TIM

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Piano Tecnologico 2022-2024

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Editoriale

Il Piano Tecnologico: la bussola per la crescita di TIM e del sistema Paese

Il Piano Tecnologico è un processo del Gruppo TIM, guidato da Crescenzo Micheli e il suo team, che ha come scopo la definizione e la comunicazione della strategia tecnologica complessiva di medio termine. La versione attuale, che copre il triennio 2022-2024, arriva in un momento di forte disruption tecnologica e ha l'obiettivo di monitorare, valutare e sfruttare tutte le evoluzioni che portino a generare valore per l'Azienda e per il sistema Paese nel suo complesso.

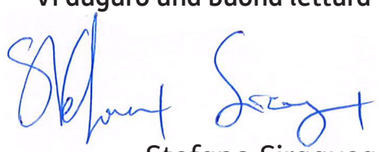
Sono due i temi che riassumono bene le sfide affrontate dal Piano Tecnologico di TIM nel prossimo triennio: da un lato lo sfruttamento di tutte le opportunità offerte dalla "softwarizzazione" delle tecnologie di rete per l'offerta di servizi Cloud e dall'altra la gestione delle piattaforme obsolete su cui viaggiano ancora molti servizi "legacy".
La crescente esigenza di soluzioni in Cloud, che siano, anche fisicamente, vicine al Cliente per soddisfare requisiti di prossimità, latenza, sicurezza e riservatezza dei dati, è lo scenario in cui TIM fa la differenza, perchè dispone delle capacità e delle infrastrutture per offrire questi servizi anche in collaborazione con i fornitori di Public Cloud o Hyperscaler. Si parla in questo senso di "Telco Cloud Continuum" o Edge Cloud. Il Telco Cloud Continuum di TIM renderà disponibile una piattaforma unica di Cloud distribuita su tutto il territorio italiano, garantendo la sicurezza e la sovranità dei dati del Paese e delle aziende che ne fanno parte.

Se l'innovazione e la definizione di nuove opportunità di business attraverso il Cloud sono centrali, non è da meno la capacità di proseguire un processo continuo e sostenibile di Decommissioning delle tecnologie obsolete. In questa ottica il piano di Decommissioning di TIM permette da un lato di raggiungere gli obiettivi ESG (Environmental, Social and Governance) e dall'altro di abilitare nuovi modelli commerciali e di servizio, che ci permetteranno di raggiungere gli obiettivi dei programmi italiani inclusi nel PNRR e indicati dall'Europa in ambito Compass 2030.

Esempi rilevanti di questa evoluzione tecnologica di TIM li troviamo in tutti i settori: dall'accesso mobile, dove si dismette il 3G per aprire al 5G, all'accesso Fisso in cui, insieme a Fibercop, si porta il 10Gbps nelle case degli italiani grazie a FTTH e XGSPON, abbandonando l'ADSL; analogamente nel trasporto trasmissivo, in cui facciamo record di performance sul trasporto ottico (600Gbps tra i due capi dell'Italia) e lavoriamo al tempo stesso per dismettere tecnologie come PDH, SDH. Sono solo alcune delle attività concrete con cui TIM fornisce un contributo sostanziale all'eliminazione del Digital Divide in Italia.

Si capisce quindi l'importanza del Piano Tecnologico di TIM e di tutte le persone che contribuiscono alla sua redazione. L'obiettivo è quello di definire un Piano Industriale sempre innovativo, che permetta a TIM di rimanere un attore essenziale del sistema Paese per la sua strada verso il futuro.

Vi auguro una buona lettura



Stefano Siragusa
Deputy General Manager, TIM

Indice

TIM

Il processo ed il valore del Piano Tecnologico TIM

Il Piano Tecnologico è un processo del Gruppo TIM, che ha come scopo la definizione e la comunicazione della strategia tecnologica complessiva di medio termine.

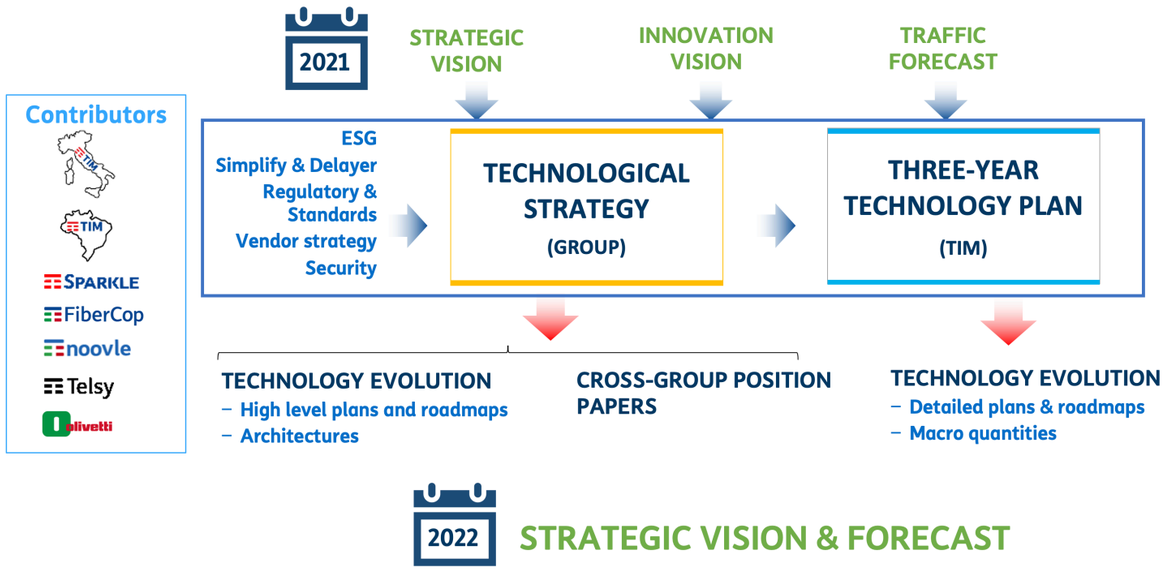
La realizzazione del Piano Tecnologico è il risultato di un ampio lavoro, sotto la responsabilità della struttura di Technology & Innovation, che vede impegnate in prima linea tutta la struttura di Network con il coinvolgimento di altre funzioni aziendali quali IT, Regulatory, Security, Procurement e delle società del Gruppo TIM, nello specifico Sparkle, TIM Brasil, Olivetti, Telsy, Fibercop e Noovle.

Il Piano Tecnologico si colloca nel più ampio contesto della Pianificazione aziendale, essendo strettamente collegato ad altri processi come il Piano Strategico, il Piano Industriale e il Piano di Sviluppo. In particolare, il Piano Tecnologico è funzionale alla definizione degli economics del Piano di Sviluppo attraverso il rilascio ufficiale delle macro-quantità tecniche.

Partendo dall'analisi dei drivers strategici, degli enablers tecnologici e di business e tenendo conto degli elementi di contesto e, in particolare quest'anno, anche dei programmi nazionali ed europei di sostegno alla ripresa (PNRR & PSN, IPCEI), vengono elaborate le linee di sviluppo funzionali, dimensionali ed architetturali nei vari domini della rete (Figura 1).

Nello specifico i domini trattati nell'edizione di quest'anno del Piano Tecnologico sono: IP e Trasporto, Core, Edge

Figura 1: Schema del processo del Piano Tecnologico TIM



e Voce, Accesso Fisso e Mobile e dispositivi, Service Layer, Telco Cloud e Automazione di rete.

Inoltre, l'evoluzione tecnologica delle società del Gruppo, pur mantenendo una propria specificità, concorre fortemente a definire la strategia complessiva, permettendo di sviluppare progetti ed azioni che sfruttino la sinergia di competenze e tecnologie per nuove proposizioni di servizi.

La sfida del Piano Tecnologico di quest'anno, che copre il triennio 2022-2024, è quella di definire il posizionamento tecnologico, evidenziando tutte le attività prioritarie e fattibili nel breve e tracciando un percorso sul triennio coerente ed efficace.

Gli obiettivi del Piano Tecnologico 2022–2024 mirano quindi all'ottimizzazione dei paradigmi Beyond Connectivity e delle disruptions tecnologiche, per creare nuovi modelli commerciali che abilitano servizi digitali e verticali per Enterprise, Industry, Government, tra gli altri.

Tali obiettivi vengono perseguiti tramite l'adozione di nuove tecnologie future-proof, aperte e sicure (anche attraverso partnership), in conformità ai principi ESG (Environmental, Social and Governance), alla regolamentazione ed alla sicurezza.

I principi fondanti del Piano Tecnologico 2022-2024 consistono nel promuovere il paradigma del "Telco Cloud Continuum" come tecnologia abilitante alla fornitura di servizi flessibili ad altissime prestazioni e nel fare leva su una progressiva semplificazione e delayering delle tecnologie in campo, per aumentare l'efficienza, l'affidabilità ed il valore.

Una novità di questa edizione è l'introduzione di documenti che si focalizzano su tematiche essenziali ed innovative individuate nella fase di stesura della Technology Strategy; queste tematiche sono: Automation, Edge Cloud Computing, Journey to Cloud, 5G StandAlone, Decommissioning e Live Video.

Di seguito una breve descrizione per ciascuno degli argomenti:

- l'Automation consiste nell'introduzione di processi e procedure automatiche per migliorare le operazioni di rete e lo sviluppo software allo scopo di ottenere benefici in termini di tempi, costi, efficienza e riduzione di errori.
- L'Edge Cloud Computing è una soluzione architetturale che avvicina contenuti e applicazioni al cliente finale per soddisfare i requisiti di latenza, sicurezza, resilienza e larghezza di banda e ottimizzare la distribuzione della capacità computazionale tra dispositivi, rete e cloud.
- Il Journey to Cloud definisce una transizione che mira a migrare gli asset aziendali sul Cloud, consentendo la diminuzione dei costi IT e di emissione dei gas serra, e l'aumento dei risultati di business e della velocità di innovazione. La strategia prevede lo spostamento di workload e applicazioni verso nuovi datacenter e la razionalizzazione degli esistenti.
- L'introduzione di 5G StandAlone facilita la semplificazione delle architetture, migliora la sicurezza e riduce i costi e consente la personalizzazione e l'introduzione di nuovi servizi su misura per i clienti aziendali, industriali e governativi.
- Il Decommissioning di reti e piattaforme legacy è una sfida per garantire la semplificazione operativa, consentire importanti risparmi, ridurre il rischio di guasti e i rischi di sicurezza, e abilitare la realizzazione di nuovi servizi.
- La fornitura di contenuti Live Video su IP è una evoluzione tecnologica che ha impatti importanti sulla rete, ma che può portare benefici al sistema paese nel suo complesso. A questo scopo TIM sta lavorando alla evoluzione della sua infrastruttura di rete e dei servizi per supportare la distribuzione dei contenuti in streaming con piattaforme innovative.

In questo numero del Notiziario Tecnico TIM vengono quindi descritti in dettaglio tutti i temi sopra riportati, offrendo una vista complessiva e trasversale che costituisce un utile riferimento per la definizione di una strategia di attuazione della trasformazione digitale.■

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Automation

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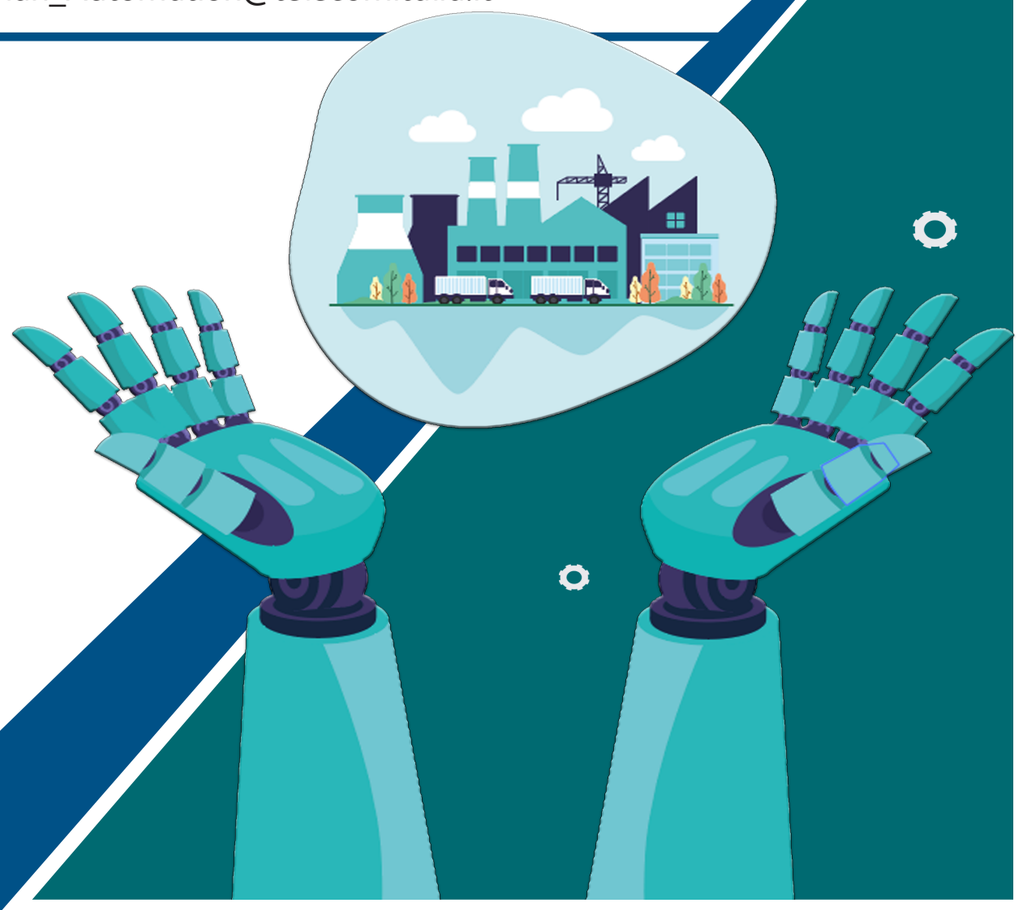


Automation is increasingly important and pervasive in company realities as it consists in the introduction of technologies that automate processes and manual activities, allowing costs saving, increase in efficiency and error reduction.
In this paper we describe TIM Group positioning on three areas where automation is being used: Network Automation, Software Developing Automation and Robotic Process Automation (RPA).

Introduction and Context

Within the company realities, automation is gaining importance and, although it is applicable in various contexts, not only technological, it is assuming a central role and is becoming an enabler of innovation.

In TIM Group we consider three main areas where automation is being used: **Network Automation, Software Developing Automation and Robotic Process Automation (RPA).**

With the term Network Automation we refer to the introduction of systems to automate network management and to orchestrate services fulfilment and assurance. This is necessary to automatically answer to customers' requests and to guarantee agreed SLAs.

Software Developing Automation deals with software development, delivery and deployment automation. It allows incremental software releases by an integrated tool ecosystem necessary when applications move from monoliths installed on physical or virtual machines towards highly distributed microservice architectures, deployed in containers in a multi-cloud environment and characterized by a high frequency of new versions' release.

Robotic Process Automation is the automation of front, middle and backoffice activities as well as repeated manual tasks. RPAs are especially relevant with legacy systems that are not machine-centric or programmable and only provide a GUI to interact with the underlying technology.

Current Situation

In **Network Automation** scope, at TIM and TIM Brasil's domains, the implementation of an end-to-end Automation framework is ongoing. Among other tasks, the automation solution must deal with lifecycle management, design, and activation of customized network slices that will serve new verticals and new business models.

An integrated management and orchestration environment is being built and gradually implemented. Each company has its peculiarities, but the common framework is the definition of a layered architecture with a network, an end-to-end resource, and a service layer.

Each domain must guarantee supported services fulfilment and assurance through closed loop automation. Cross Domain functions are provided at end-to-end resource and service layers (Figure 1).

Automation and Orchestration solutions are necessary even in the network functions virtualization area to manage the life cycle of virtualized and cloud-native network functions, to avoid any manual intervention in the Telco Cloud Infrastructure, including networking.

