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Secured autonomic traffic management for a Tera of SDN flows

D6.2: Market and business opportunities analysis and intermediate report on Dissemination, Communication, Collaboration, and Standardisation

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Abstract

This document represents the first deliverable of the TeraFlow project's business-related activities. After offering the vision of what the Consortium wants to achieve and the motivation behind it, the market context for TeraFlow is analysed and the strengths and weaknesses derived from the market environment and competitors. Identifying the business opportunities is the starting point for the potential exploitation of the results, both individually and jointly in the Consortium. Additionally, the other WP6 activities (communication, dissemination, contribution to standards and collaboration) are reported for the first 12 months of the project.

[End of abstract]

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Executive Summary

The TeraFlow project proposes an integrated solution, the TeraFlow SDN controller, for tackling various challenges of Beyond 5G (B5G) Networks and support network operators in their journey towards future networks, contributing to the expected impacts set out in the work programme under the topic ICT-52-2020: 5G PPP – Smart Connectivity beyond 5G.

To maximise the value of the project results, WP6 defines and supports an impact creation strategy that covers all the tasks and activities of the work package. Impact can be assessed by the project's innovations, i.e. any result that, by being used, delivers a benefit to someone or addresses a need, being these benefits not only economic but also societal, research, environmental, or educational.

The project proposal's key objective (number 5) is to generate "impact". Within the context of WP6, partners are reflecting on how to make society aware of the project and its benefits (**communication**), how to discuss with the scientific community about the project results and collect their feedback (**dissemination**, **collaboration**), how to foster industry adoption of its features (**standardization**) and how TeraFlow results will be accessible in order to be used, by project's partners or third parties, even when the project comes to an end (**exploitation**).

This deliverable reports on the activities conducted in WP6 in the first year of the project. In this period, the Consortium has actively participated towards its goal by creating TeraFlow visual identity and website (https://www.teraflow-h2020.eu/), the main communication channel used by the project to deliver relevant content to external audiences. In addition, the project's social media accounts on Twitter (164 followers at M12) and LinkedIn (69 followers at M12) have been used for promotion and increase of interactions among key target audiences. A TeraFlow YouTube channel has also been created to present the progress of the technical development and its results visually. To date, TeraFlow has produced different types of communication material (posters, social media banners, newsletter), which have been used at events for increasing the visibility of the project.

Generating impact and disseminating the project's findings and results among research and academic communities have been mainly done through the active development of papers and its posterior presentation and publication at important conferences (OFC 21, EuCNC/6G Summit, ONDM 21, ECOC 21, CNSM 21, IEEE NFV-SDN 21, among others) and journals (IEEE networks, MDPI Photonics). In addition, TeraFlow has also participated in external events and has organised its own events/workshops in collaboration with other initiatives and projects (OSM ecosystem day or 5G PPP webinars, for example) or co-located within more prominent and renowned venues (like MWC 21), reaching over 3000 persons of different role and background such as researchers, academics, industry and standardisation.

TeraFlow closely monitors standardisation activities and fosters collaboration with standardisation bodies to assist with forming strategies and ensure that TeraFlow objectives are met. As such, TeraFlow is taking part in relevant working groups (in ETSI, ITU, ONF, OpenConfig, IETF and TIP) and other industry fora, putting a significant effort to connect TeraFlow research by contributing with relevant documentation. Besides, TeraFlow partners recognise open-source communities as essential pillars to ensure the sustainability of the project results and uptake by third parties. The project's key objective is to design and develop a new generation SDN controller and contribute with it back to the community. Furthermore, TeraFlow involved partners are closely discussing with OSM developers to accomplish a functional integration between OSM latest release and the TeraFlow OS architecture. Also, TeraFlow is exploiting relevant channels in ONF and HyperLedger so that their users can leverage TeraFlow for research and innovation activities.

In coordination with WP2 activities on stakeholders and ecosystems, WP6 exploitation activities have analysed TeraFlow main target, the network operator, as well as other actors needed for TeraFlow ecosystem to flourish, their motivation and the interactions among them. The environment analysis has highlighted the factors that can influence our project's success and has allowed us to build on TeraFlow OS added value steaming from the market analysis and competitors. TeraFlow OS value proposition is to enable network programmability in vendor-agnostic transport networks in the new 5G use cases proposed. In light of these findings, partners of the Consortium, with different profiles and expertise, have reflected on the business opportunities they identify as a result of their participation in the TeraFlow project.

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Abbreviations

5G	Fifth Generation
6G	Sixth Generation
3GPP	3rd Generation Partnership Project
5G PPP	5G Public Private Partnership
API	Application Programming Interface
B2B	Business-to-business
B2C	Business-to-consumer
B5G	Beyond 5G
CAPEX	Capital Expenditure
DB	Database
EC	European Commission
EU	European Union
E2E	End-to-End
GSM	Global System for Mobiles
GSMA	Global System for Mobile Communications
HTTP	Hypertext Transfer Protocol
IDS	Intrusion Detection System
IETF	Internet Engineering Task Force
ISP	Internet Service Provider
IT	Information Technology
ICT	Information and Communications Technology
IoT	Internet of Things
IP	Intellectual Property
KER	Key Exploitable Result
KPI	Key Performance Indicator
L1	Layer 1
L2	Layer 2
L3	Layer 3
L3NM	Layer 3 Network YANG Model
MEC	Multi-access Edge Computing
ML	Machine Learning
MS	Milestone
MTC	Machine-type communication
MW	Microwave
MWC	Mobile World Congress
NF	Network Function
NFV	Network Functions Virtualization
NBI	North-Bound Interface
NOS	Network Operating System
OAS	Open API Specification
OC	OpenConfig
ONF	Open Networking Foundation
ONOS	Open Network Operating System
OPEX	Operational Expenditure
OS	Operating System
OSS/BSS	Operation Support System/Business Support System

OTT	Over The Top
P4	Programming Protocol-independent Packet Processors
PCEP	Path Computation Element Communication Protocol
PEST	Political, Economic, Social, Technological
PoC	Proof of Concept
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RFI	Request for Information
RFP	Request for Proposals
SBI	South-Bound Interface
SDN	Software-Defined Networking
SDG	Sustainable Development Goal
SDO	Standards Development Organization
SME	Small and Medium Enterprise
SotA	State of the Art
SWOT	Strengths, Weaknesses, Opportunities, Threats
SLA	Service-Level Agreement
TAPI	Transport API
TE	Traffic Engineering
TSP	Telecommunication Service Provider
VLAN	Virtual Local Area Network
VPN	Virtual Private Network
WG	Working Group
WP	Work Package
ZTP	Zero-Touch Provisioning

1. Introduction

1.1. Purpose

The WP6 objective is to maximise the project's impact, facilitating the adoption of its results. After deliverable D6.1[1], which gave the project's strategy towards dissemination, communication, collaboration and standardization, D6.2 is the second deliverable of this work package, providing an initial assessment of the market environment and opportunities for TeraFlow. The deliverable also reports on the various activities that TeraFlow partners are conducting, following the strategy described in D6.1, to ensure that the project findings and results influence the B5G/6G community and the relevant standards.

Disclaimer: The impact creation process described in the deliverable is based on the methodology defined and applied in all H2020 projects by ATOS Spain, leader of WP6 in TeraFlow. This methodology has been adapted to the characteristics of TeraFlow.

1.2. Relation with other deliverables

D6.2 has dependencies with D2.1[2], identifying the project's results and the related stakeholders. In addition, T2.3 (Business models analysis) and T6.3 (Exploitation) are working in a coordinated way to understand the different roles of the ecosystem where TeraFlow is being placed and how they map with the partner's motivation and their business strategy.

D6.2 has dependencies with the rest of WP6 deliverables. As such, this deliverable is directly related to D6.1, reporting on the activities conducted as per the plans the latter describes, and with D6.3[3], that will take the findings of D6.2 to build on the general exploitation strategy of TeraFlow.

1.3. Structure

The remainder of this deliverable is organized as follows:

- Section 2 is about the TeraFlow vision and the expected results to fulfil this vision.
- Section 3 analyses the environment where TeraFlow is being developed, distinguishing between the general environment and specific market analysis.
- Section 4 gives a SWOT analysis, where strengths, weaknesses, opportunities and threats of TeraFlow are identified.
- Section 5 delves into the business potential of the project's results, as seen by the partners.
- Section 6 reports on the dissemination and communication activities of the project's first 12 months.
- Section 7 and section 8 report on the standardisation and open-source efforts and the collaboration with other 5G PPP projects and activities in this project's first year.
- Finally, section 9 offers conclusions and next steps.

2. Project Vision and expected results

TeraFlow project motivation was clearly stated in the submitted proposal. Software Defined Networks (SDN) have been in the market for more than 10 years with great technological success, but the evidence shows that network operators are only slowly adopting basic SDN deployments. With TeraFlow project, the Consortium aims at implementing a clear path to introduce SDN in operators' networks, TeraFlow main target market, designing and developing TeraFlow OS SDN controller.

To understand SDN adoption barriers, the project partners are constantly looking at the external environment and have also done an internal exercise by means of the Value Proposition Canvas tool[4] with respect to its main target market. Analysing the network operator "jobs", partners have deepened into the main "pain" points and the "gains" they want to achieve or the concrete benefits they are seeking. After that, partners have reflected on how the project's main result (TeraFlow OS SDN controller) can alleviate, or even eliminate, network operator pains and maximise outcomes and benefits.

Figure 1: Value Proposition for network operators exercise. April 2021

The findings of these activities, offered in the following sections of the document, have helped partners refine TeraFlow OS functionalities and its value proposition:

"TeraFlow OS is a novel SDN controller for B5G networks. This new SDN controller will be able to integrate with current NFV and MEC frameworks, as well as to provide revolutionary features for both flow management (service layer), and network equipment integration (infrastructure layer), while incorporating ML-based security and PDL-based forensic evidence for multi-tenancy. The TeraFlow OS will be the first of a new type of secured cloud-native SDN controllers that will radically advance the SotA in software-defined networks".

As the composition of the Consortium demonstrates, with the network operator being its main focus, other players are needed for TeraFlow OS to thrive. D2.1 highlights in chapter 4 (Business Models and Ecosystem Analysis) that SDN has a whole ecosystem with several different roles and interdependencies. At the beginning of the project, a document template was used to understand the partners' motivation for participating in the project and their positioning in this ecosystem. All partners declared what their contribution to the development of the controller would be, depending on their profile (academic, industry, etc.) and their strategy. This information was included in the

TeraFlow IP Registry, an excel file to monitor partners' IP in the project and pave the way for future joint exploitation of the TeraFlow OS controller. In the following picture, there is a snapshot of TeraFlow IP Registry, TeraFlow's expected results and the partners involved in each of them:

KER			RESULT/COMPONENT	OWNER1	OWNER2	OWNER3
1	core	T3.1	Context Mngt	CTTC	TID	
2	core	T3.1	Monitoring	ATOS		
3	core	T3.2	Device Mngt	TID	CTTC	INF
3.1			P4 Device Driver Plugin	UBI		
3.2			Microwave (MW) Device Driver Plugin	SIAE		
4	core	T3.2	Service	CTTC	INF	TID
5	core	T3.3	Automation	UBI		
6	core	T3.3	Policy Mngt	UBI	ODC	
7	core	T3.4	Slice Mngt	CTTC	TNOR	NTNU
8	core	T4.2	Distributed Ledger	NEC	CTTC	
9	core		Traffic Engineering	STR		
10	core	T4.3	Compute integration	CTTC		
	netApps	T3.1	Load Balancing (K8)			
	netApps	T3.1	Auto Scaling (K8)			
	netApps	T4.1	Self-healing (K8, Google Health API)			
11	netApps	T4.1	Cybersecurity	TID	UPM	CHA
12	netApps	T4.3	Inter-domain	TNOR	NTNU	CTTC

Figure 2: TeraFlow IP Registry

3. Environment Analysis

The first ambition of WP6 task T6.3 (Exploitation Strategy and Roadmap) has been to understand the context of the project. This understanding lets the Consortium, on the one side, identify and take advantage of opportunities and, on the other side, minimise threats by anticipating them. Early investigations at the start of the project included the macro environment with the help of PEST (Political, Economic, Social and Technological) analysis and specific market analysis that entails a market definition, size and growth rates, drivers, and initial competition awareness, among other relevant aspects.

3.1. General Environment

Utilizing the PEST analysis tool, the Consortium tries to identify the drivers (positive influences) and barriers (negative influences) that can affect our project vision and extract conclusions.

3.1.1. Political

The telecom market is fragmented in Europe, with a common framework and country-specific regulations. The market regulator has focused on lowering prices and leading European operators, such as Telefónica, Orange, Vodafone and Deutsche Telecom, believe this has led to an excessive competition that is putting significant pressure on the sector, hindering their investment capacity and endangering the competitiveness of the European industry when compared to much more homogenous markets like the United States and China. For this reason, they are highlighting the need for better regulation of the telecommunications industry throughout the European Union and for receiving political and financial support from the European Commission and the Member States. GSMA, in its document "Sovereignty, Resilience and Trust"[5], stresses that Europe is lagging in the development of telecommunications infrastructure. Part of the issue, as mentioned earlier, include "*the deep regulatory intervention that is uniquely focused on the telecommunications sector*". As Telefonica CEO says in his keynote at the MWC´21, *"The current regulation is based on the last century networks; it is totally obsolete."[6]*

According to the EC, 5G is a critical building block of our digital society for the next decade as "*5G plays a key role in making better, faster and more reliable connections available to everyone throughout the EU"[7]*. Therefore, the Commission is giving full support to the sector, taking steps to bring this revolutionary technology to life in Europe with the involvement of the larger European network operators and network technology companies such as Ericsson and Nokia, and all the companies that work around them. In 2013, the Commission set up the 5G public-private partnership (5G-PPP) to secure Europe's leadership and potential in new markets like smart cities, e-health and connected and autonomous mobility, to name just a few. It was followed by the Commission's 5G Action Plan, published in 2016, which set out the roadmap for Member States to set the scene for 5G services and products. The plan includes coordinating regulatory measures, granting operators access to radio spectrum for 5G networks, incentivising investment in network infrastructure and promoting 5G trials.

More recently, the COVID-19 pandemic has increased public awareness regarding the need for advanced connectivity and has highlighted its enormous potential. The Commission has set out a European approach to a digitalised economy and society outlined in the 2030 Digital Compass Communication "Path for the Digital Decade"[8]. Leading the Digital Decade, held 1-2 June 2021, was

a two-day online event focused on Europe's digital transformation towards 2030. Whereas the strategic objectives of the 5G Action Plan remain relevant, the new 2030 target raises Europe's ambitions for the wide availability of 5G services, for the development of 5G based lead markets and for a good starting position for 6G service expected for the end of this decade, enabling the European telecommunication industry to maintain a leading position.

In addition to regulation and public investment, standards play an essential role in establishing industry leadership. Although, just as in the 1990s, the dominance of GSM over all other standards led to Nokia and Ericsson taking over the entire large telecommunications equipment sector, the strong development of Chinese companies may make it difficult for European suppliers to compete in this market. However, European actors are working to ensure that next-generation network standards are defined according to European values, seeking a balance in which technological progress continues to develop, but always putting people at its centre. Following open interfaces, data protection and human-centric approaches while meeting energy-efficiency requirements will permit European suppliers to deliver advanced service features and remain competitive. The EU aims to take the lead by committing itself to consolidate a new ethic. A significant advantage in Europe is that the political processes strongly favour collaboration, resulting in several notable consensus frameworks. The proposed European Partnership on Smart Networks and Services (SNS)[9], adopted by the EC in February 2021, will be a crucial step in that direction.

3.1.2. Economic

The evolution of 5G technology proves to be decisive because of its great importance in economic development. There is a general consensus that in 2020 when so much went wrong, telecommunications infrastructure supported economic activity on many fronts. So, in the post-pandemic period, companies in this sector are emerging economically stronger.

However, European telecom operators have experienced a fall in their income statements in the last few years. This is because they have to invest heavily in infrastructure, but due to intense competition in their markets, these investments are not reflected in the prices they charge for services. And not only that, but they are also seeing how the big OTTs use their networks to compete with them with communications services or other services related to them. The paradox is that they generate a large share of network traffic but pay nothing for their infrastructure and maintenance costs.

Because of this, European operators continue to expand their business into areas beyond basic connectivity to increase revenues. They are looking for new businesses to leverage their brand advantage and customer base and innovate in key areas such as business models and new cooperation models. Alongside large operators with network availability and virtual operators, the emergence of very concrete services will allow new specialised operators to appear offering specific services (e.g. vehicle-to-highway communication, operators on high-speed railways, operators related to different IoT applications, etc.). In short, the future growth of operators will depend on total market growth and how much of the value is delivered to other industries they are capable of capturing. Therefore, they are looking to bundle services with added value connectivity to strengthen their position in the future value chain[10].

