7 days 80 channels full line-up catch-up TV app "Gravações Automáticas".

During these years we also learned that coupling an app with content will bump its utilization. It happened

FIGURE 4 Secret Story App

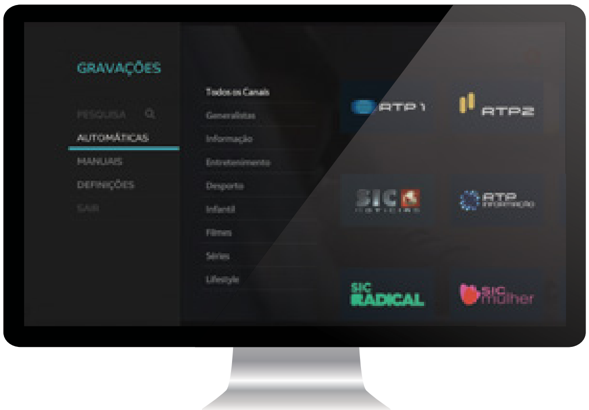

FIGURE 5 Gravações Automáticas App

for example with our karaoke catalogue, which was a premium content with very low subscriptions. Then we developed an interactive app for promoting the content and also to help the consumption and the way karaoke should be presented and this stemmed a significant increase in the subscription rate. The same happened with Disney On Demand SVOD. That is why we believe that the future of Netflix and other OTT services like HBO Now or Showtime is an app to allow interactive on demand access to content that will be presented to the customer as an interactive premium channel.

The entertainment apps that couple content with interactivity for tapping the additional dimension given by the instantaneously on demand selection of what to see are without doubt the main beneficiaries of our highly interactive platform. But we observe other kinds of apps getting intense usage, for example: the app that allows for MEO TV service customers to buy pizza directly on the TV sells more pizza than any physical store of that particular chain in Portugal. And TV is an ideal impulsive buying medium, as we can see by all the TV Shop channels that are ripe for an *appification*.

Being the biggest companion of our elderly [8], TV is poised for ensuring the actual realization of a set of ambient assisted living (AAL) enablement apps. We already saw some of this potential with our RDI activities in this area [9].

Then again, we have already seen most of those arguments in the sales pitch for connected TVs and their app stores. These stores never took off and there are less than a handful of apps actually being used, such as Youtube and Netflix. We believe that this happens because, on one hand, most of these apps have very low quality and have a really poor usage model and, on the other hand, they are not integrated with the TV experience: the way user accesses them is via an area of the TV that normally turns off the video and seems to have been created to confuse the user. In MEO platform, apps are an integral part of the TV experience, they are there to extend and complement the content and not to replace it.

We are not fully convinced that in the near future the concept of channels will be fully replaced by the concept of apps lineup, however we do believe that part of the future of TV lies on the fusion of these two concepts.

Ads

Commercial advertising has been a constant presence since the beginnings of TV. After all these years there is still innovation that can be infused on what is manifestly the most powerful way to promote a brand, product or service.

Nevertheless, TV ads have a huge shortcoming being the most used medium to advertise, because it is very difficult to actually pinpoint what works and what does not. In the words of the forerunner of marketing, John Wanamaker, "Half the money I spend on advertising is wasted; the trouble is I don't know which half" [10]. For sure we can say that the numbers for TV are even worse. That is one reason why companies and advertising agencies tried to find better ways or at least more measurable ways to minimize those proportions, minimizing the wasted half. In recent years most of these efforts have been spent on the digital arena, with a huge investment on trying to engage the customer, mainly through social networking. The digital medium and social networks in particular sold the idea that they could measure with precision and produce analytics on how well the advertising campaigns performed and how engaged the customer is with the product. For that purpose, agencies created the perfect social media campaigns, got millions of Facebook likes and thousands of new Twitter followers. But as a recent article in Financial Times recounted, **the sales for Pepsi, one company that betted a big chunk of what used to be their TV budget on social, actually declined 5%. And they returned to ads on TV** [11].

The problem of social media and most of the target advertising bandwagon is that they are preaching to the choir, i.e., they are reaching already loyal customers or even fans. The real purpose of advertising is to reach for the eventual buyer or even the one that usually buys from the competition. Like the person that does not drink cola, but is going to host a party, and then will buy the brand that has achieved highest notoriety in his mind. TV is a great way for reaching that segment of customers and achieving high notoriety, especially when promoting a brand instead of a product.

It is important to look differently to the concepts associated with digital marketing and mix them with the wide reach presented by the TV medium. For example, an ad for a sports TV channel promotion (let's say first month free for a six months' subscription) will be wasted in an actual sports TV channel customer. Perhaps this could even be detrimental, because the company is giving something to new customers and nothing to loyal ones. Completely different is an ad that promotes a match saying that it will be only available on sports TV channel. In this case there is no waste, the actual clients will have been informed of the game and the "exclusive club" they belong. The non-customers are lured and the brand exclusivity will be reinforced in everybody's mind.