In this context TIM has been deploying a large set of Virtualized Network Functions over a multi-vendor IaaS architecture and is going to deploy shortly the first set of Cloud-native Network Functions.

TIM approach to RAN (Radio Access Network) automation is based on the evo-

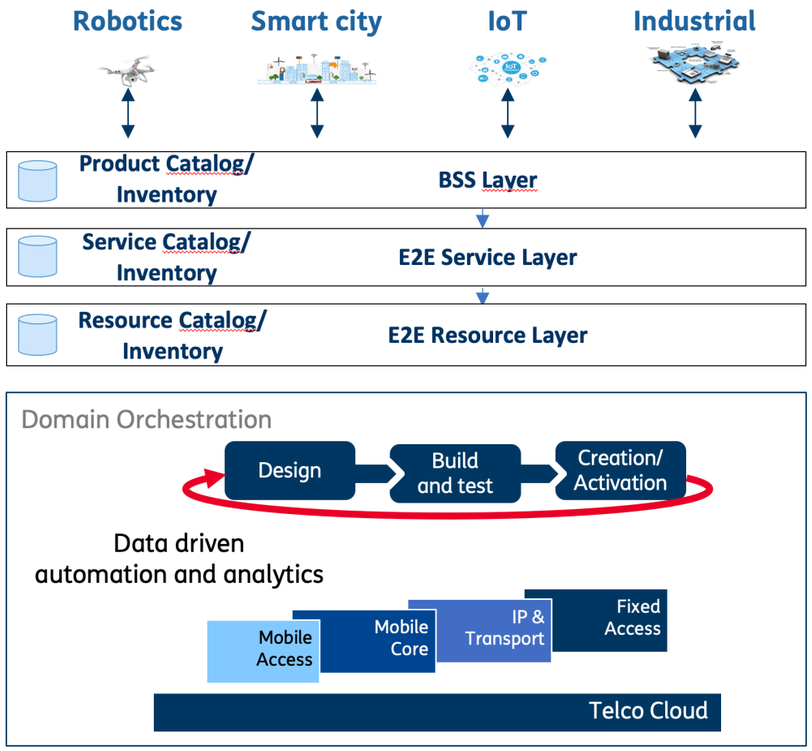


Figure 1: High level Network Automation Architecture

lution of TIM management and orchestration systems and the exploitation the use of the Open SON (Self Organizing Networks) functionalities to enable the control and optimization of all radio parameters in an automated and open way. RAN automation use cases currently address areas of optimization and configuration (i.e. for self-configuration), creation (i.e. self-establishment) and maintenance (i.e. self-healing).

On the other hand, in the SDN domain, the E2E SDN Automation tools have currently been deployed within TIM IP networks, addressing a significant number of use cases allowing effective operational activities.

A real-time assessment of the network is the input needed for a Closed Loop engine, which applies the right logic to understand and decide which actions must be taken to react to network events (e.g. Restoration of optical link in case of fault).

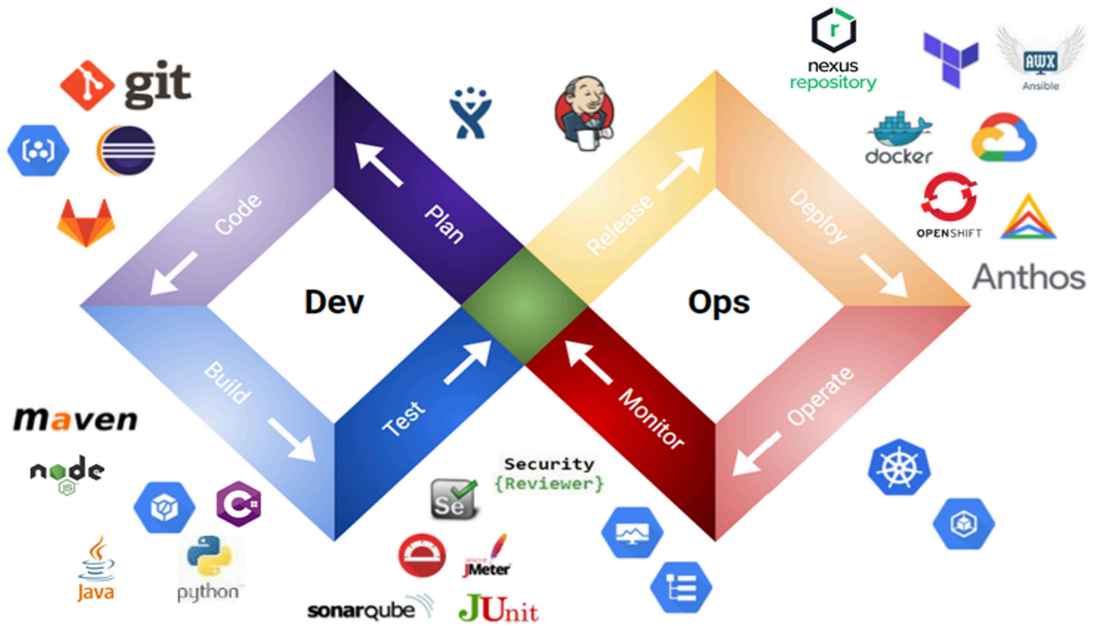
TIM Brasil, aligned with the evolutionary Group perspective, started its Automation journey in 2018 and currently is expanding its scope towards Telco Cloud Infrastructure, RAN automation through Open SON, E2E SDN for IP networks and technical operational evolution through A.I. having as example TAIS (TIM Artificial Intelligence Service).

Sparkle, as international player, has begun since 2016 to implement numerous feasibility studies on the Network Automation topic, in order to benefit from the numerous advantages offered by both SDN (Software-Defined Networking) and Intent-Based Networking (IBN) paradigms, combined synergistically to eventually achieve the so-called Closed Loop Automation.

In the Software Developing Automation context (CI/CD, Continuous Integration/ Continuous Delivery chains), the automation of Continuous Integration, Delivery and Deployment pipelines is not limited to code management, but it has various correlations with internal processes: consistency with project management systems, compliance with the Security guidelines for secure code development and, in general, integration with several internal systems (Figure 2).

Automation in Noovle is applied at various levels, both for internal processes and for external customers, especially on issues of DevOps and management of Cloud environments (private or public).

Figure 2: DevOps Chain



The **Robotic Process Automation** context is addressed by TIM domestic, TIM Brasil and Sparkle, to keep the helm firm between the increasingly challenging needs of its customers and the urgency to make the supporting business processes efficient and effective.
Digital Channel & Contact Center, Pre-Sales Business, Finance and Legal are areas of application of RPA in TIM Domestic.

"Network Intelligent Operation" (NIO) is a Sparkle program started in 2019 aimed at automating processes in Operations, Provisioning, Pre-Sales, Marketing, Security and Customer Care Areas, and based on two pillars: Operation efficiency and Customer Experience improvement (Figure 3).

Standard and Fora

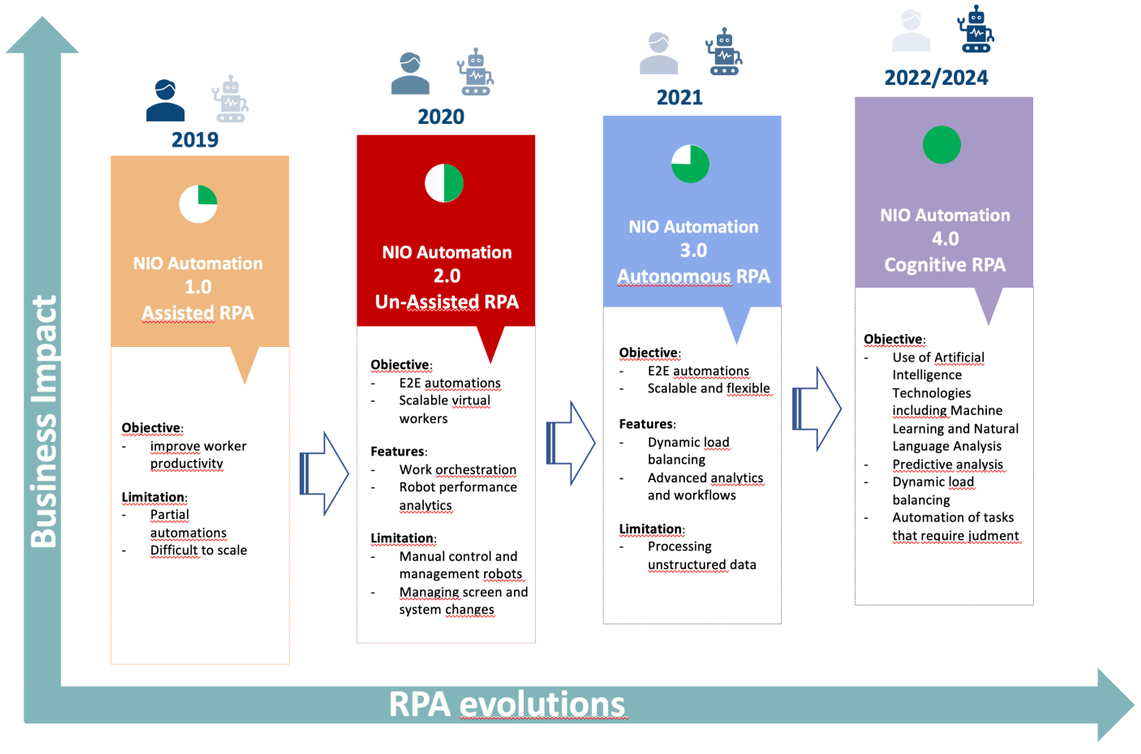
With respect to Network Automation many Standards & Open Source projects are active: 3GPP, ETSI, IETF, TMForum, ONAP, O-RAN Alliance, just to mention the ones where TIM is involved.

Several new projects integrate the existing ones on AI-based and data-driven Automation.

The topics addressed deal with moving stepwise to a fully autonomous network (3GPP), defining orchestration and automation platforms (ONAP and O-RAN Alliance) and working on PoC and Code/framework developments to deliver a "Zero X" experience (TMForum and ETSI).

The use of Artificial Intelligence in network control and management domain is addressed by TMForum while IETF is working on IP networks automation: data modelling language and protocols to configure network elements.

Figure 3: NIO Program Evolution in Sparkle



Company Position and Guidelines

As we have seen, in TIM Group different initiatives are ongoing with respect to different automation areas. These initiatives have brought several benefits, and more are expected to come.

With respect to **Network Automation** area, on VNFs/CNFs automation, important benefits have been achieved in terms of HW consolidation and reduction of time to perform tasks, that was dramatically reduced with respect to physical nodes.

For example, thanks to virtualization and automation, the time needed to accomplish capacity expansion, or healing, of a mobile packet gateway was reduced from days down to hours, and the instantiation time of a new network function instance (e.g. a new mobile packet gateway) was dramatically reduced.

On the RAN side we have many Open SON use cases already deployed on field. The evidence collected on deployed use cases show an enhancement of network performance, a reduction on congested areas and an improvement on time and effectiveness of troubleshooting.

Regarding the operational efficiency, the introduction of automation has shown a reduction on execution time as well as on the effort needed on relevant operation activities, but also the introduction of processes to enable new actions in the network.

The introduction of E2E SDN Automation has made it possible to achieve some benefits in time spent in recurrent activities deployed on large number of equipment or reduction of operator mistakes.

These benefits will increase as far as E2E SDN Automation will be extended to cover more and more operational activities and more devices in the network.
Moreover, application of automatic and intelligent reaction to different type of events allows smoother network operations, thus increasing network resilience and overall spending efficiency.

Regarding **Software Development Automation**, the advantages of a DevOps methodology are increasingly recognized.

For each new software development project, the creation and configuration of an automation environment is done in a few minutes and developers do not need

specific skills in the field of CI/CD/CD pipelines; such pipelines are configured through a descriptor file.

With respect to Robotic Process Automation, the usage of RPA technology showed excellent results contributing to:

- Extend operational working hour: robots work H24, ensuring continuous support;
- Ensure reliability of tasks execution
- Reduce errors and reworking and time-to-repair/restore, with customers experience improvement;
- Optimize and reduce execution/processing time, guaranteeing SLA compliance (e.g. MTTR, MTTO, Service Availability);
- Improve tracking, monitoring and control of Network performance;
- Extend time for higher value professional activities with focus on customer satisfaction.

Due to reported benefits and new technologies that will come in the next future, the group is confirming current choices on the three automation areas and will extend such solutions following these guidelines:

- **End to end Automation.** Complete ongoing activities in all areas to achieve automated environment. Orchestration shall be able to coordinate Service and Resource layers, and different Domains within the Resource layer.
- **Telco Cloud Continuum support.** The ability to manage both VNF and CNF on a hybrid infrastructure spanning from Public Cloud to Telco Edge Cloud.
- **Closed Loop functionalities.** Improvement of closed loop automation functions to react to network changes and maintain required SLA (Service Level Agreement) to customers
- **Artificial Intelligence (AI) and Machine Learning (ML).** Progressive extension of automation platforms, both for Network Automation and RPA, with the introduction of new advanced automation capabilities such as Cognitive, Machine Learning, Artificial Intelligence, Predictive Network Maintenance.
- **Data centrality.** Data need to be managed, orchestrated, and historicized. History of data is crucial to make ML algorithms properly work. To this end each orchestration and management layer will provide data to other layers and to the data lake.
- **Open APIs.** Exposure of reusable functionalities through open APIs available at all network layers and to customers if needed. Their combination allows for creation of new functionalities and services.
- **CI/CD solutions.** solutions to manage the CI/CD process are being evaluated. The solutions will be integrated with TIM processes, compliant with security requirements, implemented in a process repeatable and automated.
- **Fully declarative model.** All VNF/CNF must be accompanied by standard descriptors, that fully and univocally represent infrastructure requirements and life cycle management methods.
- **Fully cloud-native solutions.** Network Functions suppliers will have to deliver cloud-native software, designed to be deployed and executed in any cloud environments and managed in a full automated way.

Conclusions

TIM Group is actively working on Automation in all areas as described in the paper. We'll proceed along with the identified guidelines to achieve expected benefits and to allow digital transformation and innovation.■

Contributing Companies

Contributing companies to this article are: TIM Italy, TIM Brasil, Sparkle, Noovle.

Acronyms

3GPP	3rd Generation Partnership Project
5GC	5G Core
API	Application Programming Interface
CI/CD	Continuous Integration/Continuous Delivery
CNF	Cloud Native Function
DevOps	Development Operations
ENI	Experiential Networked Intelligence
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute
F5G	Fifth Generation Fixed Network
IETF	Internet Engineering Task Force
KPI	Key Performance Indicator
ML	Machine Learning
MTTO	Mean time To Obsolescence
MTT	Mean Time To Repair
NFV	Network Functions Virtualizations
NIO	Network Intelligent Operations
OAM	Operation, Administration and Maintenance
ONAP	Open Network Automation Platform
O-RAN	Open Radio Access Network
PoC	Proof of Concept
QoS	Quality of Service
RAN	Radio Access Network
RPA	Robotic Process Automation
SDN	Software Defined Network
SLA	Service Level Agreement
SON	Self Organizing Networks
TM Forum	TeleManagement Forum
VNF	Virtual Network Function
ZSM	Zero-touch network and Service Management

Edge Cloud Computing

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Edge Computing is an architectural solution that enables the availability of contents and applications closer to the end customer based on a flexible network in terms of traffic management, access technologies, automation and service creation and represents a central element in the "Beyond Connectivity" model.
Under the assumptions and guidelines described in the paper, Edge Computing represents the opportunity for TIM to gain the role in the value chain by leveraging customer proximity and tight integration of the telco and service components.

Introduction and Context

Edge Computing is an architectural solution that enables the availability of contents and applications closer to the end customer, to meet the requirements of latency, security, resilience and bandwidth; it also allows a more efficient distribution of computational capacity between devices and network.

The development of the Edge framework can involve a Telco Operator, an alliance of Telco Operators and Hyperscale Cloud Provider having partnerships with Telcos.