At the same time, operators have to deal with the digitalisation of their internal processes to have a lower cost infrastructure to be economically viable in a hyper-competitive market. Underlying 5G technologies are disrupting entire sectors of the economy by transforming the way services are delivered to end-users and enabling the ICT sector to solve more efficiently global communication

needs. New technological approaches, such as SDN and NFV, allows operators to deliver business agility and capture the anticipated market growth while lowering capital and operational costs and management complexity. Economies of scale and increased ability to provide specialized services are drivers for their technology adoption.

On the other hand, network equipment vendors hold a strong position due to their dominance in network management and operation systems and barriers of entry arising from the high cost and complexity of switching equipment suppliers. New business models for connectivity services and network service providers are emerging. Similarly to the internet ecosystem, where a central solution sets the tools and conditions for developing applications that contribute and enrich the initial development, SDN and NFV, decoupling data and control planes (both provisioned by network-integrated hardware vendors), are adding new layers for further development.

3.1.3. Social-Environmental

The Sustainable Development Goals (SDGs)[11] are 17 interlinked objectives adopted by the United Nations in 2015 as a universal call to action for all sectors of the society to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. To implement the United Nation's 2030 Agenda and the SDGs, in December 2019, the European Commission presented the European Green Deal to transform its economy and society to put it on a more sustainable path.

The COVID-19 crisis has shown that citizens in areas with minimal or non-existing telecommunications networks have had difficulties telework or following e-learning activities. Similarly, low-income or digitally illiterate citizens have found their ability to carry out these activities diminished, revealing their dependability in combating the economic and social gap. In these times, it has been proven that the mobile industry plays an essential role in addressing and mitigating these global societal challenges by providing access to life-enhancing educational tools and platforms, delivering the connectivity and solutions to drive enterprise productivity gains, reducing inequalities and leading efforts to combat the effects of climate change.

Talking about climate change, the 5G PPP declared energy savings as one out of seven vital technological challenges to be addressed (saving up to 90% of energy per service provided)[12]. However, ubiquitous IoT devices and related data will likely result in higher traffic, thus higher power consumption, CO2 emissions, and resource use. Furthermore, 5G could be driving the wide-spread use of energy-intense applications that do not have a sustainability focus, showing the need to find a balance between the desire to push communication technologies into all aspects of life while being increasingly conscious of the price to be paid in terms of energy and cost.

In recent years, the multitude of Internet services and apps developed have transformed the ICT sector value chain and completely changed society, social behaviour, business operations and models, and the way citizens, enterprises, and institutions interact. This new mobile technology is expected to be technologically trustworthy and societally trustworthy. At this point, it is worth highlighting the spread of fake news about 5G, as is always the case when introducing technology. On top of that, the COVID-19 pandemic has brought with it a series of false news that could slow down its deployment. Public debates about biological impacts on humans and animals of the exposure to radiation emitted by antennas are growing due to the bandwidth expansion that the new mobile technology will require, and those who raise their voices with futuristic portents of a society in which people will be under constant surveillance and recording.

In the following decade, the gradual emergence of new services will require new legal frameworks for regulating complex issues such as autonomous vehicles, automation, remote surgery, interconnection of objects, etc. This is one of the significant challenges modern societies face: prepare legislation to regulate these new services that affect people's rights and freedoms. Artificial intelligence will make decisions without human control.

3.1.4. Technological

This section provides a vision of the TeraFlow OS technologies being developed by the Consortium and outlined in the original project proposal.

Cloud-Native Architecture

The cloud-native philosophy is an IT/network approach based on deploying and executing applications in remote servers located in the so-called cloud. In recent times, the cloud-native idea has become a game-changer player for both IT and network markets. The cloud domain provides verticals and organizations with a highly secure, cost-efficient and flexible environment to perform their actions and tasks, bringing new ideas to market faster and responding sooner to customer demands. As expected, the impact of the cloud-native paradigm is not limited only to specific markets, but it is also helping in the definition of new technologies from the beginning. This is the case of the 5th generation of the Internet, 5G.

Embracing the cloud-native philosophy is essential to meet the stringent needs indicated by the 5G KPIs[13] with much higher throughput, device density, mobility and lower latency performed in an energy-efficient manner. Furthermore, in the 5G scenario and new network schemes in general, management, orchestration and automation are vital requirements. In this regard, 3GPP introduced the 5G System (5GS)[14] specifically designed to exploit the advantages of cloud-native distributed architectures. In addition, other novel 5G-related technologies, such as software-defined networking (SDN), network function virtualisation (NFV) or cloud computing, are also based on the cloud-native approach.

Nevertheless, the evolution of modern society and its current trends, where near-instantaneous service delivery is required, are demanding that content be placed much closer to users to meet the challenging minimum latency requirements related to the 5G and beyond. Thus, the enablement of moving content closer is driving its management and other basic operations from remote cloud domains to closer locations, at the edge of the network domain with networking capabilities and enough computation resources to accommodate the necessary software pieces of vertical applications or operational functionalities. The novel technology Multi-Access Edge Computing (MEC)[15] is devoted to exploiting such an idea. This is one of the critical new technologies related to the 5G and beyond, which minimise latency. Based on this fact, coupled with current trends in network research and standardisation efforts, among other factors, the edge domain likely will be a significant player in the evolution of networks (B5G/6G).

Transport Network Integration

The day-to-day life of a Telecom Transport Network involves a wide variety of processes that require massive interaction with the network. For example, the different network planning and network creation phases (strategic planning, tactical planning, capacity planning, et al.), in which the planners make decisions, need accurate views of the topology, with different abstraction levels, the deployed

hardware with up-to-date measurements. The Business-to-business (B2B) and Business to consumer (B2C) provisioning processes must quickly deploy services assure the contracted Service-Level Agreements (SLAs). As the technology evolves, all the network's potential has to be exposed to create new services and applications.

The availability of open and full standard interfaces is one of the main gaps in 6G regarding Autonomous Network Management. Currently, the industrialization process of vendor-agnostic Transport SDN solutions is becoming extremely slow due to a variety of reasons, including:

- Industrial fragmentation, competing standards addressing the same areas and use cases.
- The appearance of monolithic and proprietary vendor solutions integrating applications, such planning, inventory or performance, and ad-hoc mediators for multivendor integration.

Figure 3: Business drivers behind vendor-agnostic Transport SDN

Following open and well-defined Application Program Interfaces (APIs), the Transport Network can become programmable even if it mixes equipment from different suppliers. The discovery process of what is deployed and can be used, the analysis of the faults that unfortunately happen, retrieving performance information for its analysis and creating closed-loop automation, and the activation of the network connectivity services are simplified. The set of Operation Support Systems (OSSs) to handle those processes needed either a considerable amount of manual inputs or integrations with each vendor's technology. The SDN paradigm is shifted to a data-driven operation, where a network element, a topology, a service, etc., is represented by a software data model, which depends only on the technology and not on a vendor's interpretation. Hence, both discovery and programming of the network in real-time can be achieved, unlocking the full potential of our networks.

Unification of Network and Cloud Resource Management

Novel applications call for strict requirements considering throughput, reliability and robustness, end-to-end (E2E) latency. Moreover, other requirements include intermittent or always-on type connectivity for machine-type communication (MTC), intending to serve diverse applications that might include vertical industries[16].

The need for network flexibility and programmability is a primary OPEX driver. Today many network operations, such as port and traffic flow configurations, are done manually (e.g., utilizing a network operations person inserting commands or using graphical user interfaces). Novel abstractions are provided through SDN. They offer the applications novel programmatic interfaces, which support flexible network services and virtual topology deployment and adaptable flow processing [17]. NFV is the essential mechanism to decouple capacity (processing, storage, data transport) from functionality (filtering, analysing, forwarding, balancing) in network infrastructures.

Network slices provide the flexibility to customize mobile networks to the needs and the peculiarities of vertical innovative services using NFV. NGNM and 3GPP define a network slice as a logical end-to-end network providing specific 5G access and/or core network services. In addition, a network slice must provide the necessary Quality of Service provision guarantees to satisfy the identified business needs per vertical industry. Service providers use appropriate network functions (NFs) to fix such challenges to support the vertical players, support advanced orchestration mechanisms, and enable them to roll out their vertical industry services over isolated shared infrastructures.

Nevertheless, actual slicing mechanisms do not support the necessary agility to meet the required QoS demands of future services and applications. In current service provider systems, the requirements of the intended slices do not seem to be dynamically negotiated. Moreover, intelligent services from vertical industries add significant limitations to the design of network slicing. To enable efficient network slicing, it is necessary to compute the slice requirements, followed by resource allocation and then deployment. Resource allocation can be based on different design matrices formalized in an SLA, including energy, isolation level, latency, and QoS. The allocation of resources in network slices must be adaptive to ensure these SLAs. For instance, intelligent transportation slices have strict latency constraints[18]. The resource allocation must also consider the distributed nature of edge and cloud computation resources, considering the allocated bandwidth jointly in certain links and the necessary compute and function requirements. Moreover, more resources must be allocated to reduce the delay to cope with the latency budgets as a function of the dynamic application requirements and allocated compute resources.

ML-Based Security

"Cybersecurity and large-scale network traffic analysis are two critical areas receiving considerable attention over the last few years. This is due to the necessity of empowering the Telecom industry to adopt suitable mechanisms to face emerging and sophisticated cyberattacks. Nowadays, Internet Service Providers (ISPs) and their clients are exposed to a growing rise in the number and type of threats (e.g., network attacks, data theft over the wire), some of which also attacks at the application level using the network for identity theft, phishing, or malware distribution. In general terms, these threats severely put QoE (Quality of Experience) at risk, undermining services, network resources, and users' confidence"[33].

When an operator moves towards an automated environment, security becomes critical as network operations have to be done by software components virtually operating without human intervention or oversight. In particular, security is one of the most critical aspects that a state-of-the-art Software-Defined Networking (SDN) controller needs to provide in 5G/B5G networks. Many security threats arise from technological advancements introduced in 5G/B5G networks (e.g., NFV, network slicing) and offer new attack vectors. The evolution of security threats requires protecting both network services and the network controller from attacks. Therefore, it is required to address these needs by adopting new paradigms and techniques. In this context, one promising solution is using Machine Learning (ML) techniques to address the appearance of new points of vulnerability and exposure to new attack vectors. In particular, ML can significantly improve detection and response times to advanced cyber security threats and increase system robustness.

As stated in the DoA, "*recent studies show that popular ML algorithms, particularly "deep neural networks", have been vulnerable to malicious and well-designed attacks that can easily fool a Deep Learning model with small perturbations imperceptible to humans*"[34]. Therefore, the so-called adversarial attacks could mislead the ML-based components running on SDN controllers and cause

harmful situations in security-critical areas of the network. "*Although these sophisticated adversarial attacks are still premature, the main conclusion is that testing in training processes is insufficient because it provides a lower bound on the system's failure rate"[35]*. Therefore, to provide security guarantees, an upper bound is necessary and therefore, new techniques to produce resilient ML components need to be investigated.

Distributed Ledger Technologies

"Blockchains have applications beyond cryptocurrencies and can store and process data"[35]. For instance, data is not stored and processed in a central location; instead—a blockchain—which stores the data and the operations on the data, is copied and spread across multiple nodes, in which each node updates its blockchain to reflect a requested change, often by executing a smart contract. Consensus algorithms are used for agreeing on the blockchain state.

The key features of distributed ledger technology or blockchains, namely, decentralization, immutability and transparency, make their use appealing for managing resources and services in multi-tenant networks. In a nutshell, "*a blockchain serves here as a database or log that stores, e.g., the allocations of network resources by the various network tenants. In particular, blockchains replace centralized network management with conventional database management systems*". "*Significant advantages are the elimination of trusted third parties that maintain the databases with a single point of failures and data provenance, including data immutability and traceability. Both are cornerstones for a resilient and trustworthy platform for storing and processing sensitive data. Furthermore, smart contracts provide a universal basis to automate, simplify, and secure network management tasks that involve sensitive data from multiple network stakeholders*"[35]. Trust and multi-tenancy are improved in the SDN controllers by introducing novel security mechanisms through the usage of smart contracts and secure consensus algorithms.

Blockchains and Distributed Ledgers are expected to bring novel use cases to evolve security in B5G networks, such as smart contracts, to enforce resource allocation or real-time weaknesses analysis of network applications. Therefore, the need to promote research on the security in introducing "smart contracts" is of extreme significance in providing personalized, multi-tenant B5G networks.

The trend that we see is "Hyperledger Fabric". The Fabric introduces a novel architecture that separates transaction execution from consensus (i.e., transaction ordering). Namely, the Fabric architecture uses the execute-order-validate paradigm, which is in sharp contrast with the traditional order-execute approach used in prior blockchain and state-machine replication (SMR) deployments. Such a paradigm shift is the key enabler for the modularity and flexibility of the Fabric. Furthermore, Fabric's flexible and modular design supports the "pluggable" consensus, making it particularly attractive for different applications and use cases.

3.2. Specific Environment

In this section, the Consortium pays attention to the market growth and projections and similar solutions to highlight that there is an opportunity for TeraFlow OS capabilities.

3.2.1. Market Definition

In the last years, the exponential increase in the size and complexity of the communication networks has revealed the need for solutions to simplify and efficiently manage these infrastructures. SDN

solutions directly address these problems by providing a dynamic and flexible network architecture that can respond to constantly changing business[19], end-user and market requirements. For this reason, the majority of network operators around the globe are investing in SDN technology.

Utilizing TeraFlow project, the Consortium aims to support the needs of network operators, positioning the project's results in the software defined networking market. More concretely, if we categorise the SDN market by component (**solutions**: Physical Network Infrastructure, SDN Controller, SDN Application / **services**: consulting, implementation, training and support), TeraFlow OS is looking at the SDN controller market, the core block of any SDN infrastructure having the overall network perspective, but also to the services market, as there are several partners in the Consortium specialised in this type of professional activities.

3.2.2. Market Size and Growth

According to ResearchAndMarkets[20], the global SDN market is expected to grow from USD 13,732.2 million in 2020 to USD 32,733.1 million by 2025, at a Compound Annual Growth Rate (CAGR) of 19.0% during 2020-2025.

SDN **solutions**, where virtualization and control software belong, provide enterprises with the advanced network, compute, and storage devices and features immediately available for use. For this reason, *an increase in adoption is expected*[21] *by enterprises* and network operators to significantly accelerate the time to market for new applications and services. Besides, the "*significant shift towards cloud computing by numerous organizations due to the outbreak of the COVID-19 pandemic and the need to keep pace with rising internet traffic will increase the adoption of SDN solutions"[36]* among cloud service providers, which is opportunistic for our targeted market.

The demand for consultancy services is increasing worldwide in response to the growing pressure on organisations to remain competitive in their respective markets. Furthermore, a network SDN strategy provides its users with optimal Capital Expenditure (CAPEX) and improved energy efficiency, which helps achieve low Operational Expenditure (OPEX). Therefore, the SDN **services** segment is expected[21] to be the fastest-growing segment in the forecasted period, thanks to the need for customized approaches and a rise in demand for greater efficiency by shortening the time taken to troubleshoot a solution.

North America accounts for the largest market size, with good standards and networking regulations that help in boosting the software-defined networking market, and is expected[22] to maintain its position in the years to come, followed by the Asia Pacific region. The Asia Pacific is expected to grow fastest in the coming years, owing to many cloud-ready industries in the Asian subcontinent. Within Europe, Germany is forecast to grow at approximately 17.2% CAGR.

3.2.3. Competitors

The comparative study of SDN controllers reveals many options available between open source and proprietary software.

Open-source

Over the past years, network operators have been actively pursuing new technologies emerging from the collective efforts of the open-source community. They have been testing solutions from the Open

Platform for NFV (OPNFV) project, OpenStack ecosystem, Open Network Operating System (ONOS) and OpenDaylight projects, naming just a few. These efforts drive the adoption of next-generation network technologies, such as SDN, to improve the telecom network's efficiency, flexibility, scalability, and programmability.

ONOS SDN controller

The Open Network Operating System is a Linux Foundation project and a leading open source SDN controller for building next generation SDN/NFV solutions, the basis for several proprietary controllers like Huawei's. The excellent documentation and adoption in the market are ONOS strengths[23]. Moreover, due to a vibrant SBI support to OpenFlow, P4, NETCONF, TL1, SNMP, BGP, RESTCONF and PCEP protocols, ONOS is one of the controllers with a broader range of SBI coverage.

OpenDaylight SDN controller

Linux Foundation's widely used open source controller is the basis for several proprietary controllers such as the Ericsson SDN Controller, Fujitsu Virtuora, and others. Its strengths are its extensive protocol support in SBI as a service abstraction layer with support to a wide range of protocols such as OpenFlow, OVSDB, NETCONF, BGP, P4, LISP, SNMP, PCEP, among others[23]. On the other hand, some of its weaknesses are the small and outdated documentation of the project on its original website.