Right now we have technologies in place, on MEO service, for helping in both cases. In the first case through a segmentation platform, we can subdivide customers between the ones that have sports TV channel and the others. In the example above we will deliver the promotion just for the non-customers. Of course in this case we have full knowledge of what channels the customer subscribes or not, but the same notion can be applied to other areas, where all the investment in profiling and analytics created for social media could start to pay off, they just need to be applied to cater for the non-customers instead of engaging current ones. This technique is easier to employ when targeting products that can only be bought or subscribed once.

In online campaigns, marketers like the metrics, mostly click-through rates (CTR) and conversion rates, that is, people that clicked in an ad and people that actually made a purchase. Maybe brand awareness can not be measured by these metrics, but product promotion on TV should, not only through CTR but even more important directly through a TV frontend store which can really close the full loop.

As the result of our investments and RDI projects we already have all the needed technology in place: a set of tools including DIPR, an advertisement

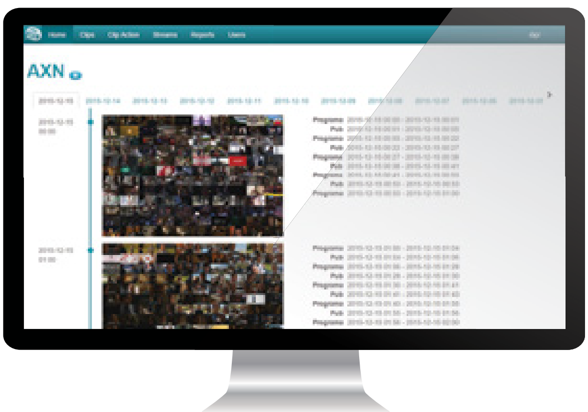

FIGURE 6 DIPR tool

detection, identification and removal system, supporting live and on-demand video streams [12].

We will use the results in two ways, both for adjusting the automatic recordings from our catch-up and also for enabling the swapping of live or recorded ads on TV, even replacing them for a segmented OTT version tailored for that customer's profile.

Furthermore, we can signal the customer that the ad has interactivity and through an app actually perceive a CTR in TV: we did that in the past with a specific carmaker advertisement, allowing potential customers to book a test drive.

Although the actual conversion rate was not disclosed, we were pleased to learn that this interactive app originated the majority of booked test drives, which were available also via the usual channels.

FIGURE 7 Interactive Advertising

Wrapping Up

Throughout this article, we addressed three apparently disjoint trends: OTT, Apps and Ads. In the end, we have shown how they are actually being combined towards increasingly innovative functionality and added value to our offers for the TV medium.

These aforementioned tools are available beyond IPTV scenarios such as MEO. **All this is also possible and quite viable even in cable operations, by means of DOCSIS integration and simpler HTML5 based development environments provided by newer STBs.**

All new on demand deployments will be based on OTT techniques like ABR. They will be coupled with interactive apps to enrich the user experience. And ads will keep their prominent presence in the TV space, but coated with new interactivity features and providing advertisers with powerful tools to get from TV the same set of indicators they are used to get in the online world.

With little extra work, this class of apps can also work as a sales channel, allowing the customer to actually buy the product or service directly from the TV and even pay for it, really closing the full loop for his/her digital journey.

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ACRONYMS

1

1/2/3/4/5G	First/Second/.../Fifth Generation
10G-EPON	10 Gbit/s Ethernet Passive Optical Network

3

3GPP	3rd Generation Partnership Project

5

5G-PPP	5G Infrastructure Public Private Partnership

A

AAL	Ambient Assisted Living
ABR	Adaptive Bitrate Streaming
ADS	Advertising
APD	Avalanche Photodiode
API	Application Programming Interface
APP	Application
AVOD	Advertising Video on Demand

B

B2B	Business to Business
B2C	Business to Consumer
B5G	Beyond '5G'
BOSAs	Bi-directional Optical Subassemblies
BPON	Broadband Passive Optical Network

C

CA	Carrier Aggregation
CEX	Coexisting element
CN	Core Network
CoMP	Coordinated Multi Point
COTS	Commercial Off The Shelf
CPE	Customer Premise Equipment
CRF	Conditional Random Fields
CSP	Communication Service Provider
CT	Channel Terminations
CTR	Click-Through Rate