Current Situation

TIM Network infrastructure

TIM network is developed on a hierarchical architecture with 3 levels of aggregation: Local Aggregator at Local sites (Central Offices), Feeder at Regional sites, Metro PoP at National sites (Figure 1).

The local and regional levels perform functions of aggregation and transport of traffic. The progressive expansion of IP technology up to Local Aggregators (R-Evolution project) is a pre-requisite for the descent of network and service functions to the Edge.

National level hosts the Fixed Core Network functions, the Mobile Core Network functions (in progressive expansion to reach all the National PoPs **with the new Cloud Native 5G Core Network**) and the service and content distribution platforms, including Content Delivery Networks (CDN) and OTT «Alien Caches». Interconnection to the Public Internet takes place at the International Peering point.

Under the current network structure, distributing the functionalities currently present (or planned) on the national sites to the regional sites, would produce an advantage of about 1ms (see Figure 1) in terms of reduction of Round Trip Time (RTT), which can be considered negligible compared to the latency requirements of most of the available applications.

Currently a subset of PoPs is hosting Telco Cloud islands, which are Data Centers featuring a single virtualization technology (NFVI, Network Function Virtualization Infrastructure), specifically designed to meet Network Functions requirements.

TIM NFVI is already evolving to further increase its footprint in all PoPs of the national backbone and, depending on market needs, at Far Edge level.

Telco Network Functions will be deployed, in virtualized and/or Cloud Native form, over such infrastructure to enable new services. Telco Cloud interworking with Hyperscale Cloud Providers (HCP) will be considered as well depending on service and commercial needs.

To support this evolution towards the Edge, TIM is working with its partners to develop the following technological enablers:

- a pre-integrated, modular Telco Cloud stack specifically designed for use at the Edge of the network;
- the automation and orchestration solutions necessary to manage all aspects

of the Telco Cloud Infrastructure and the onboarded Network Functions.

In the short-medium term, no mass market services that require latencies/throughputs not compatible with the current TIM network development are expected: development of the Edge in the national sites therefore seems to satisfy almost all applications.

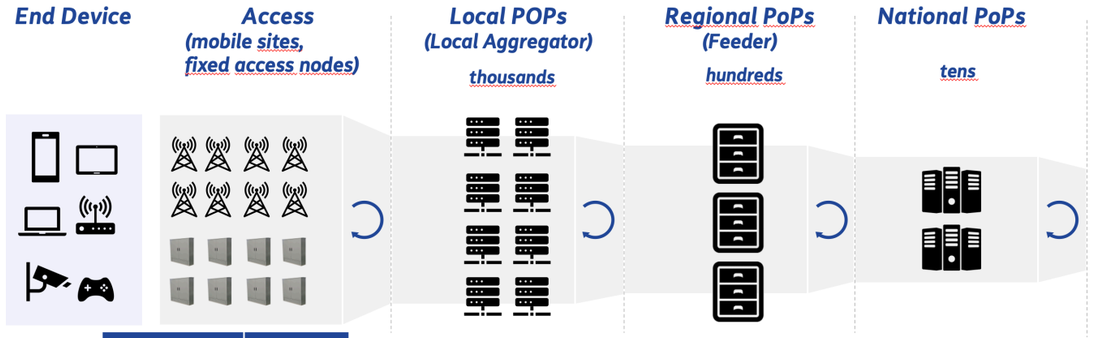
The main drivers that can move Edge beyond might be:

- activation of Ultra Low Latency services and applications (e.g: Extended Reality, Self-driving vehicles, Industrial Automation, eHealth);
- reliability, security and segregation of data in restricted areas, for services such as video surveillance, Smart Cities, Private Networks;
- efficient balancing of the computational load between device and network;
- transport network offloading;
- decreasing of nodes outages impacts;
- evolution of fixed and mobile access technologies (ORAN, OLT/LA unbundling).

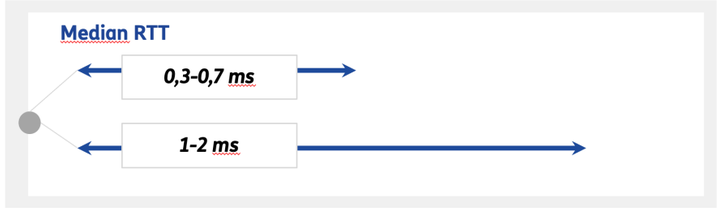
TIM Brasil also adopts a hierarchical NFVI architecture and the deployment of Telco Edge Nodes is still under discussion.

The main candidates to become Telco Edge nodes are the current DCC (Data Center Core) and DCE-R (Edge Data Centers Regionals) in synergy with the dual mode 5G/4G packet core) implementation.

Figure 1: TIM Network Architecture and RTT



Access	RTT [ms]
FTTH	1-2
FTTC	5 – 10
LTE	20 – 25
5G NSA 3.7 GHz	10 - 25
5G SA 3.7 GHz	~ 10
5G SA 26 GHz	~ 3 - 5



Services components and service layer

Regarding the platforms enabling services at the Edge, Telco and Service components will share the same virtualized infrastructure provided by TIM, depending on their requirements.

Service components can be provided by several entities: as a private cloud provided by TIM, by Hyperscale Cloud Providers, by "Telco-oriented" emerging technologies (e.g. MobiledgeX, Capgemini Ensconce).

Edge computing presents new challenges for application layer, such as managing highly distributed applications and data, as well as orchestrating Edge operations at significant scale or running real-time workloads across distributed infrastructure.

With latency being a key issue, applications that require direct connections to centralized services can be risky, so Edge applications might need to combine code and contents into single packages to ensure the best possible performance.

Moreover, with Edge-to-core bandwidth being a significant constraint, it's important to understand the costs of moving data and building application architectures that are designed to handle distributed data.

We may exploit at the best Edge Computing when a single, complete and comprehensive view of a "global state" is unnecessary, and when this is true, the application becomes much more portable to an Edge platform.

The best solutions will often include a combination of Edge and centralized Computing. In such a hybrid computing model, centralized computing will be used for compute-intensive workloads, data aggregation and storage, coordinating operations across geographies, and traditional back-end processing.

Edge Computing, on the other hand, can help solve problems at the source, in near real-time. Distributed architectures will enable to place applications at any tier from cloud to Edge, wherever it makes the most sense.

On Prem and Micro Edge solutions

Micro Edge concept is defined as an extreme extension of Edge solutions: it allows to share programmability features, orchestration and remote management platforms.

Micro Edge is a TIM resource on customer premise, more powerful than a simple network access device because its target functionalities could be dynamically reconfigured over the time on the base of customer needs, avoiding the on prem physical deployment and maintenance of additional dedicated HW devices.

Micro Edge solution fits as enabler both for fixed access telco services and for private network services: in this context partnerships with HCPs are also being evaluated, in order to provide a complete solution to the Enterprises that integrates telco functions and cloud functions together.

In the Brazilian market, there is a growing interest in private networks, showing to TIM Brasil that the Edge Computing infrastructure could be associated with this kind of scenario.

Federation and Standards

A critical success factor of the Edge deployment is the capability to federate platforms between MNOs. The federation allows customers to experience seamlessly the Edge service across the operator boundaries, creating a cloud continuum, even across different nations.

Application providers are hence able to enhance the footprint and reachability of their application over several federated MNOs. In this context, the "Telco-oriented" technologies appear to be ahead, implementing the East-West Bound Interfaces defined in the GSMA Operator Platform Group.

Other Standard Developing Organizations and fora supporting the evolution of Edge Computing are 3GPP, CNCF (Linux Foundation) and ONF.

Company Position and Guidelines

The "Beyond Connectivity" concept can be realized only by transforming the network into a real Cloud Native Platform, offering not only pure connectivity but Telco and Service capabilities.

The evolution of the network in a Cloud Native environment with Telco Enablers will allow the full network transformation in an Open Telco Service Platform as a cloud-based execution environment for Service Layer offering flexible resources, expandable through the integration of additional modules via clear interfaces (APIs).

The platform must be developed on top of a TIM Cloud Native Infrastructure, as this is the reference technology for the IT, Web Services space and industry.
The target is a hierarchy of TIM Edge Nodes from national peering down to the on-premises deployments in an Edge continuum.

TIM Egde Node, providing connectivity to all end-customers through public (or even private) coverage, will either locally break out the traffic on an appropriate service component or will allow the non-Edge traffic to flow to centralized cloud instances or the internet, based on the specific application requirements.

Among the Telco components to be deployed at the TIM Edge Node the User Planes of the Fixed and the Mobile Core Networks must be included.

A simple list of these elements might be:

- User Plane Function (UPF), with respect to the 5G core;
- Disaggregated BNG User Plane (DBNG-UP), with respect to the fixed core;
- Access Gateway Function User Plane (AGF), with respect to the context of 5G WWC (Wireless Wireline Convergence);
- Open Cache, with respect to the distribution of web/video contents.

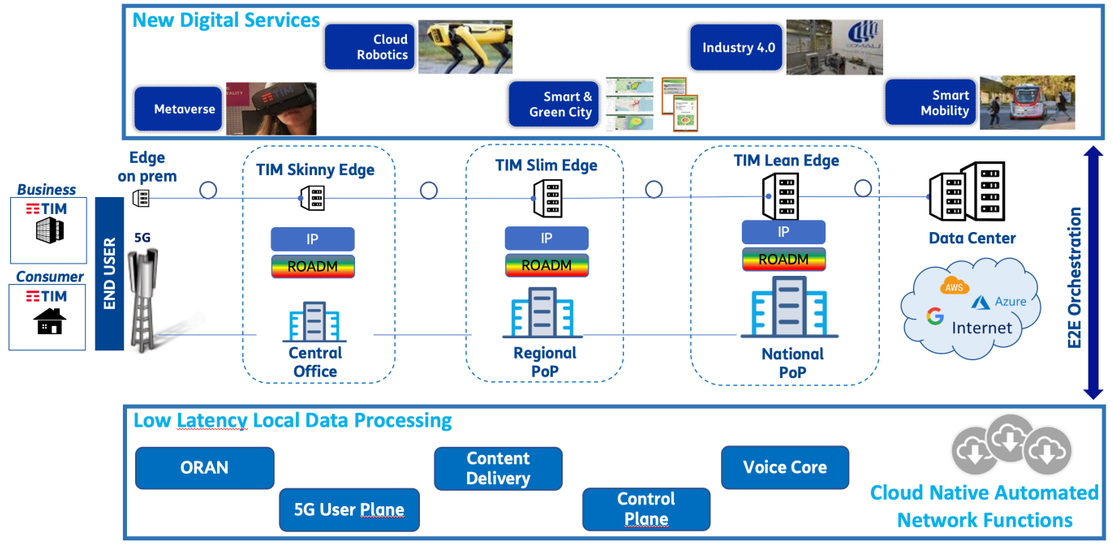
The deployment at the TIM Edge Node of the above User Plane functions, in a distributed fashion, is a key point to provide the network with the flexibility needed to reach the most convenient service components among the multiple ones available in the network.

Only the User Plane of the IP Edge functions needs to be distributed, as the Control Plane, in charge of handling the user signaling, can remain centralized: to achieve this, the new Core Network architecture in the context of the Edge Cloud deployment must be based on Control/User Plane Separation (CUPS) functionality.

Due to the increase of NFVI sites **TIM needs to deploy an E2E Orchestration and Automation solution**, being able to handle Telco Enabler (1) service requests, Telco and Service components coordination and lifecycle management, CNI lifecycle management.

The scope is reducing human intervention and reduce dramatically service

Figure 2: E2E Orchestration and Automation Architecture



Reference

(1) Telco Enablers should be containerized application built upon several simpler components (Microservices) able to expose and use specific API and should be deployed on a specific Execution environment (CaaS or K8S cluster)

creation (“Everything as Code”) exploiting the DevOps paradigms (Figure 2).

Moreover, from a business model perspective, the ownership of the E2E automation platform is strategic to avoid disintermediation from the richest part of the value chain.

Conclusion

The primary business model foresees **TIM as the customer facing entity for the Edge service**.

The objective is to leverage customer proximity and tight integration of the Telco and Service components to develop appealing Edge computing use cases, in order to remain relevant to the end-user and avoid being disintermediated by Hyperscalers.
A commercial and technical process must be defined between TIM and the Service components providers for all the phases needed to commercialize the Edge service (fulfillment, assurance, ...).

Under the assumptions and guidelines described above the Edge Computing represents therefore the opportunity for TIM to gain the role in the value chain by leveraging customer proximity and tight integration of the telco and service components.■

Contributing Companies

Contributing companies to this article are: TIM Italy, TIM Brasil, Noovle.

Acronyms

AGF	Access Gateway Function
API	Application Programming Interface
AWS	Amazon Web Services
BNG	Broadband Network Gateway
CDN	Content Delivery Network
CNCF	Cloud Native Computing Foundation
CNI	Cloud Native Infrastructure
DCC	Data Center Core
DCE-R	Data Center Edge – Regional
EASDF	Edge Application Server Discovery Function
GSMA	Global System for Mobile Association
HCP	Hyperscale Cloud Provider
IPCEI	Important Projects of Common European Interest
LA	Local Aggregator
MNO	Mobile Network Operator
NFVI	Network Function Virtualization Infrastructure
OLT	Optical Line Termination
ONF	Open Networking Foundation
ORAN	Open Radio Access Network
OTT	Over The Top
PoP	Point of Presence
RTT	Round Trip Time
SD-WAN	Software Defined Wide Area Network
UE	User Equipment
UPF	User Plane Function
VPN	Virtual Private Network
WWC	Wireless Wireline Convergence

Journey to Cloud

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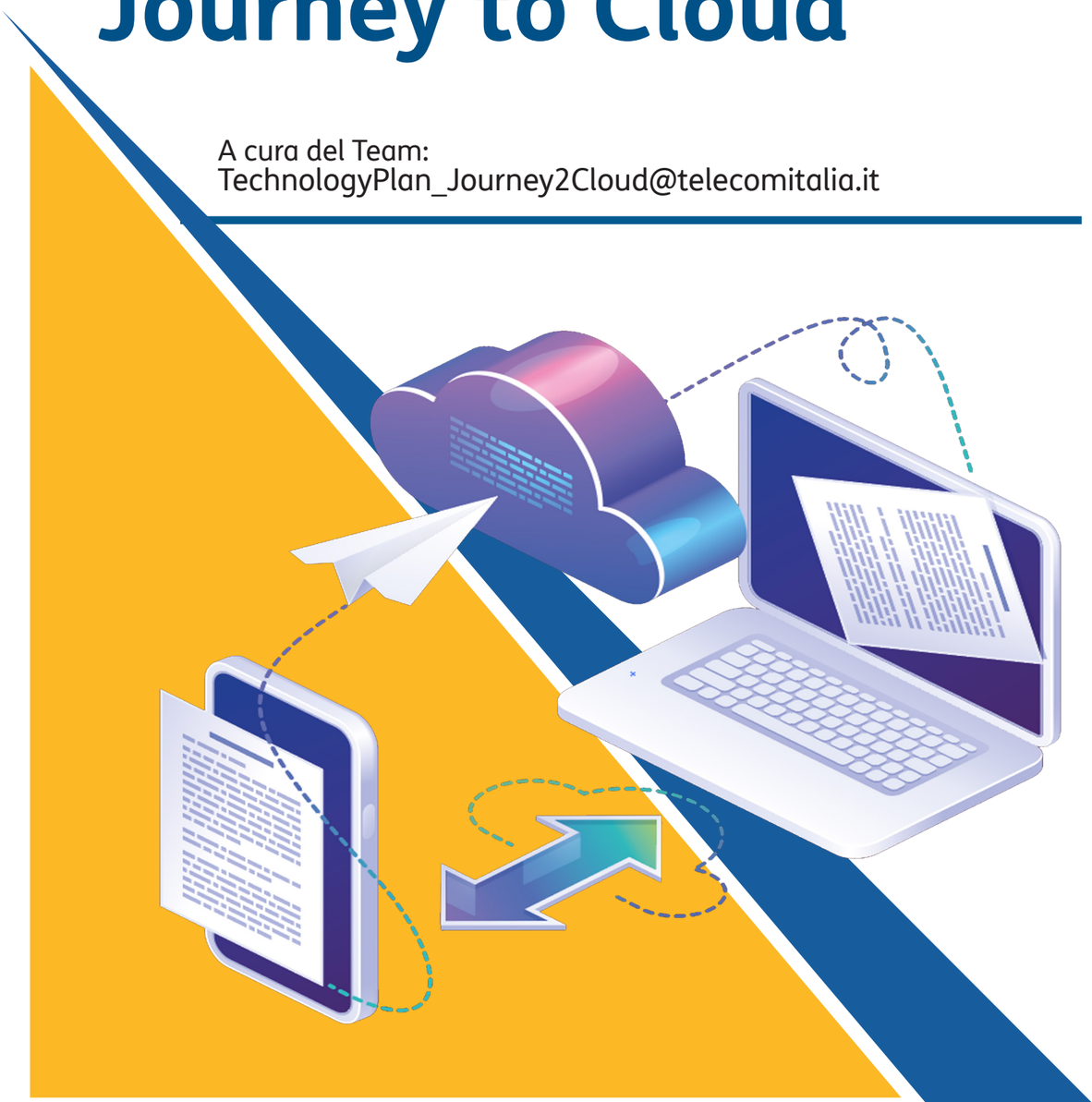

“Journey to Cloud” is a transition aiming to migrate corporate assets to the cloud, enabling IT costs and greenhouse gas emissions decrease, business results improvement and innovation pace speed up.
TIM Group, supported by trusted partners, is highly engaged in this journey by migrating own and customers’ workloads and applications, building new data centers and rationalizing existing ones, enhancing agility and resilience, and maintaining highest security levels.