Commercial

Nuage Network Virtualized Service Controller[37]:

- One of the leading SD-WAN products: deploy virtual services in the telco cloud environment; provide network virtualization and automation across any telco cloud datacenter infrastructure and automatically establish connectivity between virtualized compute resources (VM, containers, or legacy bare metal servers).
- Overcome the Neutron deficiencies and provide network plugins to scale to the 'carrier-grade' requirements.
- Analytics is embedded in the network domain controller.
- Leverage a policy engine to provide an open and highly responsive solution capable of scaling to meet the stringent needs of massive multi-tenant telco clouds → fully automate and simplify network service creation
- It can be deployed over any existing datacenter network environment
- Support for L2-L4 services. Deliver a distributed L2/L3 forwarding plane to provide traffic isolation and security between overlays.
- Use distributed routing and switching for the overlays in conjunction with an IP fabric underlay such that traffic between VMs will always take the shortest, most efficient path through the fabric.
- Ethernet VPN (EVPN, based on multi-protocol border gateway protocol (MP-BGP)) is chosen to provide control plane reliability as a distributed control plane, which in turn programs the L2/L3 forwarding plane. MP-BGP is also used for the E2E unifying control plane.
- Monitoring: mirroring is chosen to realize the real-time monitoring capabilities to discover what is happening within their network. Mirroring on virtual switches or fabric switches (for SR-IOV traffic) can be automated via API so that an external system can turn on and off the mirroring as required.
- Integrate cloud applications into managed VPNs

- Extensive data analytics and performance monitoring functionalities

Cisco ACI (Application Centric Infrastructure)[38]:

- Intent-based networking framework: capture higher-level business and user intent in the form of a policy and translate this policy into the network constructs necessary to provision the network, security and infrastructure services dynamically.
- Built on top of the Cisco Nexus 9000 platform: with tight integration between HW and SW, between physical and virtual elements
- Enable automation that accelerates infrastructure deployment and governance, simplifies management to move workloads across a multi-fabric and multi-cloud framework quickly, proactively secures against risk arising from anywhere → simplify, optimize, and expedite the application deployment lifecycle.
- Transform IT operations from reactive to proactive with a highly intelligent set of SW capabilities that analyze every component of the DC
- Centralized network management and visibility with full automation and real-time network health monitoring
- Seamless integration of underlay and overlay
- Open NBI APIs to provide flexibility for DevOps teams and ecosystem partner integration
- Cloud-ready
- Automation of IT workflows and application deployment agility
- A common policy, management, and operation models across application, network, and security resources
- Common platform for managing physical and virtual environments
- Single policy and seamless connectivity across any datacenter and public cloud

Huawei iMaster NCE-IP[39]:

- Architecture:
  - Based on ONOS and compatible with ODL architecture.
  - Supports NBIs like RESTful, RestConf, WebService, and Syslog from Layer 2 to Layer 7.
  - The Neutron plug-in supports interconnection with the mainstream OpenStack platform (standard OpenStack, Red Hat, Mirantis, and UnitedStack).
  - Supports interconnection with physical and virtual network devices using southbound protocols, such as SNMP, NETCONF, OpenFlow (1.3/1.4), OVSDB, JSON-RPC, and sFlow.
  - Supports interconnection with a computing resource management system, such as VMware vCenter and Microsoft System Center, for collaboration with network and computing resources.
- Network service provisioning:
  - Support interconnection with the mainstream cloud platform OpenStack or third-party applications from Layer 2 to Layer 7. The cloud platform or third-party applications invoke the standard interfaces to provision network services.
  - Supports independent network service provisioning (including association with computing platforms) to implement automatic network deployment.
  - Supports VXLAN Layer 2 and Layer 3 interconnection and interconnection between VXLAN and traditional networks.

    - Support hybrid access of multiple terminals, including physical servers, VMs, and bare metal servers in different scenarios.
- Automation:
    - Zero-touch provisioning: Automatically identifies and manages network devices to implement automatic deployment of underlay networks.
    - Uses the standard VXLAN protocol to implement automatic network deployment, including VXLAN protocol encapsulation.
    - Support for intent-driven network service deployment and automatically translating service intents to network models
- Service function chaining (SFC):
    - Supports the IETF-based SFC model and adopts PBR or NSH as traffic diversion technologies to guide the service traffic to different nodes for service processing. As a result, the topology-independent SFC function with graphical orchestration and automatic configuration can be implemented.
    - Provides VAS services, including security policy, NAT, and IPSec VPN.
- Security:
    - Supports micro-segmentation and implements security isolation based on refined groups, including subnets, IP addresses, VM names, and host names.
    - Supports role-based access control to implement isolation between multiple tenants and management of multiple user accounts and rights.
    - Supports password-based local authentication and security authentication, including RADIUS and AD.
- OAM
    - Support monitoring at the physical, logical, and tenant level.
    - Support visibility of the application, logical, and physical network topologies, with potential mappings from the application to logical topology, and from the logical topology to physical topology.
    - Support the precise location from the logical network to the physical network.
    - Supports intelligent loop detection and provides one-click repair.
    - Supports detection of Layer 2 or Layer 3 network connectivity between VMs, and between VMs and external networks as a means to rectify faults efficiently.
    - Supports traffic mirroring (traffic on VMs or bare metals can be mirrored to remote addresses through GRE tunnels).
    - Support load balancing at both northbound (cloud platform API requests or web access to different controller nodes) and southbound (devices on the entire network), in association with fault detection and management to avoid service interruption.
    - Supports active/standby mode to implement highly reliable remote disaster recovery.

TeraFlow OS in front of its competitors

Organizations are slowly looking at redesigning SDN controllers to handle a massive number of flows consistently and which open-source controllers might be used. Current solutions consist of a monolithic software core that can synchronize with other deployed SDN controllers through specific protocols. TeraFlow, for its part, already follows a cloud-native architecture with stateless micro-services which interact with each other to fulfil network management tasks. Being true that µONOS promises to provide a cloud-native SDN controller, only considering a microservice-based software architecture (even at the edge) is not enough to achieve this goal. There is also a clear need for hardware-specific offloading supporting B5G scenarios.

Besides, TeraFlow OS promotes open competition and innovation in two key market segments: transport network devices and network applications. This is a new approach, and the main difference with other commercial SDN solutions described previously.

While existing SDN implementations are embedding multiple network applications and tools (e.g. fault management, service provisioning, network planning, inventory, telemetry, etc) within monolithic and single vendor implementations, TeraFlow OS is decoupling network applications development from the SDN controller using OPEN and standard APIs enabling transport network abstraction and vendor-agnostic programmability. On the other hand, existing SDN solutions developed by network providers are designed to configure network elements using proprietary interfaces in their network. Therefore, multivendor interoperability can only be achieved utilizing complex and costly software adaptations in the SDN controller. Existing SDN solutions are mainly applicable for mono-vendor scenarios where the same vendor provides both network elements and SDN controllers, including network applications.

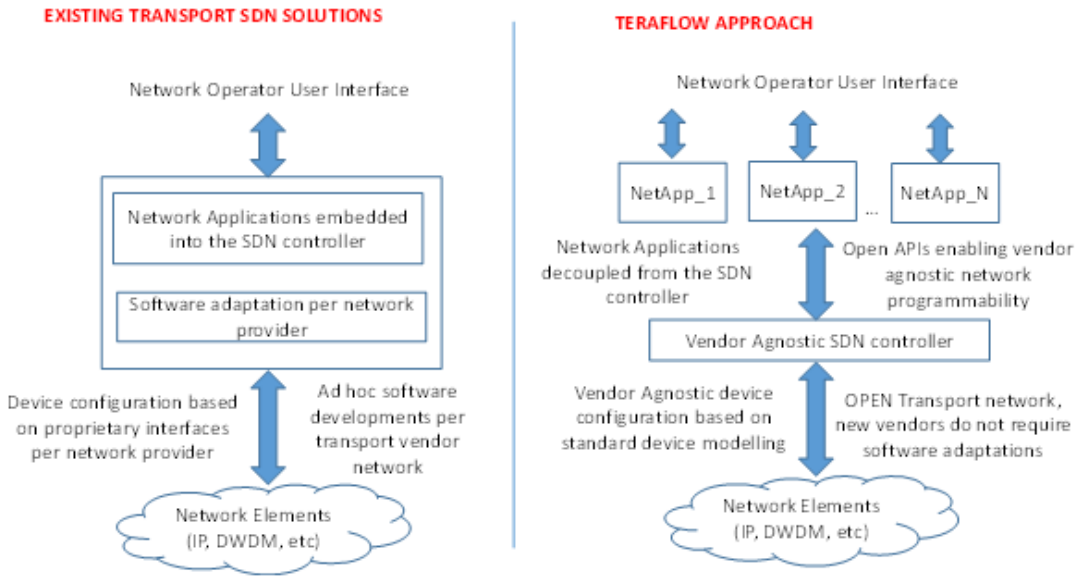


Figure 4: TeraFlow OS vs competitors

Regarding the introduction or even the modification of a given network application within a commercial solution, this is a long, costly and complex process:

- Telco operators should provide a technical specification to their SDN controller provider, including interoperability requirements with other transport vendors in the network. However, this is a captive demand, and Telco operators cannot ask other providers to implement the application.
- The SDN controller provider should design and implement the application within their proprietary framework.
- Interoperability with other vendors would require specific developments per transport vendor provider.
- The SDN controller provider would include this application within the product portfolio. Otherwise, the Telco operator would cover development costs, which requested the application.

However, the TeraFlow OS approach is very different, enabling an agile process for new network applications:

- Telco operators could launch an open RFI or RFP process to the market and select the optimum proposal among different providers.
- TeraFlow APIs provide standard network and service modelling. As a result, multiple operators with different vendors map without software adaptations can use network applications developed over these APIS.
- A combination assures multivendor interoperability of standard SBI and NBI.
- Coupled with a common and standard development framework, open competition will drive innovation. TeraFlow is implementing a set of innovative Network Applications using the interfaces designed in the project.

4. SWOT Analysis

Once we had a clear external view (section 3), we have focused internally on the TeraFlow OS to identify its business potential compared to the external environment. The Consortium has an evident vision of the result that the project will deliver (see section 2). The SWOT (Strengths Weaknesses Opportunities, Threats) analysis helps to sum up the information from the environment and competitors, separate it into **external issues** (opportunities, threats – from the environment) and **internal issues** (strengths, weaknesses – from the analysis of TeraFlow OS and its competitors) and serve as a basis for future activities related to both technical development and communication/dissemination initiatives.

Strengths	Weaknesses
• Financial support from the European Commission • TeraFlow OS promotes competition and innovation, using OPEN and standard APIs, multivendor interoperability is assured • TeraFlow development methodology fosters standardisation and is key to speed up industrial exploitation • Relies on a cloud-native architecture, supports cloud-scale number of connectivity service requests • Integration of transport network with the telco cloud and MEC • TeraFlow OS components can be deployed in edge nodes • TeraFlow OS uses blockchain for managing critical data • Incorporates ML to fight cyberattacks • Is aligned with the transition to a green economy and a sustainable development	• Open APIs proposed by TeraFlow would have limited impact if they are not widely supported by industry • The implementation of a single and common OpenConfig model for every vendor could take more than 3 years • TeraFlow is covering a limited number of the use cases needed in a Telco Operation

Opportunities	Threats
• Good projections because of the growing need and demand for mobility • Political support from the European Commission • Operators are looking for new ways of making money: externally and also internally by optimizing their own processes • New technologies, like SDN and NFV, are changing vendors traditional business model, lowering barriers for other players to enter the market • Collective efforts of the open-source community and industry, support of big players to standard interfaces • Environmental awareness and institutional support for going "green" in all areas of human activities • Cloud-native paradigm and MEC are defining the new mobile technology architecture	• Industry fragmentation and competing standards • Telco operators' dependency from the hyperscalers (telco cloud) • Lack of Regulation in new activities enabled by the new mobile communication technology • Ubiquitous edge devices meaning higher CO2 emissions • Growing rise in the number and type of threats that may put QoE at risk • Network security risks due to centralized nature of data plane • Slow market adoption, transforming the existing technology and traditional infrastructure (legacy) is a major challenge • Complexity of SDN architecture and lack of skilled professionals • People's concerns about the new technology and the incorporation of artificial intelligence into the process • Spread of fake news around 5G

Figure 5: TeraFlow OS SWOT Analysis

In the following lines, we highlight the main strengths of TeraFlow OS:

TeraFlow aims to speed up the implementation of vendor-agnostic Transport SDN

TeraFlow proposes a new Transport SDN architecture enabling an open environment for both network applications and devices using full standard interfaces for network programmability and device configuration. TeraFlow aims to speed up the implementation of vendor-agnostic Transport SDN by designing, implementing and testing SDN interfaces based on standard device, network and service modelling.

Firstly, we have defined an architectural framework based on functional blocks interconnected by standard interfaces and following a hierarchical architecture. Such architecture includes SDN domain controllers per technology (IP, optical and MW) and a hierarchical controller on top for multidomain and multilayer use cases (e.g., E2E network planning and discovery).

TeraFlow is focused on the specification and validation of the interfaces between blocks.

- Device configuration interfaces between network devices and SDN domain controller. In this case, we define vendor agnostic device modelling.
- Network programmability interfaces between SDN controllers and OSS using network abstraction and standard service and network modelling. These interfaces per use case should be implemented at both SDN controller and network applications.

TeraFlow working methodology is promoting standardisation and the speed-up of industrial exploitation

TeraFlow follows a continuous process per use case: starting with a use case definition according to telecom operator inputs, then we specify the use case modelling using available standards. This is critical because we propose a common use case modelling including device, service and network modelling using the most mature and available standards. TeraFlow is not reinventing the wheel by proposing new standards; we select the most mature ones to implement the use case. However, if we identify a gap in the standardization, we also actively work on the specific standardization body to solve it (e.g., OpenConfig, IETF, ONF).

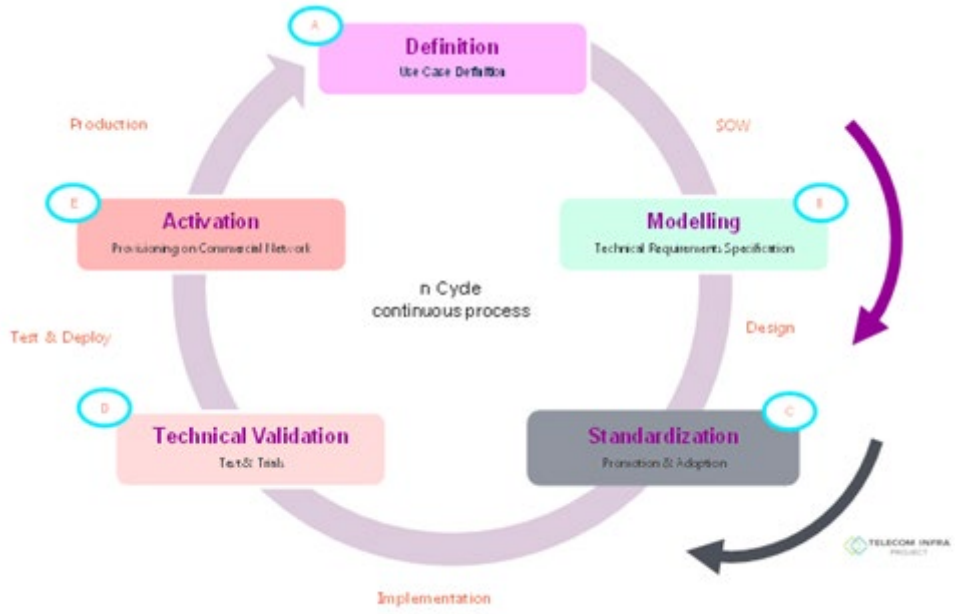


Figure 6: TeraFlow working methodology

Finally, once a vendor implementation is ready, telecom operators can do a lab technical validation using the testing software developed in TeraFlow. The use case could be ready for production if the vendor passes it. This technical validation process is done in TID Future Network Lab.

TeraFlow OS follows a cloud-native architecture

TeraFlow project proposes a novel network controller, TeraFlow OS, based on a distributed cloud-native architecture. The TeraFlow solution was distributed by defining specific blocks/components (microservices) according to their functional nature, an approach away from a traditional monolithic design where the platform/application must be deployed as a single instance. Additionally, TeraFlow OS will be capable of interacting with modern orchestration software-based tools related to the cloud and edge domains, such as Kubernetes or Open-Source MANO (OSM), to be applicable at different levels of the B5G network model.

Evaluating the current state of the networks and their evolution, the TeraFlow OS can be easily adapted not only to be run from the cloud, but its structure in several components allows its deployment (at least partially) in multiple locations, some of them suitable to be deployed in edge nodes with reduced computational availability. Furthermore, using this revolutionary cloud-based modular approach, TeraFlow OS is expected to achieve a remarkable goal in line with the B5G/6G

evolution, such as establishing control plane flows below 10ms or managing at least ten times more flows than the capabilities of current SDN controllers. In this way, TeraFlow OS can play a significant role in meeting the demands of the most challenging services or vertical needs, either now or in the future.