D

D2D	Device-to-Device
DASH	Dynamic Adaptive Streaming over HTTP
DBR	Distributed Bragg Reflector laser
DC	Data Centre
DFB	Distributed Feedback lasers
DHCP	Dynamic Host Configuration Protocol
DIPR	Detection and Identification of Publicity and Removal
DOCSIS	Data Over Cable Service Interface Specification
DRM	Digital Rights Management
DWBA	Dynamic Wavelength Bandwidth Allocation

E

EC-GSM	Extended Coverage GSM
eMBB	enhanced Mobile Broadband
eNB	eNode-B
EPC	Evolved Packet Core
EPON	Ethernet Passive Optical Network
eSIM	Embedded SIM Card
ETSI	European Telecommunications Standards Institute
eUICC	Embedded UICC

F

FD	Full Dimension
FG	Forwarding Graph
FSAN	Full Services Access Network

G

GPON	Gigabit PON
GRE	Generic Routing Encapsulation
GSM	Global System for Mobile Communications
GSMA	GSM Association

H

HCI	Human Computer Interaction
HD	High Definition
HLS	HTTP Live Streaming
HQ	High Quality
HSI	High Speed Internet
HSS	HTTP Smooth Streaming
HTTP	Hypertext Transfer Protocol

I

IMT	International Mobile Telecommunications
InP	Indium Phosphide
IoT	Internet of Things
IP	Internet Protocol
IPTV	Internet Protocol Television; Television over Internet Protocol
ITU-R	International Telecommunication Union-Radiocommunication

K

KPI	Key Performance Indicator

L

LAN	Local Area Network
LPWAN	Low Power Wide Area Network
LTE(-A)	Long Term Evolution (-Advanced)
LTE-M	Long Term Evolution M2M
LTN	Low Throughput Network

M

M2M	Machine-to-Machine
MAC	Medium Access Control
MBB	Mobile BroadBand
MBH	Mobile Backhaul
MdT	Máquina do Tempo
MEC	Mobile Edge Computing
MIMO	Multiple Input Multiple Output
ML	Machine Learning
mMTC	massive Mobile Type Communications
MPW	Multi Project Wafer

N

NAT	Network Address Translation
NB-CIoT	Narrowband Cellular Internet of Things
NE	Network Elements
NER	Named Entity Recognition
NERD	Named Entity Recognition and Disambiguation
NF	Network Function
NFV	Network Functions Virtualization
NFVI	Network Function Virtualized Infrastructure
NFVO	Network Function Virtualized Orchestrator
NG-PON2	Next-Generation Passive Optical Network 2
NGMN	Next Generation Mobile Networks
NLP	Natural Language Processing
NN	Nearest Neighbour
NS	Network Service

O

ODL	Open Day Light project
ODN	Optical Distribution Network
OLT	Optical Line Terminal
ONF	Open Networking Foundation
ONT	Optical Network Terminator
ONT RGW	ONT Remote Gateway
ONU	Optical Network Unit
OTDR	Optical Time-Domain Reflectometer
OTT	Over-the-Top
OVS	Open V Switch

P

PDN	Packet Data Network
P-GW	Packet Gateway
PICs	Photonic Integrated Circuits
PMD	Physical Media Dependent
PNE	Physical Network Element
PNF	Physical Network Function
PoC	Proof-of-Concept
PON	Passive Optical Network
PoP	Point of Presence

Q

QAM	Quadrature Amplitude Modulation
QoE	Quality of Experience
QoS	Quality of Service

R

R&D	Research and Development
RAN	Radio Access Networks
RAT	Radio Access Technology
RDI	Research, Development and Innovation
RPMA	Random Phase Multiple Access
RTSP	Real Time Streaming Protocol

S

SaaS	Software as a Service
SD	Standard Definition
SDK	Software Development Kit
SDO	Standards Development Organization
SDN	Software Defined Network
SDR	Software Defined Radio
Si	Silicon
SIM	Subscriber Identity Module
SLA	Service Level Agreement
SMARTER	Study on New Services and Markets Technology Enablers
SOA	Semiconductor Optical Amplifier
SON	Self Organized Network
STB	Set-Top Box
SVM	Support Vector Machine
SVOD	Subscription Video on Demand

T

TriPleX	Combination of Silicon Nitride – Si3N4 and Silicon Dioxide – SiO2
TVOD	Transactional (traditional) Video on Demand
TWDM PON	Time and Wavelength Division Multiplexing PON

U

UE	User Equipment
UICC	Universal Integrated Circuit Card

V

V2x	Vehicle-to-X
vHGW	Virtual Home Gateway
VIM	Virtual Infrastructure Management
VLANs	Virtual LANs
VM	Virtual Machine
VNE	Virtual Network Element
VNF	Virtual Network Function
VOD	Video on Demand

W

WAN	Wide Area Network
WRC	World Radiocommunication Conferences

X

XG-PON	Ten-Gigabit-Capable Passive Optical Networks