Introduction and Context

Within EU (1), 42% of enterprises used cloud computing in 2021. Compared with 2020, cloud computing use increased by 6%.

Cloud computing use within Italy jumped from 23% in 2018 to almost 60% in 2021 (47% with high level dependence) while in Latin America, also due to Covid-19 pandemic, IT spending in cloud computing boosted (IDC expects growth of 43% for IaaS (2)).

Companies are migrating their corporate assets (workloads (WLs) or managed services, etc.) to the cloud to lower IT costs (reduce TCO up to 60% (3)), decrease greenhouse gas emissions, maximize business results and speed up innovation pace.

Telcos are also part of this trend, with different adoption speed and involvement levels: worth to be noted is AT&T which is deploying its new 5G Core network to the cloud (4).

This position paper summarizes TIM Group’s current situation, a positioning proposal, and some matured guidelines collection.

Current Situation

Focus on TIM’s Group current situation for J2C is presented, both from cloud services / applications migration and datacenter (DC) availability perspectives.

TIM relies on trusted partners (5) for its J2C. Since early 2020 strategic partnerships started with Google, Oracle and Microsoft Azure.
Nevertheless, TIM reserves the right to adopt other Hyperscale Cloud Provider (HCP) solutions as needed.

Moreover, Noovle (Jan. ’21) was created as **new company** within TIM Group to become a cloud enabler and Center of Excellence supporting Italian public and private companies’ digital transformation, leveraging a network of cutting-edge and sustainable Italian DCs.

A stepwise migration path was adopted for J2C; first achievements were to

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(2) https://www.zdnet.com/article/pandemic-accelerates-cloud-adoption-in-latin-america/
(3) Google’s Economics estimates, https://cloud.google.com/pricing?hl=it
(4) AT&T to run its mobility network on Microsoft’s Azure for Operators cloud, delivering cost-efficient 5G services at scale, https://about.att.com/story/2021/att_microsoft_azure.html
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move existing applications with “lift and shift” approach (6), enabling on-prem application decommissioning.

Regarding **TIM in Italy**, within the partnership with Google, a plan started in H1 20 to massively migrate workloads to Google Cloud Platform (GCP).

Migration is executed in collaboration with Noovle and addresses specific aspects such as:

- infrastructure architecture evolution to improve services’ resilience;
- Risk Analysis to address security requirements;
- Greenhouse gas emissions savings;
- Multi-Cloud openness.

Regarding **TIM Brasil**, strategy for WLs migration is:

- **IT application WLs** (IT J2C) **to public cloud**; journey started stepwise utilizing Microsoft and Oracle available active regions near to TIM Brasil’s DCs (São Paulo, Rio de Janeiro). Easiest WLs to be migrated with minimal adjustments were those of IT Applications, already running over a virtualized environment. Migration also includes **Big data** applications, based on GCP PaaS model.
- **Network function WLs** (Net2Cloud) **to hybrid cloud**; journey is primarily focused on “cloud-ready” WLs (e.g., VAS, OSS), while for others, requiring strong SLA requirements or implemented on proprietary hardware /bare metal, preliminary studies are ongoing.

Concerning **DC evolution**, TIM Italy’s NFVI (Network Functions Virtualization Infrastructure) DCs a consolidated reality where virtualized network functions (e.g., mobile core, etc.) are deployed.

For remaining **Italian DCs**, formerly hosting TIM’s Business and Consumer WLs as well as “IT” WLs (e.g., OSS), a reorganization plan, coordinated by Noovle, initiated to create six Hyperscale DCs (realizing two new Google regions) and decommission minor sites.

Two first Milan region poles are ready; a third Milan region pole and Turin region’s poles are in roadmap for ’22. Those DCs will also address TIM’s Business/Corporate Markets and Noovle’s direct market by realizing interconnected Hybrid PoPs.

TIM Brasil DC assets consist of dedicated DCs for Network (Core and Edge DCs), for IT and OSS. Figure 1 depicts distinct migration paths: IT workloads towards Public Cloud (HCPs or remote sites) based on a Multi Cloud strategy; network workloads towards Hybrid Cloud.

Companies for N2C are to be intended as possible partners, while for J2C real partners are already chosen.

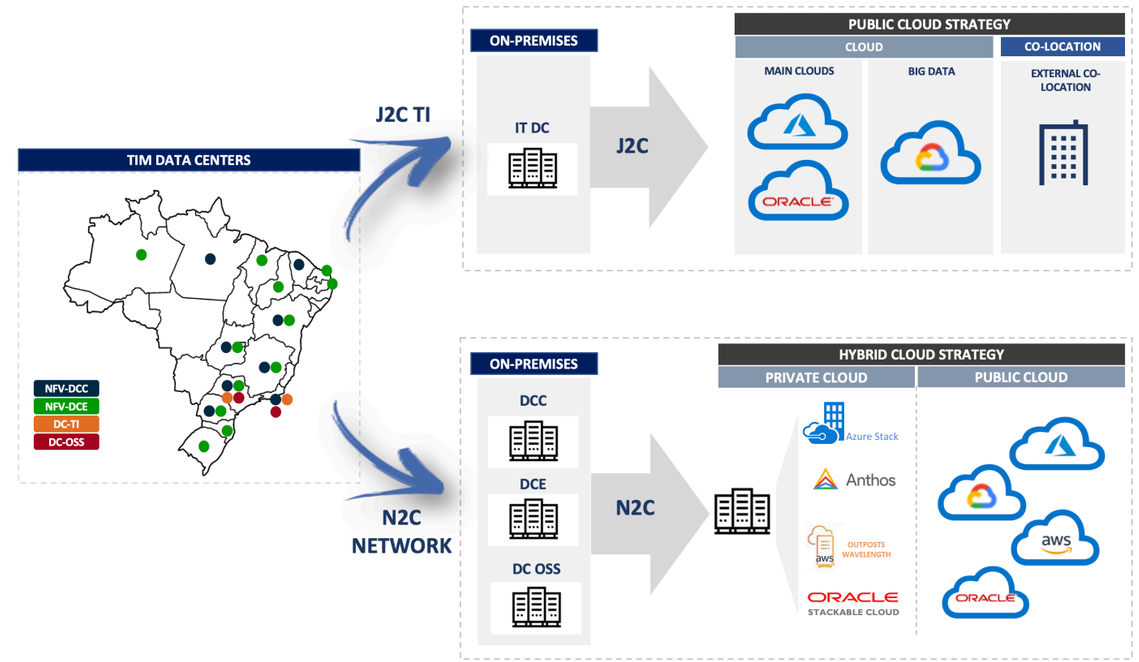
Finally, J2C imposed to strengthen **Security measures** in respect of national regulations (e.g., Golden Power for Italy) to guarantee company data confidentiality and integrity (7), (8).

Standard and Fora

Worldwide several national and international cloud computing standardization initiatives are ongoing.
Hereafter a summary of main initiatives in which TIM is involved is highlighted.

International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) through Joint Technical Committee 1 (**ISO/IEC JTC1**) - SC38 (9), together with ITU-T, released two cornerstone International standards, **Overview and vocabulary** and **Reference architecture** to provide a cloud computing overview along with a set of terms and definitions.

Figure 1: TIM Brasil J2C migration strategy



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(6) Boston Consulting Group, “Six Simple Steps Pave the Way to the Cloud”, Feb. 2019, https://www.bcg.com/publications/2019/six-simple-steps-pave-way-to-cloud

(7) http://www.astrid-online.it/static/upload/dpcm/dpcm-golden-power.pdf

(8) “Lei Geral de Proteção de Dados Pessoais (LGPD)” https://www.gov.br/cidadania/pt-br/acesso-a-informacao/lgpd and “Marco Civil da Internet”, https://www.lgpdbrasil.com.br/

(9) ISO/IEC, JTC 1/SC 38 “Cloud computing and distributed platforms”, https://www.iso.org/committee/601355.html

Within ETSI, **ISG NFV** became NFV's reference standard initiative (10).

NFV Release 4 contains the first normative **specification on "Cloud-native VNFs and Container Infrastructure management".**

BBF (Broadband Forum) has several projects defining access network infrastructure's cloudification and virtualization, among which **CloudCO** (11), to enable cloudification of network functionalities usually located within Operator's Central Office.

In **TM Forum**, the **Transformation Project Framework** (12) is working to support operators in Digital Transition with guidelines and assessment metrics.

Company Position and Guidelines

A focus on TIM Group's position is presented and some guidelines are provided, to identify a common vision on the cloud journey.

Applications Evolution

Current **WL migration plan** continues with the objective for Italy reach completion by H1 23, and for Brazil to complete IT WL migration by H2 23.

Guidelines for cloud services adoption and applications services engineering were set up and are progressively updated/made available to optimize cloud migrated applications' TCO.

Application Design

TIM adheres to Cloud Native Applications (CNA) principles and architectures for applications development (13), amongst which the most relevant design criteria are:

- package applications components in containers;
- decouple architectural components;
- allow easier stateless components' management by isolating stateful ones;
- use APIs to interconnect components minimizing dependencies from underlying technologies and to control interactions' security.

Everything as code

Applications management adheres to the "everything as code" principle: high-level automation, formal documentation, infrastructure versioning and configuration, and repeatable deployment processes.

Performance

Within the telco context, J2C requires high attention on performance issues, e.g., applications migrated to cloud must not worsen customer experience.

In this regard, main requirement to consider is "end-to-end latency" (i.e., time necessary for transmitting information over the network from a source to a destination) whose related guidelines are:

- WLs not carrying high-sensitive latency requirements are primary candidates for migration to public cloud solutions;
- where migration to hybrid cloud is considered convenient (e.g., for TCO reduction), same end-to-end latency as the one guaranteed by private cloud solutions must be granted to avoid customer experience worsening;
- in presence of high-sensitive latency requirements, shift to hybrid and/or edge cloud solutions should be considered.

Cost control

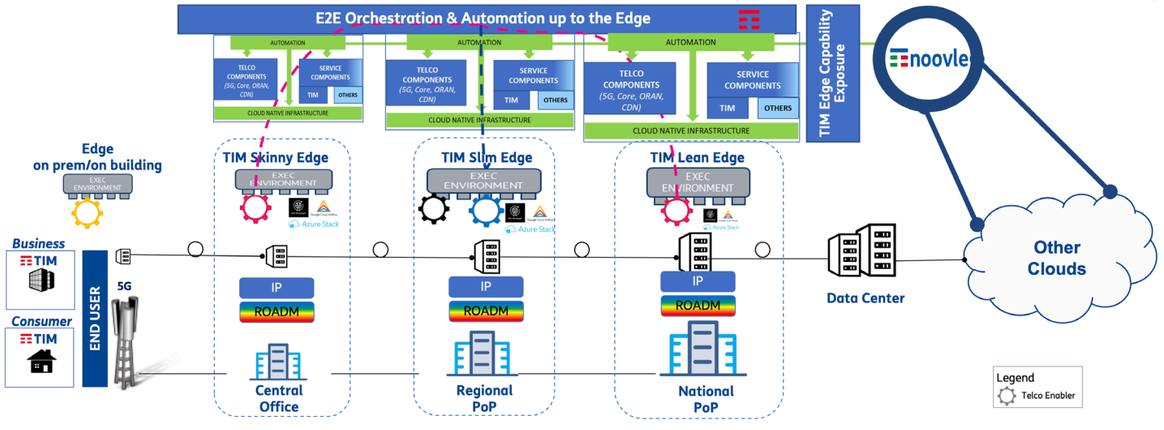
Immediate resource consumption information, cost forecasts and budget alerts must be provided.

Network functions evolution

TIM Italy's NFVI represents a well-suited private cloud environment, expanding its footprint and addressing most network functions' requirements in different domains (e.g., radio access).

Nevertheless, for functions with specific requirements such as high-intensive memory/storage usage, feasibility studies started to analyze hybrid cloud solutions.

Figure 2: TIM Italy's Telco Cloud Continuum



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(12) TMF Forum Transformation project Framework (TPF): https://www.tmforum.org/resources/standard/gb1011-transformation-project-framework-tpf-v1-0-0/

(13) Microservice architectures (https://microservices.io/); the twelve factors (https://12factor.net/)

From a network evolution perspective, Figure 2 represents the Telco Cloud Continuum target scenario, which is composed by a hierarchy of TIM Edge points of presence from national peering down to the on-premises deployments in an Edge continuum.

An automation solution will handle service requests, coordinate telco and service components, deploy cloud native infrastructure and guarantee scaling.

TIM Brasil's Net2Cloud project plans to migrate network functions' WLs to hybrid cloud and OSS WLs to public cloud. The plan is to centralize all virtual environments to the public cloud by 2023.

For those WLs to be deployed closer to end customers (e.g., related to user plane functions), TIM Brasil is evaluating to re-engineer and to deploy them on target remote sites.

Net2Cloud is organized in four distinct migration waves, based on "cloud readiness" requirements; first waves are dedicated to already virtualized WLs (e.g., VAS), the latest to address harder virtualization and latency issues.

Security

From **security** perspective related to Italian policies, based on Prime Ministerial Decree - October 16th, 2017 (7) - and with reference to Classified Perimeter regulations, main general constraints to be considered in migrating a service to a cloud or in adopting cloud model for a new service are:

- clear Security Organizations' shared responsibility boundaries and cyber-security events intervention optimizations;
- functions and Sensitive Data processed by a Cloud Service Provider (CSP) must reside in Italy (or alternatively within the EU);
- encryption Keys must preferably be located and managed within TIM and not within CSP;
- strong Authentication mechanisms and event tracing must be ensured. Log management tools must be available;
- CSP must send anomalous/suspicious events to TIM Security Operations Center, comply with TIM Audit Right contractual clauses, and own necessary security certifications.

Datacenter Evolution

On the **Italian** side, strategy is based on three main guidelines: building new DCs, rationalizing existing ones, increasing automation and efficiency:

- consolidate new DCs to allow both WLs migration and new greenfield projects creation;
- reduce DCs, free up space for new initiatives and decommission older equipment;
- increase automation and system's lifetime.

Figure 3 depicts cities in which Noovle DCs will be hosted by end '22.

Noovle's objective is to become the only Public Cloud Provider enabled to deliver Google Cloud regions in Italy (100GE fiber connection) and offer Business Continuity and Disaster Recovery solutions, also thanks to a minimum distance of 100 km between the two regions.