TeraFlow proposes the integration of transport network with the telco cloud and MEC

The objective includes the integration of the TeraFlow OS as an SDN controller in a global and B5G network architecture. NFV and MEC solutions are considered to provide a continuum of compute-network resources that embrace the network edge out to the network core. As anticipated in the DoA[35], edge solutions such as OpenNess and Akraino will be incorporated, and a cloud-native solution such as Kubernetes will be considered. Network resources handled at the edge will be visible to the TeraFlow OS, and efficient flow management will be provided. ONAP and ETSI OpenSource MANO orchestrators will be considered for integration with the TeraFlow OS.

TeraFlow OS uses blockchain for managing critical data

TeraFlow will embrace the advantages of blockchains for network management. In particular, the TeraFlow OS will use blockchain technology to provide a trustworthy and resilient platform for storing, querying, and processing critical data about network resources and services owned and governed by different network entities. Furthermore, it will be privacy-aware and transparent, resulting in an open, traceable, and fair sharing of network resources and services between stakeholders[35]. In addition, TeraFlow will contribute to blockchain technologies by providing research results on consensus algorithms and tools for analysing smart contracts' security.

TeraFlow incorporates ML to fight cyberattacks

TeraFlow OS incorporates network's cybersecurity needs from several perspectives, incorporating distributed and centralized solutions. TeraFlow proposes a distributed Machine Learning (ML)-based Intrusion Detection System (IDS) deployed at the network edge to detect malicious flows at the data plane. A distributed IDS is expected to improve scalability and response time to detect malicious flows while reporting a holistic network security assessment to the centralised controller. The centralized cybersecurity component will perform a security assessment of end-to-end physical channels to detect malicious attacks targeting the network infrastructure. The service-layer security assessment reports received from the edge IDSs merged with information from the infrastructure layer will enable cross-layer security assessment.

Machine learning models, especially deep neural networks, are vulnerable to malicious inputs modified to yield erroneous model outputs while appearing unmodified to human observers. Adversarial examples are inputs to machine learning models that an attacker has intentionally designed to cause the model to make a mistake. They could be understood as optical illusions for machines. Potential attacks to machine learning in the context of networks include having malicious content like malware or network attacks identified as legitimate. TeraFlow researches the application of novel techniques to provide resiliency to SDN ML-based components against such adversarial attacks.

TeraFlow is aligned with the transition to a green economy and a sustainable development

Deploying Machine Learning (ML) models at the network edge in a distributed fashion implies fewer resources per edge node while maintaining the same accuracy and performance level. Therefore, TeraFlow will research "green AI approaches" and the deployment of ML-based threat detectors in

resource-limited nodes (e.g. when deployed in P4 capable switches) by utilizing Auto-ML techniques to reduce model complexity while maintaining threat detector performance and effectiveness concerning the original models.

Moreover, novel algorithms for latency in TeraFlow OS shall improve network resource consumption by 30% by providing joint strategies for allocating compute-network resources.

5. Business Opportunities

The Consortium is composed of different partners with different profiles. Analysing the environment in the previous sections, it is only natural that, apart from supporting their initial strategy, they find new opportunities in the areas of their expertise. In section 5, partners give a vision of these opportunities.

For the collection of this information, two templates have been defined. The first one was circulated at the beginning of the project for the Exploitation Manager to have a clear idea of each partner's motivation. Following the environment and SWOT analysis, the second one is for the partners to identify new opportunities.

The section is divided according to the different profiles of the partners.

5.1. Industry

5.1.1. INFINERA (INF)

Brief description of the partner and role in the stakeholders' ecosystem

Infinera is a provider of IP/MPLS routers and IP/MPLS router software called CNOS. The routers can be configured and monitored using Infinera network management tool or CLI. OpenConfig is an emerging approach for the same purpose, to configure/monitor the IP/MPLS routers.

Role in the ecosystem: from an ecosystem perspective, Infinera would be a vendor whose device can be configured/monitored with TeraFlow OS.

Strategy for joining the project

Within the TeraFlow project, Infinera has continued developing OpenConfig interface/models to the CNOS software. Participating in the project allows Infinera visibility to future trends, additional confidence that OpenConfig design developed aligns with what operators will expect in the future, and aligning with how SDN developers will use the OpenConfig. Therefore, an important reason to join TeraFlow was essential to secure Infinera to develop the correct OpenConfig components to succeed with the CNOS software.

In order for TeraFlow to become widely deployed by different operators, it is evident that several equipment vendors need to be compatible with TeraFlow OS. Infinera alone will not be enough, and several prominent players should also support OpenConfig. Therefore, from the ecosystem development perspective, the Infinera DRX-30 will be one of the first OpenConfig platforms to experiment and demonstrate the TeraFlow OS capabilities.

Results and business opportunities

Name and type of result: OpenConfig implementation in CNOS software, Device embedded software

-Description: Infinera will not contribute to the TeraFlow SDN controller as such, but instead provides a device that can be configured/monitored with TeraFlow SDN, that is, INF will provide OpenConfig YANG models to Infinera CNOS software for their IP routers targeting L2/L3 VPN services.

-Partners involved: only INF

-TRL expected at the end of the project: TRL5

-Business opportunities identified:

Introducing a new approach for configuring/monitoring CNOS software with OpenConfig, makes CNOS valid for opportunities where OpenConfig is required. OpenConfig implementation in CNOS can be used in any other context where SDN (also other than TeraFlow) supports interface/plugin towards OpenConfig, so we can target any SDN developer.

5.1.2. SIAE Microelettronica SPA (SIAE)

Brief description of the partner and role in the stakeholders' ecosystem

SIAE produces fixed wireless transport network solutions, ranging from hardware (microwave and mm-wave radio telecom equipment), to software (device management and network management tools), and related added-value services. Most of SIAE customers are network operators, with a base of installed elements of around half a million, deployed over the last 5 years. Telefonica and Telenor, stakeholders in the project, are SIAE customers in several countries, where the microwave installed base vary between hundreds and some thousand links per network. Pushed by the upcoming requirements for 5G/B5G, the SDN paradigm has already impacted several SIAE product lines, especially on our network management software.

SIAE network management software has been evolving from a classical, monolithic and full-proprietary FCAPS manager to a modular solution comprising a radio domain controller and several SDN applications. In particular, the controller (SM-DC) implements open, standard interfaces both in southbound (i.e., NETCONF/YANG towards managed radio equipment) and in northbound (i.e., RESTCONF towards an SDN orchestrator or a hierarchical controller). SIAE SDN applications (SM-Apps) leverage the full potentiality of SDN to enable advanced features for the control and monitoring of the SIAE radio transport network.

Role in the ecosystem: Hardware Solution Provider (vendor)

Strategy for joining the project

SIAE main motivation is to deepen our know-how and strengthen our expertise in the fields related to SDN and 5G/B5G. Being part of TeraFlow allows us to access the network of competences created by research centres and universities that provide a view on SDN architectures' future evolution.

Our strategy consists in embedding in R&D the knowledge acquired from TeraFlow, to develop the next generation of our commercial software, featuring:

- A more modular and open software implementation that might ease the evolution towards NFV software architectures based on micro-services and containers;
- An enhancement of interoperability both at SBI with hardware from other vendors and at NBI with third-part orchestrators and OSS/BSSs;
- An increase of the market share thanks to the inclusion of more open interfaces, protocols and data models.

Results and business opportunities

1. Name and type of result: Microwave (MW) Device Driver plugin (part of KER 3[2]), software

-Description: Driver plugin, embedded into the Device Core TeraFlow OS component, for the SBI management of MW devices. The plugin shall implement in SBI open interfaces and data models, based on ONF TR-532 and IETF Network Topology models. It shall not interface directly with MW network elements, but through an intermediate controller provided by SIAE, which is external to the TeraFlow OS (i.e., regarded as a black box by the TeraFlow OS). This piece of software is essential to enable the integration of MW devices into the end-to-end carrier transport network and their full management by the TeraFlow OS.

-Partners involved: only SIAE

-TRL expected at the end of the project: TRL5

-Business opportunities identified:

Being an internal sub-component of the Device component, the MW SBI Driver module is tightly coupled with the component implementation, and it cannot be reused as a separate entity. But, if considered an internal part of the whole Device component, which can be easily reused since it is implemented as a microservice, this software could be used in other contexts. The reuse of the Device component microservice (which includes the MW SBI driver) can be beneficial to both: network operators, willing to integrate a wide range of network devices into their existing management/orchestration systems; and also software providers, willing to develop SDN applications based on a common abstract model of network devices.

SIAE sees an opportunity for commercialization of new products which include novel open interfaces, protocols and data models (e.g., gNMI protocol, OpenConfig models); improve interoperability of management plane with hardware from other vendors; enhance integration with third-part orchestrators, OSS/BSSs and NFV MANO framework; fully integrate with 5G and B5G architectures for the management of end-to-end services based on SDN automation and transport slicing.

At this stage, SIAE foresees:

- Incorporation of results (interfaces, models, open-source components) into existing SIAE software: SIAE Microwave Domain Controller (SM-DC) and SDN Apps (for instance, SIAE network analytics tool);
- Commercialization of new software inspired by real-world use cases (as a possible example: SDN Apps for multitenant-based provisioning and monitoring of wireless transport network slices).
- We also foresee business opportunities in the standardization activities within ONF and ETSI we are participating. A possible example: define and/or upgrade SDN interfaces/models for microwave and mm-wave transport, both in southbound and in northbound, taking into account TeraFlow requirements and use cases.

5.1.3. NEC Laboratories Europe GMBH (NEC)

Brief description of the partner and role in the stakeholders' ecosystem

[2] See section 2, TeraFlow IP Registry

NEC Labs Europe conducts research, development and standardization on innovative ICT technologies. We transfer technology to business units as well as to global subsidiaries like the 200+ affiliates of NEC. A defining attribute of NEC Labs Europe is our inclination towards open innovation. We collaborate with universities, research institutes, other corporate research centres and potential users in a co-creation mode, leading to breakthrough innovation combined with market-orientation.

Role in the ecosystem: Research in ICT company

Strategy for joining the project

NEC Laboratories Europe is in constant contact with NEC's business units and its customers that are eager to learn about and use results from research projects for future NEC products.

NEC will focus on enhancing the TeraFlow OS's security and contributing to the general architecture and the APIs for interacting with the distributed ledger component. NEC will also focus on smart contracts that automate and enforce business logic.

NEC's work within the TeraFlow project on distributed ledgers and smart contracts will enhance the company's own blockchain security portfolio. Concretely, the developments and findings from the TeraFlow project will be presented to the business units that operate and develop network and digital services for smart cities and IoT platforms.

Results and business opportunities

1. Name and type of result: Distributed Ledger Technology and Smart Contracts (KER 8), software

-Description: Core TeraFlow OS component for zero-touch (i.e., automated) device management. Allows the TeraFlow SDN controller to fully automate device provisioning operations, such as onboarding of new devices, device configuration, and processing instructions, etc. This feature is not crucial from a functional viewpoint, as device onboarding can also be done manually. However, manual processes are (i) costly in terms of personnel time translated into salary and (ii) error-prone due to the human factor involvement. Thus an automated device onboarding is greatly desired by network operators to date.

-Partners involved: NEC, CTTC

-TRL expected at the end of the project: TRL5

-Business opportunities identified:

The DLT component could be used as a data orchestration and management layer for apps or ecosystems surrounding the TeraFlow domains.

Results from the TeraFlow project will leverage digital innovation for NEC's blockchain technologies, including new applications and business models in B5G networks integrated distributed computing. In particular, NEC expects that research results from the TeraFlow project will advance blockchain technology to provide security and trust mechanisms in the smart/ubiquitous connectivity domain.

Furthermore, NEC's work within the TeraFlow project on distributed ledgers will enhance the company's own blockchain security portfolio and contribute to the development and deployment of secure, scalable, and efficient management of networks and services.

NEC participates in discussions and regular meetings of Hyperledger Labs. The Blockchain technology developed for the distributed ledger component of TeraFlow OS (like improved consensus algorithms) will be of interest for Hyperledger Lab.

NEC is a founding member of ETSI ISG PDL (Industry Specification Group Permissioned Distributed Ledger). NEC will closely monitor standardization activities in ISG PDL and actively connect TeraFlow project research results related to DLT with PDL work items.

5.1.4. ATOS IT Solutions and Services Iberia SL (ATOS)

Brief description of the partner and role in the stakeholders' ecosystem

Atos is a global leader in digital transformation with 110,000 employees and annual revenue of €12 billion. European number one in cybersecurity, cloud and high-performance computing, the group provides tailored end-to-end solutions for all industries in 73 countries.

As a leader in digital transformation, Atos must successfully address its clients' concerns and facilitate and accelerate their journey towards this transformation. In the Telecom market, Atos aims to support its operator clients to move to next-generation networks, making a seamless transition from traditional infrastructure to virtual infrastructure without loss of service, reputation or revenue. To this effect, Atos needs to be strategically positioned in the new telecommunications paradigm and forefront of the latest technology, methodologies and industry trends.

Role in the ecosystem: SW provider, consulting services provider, integrator

Strategy for joining the project

Replicating the global organisation of the company, and to facilitate the integration of research and innovation activities, Atos Research and Innovation (ARI) is divided into 6 Markets (which correspond to the Atos Industries) and, within those Markets, specialised units designed to foster collaboration between Atos Industries and the emerging lines of innovation research in the EU. One of these ARI Markets is Telecommunications, Media and Technology (TMT). In this group, the Smart Networks and Services (SN&S) Unit is the team participating in the TeraFlow project.

The SN&S Unit focuses on the research and definition of novel network architectures and on the enhancement of network protocols to enable the continuous evolution and improvement of the performance of telecommunications networks. They have expertise in technologies that enable the development of next generation telco networks, coming from 5G, now beyond 5G and already looking at 6G. The ultimate goal of the unit is to get internal/external support for developing assets further, bring them to a market-ready stage and incorporate them to the sales portfolio for the benefit of the European research, the company TMT business and the digital transformation of Atos customers.

Results and business opportunities

The results that Atos expects to achieve at the end of the project are related to (1) knowledge, (2) asset development and (3) expansion of its network of contacts.

The participation of Atos in TeraFlow involves acquiring knowledge (1) that can be monetized in the form of consultancy services (in Atos Telecom Industry) and reputation towards Atos clients. Attending to the opportunities spotted in the environment analysis, software networks: Management and Orchestration (MANO) and Operations Support Systems (OSS), including network slicing are topics

where market is lowering barriers for the entrance of players like Atos, that could monetize this knowledge and deliver solutions for telco operators in the context of TeraFlow.

Regarding the asset that we are developing in the context of the project (2):

1. Name and type of result: Monitoring Component (KER 2), software

-Description: Monitors network and computational metrics and shares these metrics with the other components of the TeraFlow SDN Controller. So far, the Monitoring component interfaces with the Context and Device components and the Grafana visualization tool. The monitoring component is part of TeraFlow OS core.

-Partners involved: only ATOS

-TRL expected at the end of the project: TRL5

-Business opportunities identified:

This component will be part of the core of the TeraFlow SDN controller. For this reason, it is targeted to the telco operator that deploys the SDN controller in its network. However, the Monitoring component could be used in other infrastructure contexts since it has been designed following a microservice architecture. Existing monitoring solutions are context-dependent (monolithic), so it is difficult to decouple them from the context they were designed for. The fact that the Monitoring component is designed following this plug&play fashion, with open interfaces that permit to connect to other architectures (not TeraFlow-specific), will allow us to evolve it in other research projects, that may investigate other frameworks. Here is where we can find new business opportunities, further use of the asset in a research context. In fact, ATOS has some assets, result from previous research projects, concerning predictive monitoring and scalability of the network, so we expect to acquire knowledge and experience in TeraFlow that can be very relevant for this research line. The SN&S Unit is interested in this asset evolution because it is fully aligned with the Next Generation Telecom Networks offering of the Global TMT portfolio of the company. ATOS holds regular meetings in the SN&S units to align results from different projects and coordinate the strategy. Additionally, we are in contact with the TMT industry to understand where the trends are heading and the competence centres to align with the company strategy.

Building on the key relationships (3) that Atos is forging during the course of the project, the Unit will work on new joint proposals for new functionalities aligned with the asset's development roadmap and market trends, strengthening the software networks industry in Europe, hence increasing its competitiveness.

5.1.5. UBITECH (UBI)

Brief description of the partner and role in the stakeholders' ecosystem

UBITECH is a software house and systems integrator SME with innovative solutions in various IT sectors, including cloud computing, programmable networks, 5G and beyond systems, Internet of Things, security and trust, artificial intelligence, and Big Data analytics. In the context of TeraFlow UBITECH participates through the Network Softwarization and IoT (NSIT) department, focusing on programmable control and data plane networking solutions for the TeraFlow SDN controller.

Role in the ecosystem: SW provider

Strategy for joining the project

UBITECH's TeraFlow activities aim to design and develop two core SDN controller components, namely (1) a zero-touch provisioning component for network automation and (2) a policy management component for device and network-level policy enforcement. These SDN control plane components will manage programmable devices of various types, such as OpenConfig, NETCONF/YANG (developed by other TeraFlow partners), but also next-generation SDN devices, such as P4 Whitebox switches. UBITECH will design and develop a P4 device driver plugin for the TeraFlow device component subsystem to support the latter devices.

With all these components in place, UBITECH will expand their Vertical Application Orchestrator (VAO) platform towards the network by leveraging the additional network-level programmability offered by P4 devices through the TeraFlow SDN controller. To date, the VAO is strictly a cloud-level application orchestrator platform that allows to easily onboard, deploy, and manage cloud microservices atop public or private cloud infrastructures, e.g., through OpenStack and/or Kubernetes cloud controllers. Atop these cloud controllers, VAO offers an advanced UI with quick application onboarding, a policy engine that allows to associate application components with SLAs, a runtime monitoring engine with relevant visualization tools, and scaling capabilities for individual cloud application components. By offering network services to the VAO through the TeraFlow controller, UBI expects to enhance the VAO resource management procedures towards the network, which is an unknown territory for the VAO to date.

Results and business opportunities

1. Name and type of result: Zero-Touch Provisioning (Automation) Component (KER 5), software

-Description: Core TeraFlow OS component for zero-touch (i.e., automated) device management.

Allows the TeraFlow SDN controller to fully automate device provisioning operations, such as onboarding of new devices, device configuration, and processing instructions, etc. This feature is not crucial from a functional viewpoint, as device onboarding can also be done manually. However, manual processes are (i) costly in terms of personnel time translated into salary and (ii) error-prone due to the human factor involvement, thus an automated device onboarding is greatly desired by network operators to date.

-Partners involved: only UBI

-TRL expected at the end of the project: TRL5

-Business opportunities identified:

As TeraFlow components are developed as individual microservices, other SDN controllers could leverage it if they share a similar device and context API. Potential integration with industry-grade SDN controllers (e.g., ONF's upcoming µONOS) could be investigated.

UBI plans to transfer the knowledge acquired with this software development to the company to automate relevant testbed activities, such as onboarding new networking devices into UBI's testing and production platforms. It is expected that this will yield economic benefits for the company.

In the context of the P4 activities that UBI is carrying out in TeraFlow, the automation component will be leveraged to provide automated P4 device onboarding onto UBI's experimental testbed. Upon

success, the acquired experience will allow UBI to automatically onboard P4 switches to their production cluster in Athens.

2. Name and type of result: Policy Management Component (KER 6), software

-Description: Core TeraFlow OS component for device-level and network-wide policy definition and enforcement following the event-condition-action (ECA) policy model.

Allows the TeraFlow SDN controller to enforce network policies into SDN infrastructures managed by the TeraFlow SDN controller. This is a crucial feature for network management as it allows network operators to quickly and easily translate their high-level network behaviour objectives into low-level network configuration commands

-Partners involved: UBI (design and implementation) and ODC (design and relation to standardization activities).

-TRL expected at the end of the project: TRL5

-Business opportunities identified:

The north-bound API of the policy component could be exploited by an existing SDN controller or a network operator's panel following the ECA policy model. Once triggered, the policy component could undertake to enforce the received policy(ies) into a network managed by the TeraFlow SDN controller. Potential integration with industry-grade SDN controllers (e.g., ONF's upcoming µONOS) could be investigated.

Knowledge transfer to the company in order to formalize/improve common network policies applied by UBI's system administrators with respect to existing products. This will result in higher quality services provided to UBITECH's customers.

In the context of the P4 activities that UBI is carrying out in TeraFlow, the policy component will be leveraged to enforce e.g., monitoring or other network management policies atop P4 devices in UBI's experimental testbed. Upon success, the acquired experience will allow UBI to provide these policies as a service to their customers through an extended version of UBI's vertical application orchestrator (VAO) product.

3. Name and type of result: P4 Device Driver Plugin (part of KER 3), software

-Description: Core TeraFlow OS driver plugin for managing P4 devices. This is a software module which belongs to the device TeraFlow core component.

Allows the TeraFlow SDN controller manage P4 whitebox switches. This feature is a crucial for managing next-generation SDN devices that comply with the P4 SDN standard. Without this feature the TeraFlow SDN controller will still be able to manage software-defined networks comprised of other device types (e.g., OpenConfig, NETCONF, etc.)

-Partners involved: only UBI

-TRL expected at the end of the project: TRL5

-Business opportunities identified:

The north-bound API of the P4 device driver could be exploited by another SDN controller that has currently no means to manage P4 devices. The requirements to integrate a P4 driver into TeraFlow

may result in relevant extensions that could be contributed to the P4 community (e.g., ONF's Stratum OS, ONOS P4 device driver, etc.).

Knowledge transfer to the company in order to acquire the know-how on P4 device management, thus modernize UBITECH's network infrastructure and network programmability assets. Also, potential contribution to the P4 open-source community (e.g., ONF's Stratum OS).

Incorporation of P4 devices into TeraFlow's testbeds. Upon success, the acquired experience will allow UBI to provide advanced network programmability services to their customers through an extended version of the vertical application orchestrator (VAO), which leverages P4 programmability

In general, UBI plans to contribute to the success of the TeraFlow OS project, even when the project finishes:

- Contribute to the automation, policy, and P4 driver components to the public TeraFlow OS software repository along with material that would allow new TeraFlow users to quickly educate themselves on (i) basic TeraFlow concepts and (ii) specifically on these components as well as quickly allow them to setup a working TeraFlow prototype for research and innovation purposes, thus further advertise TeraFlow to relevant communities.
- Additional dissemination could be achieved through demo activities or online hackathons that will allow potential TeraFlow users to better understand technical details about TeraFlow as well as develop skills (through hands-on activities) on TeraFlow components of their interest.
- After the project end, UBI will still contribute to the TeraFlow repo, mainly for our software maintenance, not for adding new features to the components. In return to this effort, UBI expects new contributions from the community to be exploited by UBITECH for own purposes (either internally or as assets to our customers).

5.1.6. DIPL. PHYS. Peer Stritzinger GMBH (STR)

Brief description of the partner and role in the stakeholders' ecosystem

Peer Stritzinger GmbH is a software development partner with expertise in distributed computing from cloud to edge including networking and routing protocols. The initial role was as a development partner of VOLTA to build a second implementation of a distributed SDN controller in Erlang. Due to the departure of VOLTA from the project this is no longer feasible, so STR is picking up on the increased interest in Traffic Engineering. Plan is to now build a component of TeraFlow OS for distributed smart traffic engineering. This aligns well with the implementation work on PCEP STR did in the first year which is a necessary component.

Strategy for joining the project

On joining the strategy was to be a Development partner for VOLTA which was doing the main architecture work. Exploitation was planned as partnering with VOLTA on productising the distributed SDN controller jointly developed on top of VOLTA's lower-level routing stack.

Results and business opportunities

We have created a working implementation of PCEP which will be usable in the Traffic Engineering component of TeraFlow OS. STR is still exploring the new opportunity for business in the smart Traffic-Engineering space by learning more from the partners in the Telco space about their pains and gains

in Traffic-Engineering. There are likely spin-offs in the Industrial Manufacturing space, especially reservation and optimisation in industrial field-bus implementations based on Ethernet TSN.

5.1.7. Old Dog Consulting LIMITED (ODC)

Brief description of the partner and role in the stakeholders' ecosystem

ODC are Internet standardisation experts specialising across several technology areas, including routing, traffic engineering and optical networking. Our focus is on the IETF, MEF, ETSI, ITU-T and ONF, where we have many years of experience and different leadership roles. Our customers range from large international network operators and equipment manufacturers to early-stage start-ups and consultancies. Our business depends on continually being at the forefront of research, innovation, and standardisation within the SDOs.

Role in the ecosystem: contributor to SDOs

Strategy for joining the project

TeraFlow is developing several innovative areas of technology that will enable mutual benefit for project partners and ODC. We will bring our experience to assist the project partners and develop their ideas within the SDOs. At the same time, we will bring our technical contributions to build on the TeraFlow effort and demonstrate a credible presence in the SDOs. We will also highlight TeraFlow technology leadership via industry conferences and workshops that ODC are often invited to present cutting edge technology and chair panel sessions. Additionally, ODC needs to remain informed about the latest developments in routing and SDN. TeraFlow is at the leading edge of research in this area: being part of it will be very helpful to keep us up-to-date and relevant and allow it to seed new ideas for future ODC areas of technology development and innovation.

Results and business opportunities

Although ODC is not directly developing or implementing TeraFlow OS components, it provides technical input and guidance that directly impacts how TeraFlow partners may implement their components. Furthermore, critical technical developments within the project may support standardisation efforts, and ODC will work with partners to bring those contributions into the SDOs.

Key innovations that ODC will facilitate within TeraFlow and engage with standardisation efforts include:

- Scoping and mapping network intent to the policy via Event Condition Action (ECA) framework and models. Directly helping develop the TeraFlow Policy component and possible SDO contributions. (KER 6)
- Providing input on the mechanism used for TeraFlow network slicing and IETF compliance.
- Highlighting key YANG models for the control and management of network resources.
- Develop architectures and applicability statements to use standards-based YANG models for top-to-bottom automated provisioning of customer services.
- Develop end-to-end architectures and frameworks, including Abstraction Control Transport Resources (ACTN) for resource management and Network Slicing as a Service (NSaaS).

These contributions are made through the portals of the SDOs and are presented as XML and text files. They are usually made immediately visible to other participants in the SDO, and some SDOs have open access to all contributions. Regarding open-source contributions, they are usually publicly visible.

It is expected that, by the end of the project, many aspects of the results will be stable and ready for widescale implementation to ensure interoperability. In addition, some SDO activity aspects (especially architectures and YANG models) will also have been prototyped and tested within the project, providing helpful feedback for SDO participants.

With this type of contribution, writeup SDO implementation findings from TeraFlow, it is expected that both network operators and software/equipment developers across the industry benefit from the project. In this way, TeraFlow project will make a significant impact, as the development of architectures and protocol standards help the industry converge on interoperable solutions that facilitate market growth and enable vendors to participate in different environments and solution spaces.

ODC is very actively disseminating this activity by contributing to conferences in the form of presentation slides that are, of course, visible to the conference attendees and are often published for public consumption according to the copyright rules of the conference. Also, publications that are not normally made immediately accessible through open access are available to subscribers to journals or websites, invited talks, and panel chairing on TeraFlow topics.

Further work for ODC is expected to follow as a direct or indirect result of the exposure created by leadership demonstrated by the results described above. Additionally, ODC will be willing to support the TeraFlow OS community when the project is contracted to liaise with the relevant SDOs.

5.2. Research/Academia

5.2.1. Centre Tecnologic de Telecomunicacions de Catalunya (CTTC)

Brief description of the partner and role in the stakeholders' ecosystem

CTTC is a research institution that collaborates with the telecom ecosystem to trigger innovation and advance knowledge in telecommunications. To this end, CTTC looks for partnerships and agreements between several academic and industrial players to fulfil its view. CTTC is also active in Standard Developing Organizations and Open-Source Software communities. This approach allows to influence current telecommunications trends as well as advancing knowledge.

Role in the ecosystem: academia

Strategy for joining the project

CTTC focuses its strategy on a three-fold perspective: i) generate knowledge and expertise within the context of B5G software networks area; ii) strengthen the collaboration with leading European and National industrial players; and iii) active involvement and contribution on related open-source software projects. As an academic partner, CTTC prepares short courses, tutorials, or in-house seminars to industry stakeholders regarding knowledge generation. CTTC has several collaboration agreements with industry players, in heterogenous formats such as courses, technology transfer, IPR transfer, knowledge generation, etc. Additionally, CTTC is being involved into the ONF ONOS and ETSI OSM projects, with the objective to contribute with TeraFlow innovations. This allows CTTC a lot of visibility in open-source community, which is monetized with industrial agreements.

Results and business opportunities

1. Name and type of result: Context (KER 1), Service (KER 4) components as part of High performance SDN framework, software

-Description: High-performance capabilities to the TeraFlow OS, offering a notable increase in the number of realized connectivity requests over time, increased flow processing capacity, and resilience mechanisms for the TeraFlow components. These components are part of TeraFlow OS core.

-Partners involved: Context CTTC, TID. Service: CTTC, INF, TID

-TRL expected at the end of the project: TRL5-6

2. Name and type of result: Device Component (KER 3) as part of Hardware and L0/L3 multi-layer integration, software

-Description: Some of the supported models for optical/microwave (layer 0-2), smart programmable hardware (layer 2-3), and IP routers (layer 3) integration are defined in the following SDOs: IETF, ONF. This component is part of TeraFlow OS core.

-Partners involved: TID, CTTC, SIAE, INF, UBI

-TRL expected at the end of the project: TRL5-6

3. Name and type of result: Distributed Ledger Component (KER 8), software

-Description: Smart contracts and the usage of blockchain technologies with low TRL allows us to detect applicability use cases for further study. This is a nice to have functionality of the controller, not needed to give the main functionality.

-Partners involved: NEC, CTTC

-TRL expected at the end of the project: TRL5-6

4. Name and type of result: Compute Component (KER 10), software

-Description: Compute integration with NFV/MEC orchestrator. This is a nice to have functionality of the controller, not needed to give the main functionality.

-Partners involved: only CTTC

-TRL expected at the end of the project: TRL5-6

5. Name and type of result: Inter-domain Component (KER 12), software

-Description: Inter-domain interconnection between different TeraFlow-controlled domains. This is a nice to have functionality of the controller, not needed to give the main functionality.

-Partners involved: TNOR, NTNU, CTTC

-TRL expected at the end of the project: TRL5-6

For all these results, CTTC sees business opportunities in different fields.

-Business opportunities identified:

- Some of these components could be used in another context, also targeting network operators and vendors.
- Further research/education: extensions with new features.

- Knowledge transfer: micro-service oriented development.
- Knowledge dissemination: Scientific works, demos, tutorials, etc…
- Contribution to open-source projects: TeraFlow OS and ETSI OpenSource MANO. Our intention is to accomplish TeraFlow sustainability, which is monetized with industrial agreements.

5.2.2. Chalmers University of Technology AB (CHAL)

Brief description of the partner

Chalmers University of Technology AB (www.chalmers.se) was founded in 1829 and is an independent foundation university. Chalmers offers MS.c. Eng., M.Arch., B.Sc. Eng., Nautical, Licentiate and Ph.D. programs, and ongoing development programs for professionals. Chalmers has about 11,000 students (incl. 1000 PhD students) and 2700 employees. Around 350 Ph.D. and Licentiate degrees are awarded and 1000 M.Sc. Eng. and M. Arch each year. The department of Electrical Engineering (E2) is conducting world-leading research and education in advanced wired and wireless telecommunication systems. The Optical Networks Laboratory (ONLab) is one of the research labs at E2, with a specific focus on design and operation strategies for communication network infrastructures.

Role in the ecosystem: academia

Strategy for joining the project

CHAL motivation for joining the project was twofold. First, the architecture, reference scenarios, business models, and the specification of the components/processes created in the frame of the project will give a solid base for further study in the area of security, anomaly detection, and cloud-scale orchestration in 5G and B5G scenarios. Second, CHAL sees attractive commercial potential in the TeraFlow work and is open to exploring commercialization initiatives based on the outputs of this work. This will be possible by also leveraging on incubation possibilities available at CHAL through the Chalmers Ventures program (https://www.chalmersventures.com/programs/). Finally, CHAL will use the knowledge from the project by updating/developing current/new graduate-level courses addressing the communication infrastructure at large.

Results and business opportunities

1. Name and type of result: Cybersecurity component of TeraFlow OS (KER 11), software

-Description: ML-based techniques for the identification and mitigation of cybersecurity threats, including orchestration methods for traffic steering and failure/attack recovery. This result is one of the functionalities required by the SDN TeraFlow SDN controller.

-Partners involved: TID, UPM, CHAL

-TRL expected at the end of the project: TRL5

-Business opportunities identified:

The concept behind the software implementation can be used in any context dealing with anomaly detection and countermeasures. Intended for network operators mainly, also system providers should like to provide this functionality to customers.

CHAL is also acquiring knowledge from other functionalities of the TeraFlow OS controller, like in load Balancing, Monitoring, Slice Management and healing. With this knowledge, CHAL expects to improve or incorporate new research directions, update and/or develop new graduate courses.

The creation of a simulation/emulation cluster where to deploy/run TeraFlow can also be used in other contexts and bring new opportunities to CHAL.