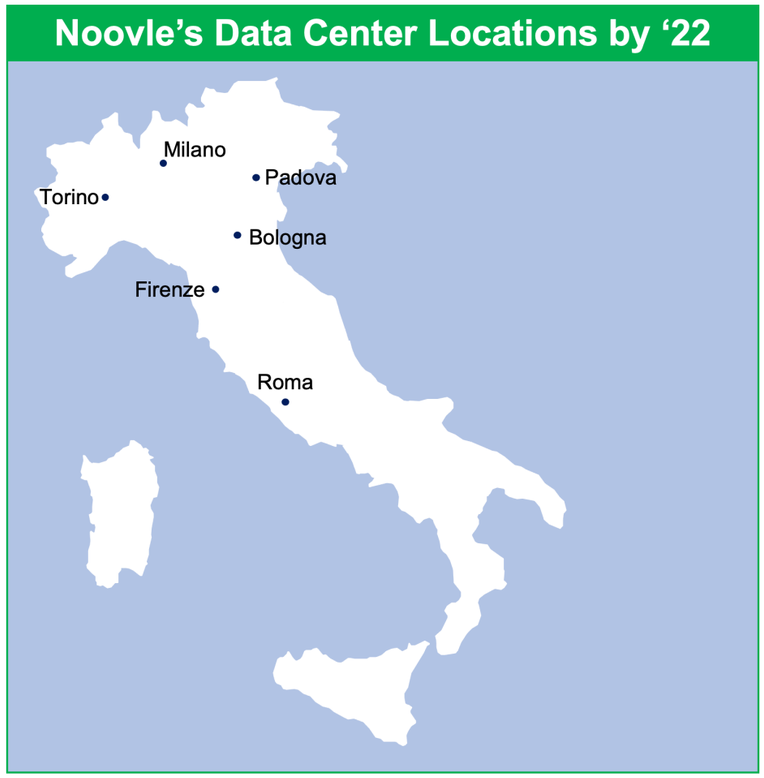
TIM Brasil's strategy is to decommission its IT DCs (São Paulo and Rio de Janeiro) by H2 23 migrating all IT WLs to public cloud.

ESG

According to TIM Group's ESG objectives (e.g., greenhouse gas emissions reduction up to 90% (14)), following criteria are considered:

- Green by Design: efficient space usage, energy consumption, energy usage from renewable sources, etc;
- circular economy models: circular economy adoption for servers and equipment regeneration to increase their useful life;
- Annual Impact Report: report obtained results and measure social and environmental impacts.

Figure 3: Noovle's Data Center Locations



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Managed and Professional Services
Main guidelines on professional and managed services to assist TIM Group's customers in their journey are:

- provide Program/Project Management services;
- offer professional services, from applications development to infrastructure migration to cloud;
- provide managed operations "as a service".

Conclusions

This position paper presents TIM Group's J2C, focused on workload migration and DCs reorganization / modernization and provides a set of matured guidelines both for Italy and Brazil.

The journey is well ahead and strategic, and it will become even more pervasive in the next future.
TIM Group actively pursues this strategic approach to improve value proposition for its customers.■

Contributing Companies

Contributing companies to this article are: TIM Italy, TIM Brasil, Noovle.

Acronyms

AT&T	not an acronym (originally American Telephone & Telegraph)
API	Application Programming Interface
AWS	Amazon Web Services
BSS	Business Support System
CNA	Cloud Native Application
CSP	Cloud Service Provider
DC	Data Center
EU	European Union
ESG	Environmental, Social and Governance
GCP	Google Cloud Platform
GE	Gigabit Ethernet
HCP	Hyperscale Cloud Provider
IaaS	Infrastructure as a Service
IDC	International Data Corporation
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
IT	Information Technology
ITU-T	International Telecommunication Union – Telecommunication Standardization Sector
J2C	Journey to Cloud
N2C	Network to Cloud
NFV	Network Functions Virtualization
NFVI	Network Functions Virtualization Infrastructure
OCI	Oracle Cloud Infrastructure
OSS	Operation Support System
PaaS	Platform as a Service
PoP	Point of Presence
SLA	Service Level Agreement
TCO	Total Cost of Ownership
TPF	Transformation Project Framework
VAS	Value Added Service
WL	WorkLoad

5G StandAlone

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5G SA (StandAlone) will exploit the true potential of 5G and will be the evolution of currently deployed 5G NSA networks, guaranteeing a better quality, minor cost and a more satisfying customer experience.
Among the main benefits we can mention significantly lower latency enabling for example industry 4.0 and self-driving car use cases, or massive IoT support and the introduction of 5G private networks through network slicing functionality.

Context and Introduction

Operators are increasingly experimenting with and deploying 5G StandAlone (SA) networks. Introduction of 5G SA is expected to simplify architectures, make network deployments easier, improve security and reduce costs.

5G SA is expected to enable customization and open up new services and revenue opportunities tailored to enterprise, industrial and government customers.

As well-known, SA enables the following three service categories:

- Ultra Reliable Low Latency Communications (URLLC);
- Enhanced Mobile Broadband (eMBB) services;
- Massive Machine Type Communication (mMTC);

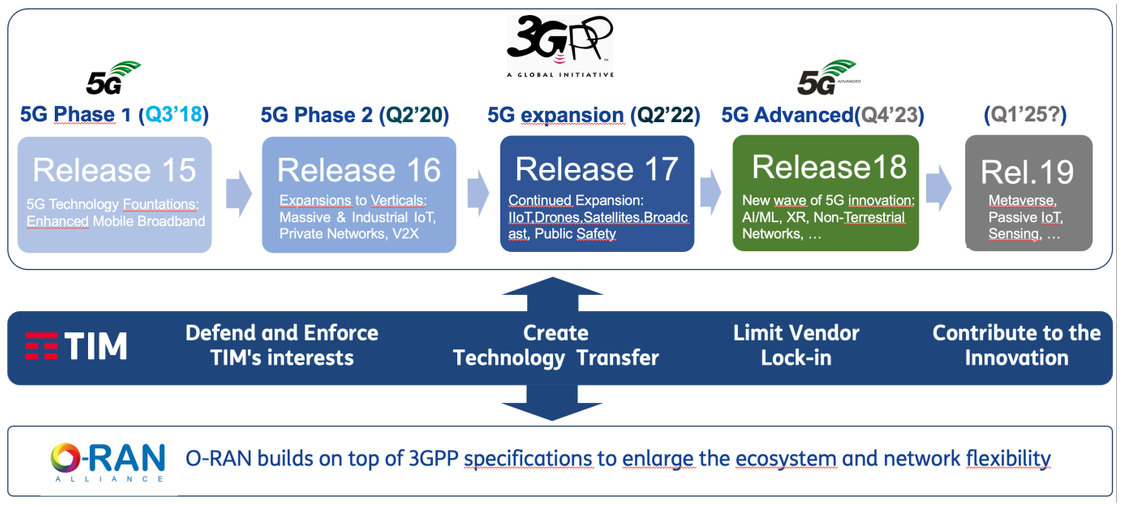
as well as the Network slicing capability, that is the possibility to offer customized service quality and privacy.

Standardization Roadmap

The first set of 3GPP 5G SA specifications were delivered as part of Release 15 in June 2018. Often referred to as “Phase 1” of 5G, it was mainly focused on enabling traditional mobile connectivity services (eMBB), including enhancements to LTE/EPC (e.g. for interworking aspects) as well as security and network management aspects related to the operation of the new radio and core.

Release 16, or 5G “Phase 2”, was completed in June 2020 aiming at improving the performance of the NR access and the 5G Core in terms of latency and reliability (URLLC) and high density of connections (mMTC), From Release 16 onwards, 3GPP scope also includes application layer standards defining new

Figure 1: 3GPP Roamap for 5G System



Application Enablers to help Verticals make best use of 3GPP systems.

"Phase 3" of 5G is currently being completed in 3GPP by March 2022, with a 9-months delay due to the pandemic.

It aims at enabling even more vertical markets (e.g. Satellite, Public Safety, …) in addition to the increase of radio performance and efficiency and to the definition of new architectural enablers (e.g. Multicast/Broadcast, Direct Communications, …).

In December 2021, 3GPP agreed the new package of Studies that will characterize the next phase of 5G, Release 18 (branded also as "5G Advanced").

Rel18 is expected to deliver some innovative technologies to further support vertical markets (e.g. Edge federation, AI/ML support, "Timing-as-a-service", XR and AR communications…) anticipating use cases / trends that will only see full maturity in 6G.

Market overview

Market is seeing the rising of a strong 5G SA ecosystem with chipsets and many types of devices (663 announced devices with claimed support for 5G SA).

On January 2022, it has been identified 98 operators in 50 countries/territories worldwide [GSA] that have been investing in public 5G SA networks (in the form of trials, planned or actual deployments).

At least 20 operators in 16 countries/territories are now understood to have launched public 5G SA networks.

Current Situation

Currently in Italy operators are deploying NSA 5G networks. 5G is mainly associated with 3.7 GHz frequency band, thus identifying 5G with a boost in throughput.

One operator is massively using DSS (Dynamic Spectrum Sharing) to activate 5G on legacy frequencies and so enabling 5G logo to be displayed in most service area, even though with limited performances.

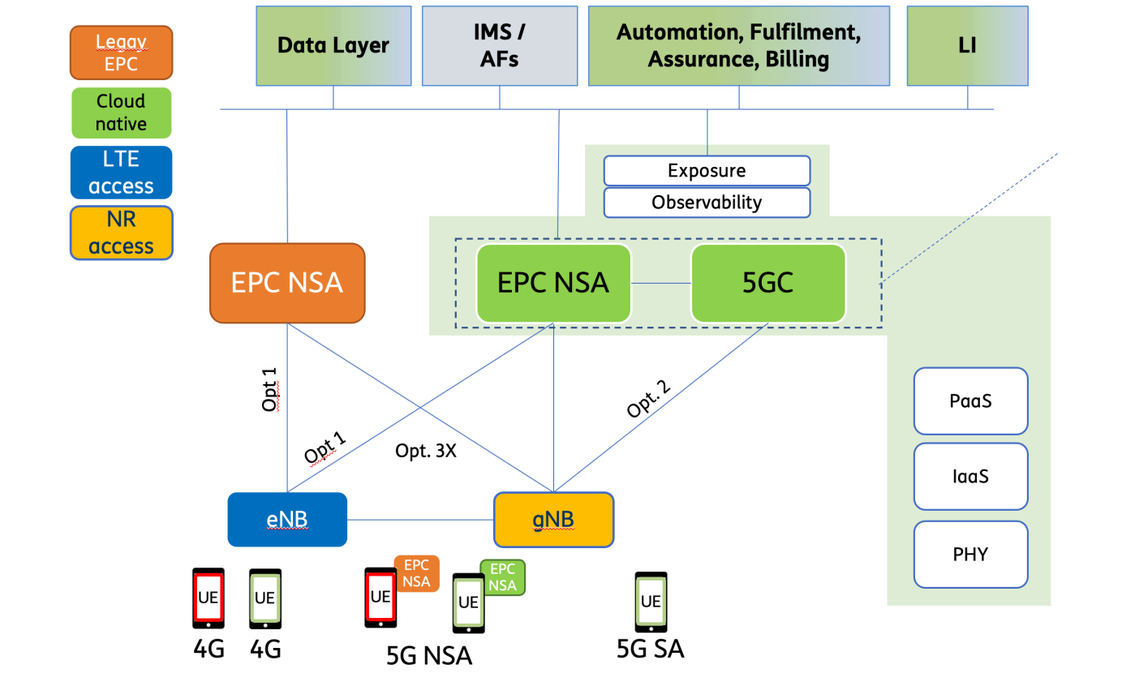
One operator has announced the use of 5G SA for FWA service. In Italy there isn't any regulatory push to deploy a 5G SA network: reasons for deployment should be found based on Market requirements, network costs reduction or technological positioning.
In Brazil there are few 5G DSS deployments. The newly assigned 3.5GHz band has many regulatory obligations associated, among which the duty to deploy a SA release 16 compliant network.

So, by mid-2022 in Brazil there will reasonably be at least four 5G SA networks.
The presence of a large LTE customer base, the current small penetration of 5G SA capable terminal and the necessity for the two technologies to coexist poses a series of issues and related costs that it is necessary to highlight.

Hereafter a short list of higher priority topics:

- Coverage for eMBB in SA: 3.7 GHz frequency range allows a significant performance boost compared to 4G, but it appears barely suitable (unless a massive and capital intensive deployment is implemented) to provide nationwide and indoor coverage. For this reason, in order to offer a nation-wide SA coverage based on 3.7 GHz band, also providing throughput performances equal or greater than the ones offered by 4G networks, a concurrent deployment on low frequency bands must be considered by operators. This can be achieved using the 700 MHz band or the aforementioned Dynamic Spectrum Sharing (DSS), in order to use legacy 4G frequencies in 5G NR. Unfortunately, DSS introduces some inefficiencies, consuming 4G and 5G capacity. Therefore, widespread usage of DSS may imply, where necessary, not negligible investments on 4G capacity at least until 5G traffic is not dominant.
- Band aggregation: NSA users can benefit from the full 4G bands plus 5G NR bands. 5G SA users can benefit only from the NR bands, with some limitations (at least at the beginning) due to terminals capability in multiple bands carrier aggregation.
- Voice: until Voice over New Radio (VoNR) will not be available, 5G SA users will be redirected on VoLTE for voice calls, with some inefficiencies in terms of call set up time.
- 4G interworking: until NR SA coverage will not be continuous, 5G SA users will experiment frequent inter system handovers towards 4G.

Figure 2: NSA and SA planned architecture



- NB-IoT: currently 5G SA does not support narrow band IoT devices. So 4G will still be important for such kind of services. It is however commonly recognized that NB-IoT technology satisfies the 5G KPIs for massive IoT traffic (device density, power consumption, …), so it can be considered part of the 5G solutions for mMTC as well.

Roadmap towards 5G SA

TIM Italy Roadmap

Network

TIM is implementing the new 5G Cloud Native Core Architecture (Figure 2) to support 4 specific categories of service: 5G Verticals, FWA, MBB, IoT:

- 5G Verticals will be the first deployments of 5GC/5G SA;
- the next step will be FWA on 5G SA accesses with deployment of the 5GC slice for FWA;
- the deployments of 5GC slices for eMBB will be made based on the availability of 5G SA smartphones with voice support in VoNR mode and 5G NR carrier aggregation radio technologies;
- for IoT, the 5GC slice deployments are expected in accordance with the timing of the Release17.

5G SA cloud native service platforms make it more effective for TIM to “Platformize” its Network Functions (NFs), opening the 5G network to (internal and external) 3rd parties through the exposure of open, secure and programmable APIs (“Network as a Service” model).

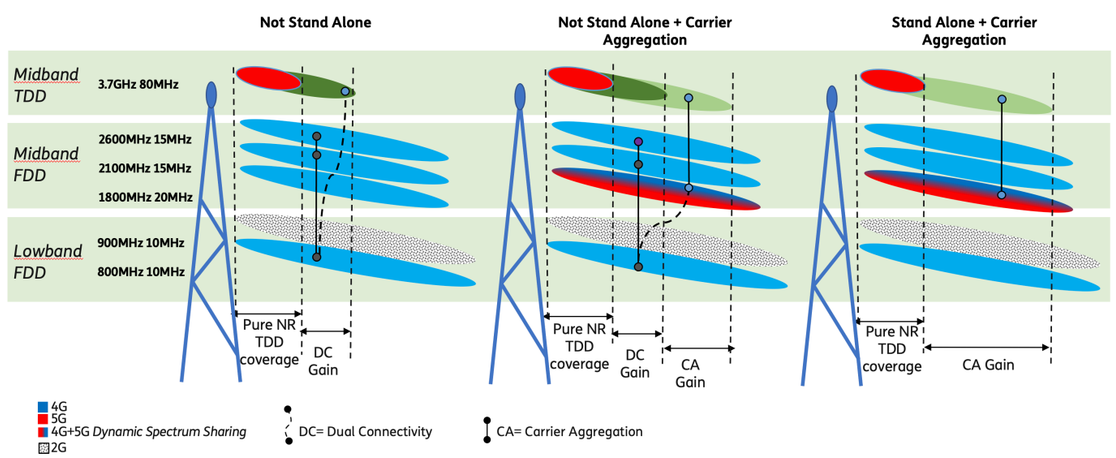


Figure 3: NSA and SA planned architecture

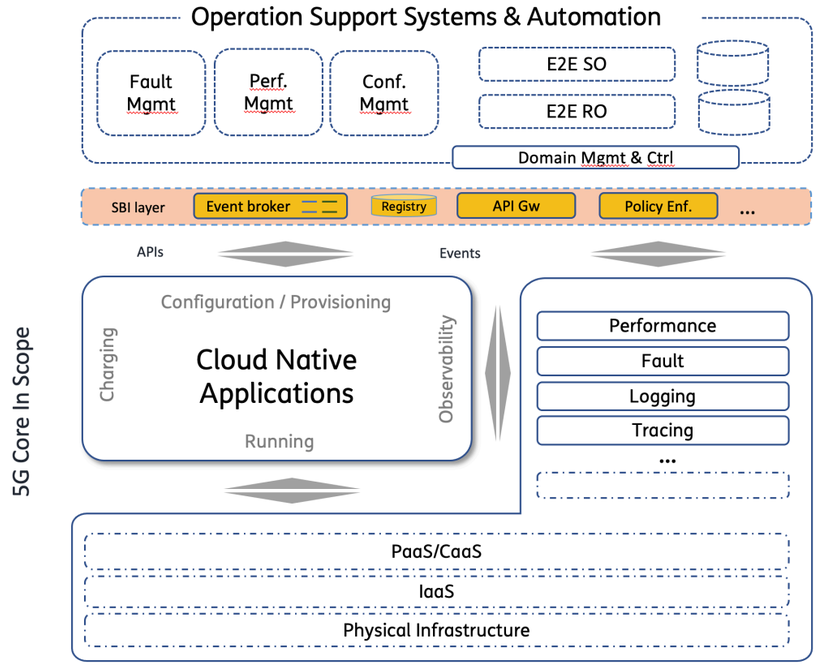


Figure 4: NSA and SA planned architecture

This will be made possible through the NEF (Network Exposure Function), that represents the natural evolution of the exposure path already in place in TIM.
Radio deployments will follow 5G Core Network plans and will be driven by specific Customer’s requirements (i.e. in particular low latency use cases).

As anticipated, if compared to NSA solution, SA cannot rely on LTE carriers: so, in order to boost performances, it is of fundamental importance to aggregate more NR carriers (Figure 3), for example Sub6GHz mid and low bands.

In terms of radio configurations, different scenarios could be of higher interest:

- SA using Sub6GHz TDD mid bands (3.7 GHz) + Sub6GHz FDD Mid/Low bands.

In this scenario, NR coverage and radio performances could be significantly enhanced by using Carrier Aggregation between 3.7 GHz and Sub-6GHz bands exploiting DSS (Dynamic Spectrum Sharing):

- SA using mmW TDD high bands (26 GHz) + Sub 6GHz Mid/Low bands.

This scenario represents a good solution to further enhance throughput performances, due to the introduction of mmW layer, typically very challenging in terms of coverage range.

Main driver for DSS implementation is 5G coverage extension, when coupled to a mid band layer (e.g. 3.7 GHz). In general, it can be noticed that:

- DSS allows massive extension of the area where 5G connectivity is perceived as available (the 5G icon on the terminal);
- DSS improves the NR TDD@3.7 GHz coverage for downlink, through NR carrier aggregation by using a lower frequency band in DSS mode as primary component carrier and the 3.7GHz mid-band as secondary component carrier.

Even though DSS can be implemented in both NSA and SA architecture , it must be considered an important enabler for the transition from NSA to SA, together with Carrier Aggregation.

Support Systems

OSS Architecture (Fault, Configuration & Performance Management)

In order to support FCAPS functionalities to guarantee Network Elements (NEs) Operation & Management (O&M) from 5GC as dual mode EPC-5GC cloud native, with support for all 4G and 5G SA/NSA accesses, TIM will utilize at first Vendor-provided Element Management System (EMS).

In a second phase, not yet planned, Target OSS Integration Architecture will be compliant with 3GPP-SA5 Service Based Architecture (SBA): 5G network functions and the related management functions will be implemented through innovative software development techniques such as microservices, containerization, etc.

The next figure represents one possible 5G target OSS integration architecture in a cloud-native environment.

BSS Architecture (Usage to Bill)

The introduction of the 5G SA core network requires an architectural re-engineering of the online mediation system in the Usage Collection domain and of the Online Charging System in the Billing area.

To this end, an architectural evolution roadmap has been defined in the Usage-To-Bill area, aimed at the native integration of the 5G SA core network, enabling the support of new 5G SA offer models and services.

In the target architecture the new online mediation component will have to allow integration with both the core 5G network and legacy networks for both prepaid and postpaid mobile customers.

The To-Be architecture will enable converged mobile rating, with the ability to extend it to wireline customers, enabling converged native billing.

The Charging and Billing capabilities supported by the platforms, deployed on cloud architecture to guarantee performances, scalability and resilience, will be accessible via Open API designed according to the main industry standards.

TIM Brasil Roadmap

As already mentioned, Anatel included in the 5G auction rules, published in February 2021, a set of obligations among which the requirement that the 3.5GHz frequencies should be used in 5G Stand Alone Release 16 or higher and specific coverage obligations in 3.5GHz.

This means that Brazilian operators are not allowed to rely on DSS technology to fulfill 5G coverage obligations, meaning that 5G SA networks must be deployed on 3.5GHz.

Anatel stated that 5G SA will be available in the capitals of all 27 states of Brazil by July 2022. This will be the first 5G coverage obligation to be fulfilled by the winning bidders.

The target architecture for 5G SA is a fully 4G/5G Convergent infrastructure, contemplating all the network functions specified by 3GPP for the 5G Core, as well as the evolutions foreseen for the RAN layers and with a high degree of automation, orchestration, and programmability.

Having as initial base the functionalities specified by 3GPP in Release 16, TIM Brasil will follow the evolutions foreseen for the subsequent releases, aiming, in particular, to ensure the use of the new functionalities to support the new applications and monetization opportunities brought by the eMBB, URLLC and mMTC dimensions.

The access layer infrastructure will evolve gradually to explore also O-RAN solutions, establishing a hybrid environment, combining O-RAN with traditional RAN architectures and the coverage will be expanded based on, mainly, the 3.5 GHz and 26 GHz, and later, the 2.3GHz that will, initially, be used for the LTE Network.

New services such as mMTC and URLLC will be added as the Network and Transmission grid evolves and reduction on latency is inherent to the 5G SA technology.
Another highly probable new service will be the Private Networks, that had an evolutionary leapfrog with the launch of the 5G Network, Network Slicing and Edge Computing.

The coming challenge will be the layer management, as LTE traffic will continue growing until 2025 and refarming from 4G to 5G will gradually be done. Providing the best possible experience to the subscribers will be the key, regardless of the type of terminal they use.
NR brings new antenna configurations that shall be applied to the different coverage scenarios as MIMO 32x32 and 64x64 for outdoor or 8x8, mainly for indoor use.

Voice Services (VoNR), Network slices and Exposure will be supported and an E2E automation framework for operation, dynamic network slices implementations, allowing to explore new business models and the fully potential that new functions like NWDAF and NEF can offer.

In BSS environment, the service-based architecture for charging and billing systems for 5G SA and the corresponding functions and interfaces

that support this new architecture will need to evolve significantly and will be service based interfaces (SBI).

There will be a convergent billing interface covering online charging, automatic charging, and data recording.
As part of 5G SA evolution support some of IT BSS ongoing and in planning initiatives are listed below:

- 5G CHF – 5G Charging function implementation;
- 5G CCS – Convergent Charging System;
- MIoT – Massive Internet of Things platform;
- Network Exposure Function (NEF) Northbound APIs / Open Telco API Management.

Conclusions

Introduction of 5G SA is expected to simplify architectures, make network deployments easier, improve security, reduce costs and empower new use cases.
5G SA will be enabled by the new 5G Cloud Native Core Network. Regarding network access, considering that 3,7GHz band will take long time in order to provide a nationwide outdoor/indoor coverage, the support of existing 4G frequency bands and the new 700MHz one need to be considered in order to provide a good quality of service also through the use of Dynamic Spectrum Sharing (DSS).

TIM Italy will deploy SA in conjunction with Telco Cloud Continuum, starting from specific areas, mainly focused on some vertical use cases, and afterwards, gradually, in other areas using a business driven approach.
TIM Brasil will comply with the regulatory rules and the synergistic use between 5G SA and the 3.5GHz band.■

Contributing Companies

Contributing companies to this article are:
TIM Italy and TIM Brasil.

Acronyms

3GPP	Third Generation Partnership Project
5G NR	5G New Radio
5G SA	5G StandAlone
BSS	Business Support System
CCS	Convergent Charging System
CNFs	Cloud-native Network Functions
DSS	Dynamic Spectrum Sharing
eMBB	enhanced Mobile Broadband
EMS	Element Management System
EPC	Evolved Packet Core
EPC- 5GC	Evolved Packet Core - 5G Core
FDD	Frequency Division Duplex
FCAPS	Fault Configuration Accounting Performance Security
IoT	Internet of Thing
LTE	Long Term Evolution
MBB	Mobile Broadband
MIMO	Multiple Input Multiple Output
MIoT	Massive Internet of Things platform
mmW	millimeter Wawe
NEF	Network Exposure Function
NR	New Radio
NSA	Non-StandAlone
NWDAF	Network Data Analytics Function
O-RAN	Open Radio Access Network
OSS	Operation Support System
SBA	Service-Based Architecture
SBI	Service Based Interfaces
TDD	Time Division Duplex
URLLC	Ultra Reliable Low Latency Communications
VoLTE	Voice over LTE
VoNR	Voice over New Radio

Legacy Technology Decommissioning

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The spread of 5G and optical technologies in the access network and in the backbone, together with Edge Cloud Computing, Virtualization and Automation of networks allows a wide range of very high quality and low latency service offers capable of adapting quicky to traffic growth and demand change.
This continuous evolution over the years, as well as the complexity of switching off services from old networks, has led to technology stratification with some very obsolete platforms still in use. In this scenario it is exceedingly essential to find ways to modernize all network layers making them more efficient, lean and future proof.

Introduction and Context

Decommissioning of legacy networks and platforms (local exchanges, copper, 2G/3G, PSTN, ATM, SDH, PDH, ...) is a challenge to guarantee operational simplification and to implement important savings (e.g. related to energy consumption, facilities management, rental fees), reduce the risk of faults and enable revenues (e.g. selling equipment, copper cables, real estate).

The process is mostly driven by ultra-broadband deployment, allowing new customer services and collecting possible government incentives.

Decommissioning hence, contributes to the achievement of Government Digitalization targets (1Gbit/s to all Italian families by 2026) and of the Green Revolution (reduction of greenhouse gases) included in the National Recovery and Resilience Plan.

In addition, there are serious security risks related to legacy technologies still in use: long transformation periods of both network equipment and IT systems (often imposed by external constraints) increase the risk of attacks, as there are often no more updates available to secure legacy systems.

On the other hand, customer reluctance, major investments in the short term and long notice periods are the main barriers as well as the obligation to continue providing legacy services at the wholesale level.

Decommissioning in Italy: legislative framework and regulatory constraints

In Italy AGCOM regulates decommissioning activities with resolutions on different issues.

Regarding the possibility of dismissing central offices, there are constraints on broadband services coverage and penetration, while, concerning low speed transmission circuits on legacy technologies, there has been the withdrawal of obligations on new activations (1), (2).
In any case, a long way must still be gone to obtain, for example, End of Life and End of Maintenance status of old network platforms such as PDH and SDH.

However, it should be noted that the switch-off of local copper exchanges is object of a specific article of the New European Communications Code (3) that gives the National Regulatory Authority the possibility of withdrawing access obligations relating to the copper network, once an adequate migration process has been established.

This with the objective of creating a legislative framework favourable to decommission legacy networks.

References

(1) Delibera n. 348/19/CONS - AGCOM
(2) Delibera n. 333/20/CONS - AGCOM
(3) art. 81, European Electronic Communications Code (EU Directive No. 2018/1972), transposed in Italy in November 2021 with Legislative Decree 207/2021.

Decommissioning outside Italy: what is the trend?

The following two pictures summarize what is going on with respect to copper and 2G/3G.

In general, to promote the decommissioning of legacy networks, European regulatory best practices encourage migration to the best technology available by increasing wholesale prices of legacy services and declaring the End of Sale.

Furthermore, a new rule of the Code of Electronic Communications allows operators to upgrade fixed access technology without customer's consent.

Current Situation and Plans

In the next paragraphs a summary of obsolescent TIM (and subsidiaries, where specified) networks/platforms will be given, specifying decommissioning plans and strategies when available.

As a general consideration, dismission or substitution of old equipment ensures savings on energy and operating costs and reduces the risks of faults, strengthens IT security and enables newservices provisioning.
These benefits won't be repeated in the following, while other specific advantages or peculiar issues will be described in detail.

Central Offices

The decommissioning of Central Offices, besides great savings on energy and rental fees, brings revenues from building disposal: about 6.700 Central Offices out of a total of more than 10.500 could be released when copper-based services will be migrated to new fiber-based ones.

In relation to that, accelerating NGAN/FWA plans is critical in achieving the goal and is compliant with the constraints imposed by the already mentioned regulatory rules.

Fixed & Mobile Access

On fixed access, ATM DSLAMs need to be migrated to IP ones since they are obsolete and out of support (a swap plan started in 2015 and is still on-

Figure 1: From Arthur D Little- Copper switch off: Opportunity to drive infrastructure convergence? October 2021