5.2.3. Universidad Politécnica de Madrid (UPM)

Brief description of the partner

Universidad Politécnica de Madrid (UPM) - Technical University of Madrid - is the largest Spanish technological university. With two recognitions as Campus of International Excellence, it is outstanding in its research activity together with its training of highly-qualified professionals, competitive at an international level. More than 2,400 researchers carry out their activity at the UPM, grouped in 204 Research Groups, 19 Research Centres or Institutes and 55 Laboratories, all of them committed to transform the knowledge generated into innovation advances applied to the production sector, contributing to solve the challenges of the European citizens.

UPM signs annually around 600 contracts with private businesses, due to its traditional and close relationship with the industrial and business sector, which supports and back its research and technology development in all Engineering fields. UPM obtains around 40 patents per year, demonstrating a high commitment to innovation. One of the main UPM technology transfer driver is the business creation, such as the ActúaUPM program that has generated +200 businesses in the last 10 years, 80% of which still exists.

Role in the ecosystem: academia

Strategy for joining the project

As an academic institution, UPM is interested in leveraging TeraFlow innovation results and the knowledge and experience acquired from them in future R&D projects.

Results and business opportunities

1. Name and type of result: Cybersecurity component of TeraFlow OS (KER 11), Knowledge

-Description: Distributed Machine Learning based attack detectors. Machine Learning components resilient to adversarial attacks. This cybersecurity component (distributed detector) wants to demonstrate that certain attacks can be detected using ML in a distributed manner, that is, the attack detection processing is not done in the SDN controller alone, but we use external components to assist in the detection either by pre-processing data or by doing simple event detection which then combined in the controller results in the detection of the attack.

-Partners involved: TID, UPM, CHAL

-Business opportunities identified:

To date, we have particularised it for the detection of cryptomining attacks, but the plan is to extend it to other attacks of interest to an operator, such as Telefonica (DoH: DNS over HTTP).

UPM sees other opportunities for publication and presentation of project achievements and innovation results in technical journals and conferences, use TeraFlow results in Master and PhD

courses and seminars and finally we plan to propose master theses related to TeraFlow and attract students to these in the next years.

Regarding further research and development, we will investigate new research areas extending project results and finding synergies and collaboration opportunities in future projects and applications, both at the regional and the international level.

In addition, we will explore options to secure IP generated within the project and launch and incubate spin-offs or license the IP, all with the ultimate goal of introducing innovative services and/or products into the market. UPM created the Centre for Support for Technological Innovation (CAIT – its initials in Spanish) in 2010 with the fundamental objective of promoting the exploitation of the results of R&D activities as well as serving as a stimulus to the innovation process in the business ecosystem close to the UPM. In this context, CAIT will explore options to secure IP generated within the project and launch and incubate spin-offs or license the IP, all with the ultimate goal of introducing innovative services and/or products into the market.

5.2.4. Norwegian University of Science and Technology (NTNU)

Brief description of the partner

NTNU is Norway's largest university with more than 40 000 students and is the primary Norwegian university in engineering and technology. More than 400 PhD degrees are awarded yearly. Research will be mainly conducted in the Faculty of Information Technology and Electrical Engineering, at the Department of Information Security and Communication Technology (IIK). IIK (https://www.ntnu.edu/iik) hosts several national and NTNU research laboratories/centres.

Role in the ecosystem: academia

Strategy for joining the project

Within the strategy of NTNU (networking group within the IIK department), service differentiation has been identified as one core component required to increase the sustainability of communications technology. NTNU joined the TeraFlow Consortium since it includes inter-operator connectivity beyond pure reachability as provided by the BGP protocol thus allowing to investigate the capabilities of beyond best-effort packet forwarding in multi-provider scenarios. NTNU plans to use the results of these studies to influence policymaking, standardization, and regulation on a national and European level. This includes participation at events and meetings like the TM-Forum and relevant ITU-T study groups. Further, the results will be used within specific lectures like TTM4128 "Network and Service Management".

Results and business opportunities

NTNU is generating knowledge from the SDN automation and transport slicing and aggregation focusing at mapping of flows to transport aggregates, inter-domain networking across B5G networks and business models analysis.

-Business opportunities identified:

Generally speaking, we believe that the knowledge acquired from TeraFlow project can help NTNU for further research lines and education within available courses. To support this, we are planning to co-author 4-5 paper submissions to conferences and journals related to the project.

Evaluation of the impact of new technologies on the existing and newly created business models will show their economic impact and demonstrate the applicability of the TeraFlow system.

Efficient and application-specific aggregation and mapping of flows to aggregates might enable a more efficient usage of network resources.

Interdomain signalling approaches have been around for some time now, but no technology-independent solution beyond BGP, which offers pure connectivity, exists. By enabling inter-domain QoS signalling approaches new business models for telcos like connectivity with assured QoS guarantees might be enabled.

5.3. Operators

5.3.1. Telenor Norway AS (TNOR)

Brief description of the partner and role in the stakeholders' ecosystem

TNOR is an international provider of high-quality telecommunications, data and media communication.

Role in the ecosystem: TNOR has the perspective of a network service operator (NSP), mostly denoted "operator" in TeraFlow.

Strategy for joining the project

TeraFlow is addressing a core technological and business area for network operators and can enable TNOR to enter the more mature 5G and B5G market phases with key service and operational capabilities and services concepts and offerings. A general strategy is to enter into many vertical markets with new 5G/B5G services. In particular, TNOR aims to offer Network Slice as a Service (NSaaS) to both external enterprise customer, company internal units (the internal communication service provider (CSP)), and other network operators. In this respect, the service concept of Logical Network as a Service (LNaaS) will be key for the success of telecom operators. At the heart of LNaaS and NSaaS the service concept of Transport Network Slice as a Service (TNSaaS) will be a highly critical service and operational capability. TeraFlow, is addressing these service components both from a technical and a business enabler point of view while considering automation and realistic operational contexts. In summary, TNOR has the following motivation for joining TeraFlow:

- Develop key 5G/B5G operational capabilities, where automation and SLA management are key topics
- Develop 5G/B5G services concepts and offerings
- Develop service enablers building on LNaaS / NSaaS / TNSaaS service concepts, focusing on LNaaS

Drawing on previous EU projects ETICS and 5G-Exchange, as well 5G-VINNI, TNOR expects to achieve results within innovative service concepts, SLAs, and related mechanisms for provisioning and automation. The service concepts firstly address offerings to and interaction with various tenant and customer actor roles. Second, the services concern NSP – 2 – NSP, or a next generation of Telco peering. The general concept of Point-of-Interconnection (PoI) – 2 – Region will be further developed in the context of various business relationship and traffic engineering mechanisms. From the CSPs' angle, TNOR's goal is to develop a new generation of value-added connectivity (VAC, aka. Specialized

Connectivity Service, SCS) service layers, fitting into various NSaaS / LNaaS settings. The goal includes technological as well as business capabilities.

Results and business opportunities

1. Name and type of result: Slice Manager component of TeraFlow OS (KER 7), knowledge on 5G/B5G operational capabilities

-Description: Build testbed to demonstrate and validate the possibility to implement a standardized and open SDN controller in the transport network. The same for innovative NetApps. Identify success and failure factors.

-Partners involved: TNOR

-Business opportunities identified:

Joint contribution in terms of operational tasks addressing SLA management, including service assurance, based on zero-touch automation principles. From this, we expect to share, assess, align, and implement key 5G/B5G operational capabilities in TNOR as well as to exchange insight with strategy and operation units in the Telenor Group.

2. Name and type of result: Interdomain component of TeraFlow OS (KER 12), knowledge on 5G/B5G services concepts and offerings, as well as on Logical Networks as a Service enablers

-Description: Elaborate on operator's point of view and thus, contribute to design, implementation and experimentation of e.g., Transport network slice as a service. Design, and experiment and evaluate the technological viability of Logical Network as a Service, enabled by TeraFlow developments

-Partners involved: TNOR, NTNU, CTTC

-Business opportunities identified:

Joint contribution in terms of service and information models, APIs, and their workflows. From this contribution, TNOR aims for 5G/B5G commercialization and the results will be progressed directly into ongoing strategies and activities. Service Concept development, assessment, and alignment within TNOR and with partner Telcos. Exchange insight with strategy and operation units in the Telenor Group. This will include addressing of international and partner activities for standardization, collaboration, and service concept alignment.

5.3.2. Telefonica Investigación y Desarrollo SA (TID)

Brief description of the partner and role in the stakeholders' ecosystem

TID is a research centre associated with a large national telecommunications operator. It has a proven track of direct activity and leadership in activities and projects related to 5G and Beyond-5G in the area of transport networks.

Role in the ecosystem: TID has the perspective of a network service operator (NSP), mostly denoted "operator" in TeraFlow.

Strategy for joining the project

Telefonica joined TeraFlow because it is totally aligned with our Transport SDN architecture and implementation methodology. Both Telefonica and TeraFlow architectures are based on standards interfaces enabling network programmability in vendor agnostic transport networks. According to it, we aim to design, standardize and implement the required interfaces for new use cases in 5G networks (e.g., network slicing). Telefonica aims to implement these interfaces in transport networks once they are designed, standardized and technically validated.

In the security area, we are interested in identifying new technologies for securing SDN architectures on Telco networks, before mainstream adoption. To this end we will investigate new tools and mechanism based on AI and network telemetry, so it can be standardized and transferred to industry (IPR, proof of concepts, opensource). We will rely on partners (universities, technological centres, SME, providers, etc.) for collaboration.

Results and business opportunities

1. Name and type of result: Service and Device components (KER 4, KER 3)

-Description: Standard programming interfaces (APIs) which could be implemented in vendor agnostic transport networks for the new 5G use cases proposed in TeraFlow. Some of the analysed interfaces are part of the Service and Device components and detailed in D2.1[2].

-Partners involved: TID, CTTC, SIAE, INF, UBI.

-Business opportunities identified:

Network operators could have more open and flexible networks. Open market for both network application developers, which could use standard programming interfaces, and “white box” providers which could easily integrate their solutions in vendor agnostic SDN architectures using standard device configuration interfaces.

2. Name and type of result: Cybersecurity component (KER 11)

-Description: Adoption of cybersecurity netApp in the SDN Control plane will be focus to Telefonica as network operators as an internal service, but it is also open to commercial security services.

-Partners involved: TID, UPM, CHA.

-Business opportunities identified:

In security area knowledge transfers to internal business units and, based on case by case agreements, to vendors (for example prototype software transfer, patents). Also, standardization process is proposed to adopt common results in terms of interfaces and protocols.

6. Dissemination and Communication Activities

As described in D6.1, communication and dissemination activities represent an essential effort of the project to raise awareness and maximise the visibility of the project results and progress among key stakeholders potentially interested in adopting the technologies and solutions developed within the project, and among a wide range of audiences to demonstrate the commitment and interest of the European Commission to boost European innovation of ICT for various sectors through this type of projects.

TeraFlow strategy considers both dissemination and communication activities. The first one refers to the public disclosure of the results to various stakeholders such as research peers, industry, potential end-users, policymakers, standardisation bodies, and others that could adopt and integrate the results in their work. On the other hand, communication covers the promotion of the action and results to many audiences, including media and the public to build strong relationships and reach society.

This deliverable presents the report of communication and dissemination activities done by the Consortium partners between M1 and M11 of the project. The activities and metrics corresponding to M12 will be presented together with the report of the second reporting period on D6.4 (M30): Final report on Dissemination, Communication, Collaboration, Standardisation and Exploitation.

Within this period, T6.1: Stakeholder engagement, communication and dissemination has been working on various activities related to the objectives set and presented on D6.1:

- Ensuring maximum visibility and awareness of the project, its progress and results among key audiences by delivering relevant content to key target audiences on various digital channels.
- Boosting online and offline visibility by creating valuable content in different formats considering the brand and visual identity defined for the project.
- Disseminating the research and technological knowledge produced within the Consortium through the development, submission and publication of scientific papers and specialized articles.
- Attracting potential users, customers, early adopters, and related initiatives to support the exploitation strategy, validate the business models, promote the early uptake by organising events, demo sessions and workshops focused on engagement, generation of value and establishing long-lasting relationships.

As shown in Figure 7, the strategy comprising the various dissemination and communication activities were defined taking into consideration the duration of the project, the experience and potential contribution of the partners, the planned technical progress, and the main milestones in relation to the launch of the TeraFlow OS and components.

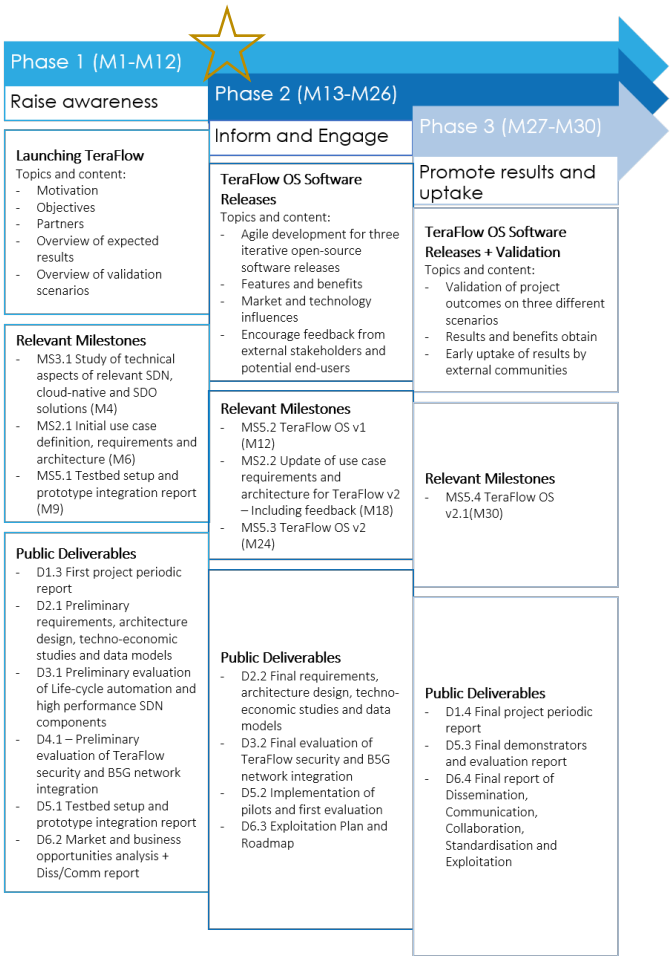


Figure 7: TeraFlow Communication & Dissemination Strategy

Right now, we are reaching the end of the first phase where all the efforts have revolved around raising awareness about the project motivation, objectives, partners, expected results, and validation scenarios.

Within the first year, the Consortium has actively participated towards this goal by presenting TeraFlow at various events, conferences, standardisation meetings, and by submitting multiple scientific papers to renowned journals and conferences. Moreover, partners have leveraged various opportunities to liaise with related projects and organise workshops to raise awareness about the project.

To support the participation of partners and give visibility to the multiple activities executed, TeraFlow has promoted all of these on the project website and social media accounts which by the date of development of this document have reached a significant number of followers and metrics indicating that the content developed is attractive and therefore well received by audiences.

The activities to be executed within Phase 2 of the project, starting January 2022, will aim to support and promote the launch of the TeraFlow OS as the main milestone reached within that period, to inform and engage with key stakeholders. The availability of more mature and robust results encompassed with the release will allow the set-up of more business-oriented activities that can be leveraged by the business modelling and exploitation tasks to gather feedback and validate plans which will require the expectations and needs of these groups.

The following sections describe and report the specific activities and KPIs achieved until M11.

6.1. TeraFlow Website

The project website (https://teraflow-h2020.eu/) was created on Drupal CMS considering various SEO best practices and requirements for enhancing the organic positioning on search engines, such as the monitoring and analysis of keywords, increasing the number of internal and external links, and fulfilling accessibility requirements to offer valuable content to visitors regardless of the type of device they use to visit the website.

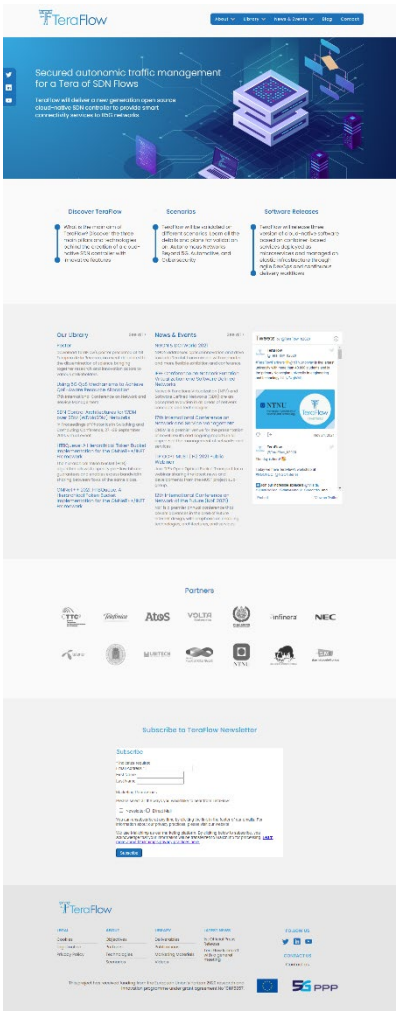


Figure 8: TeraFlow website - homepage

The website is the main communication channel used by the project to inform external audiences of the motivation, progress, knowledge, and various activities aiming to raise awareness and increase the visibility of the action.