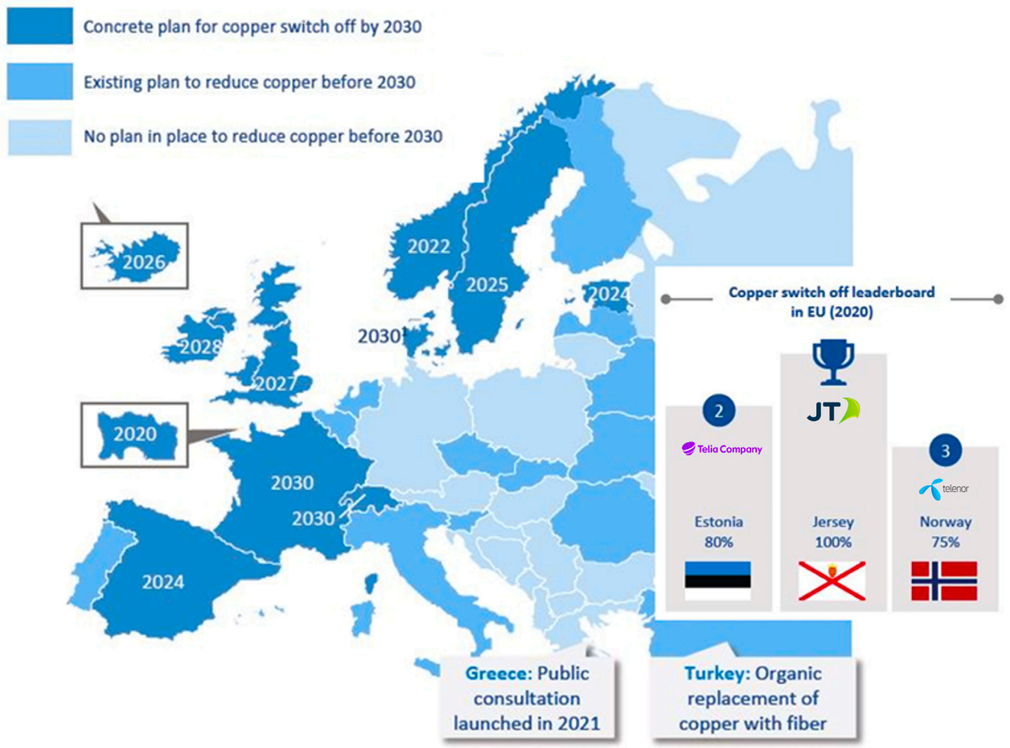
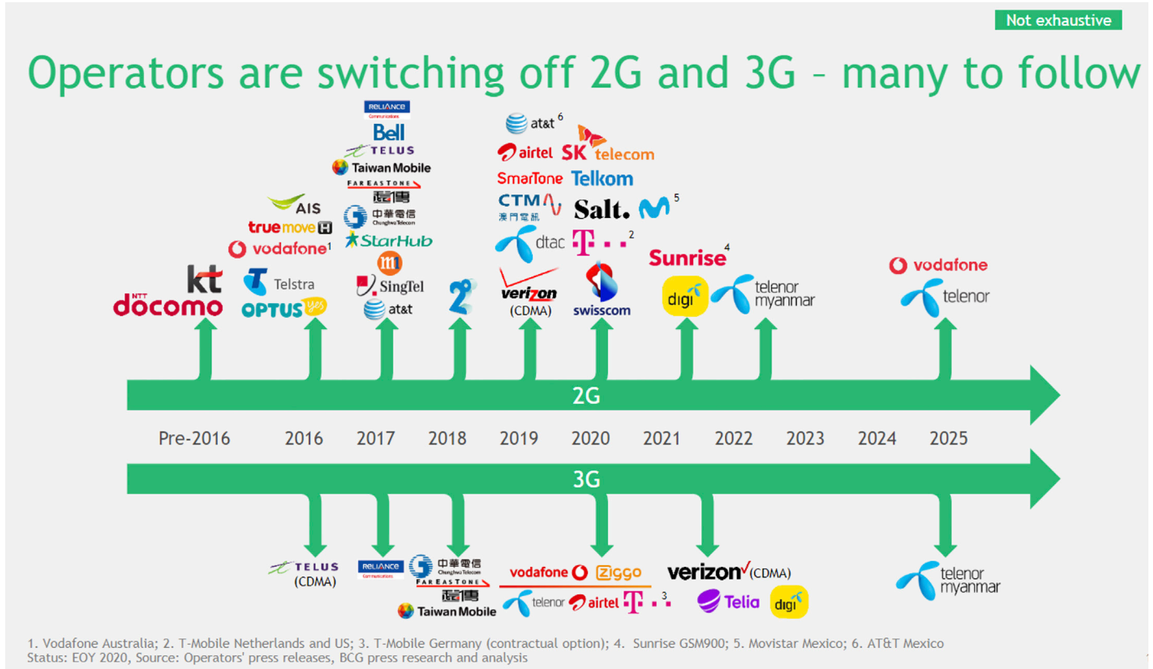


Figure 2: Boston Consulting Group 2021 Benchmark for TIM



going), and moreover migration from ADSL (based on copper) to FTTx services (based on fiber) should be boosted, as already said, also on the regulatory level.

On mobile radio access, the 3G switch-off project aims at closing 3G service and reusing related frequencies for more advanced technologies: it will start in April 2022 with a closing target by June 2022.

In addition to the costs and benefits common to all decommissioning projects, 3G Switch Off requires marketing expenses, for dimensional extensions (e.g. VoLTE) and interconnection systems but enables the release of backhauling and core network resources.

About 2G, there's no switch-off plan at the moment, rather its capacity will be pushed to support the voice traffic swap from 3G.

In addition to what described above, around 60 Operational Support Systems of access domain competence are in an obsolescence state, but their replacement is not always feasible because of the obligation to keep running some outdated services (e.g., for regulatory and/or marketing constraints).

Transport

Transmission networks have been evolving since the '80-90s starting with PDH, SDH and then WDM: most of those pieces of equipment are still running, despite the End of Sale/Support of the technology or even supplier withdrawal from the market.

Spare parts shortage, shorter life cycle after repair, skilled support hardly available are just examples of the issues to manage and about the same ones can be applied for their Element Managers (many different systems with multiple instances each).

Although a decommissioning project of SDH/PDH and old DWDM networks has been analysed several times in the last two decades, two main reasons have prevented its realization: extremely high costs and regulatory constraints on commercial services.

Indeed, the only way to empty and switch-off PDH/SDH networks in a sustainable way would probably be to migrate the customers towards Ethernet based connection services. Even, if necessary, with regulatory imposition.

With regard to obsolescent packet transport technologies, there are ATM nodes, ATM to IP gateways, Switches and old routers mostly in End of Support, without forgetting tens of thousands of old Ethernet CPEs.

Switches will be removed as the R-Evolution project (Ref. 4) is implemented, while for the other equipment a plan must be still defined, considering that some business and wholesale services can't be properly replaced.

References

(4) La R-Evolution del trasporto. Notiziario Tecnico TIM-3-2020.

Edge and Core Network

This network segment contains platforms enabling both fixed and mobile, voice and data services, characterized by different stages of technology (physical, virtualized, cloud native) and aging.

For this reason, a general treatment is not suitable and some hints about the main legacy platforms are reported in the following.

Legacy Fixed Voice Transit Network (BBN)

BBN network was the first Telecom Italia technology for long distance fixed calls using IP and replaced the full TDM SGT network.

Since 2011 a new full IP Class IV network (GTW/M) has been deployed but currently on BBN there are still fixed OAOs interconnected in TDM: the nodes can be turned-off only if all OAO traffic migrates on IP interconnection and actions must be taken at regulatory level to achieve this goal.

Legacy VoIP Platforms

The first Voip solution for consumer and small business customers in Telecom Italia network (Pk3) was implemented in the 2000s.

Starting from 2014, the IMS technology was added to manage all types of customers and services and the migration towards it is about to be completed.

For private telephone networks, a new cloud native and IMS solution was deployed in 2020 to replace the old one (Pk0), and since 2021 migration has started but a swap tool that applies to all on-premises PBXs must still be developed.

Interactive Platforms & "Voice" Services

An evolution path of the bare metal nodes of the legacy platforms towards a modern, agile, flexible, scalable, secure architecture is ongoing and enabling advanced interactive services through the use of innovative voice resources (e.g. IVR Services, Digital Contact Center, Vocal Portal, Voting, Fundraising, Utility, etc.).

Wireline Service Layer

Many transformation solutions have been (or are being) defined for legacy telephony services (e.g., Public Telephony Service, Carrier Selection, Number Portability and others) to migrate to a cloud environment and operative plans are still under evaluation.

Signaling Network Evolution

The current platform (Eagle5ISS) handles all wireline network signaling layers and a migration towards a new virtual/cloud application named vSTP has been defined. One couple of virtual nodes is already handling traffic but another one is needed to complete the migration.

NAM and FEV platforms

The FEV (Voice/Signaling Front-End) and NAM (Multifunction Access Nodes) platforms deliver mobile traffic and signaling to the transit devices towards the IP/MPLS BackBone (OPC).
Both platforms are critical assets for the Italian Government Resilience Decree and their traffic will be migrated to the new NAM+ nodes by the end of 2025.

RA/PE Business connectivity platforms

At the end of 2021, there were hundreds of obsolete ATM and IP devices in these platforms and the migration for those devices is following different approaches.

A decrease of customers is expected for ATM because of autonomous termination of contracts while on obsolete IP devices there may be a decrease in customers also due to swap towards a most recent technology.

Anyway, customer migration is very complex as there are multiple services on each node and above all the deployment of new resources will be needed.

Service Platforms

At the Service Layer level, platforms decommissioning is considered as part of the Transformation path for systems and platforms evolution, where it is essential to identify and assess (measure, control and reduce) vulnerabilities and obsolescence.
Transformation projects are complex with multifaced activities including optimization of systems/platforms processes with simplification (keeping platforms) and rationalization (some platforms are decommissioned).

A target of such transformation is becoming “lean”, that is minimizing complexity, delayering, and pushing innovation. In the medium/long term, efficiency will become the main objective with growth achieved by means of flexible resources.
Opportunities associated to obsolescence management and decommissioning are numerous, for example: facilitating the connection to the ecosystem, through the microservice/API approach; taking advantage of optimization for migration to the cloud; replacing equipment with more eco-responsible solutions; increasing the number of Service Platforms developed internally.

Expanding internal development capabilities for new native cloud platforms and re-platforming of existing platforms is allowing TIM to pursue significant benefits such as renewing internal competencies reducing time and costs, governing strategic assets, eliminating vendors’ lock-in increasing flexibility for services go live.

Through this Transformation projects path for Service Platforms, TIM will be able to play a key role in a wider ecosystem of application service offering, an opportunity to create and deliver (jointly with partners) new revenue-generating enterprise services.

IT

IT decommissioning plan is part of the ongoing transformation initiatives guided by the following rationalization and simplification principles:

- simplifying the company architectural landscape and overcoming technology obsolescence;
- enabling integration and synergies among Software Development factories;
- implementing future-proof technologies in all the application domains;
- rationalizing costs for Application Development and Application Maintenance.

Consistently with these guidelines, in general the initiatives involve two different activities:

- implementing a new application or service to replace the functionality of an old one;
- removing the old application while ensuring effective access to data that must be kept for regulatory or legal purposes.

In the coming three year plan, the commitment to reduce applications will continue: while the main objective is always the implementation of new services/capabilities, the decommissioning stream is critical to achieve simplification and exploit the opportunities of new technologies.

Subsidiaries

Sparkle

The main decommissioning activities in 2021-22 include old DWDM and SDH, the older PEs and core routers, while on the IT side they concern the older ticket monitoring, inventory and management systems.

Furthermore, on the basis of specific agreements made with the involved consortia, two submarine cables will be released within next year after the two already dismissed in 2020-21.

Noovle

Noovle strategy to become the only Public Cloud Provider authorized to deliver Google Cloud services in Italy is based on three main guidelines: building new DCs, rationalizing existing ones, increasing automation and efficiency.

To achieve these objectives, it is mandatory to renew the connectivity among existing DCs: the target solution is to connect each DC to dedicated PEs into TIM national central offices with new high-capacity connections, thus replacing the old VDCN network.

TIM Brasil

On mobile network TIM Brasil and VIVO, another Brazilian mobile operator, decided to reduce 2G footprint through an agreement, in which one of the operators turns off its 2G network where both are present, inside a perimeter of about 1100 cities, enabling the possible frequencies refarming for 4G.

In addition to this, TIM Brasil is planning to complete switch off legacy 3G Network within 2025.

In this meanwhile, 3G coverage can be partially deactivated in cities and regions where 4G devices penetration is close to 100%, and both voice and data services can be held by LTE network, also allowing refarming to 4G.

Other initiatives are ongoing to reduce the consistency of SDH, PTN, old DWDM and old IP routers.

Conclusions

The evolution of Telecom Italia network over the years has led to a technology stratification with some very obsolete platforms that cannot be dismissed yet for various reasons (customer reluctance to migration, costs, regulation, ...).

If the shutdown of obsolete technologies involves considerable investments, on the other hand it's crucial to guarantee a higher efficiency in energy consumption as well as to improve network resilience to the risk of failures and avoid increasing difficulties in maintenance.

A way to reduce decommissioning expenses would be to address a migration towards services based on new technologies rather than replicating them on new equipment.

This process anyway, as we can see in some other countries, should be accelerated by a proper regulation in line with the New Electronic Communications Code (4) and with the governmental objectives expressed in the PNRR.■

Contributing Companies

Contributing companies to this article are: TIM Italy, TIM Brasil, Sparkle, Noovle, Fibercop.

Acronyms

ADSL	Asymmetric Digital Subscriber Line
AGCOM	Autorità per le Garanzie nelle COMunicazioni
API	Application Programming Interface
ATM	Asynchronous Transfer Mode
BBN	BroadBand Node for fixed voice calls transit
DCME	Digital Circuit Multiplication Equipment, a voice compression device
DSLAM	Digital Subscriber Line Access Multiplexer
DWDM	Dense Wavelength Division Multiplexing
FEV	Voice / Signaling Front-End
FTTx	Fiber To The x (FTTC, FTTB, FTTH, FTTO etc.)
FWA	Fixed Wireless Access
IMS	IP Multimedia Subsystem
ISDN	Integrated Services Digital Network
IVR	Interactive Voice Response
LTE	Long Term Evolution
MPLS	Multi Protocol Label Switching
NAM	Multifunctional Access Nodes
NGAN	New Generation Access Network
OAO	Other Authorised Operator
OPC	Optical Packet Core
PBX	Private Branch Exchange, equipment for private telephone networks
PDH	Plesiochronous Digital Hierarchy
PE	Provider Edge router, a boundary device between a service provider's area network and a customer's one
PNRR	Piano Nazionale di Ripresa e Resilienza
PSTN	Public Switched Telephone Network
SDH	Synchronous Digital Hierarchy
SGT	Stadio di Gruppo di Transito
STP	Signal Transfer Point
TDM	Time Division Multiplexing
VDCN	Virtual Data Center Network
VOIP	Voice over IP
VoLTE	Voice over LTE
WDM	Wavelenght Division Multiplexing

Live Video

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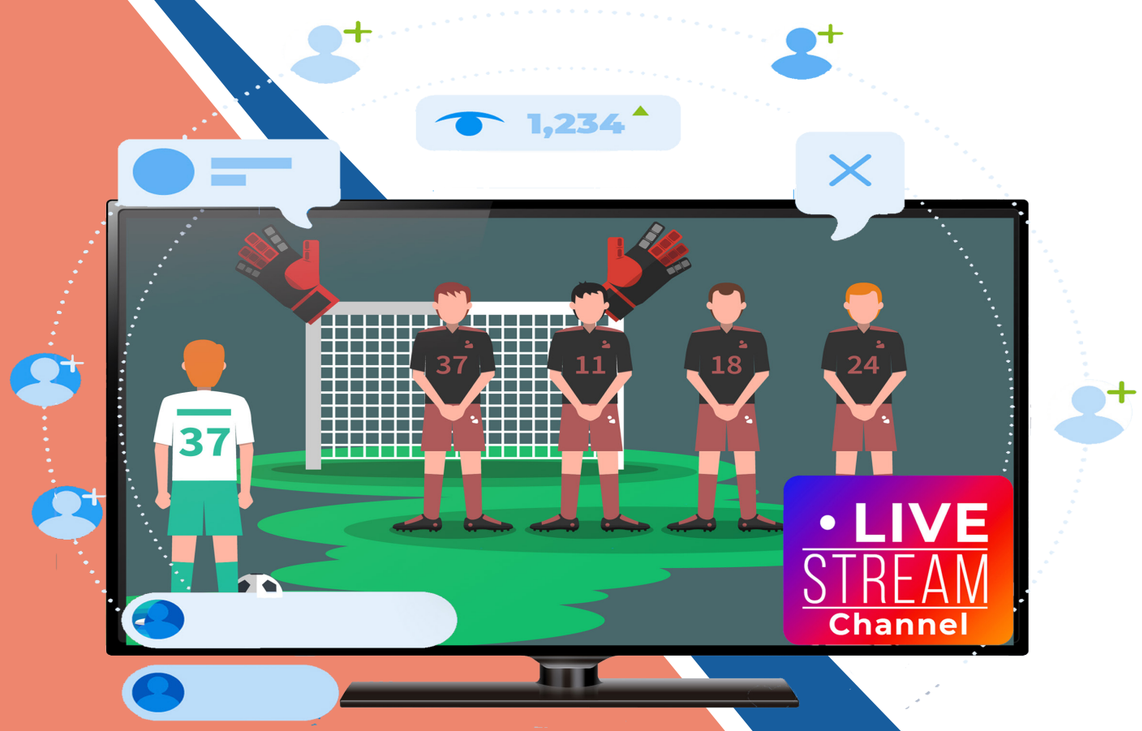


Internet distribution of major sport events, such as TIM Serie A, has proven that a transition from traditional digital television to video streaming is now technically viable at scale. Streaming content management and distribution platforms on broadband and UBB, including 5G, are gaining a central role. OTT video streaming services use, to date, a combination of adaptive protocols (ABR streaming) in unicast with a set of different Content Delivery Networks (CDN).
The complexity of OTT streaming distribution architectures can lead to very different levels of overall Quality of Experience (QoE) for a specific service. To overcome these issues, a solution capable of ensuring service levels comparable/better to those of the broadcast television system is necessary. TIM is working to evolve its network infrastructures and services to support content streaming distribution with innovative platforms (e.g. in the Head-End), increasing the CDN capacity and using Multicast-ABR. TIM can enable an open, common and interoperable initiative at a national level, capable to satisfy Italian content market specific requirements and to ensure its future evolution.