With some static pages, until now, the website presents general information about the project on the "About section", including the project objectives, partners, technologies, and validation scenarios. Nevertheless, it is important to state that to reflect an up-to-date status of the project, these static pages will be updated with every launch of the TeraFlow OS and with the release of the components. Also, the main menu structure will be modified to give more visibility to other pages as the new content and results become available. As such, the releases and validation scenarios pages will be moved to the main menu, and specific pages will be created for each one of the scenarios.

Furthermore, the website has some pages that are constantly updated as new activities or content are developed by Consortium partners. These pages present information regarding deliverables, publications, videos, marketing materials, news, events and newsletters.

Likewise, the website will have a blog section in 2022, with a first blog post on the TeraFlow OS. The idea is that the content presented in this section will cover a wide range of topics where the project is working and developing innovative components to communicate the technical progress and share the partners' knowledge through relevant content.

All the new content uploaded to the website is highly promoted through the project and partners' social media accounts to maximise the reach, inform followers and interested parties, and then drive traffic to the website where visitors can get more information about a specific topic.

We use Google Analytics to monitor and measure relevant metrics that indicate the traffic of the website to understand if the content provided is well received by visitors. Figure 9 presents data on the number of users, session, page views, and average session duration.

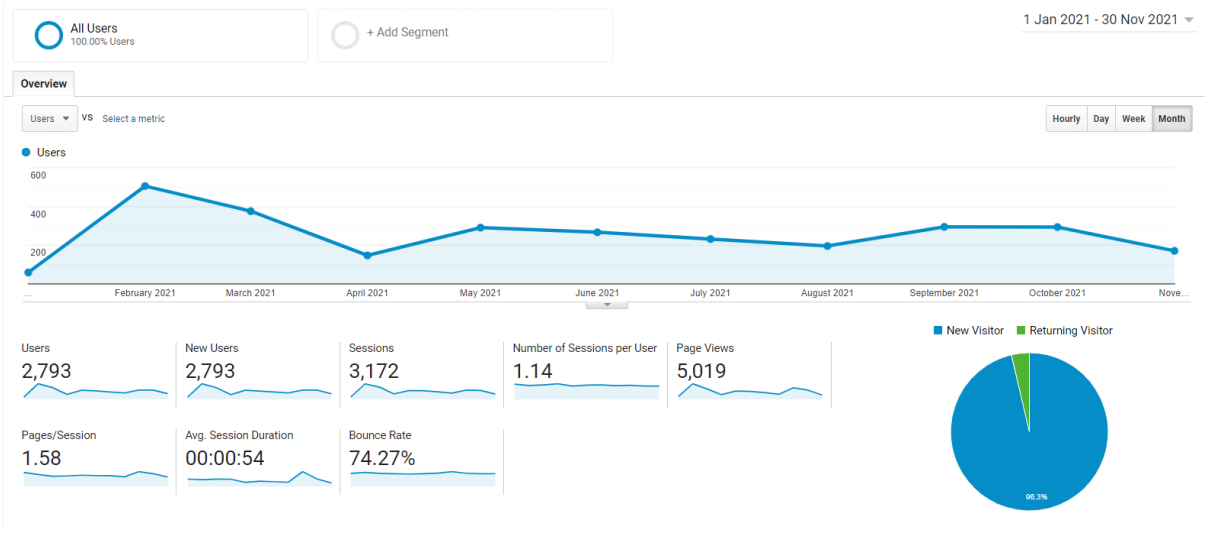


Figure 9: Website Audience Overview - M1-M11

According to the data presented, over the first eleven months of the project, we have had 2,793 users who have initiated at least one session of the website. This number is a good indicator so far that we are meeting the objective of increasing the visibility of the project and raising awareness about its objectives and expected results. Also, we have had 3,172 sessions, which is the period of time a user is actively engaged with the website, resulting in over 5,000 page views of the different content offered. Regarding average session duration, 00:54 is a good metric for an informative website as it is the purpose of TeraFlow's by presenting general information about the project. We intend to raise this time through the launch of the blog posts and the revamp with content and structure that gives more visibility to the TeraFlow OS release and the validation scenarios. The fact that more than 96% of the traffic corresponds to new visits supports the objective of raising awareness about the project.

Most of the visits come from countries represented by TeraFlow partners such as Spain, Germany, Italy, UK, and Norway. However, it is interesting to see that there are visitors from other EU countries as France and Netherlands, and from non-EU countries such as the United States, China and Brazil, which means that the content and work done by the project is reaching other territories which are also driving innovation and research on the topics covered by TeraFlow.

	Country	Users	% Users
1.	Spain	521	18.62%
2.	United States	303	10.83%
3.	Germany	246	8.79%
4.	Italy	238	8.51%
5.	China	224	8.01%
6.	France	127	4.54%
7.	United Kingdom	126	4.50%
8.	Brazil	106	3.79%
9.	Norway	93	3.32%
10.	Netherlands	75	2.68%

Figure 10: Website traffic by country - M1-M11

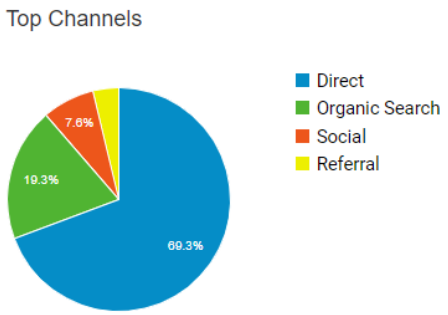


Figure 11: Website traffic acquisition - M1-M11

Most of the traffic (69.3%) comes from direct search, which means visitors that entered the site address in the browser, accessed through a saved tab, or clicked on a specific link containing the website address. This is a result of the link-building strategy and the achievement of non-scientific publications on external websites that are adding information about the project, and in some cases, the link to the website. The organic search (19.3%) is the traffic coming from unpaid search results on search engines such as Google, Yahoo, or Bing. This is directly related to the SEO positioning thanks to the monitoring and use of relevant keywords in the content provided, following accessibility guidelines, and having a strong link-building strategy. Finally, the social traffic (7.6%) reflects that a good portion of visitors is coming from the publications made on social networks of the project, partners, and 3rd parties, especially on Twitter and LinkedIn, which is one of our main tactics to increase the traffic of the website.

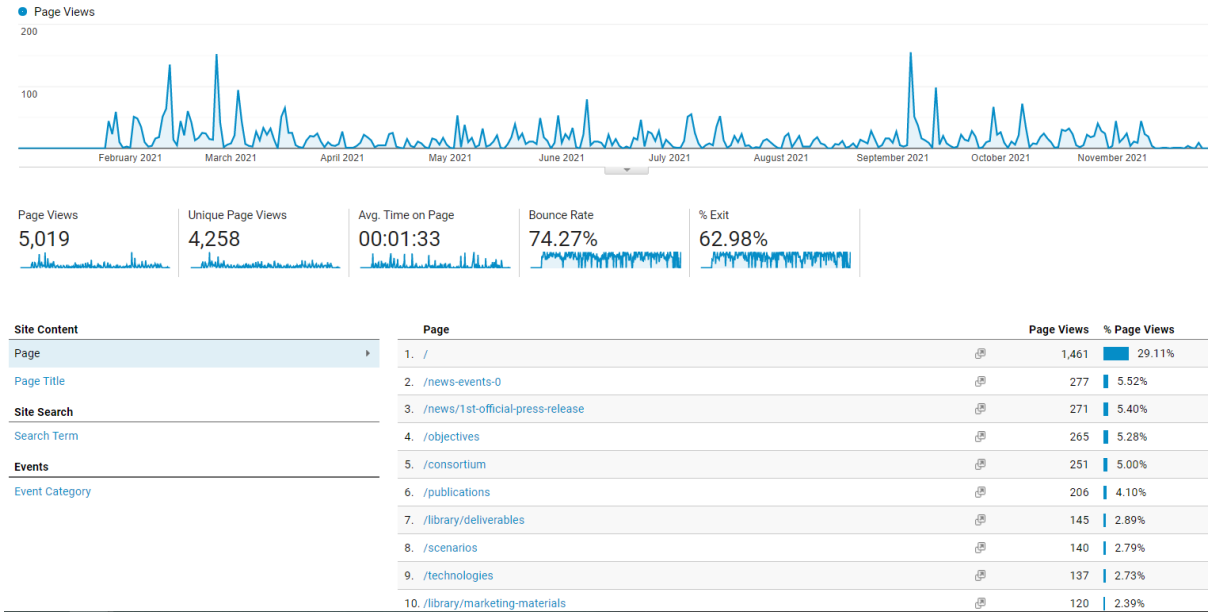


Figure 12: Website - Overview of visitors' behaviour - M1-M11

In summary, Figure 12 presents a more in-depth analysis of the 5,019 pageviews which are related to the 4,258 unique page views indicating the number of sessions during which a specified page was visited at least once. In this case, the average time on page increases to 1:33. The homepage, news and events section, and the press release are the most visited pages. The idea for phase 2 is to increase traffic to publications, deliverables and release sections as a way to demonstrate that the content about the progress of the project is being read by visitors.

The metrics achieved so far are in accordance with what was expected and in line with the KPIs presented at D6.1.

6.2. Social Media

Social media accounts of the project on Twitter and LinkedIn have been used to promote and give visibility to specific actions and information about the TeraFlow project, the results, partners, and other topics identified. Also, there has been some work in relation to tracking relevant conversations and identifying related accounts that might be interested in the work done within the project to engage with specific initiatives, projects, and organisations.

On the other hand, the publication of posts about TeraFlow on the social media accounts of partners, standardisation bodies, 5G PPP, among others, has been beneficial in terms of the increase of engagement rates and interactions among key target audiences that at the same time boosts the visibility and positioning of the project.

6.2.1. Twitter

The Twitter account (@TeraFlow_h2020) promotes general information about the project progress with a special focus on publications, news and events. Content about different topics is posted regularly to provide followers with relevant information. Also, information posted by other accounts is retweeted and liked to generate interaction with key accounts while also amplifying the scope of the content offered by TeraFlow.

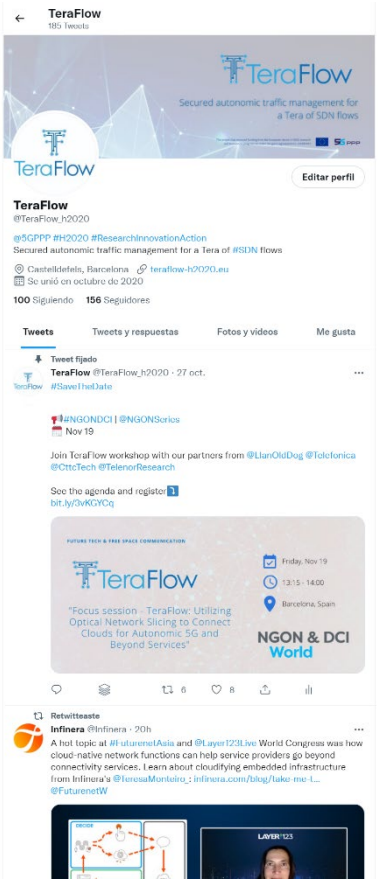


Figure 13: TeraFlow Twitter

As mentioned in D6.1, some best practices are being followed to boost the positioning of the account, such as:

- Use analytics to monitor if the content created and posted is attractive enough for followers and based on that, identify topics that should be covered on social media
- Monitor accounts of events, projects, thought leaders, and organisations either working on similar topics, or potentially interested in adopting the project's results
- Plan campaigns about specific topics in advance to guarantee variability of content and leverage all the communication opportunities arising from partners' activities
- Use relevant hashtags to amplify the reach and get involved with trending topics that apply to TeraFlow's field of action
- Make clear calls-to-action to drive traffic from Twitter to the website of the project, which helps to increase the number of unique visitors
- Use attractive banners, visuals and emojis increase engagement rates and interaction of followers with our content

Between M1 and M11, a total of 188 tweets have been done at the TeraFlow account. From the total, 93 correspond to original content posted from the account, and 95 have been done via RT or interactions with other accounts. This demonstrates a good balance of content about the project and content related to the topics of interest which are being shared. From this, we can highlight the variability of content and interaction with other accounts for paving the way for potential

collaborations in the future. The following graphic presents the number of original posts done by TeraFlow each month.

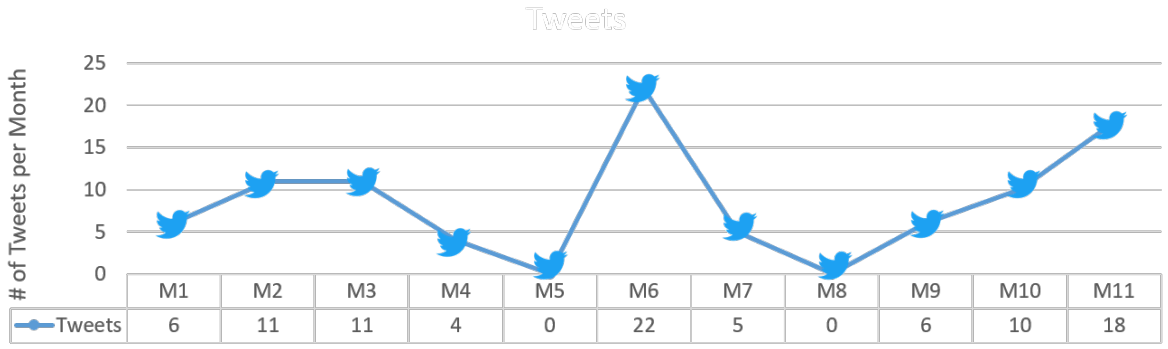


Figure 14: TeraFlow - Tweets per month

The number of posts is related to the number of activities and events where the project is participating. As shown in the image, no original posts were made in May and August, which is related to the lack of events or content to share and the end of the summer period, respectively. Nevertheless, the interaction and reposting of other accounts' content contributed to raising other metrics such as impressions, followers and engagement rate. We prioritize quality over quantity, although it has been established that we should tweet original content at least twice a week for keeping followers engaged and informed with TeraFlow's work.

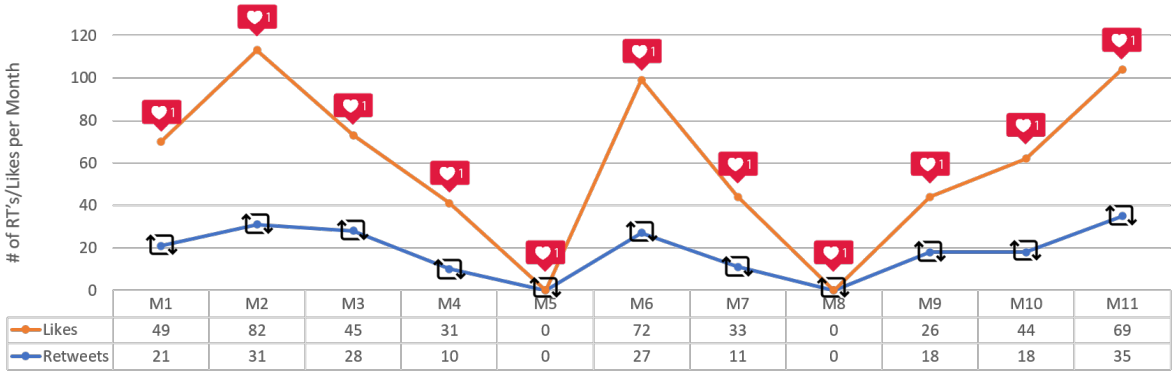


Figure 15: Likes and RT's per month

The metrics achieved for likes and retweets demonstrate how the original content is perceived by the followers or Twitter users in general. Until M11, we have 199 retweets and 451 likes which have contributed to amplifying the reach of our posts and maximising the impact of the project's communications. The numbers accomplished align with the expectations especially considering the frequency of posts done per month. As mentioned previously, by guaranteeing at least 2 original posts per week we expect to increase these numbers. Also, the organization of events in collaboration with other projects during 2022 will contribute to more relevant content to post and enhance interaction actions.