Introduction and Context

Introduction

2021 represented a turning point for the offer of digital audiovisual content in the Italian market. Distributing major sport events on the internet, such as Serie A TIM, highlighted that transition towards streaming is now not only technically viable, but represents entertainment natural evolution in our country as well.

Content distribution via IP becomes increasingly relevant and convenient in Europe. Telecommunication Operators (and broadcasters) are in a position to seize this opportunity.

In this transition, Telecommunication Operators are moving with different business models to offer Video Streaming solutions to end customers or broadcasters in Wholesale mode (Figure 1).

Video streaming: the new television

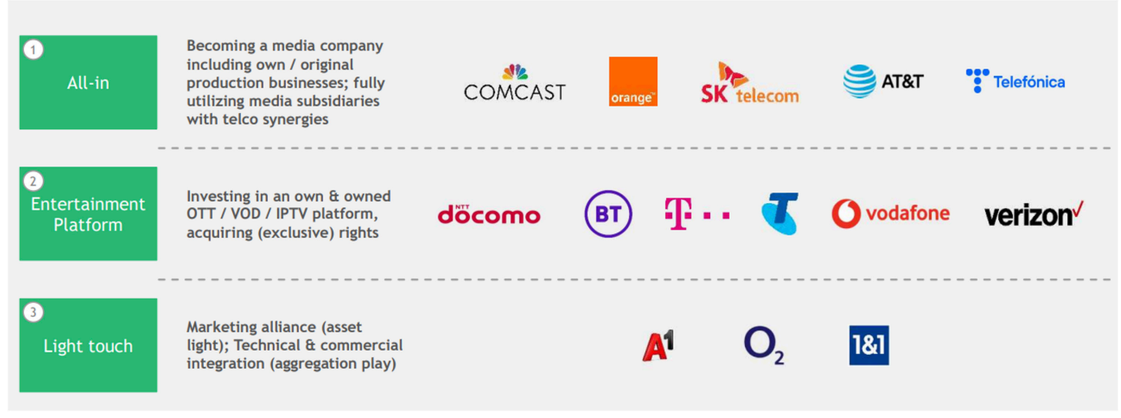
In Italy, streaming broadband and ultra-broadband content management and distribution platforms, including next-generation mobile networks (5G), are assuming an increasingly central role in broadcaster plans.

All broadcasters operating on the Italian market have started trials and, in many cases, real commercial streaming services to place beside traditional linear programming.

“Over-the-Top” video streaming services use, to date, a combination of adaptive protocols (ABR streaming) in unicast with a set of different Global Content Delivery Networks (GCDN) to handle the distribution of the video streams.

Different CDNs may differ in terms of performance, reliability, traffic management capacity, methods of interconnection and

Figure 1: Leading Telecommunication Operators opting for different competitive strategies



dissemination of distribution nodes on the Italian territory or just outside it.

Furthermore, by its nature, unicast distribution imposes scalability limits in traffic volumes linearly growing as a function of simultaneous access number to the same content.

The result is a non-uniform overall quality of experience (QoE), but also operational difficulty in identifying and resolving problems.

A situation that gets more critical as more highly popular live events' distribution is addressed.

These are consequences of using platforms and solutions originally conceived for web and html resource distribution and, over time, adapted, combined, and improved to manage audiovisual content, but still not aligned with the stability and performance characteristics typically required by broadcasters for their linear television services.

Current Situation

TIM video Platform

TIM has long focused on evolving its network infrastructures and services to support content streaming distribution.

Transition from traditional IPTV, managed and vertically integrated, to OTT on-demand mode on a variety of devices represented the first step of a strategy aimed at **creating a set of interconnected and interoperable platforms** for acquisition, content processing and delivery, including live, capable of ensuring service levels comparable to those of broadcast television system.
An infrastructure supporting in-house video services (TIMVISION), but whose components are also commercially available to third parties (e.g. CDN).

The recent technological **partnership with DAZN for Serie A TIM Championship** streaming distribution has further accelerated this evolution process, with major investments in capacity building on its CDN and new technologies' experimentation and adoption.
It has also enabled TIM, as a telecommunications operator and premium content distributor, to defend its customer base from competitors (a recent example is SKY Italia) that leverage on content offering to also propose their own connectivity services.

In addition to communication infrastructures traditionally owned by an operator, today TIM has assets such as:

- TIMVISION, a streaming service and platform for on-demand and live content use, webTV and linear television channels offered over IP.
- A Content Delivery Network (CDN) with widespread Italian territory coverage through geographically distributed POPs.
- A platform able to generate multicast flows in the M-ABR standard.
- A contribution network able to acquire broadcast signals directly from major partners' video production centers in Milan and Rome, to support a multiplicity of formats and transport standards and to offer primary and secondary fallback connections to guarantee service continuity.
- A head-end capable of handling signals up to 4K resolution in a variety of formats and codecs, and production, transcoding, protection and packaging chains.
- A multi-DRM/CAS component aligned with content providers' most stringent requirements for on-demand and live digital content protection.
- A server-side digital watermarking application component.
- OTT cache hosting.

Video content distribution architecture

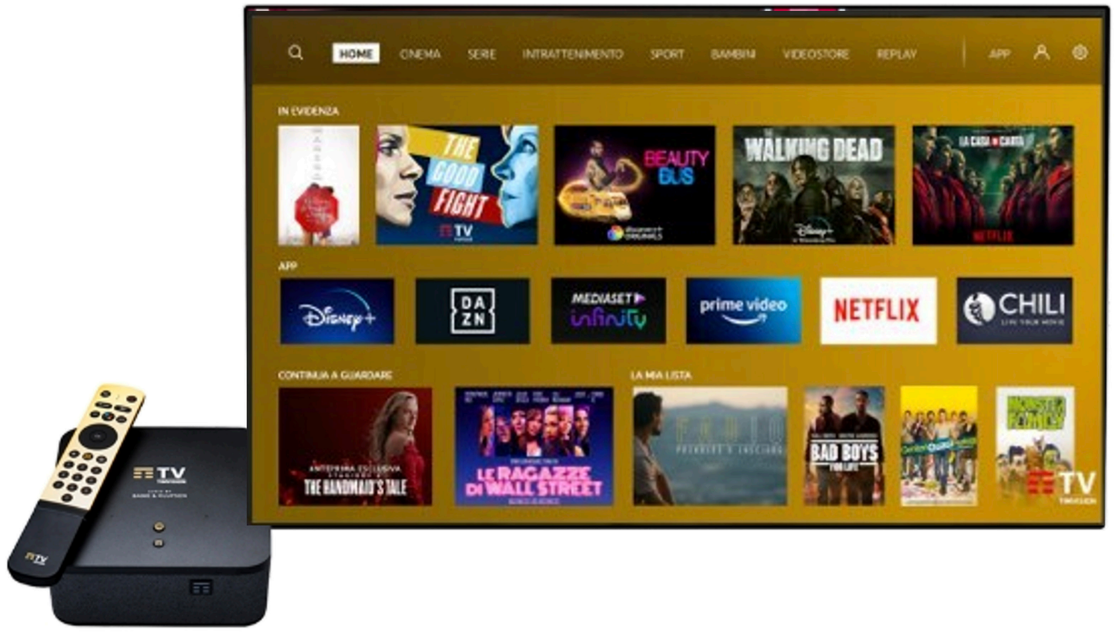
For several years TIM had a **CDN platform** distributed on all OPC POPs accessible to TIM fixed and mobile customers as well as to other operators' customers (e.g. for TIMVision services).

The platform is suitable for distribution of both VoD and live content. The TIM CDN is used to distribute TIMVision contents as well as those of CPs joining in a distribution contract (e.g. DAZN, Mediaset, etc.).

Since 2021 TIM has deployed in its network a platform for Multicast content distribution, compliant with ETSI M-ABR standard, capable of increasing overall scalability in case of massive events, such as sports, and integrated transparently with the existing ABR unicast model.

In parallel to traditional unicast CDN, the M-ABR platform can transport ABR streams from one or more acquisition points to the end user through an operator's **multicast network**, optimizing IP

Figure 2: Tim Vision Box and User Experience



packets replication at router level and avoiding traffic linear increase on network segments affected by an increasing number of concurrent requests.

Benefits of this content distribution method are many: from traffic peaks' efficient management on backbone and access networks to a consequent offload unicast CDN, up to, ultimately, a more stable experience compared to traditional streaming.

M-ABR technology is transparent to the user, and to apps and devices. It relies on ad-hoc software components capable of carrying out Multicast/Unicast conversion within the home network, maintaining intact content and ensuring existing players' streaming and playback logic correct functioning.

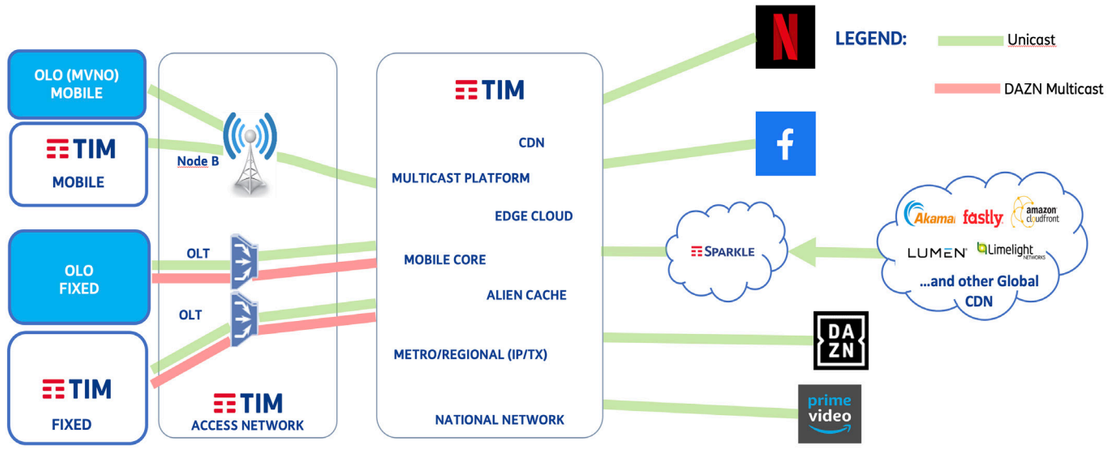
M-ABR platform introduced by TIM has high reliability characteristics being redundant both locally and geographically.

Over the last 4 years TIM has considered it convenient to **activate some OTTs' caches** (Netflix, Facebook, Google and, although with different characteristics, DAZN), identified as **Alien Caches**, in its network.

For OTTs convenience consists in the possibility to offer **better QoE** to end users (leveraging lower latency) while for TIM convenience derives from important **traffic offloading** in peering with TIS and in OPC's geographical links.

At the moment these alien caches are mainly used for VoD content; excepted DAZN caches which are used for live content (Calcio Serie A) and act as a backup with respect to TIM CDN.

Figure 3: Architectural Schema for video content (live and VOD) distribution



TIM OTT peering

Currently OPC (Optical Packet Core) backbone is connected to Big Internet through Sparkle at interconnection points in Milan.

However, it itself has direct connection points with main OTTs worldwide.
Direct connections (also called PNI) with OTTs are essentially functional to filling alien caches for video content delivery and for live contribution flows to CDN TIM and M-ABR platform.

Company Position and Guidelines

National Video Distribution Platform: an opportunity for TIM

Due to the upcoming transition to distribution via IP (forced also by the refarming of the DTT 700 MHz bands for future use by mobile operators), the options available to broadcasters to secure television system future are limited: build and operate a proprietary IP distribution infrastructure, facing huge up-front investments and technical-regulatory constraints or support and join an open, common and interoperable initiative, capable of fulfilling Italian content market's specific requirements and ensuring its future evolution.

TIM should exploit the opportunity that is being created in the television market to propose, at national level, **an innovative and horizontal infrastructure for content management and distribution over IP meeting broadcasters' operating in Italy specific requirements.** This infrastructure shall be, in principle, open to all the actors interested in distributing their own content. Compared to possible Business Model described in the first paragraph (Figure 1), the objective is to leverage on the Entertainment Platform model with the addition of dedicated advertising management.

Main features of the National Video Distribution Platform (NVDP) shall be:

Seamless integration into the television ecosystem: linear content delivered via IP shall be provided with similar mechanisms to those currently available for broadcast content on TV receivers. This is possible through DVB-I technology support for definition, discovery and access to media services.

Hybrid Multicast/Unicast distribution mode: depending on the type of event, its popularity and support on network side, access gateway and user devices, the platform shall be able to transparently use either unicast or multicast distribution modes, maximizing solution scalability.

Possibility of Wholesale mode offering in video: important investments made by TIM for CDN platform expansion and M-ABR platform introduction could be exploited to create a wholesale services portfolio for video content distribution to be addressed to those OAOs that are not going to support infrastructure investments for video distribution.

Direct connections Evolution: apart from live events (that are very impulsive by nature) Global CDN regularly delivers several hundred gigabits of video content; it is worthy checking the opportunity to open further direct interconnections with other important ITZ players (OTT, CP, etc.) to get the end user "closer" to multimedia contents available on

global CDNs and to ensure greater resilience at the same time.

Mobile Streaming: mobile networks evolution allows video traffic management on smartphones and tablets no more as a simple appendix to the Main Screen offer, but rather as a real component integrated in a hybrid distribution platform. 5G Media Streaming (5GMS) defined by 3GPP and further eMBMS extensions are initiative to accelerate transition of the video architecture on mobile to OTT streaming models.

End-to-End delay: In Italy, terrestrial and satellite broadcast channels have delays estimated to be between 3 and 7 seconds, while streaming services based on ABR protocols typically have between 20- and 40-seconds delays, with peaks exceeding one minute in network congestion case.
However, already today, it is possible to reach delays comparable to those of digital television by adopting DASH and HLS solutions' low latency extensions.

Content Security and Protection: in compliance with requirements expressed by content providers, TIM platform integrates security measures and content protection technologies necessary to guarantee contents authenticity and their lawful use by users.

Thanks to MPEG Common Encryption (CENC) standard, content is protected to simultaneously support different Digital Rights Management (DRM) systems. Server-side watermarking techniques are also used to protect copyright and avoid unauthorized content re-distribution.

AD Insertion and Targeted AD: advertising space sale represents a primary income source for the television industry. It is therefore natural that a multi-network and multi-device model includes a wide range solution support to manage advertisements and increasingly accurate audience profiling, fully exploiting broadband connectivity potential.

Conclusions

TIM is today the only organization operating in Italy with infrastructure, technologies and skills to design and implement a convergent national platform for video content distribution.

The platform shall be horizontal, interoperable, and open to broadcasters, service and content providers.

Availability of existing content distribution assets in TIM is unique in the national industry landscape, allowing to start immediately the process of integration and technology evolution towards a single platform.
A national content distribution platform represents a central asset for the Media Industry development and, more generally, for the entire digital publishing market in our country, helping to strengthen its competitiveness at European and global level.■

Contributing Companies

Contributing companies to this article is: TIM Italy.

Acronyms

3GPP	Third Generation Partnership Project
5GMS	5G Media Streaming
ABR	Adaptive Bitrate
AENF	Architecture Enabled Network Function
CAS	Conditional Access Systems
CDN	Content Delivery Network
CP	Content Producer
DRM	Digital Right Management
DTT	Digital Terrestrial Television
DVB	Digital Video Broadcasting
ETSI	European Telecommunications Standards Institute
ITZ	International
M-ABR	Multicast Adaptive Bitrate
NVDP	National Video Distribution Platform
OAOs	Other Alternative Operators
OTT	Over The Top
OPC	Optical Packet Core
PNI	Private Network Interconnection
PNDV	Piattaforma Nazionale Distribuzione Video
QoE	Quality of Experience
TIC	Transparent Internet Caching
VOD	Video On Demand

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