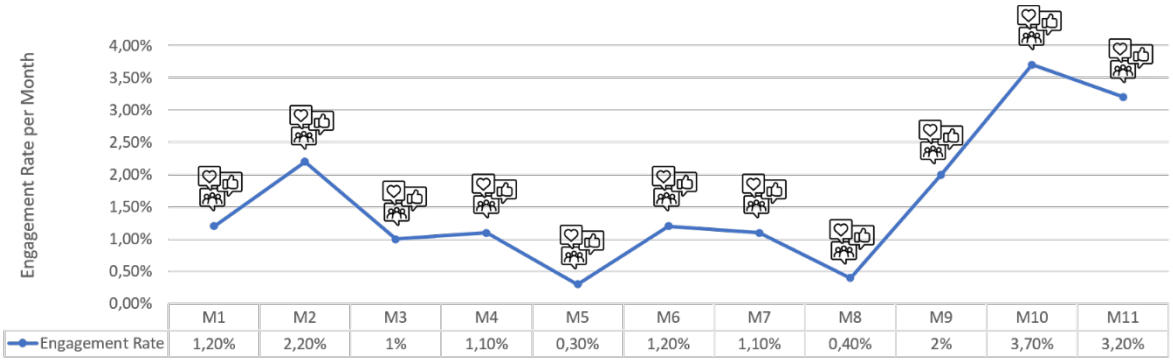


Figure 16: Twitter Engagement Rate

To measure the level of interaction by followers from content created by TeraFlow, the engagement rate indicates a % over the number of posts and interactions, which was presented on the two previous images. As stated in D6.1, the target by the end of the project for this metric is ≥ 1.2%. It can be seen in the image that in most months this percentage has been exceeded what makes it possible that the average of the first eleven months is 1.7%. Even though there were no original posts made by TeraFlow in May and August, followers interacted with content already presented in the account which resulted in rates of 0,30% and 0,40% respectively. We intend to continue having an average of at least 1.5% for Phase 2.

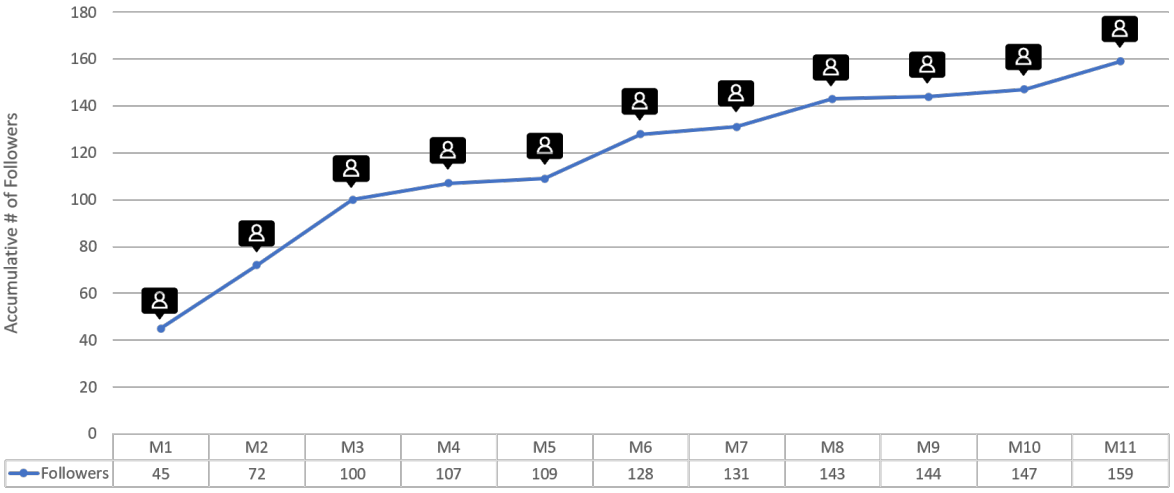


Figure 17: Twitter – Followers' evolution - M1-M11

Despite some negative peaks in terms of no original content posted, Figure 17 demonstrates how the account has been getting followers at a steady pace that increases between 2 and 8 new followers each month. Recently the project announced surpassing the first 150 followers, which can be considered an important milestone for the Twitter account.

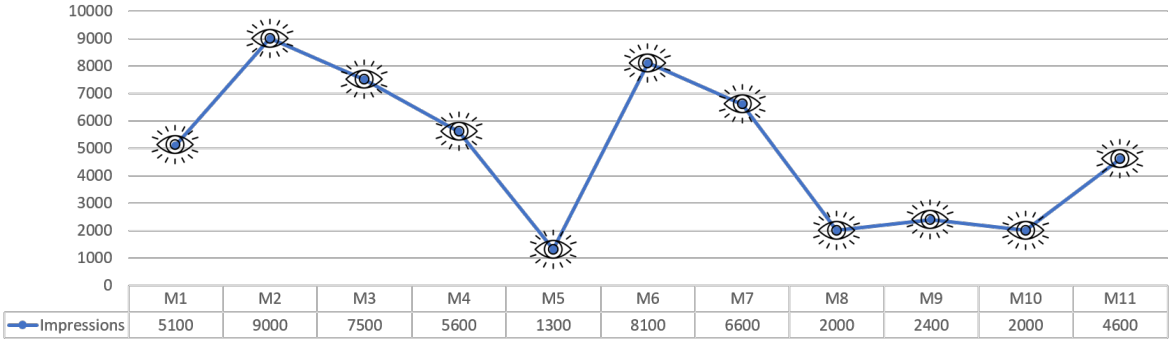


Figure 18: Twitter impressions - M1-M11

The final metric analysed on Twitter corresponds to the impressions, which are the total of times a user has seen TeraFlow's own tweets. In this case, the total accumulated of 54,200 impressions have been gathered organically. With some ups and downs, the minimum number of impressions was 1300 during May and since August it has started to grow thanks to the increase of the post frequency slowly. It is wished to have at least 2000 impressions per month until the end of the project.

6.2.2. LinkedIn

TeraFlow's Company page on LinkedIn is another essential part of the project's digital strategy. This social network targets more professional audiences and connects the project with specialized profiles that could be potentially interested in the project results.

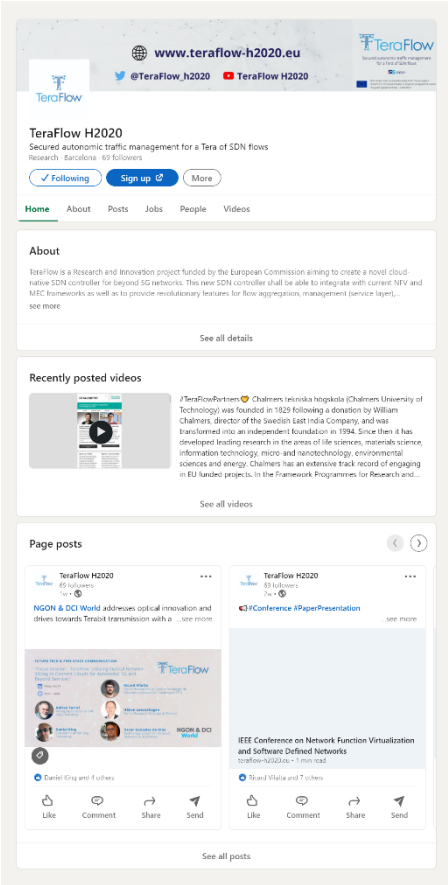


Figure 19: TeraFlow LinkedIn

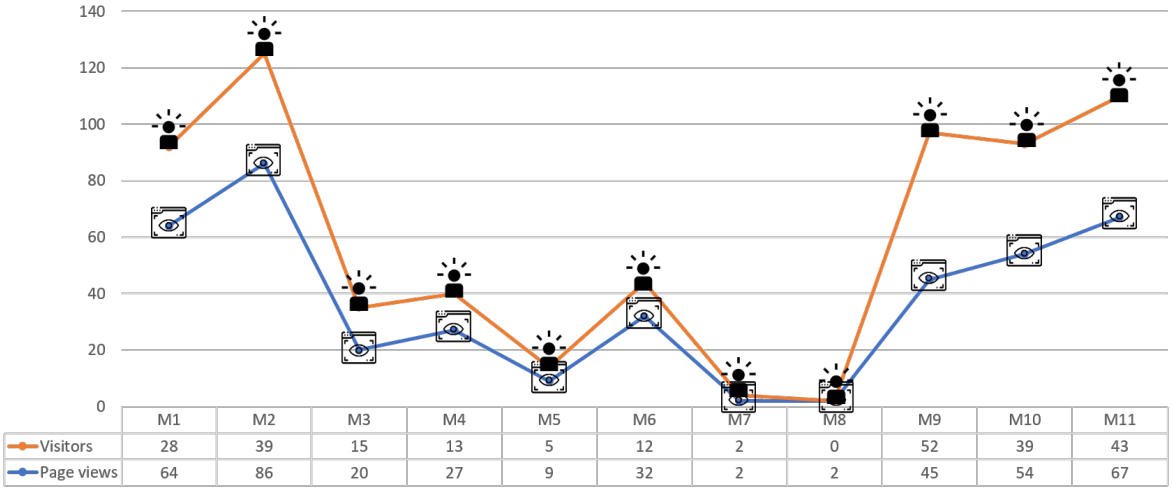
The frequency of posting on LinkedIn is less in comparison to Twitter, but at the same time, the length and information included in these posts cover what can be covered over 3-4 Tweets. In this case, what matters are the rates and metrics indicating reactions from followers, which indicate if the content is well received by followers or not.

For this purpose, the project is also following some best practices focused on B2B marketing to provide the community of interest around TeraFlow with valuable content that will be helpful for us to engage directly with them in upcoming phases of the strategy. These are:

- Make a monthly analysis of the content, and the interactions achieved using the analytics provided by LinkedIn
- Use original visuals and banners to increase reactions and engagement rates
- Repost content mentioning TeraFlow, and interact with posts made by 3rd parties working on similar topics
- Include calls-to-action to visit the website for getting more information about the specific topic promoted on the post

As part of Phase 2 of the strategy and to strengthen thought leadership, LinkedIn will become an essential tool to share the blog posts produced within the project by the various partners participating in TeraFlow. Also, to better engage with external parties and other H2020 projects, TeraFlow will have guests providing content as a blog post for LinkedIn.

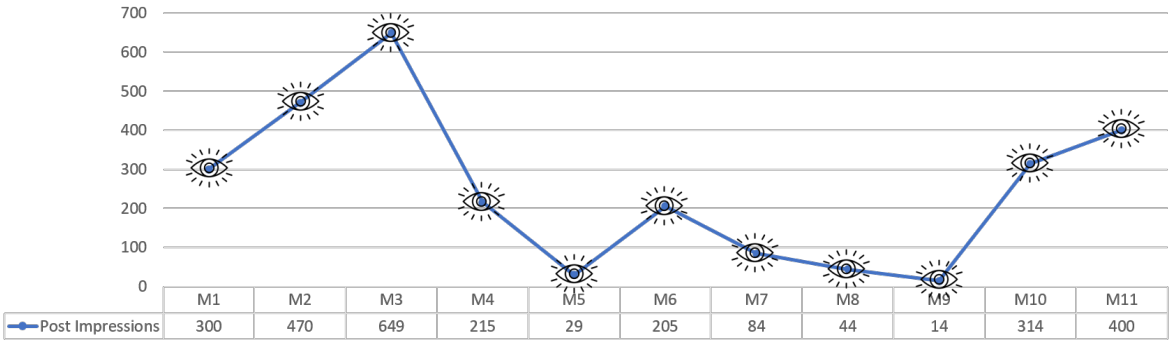
The following figures present an analysis of the metrics achieved per month on the LinkedIn account:



	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
Visitors	28	39	15	13	5	12	2	0	52	39	43
Page views	64	86	20	27	9	32	2	2	45	54	67

Figure 20: LinkedIn Visitors and Page Views - M1-M11

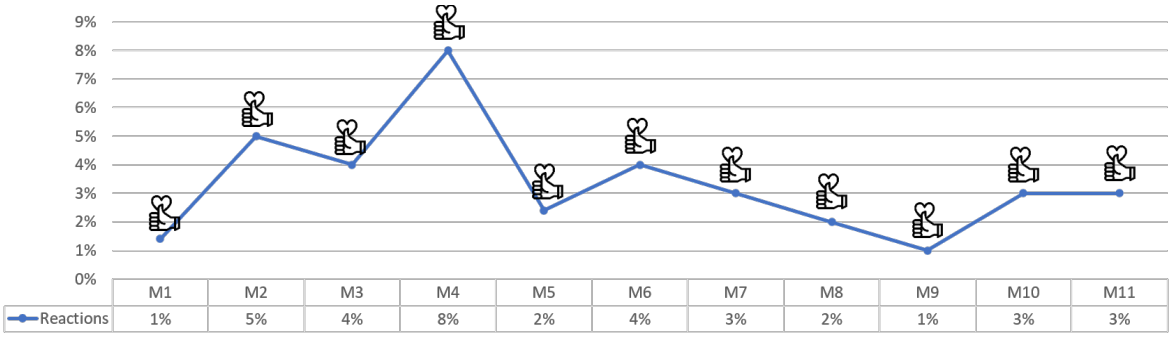
The number of visitors and page views has been fluctuating between M3 and M8 with some high peaks during months of more events such as June. Since September, the account has experienced a considerable increase on numbers with more than 40 visitors and page views per month. These metrics are tightly related to the content shared on the account which is not as frequent as in Twitter. Therefore, the team will increase the number of posts with the publication of blog posts and other original content from the project and/or related initiatives. In total, there have been 408 page views and 250 visitors within the first 11 months of the project.



	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
Post Impressions	300	470	649	215	29	205	84	44	14	314	400

Figure 21: LinkedIn Post Impressions - M1-M11

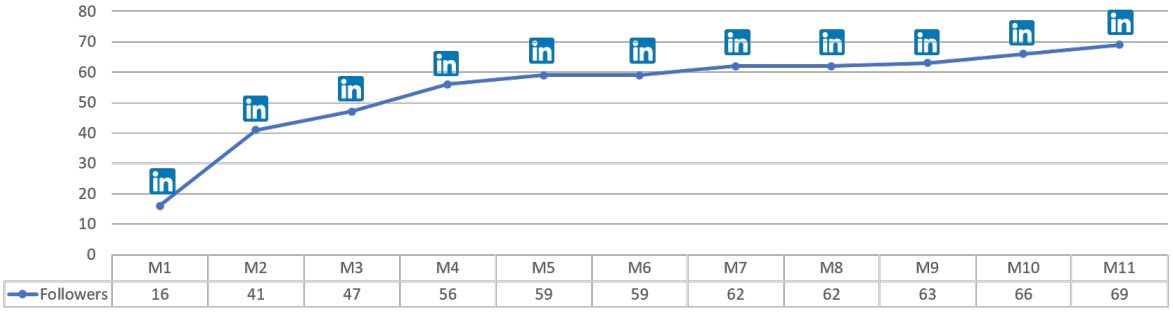
In a similar fashion, the post impressions have decreased after M3 and have been fluctuating until M9, being June the month with most post impressions within that period. After M9, the impressions of the posts have increased which is a direct relation to the increase of the posts to at least 3 posts per month. In total, we have achieved 2724 posts impressions until M11.



	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
Reactions	1%	5%	4%	8%	2%	4%	3%	2%	1%	3%	3%

Figure 22: LinkedIn Reactions - M1-M11

Even though the number and frequency of posts have been lower, in comparison to Twitter, the reactions percentage demonstrates that we are providing quality content on LinkedIn that followers and visitors are interacting with. We have had an average reaction rate of 4% since the beginning of the project which is a really good indicator that the posts have meaningful interactions.



	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
Followers	16	41	47	56	59	59	62	62	63	66	69

Figure 23: LinkedIn Followers

The followers on the LinkedIn account have been slowly increasing since the beginning of the project until reaching 69 by M11.

In general, the performance on this social network has been good in accordance with the target set by the end of the project. Still, there's room for improvement in terms of increasing the number of posts with content such as the blog post which will positively impact the other metrics on reactions, page views, posts impressions, among others. Moreover, in the next phases, we intend to actively engage with relevant professionals that could be potentially interested in collaborating with the project.

6.2.3. YouTube

A TeraFlow YouTube channel was created to upload different types of videos such as animated videos on the project objectives and results (e.g., TeraFlow OS release), video interviews with partners, recordings of event's presentations, webinars, and tutorials/demos produced by the project partners to present the progress of the technical development and its results in a visual way.

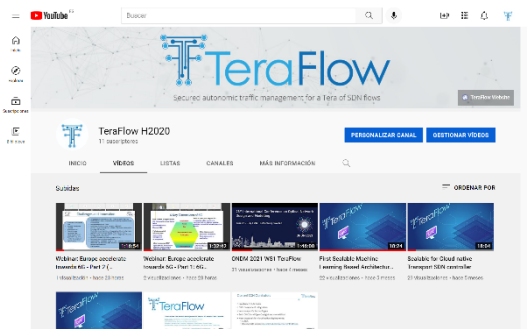


Figure 24: YouTube Channel

At M11, the channel has 11 subscribers and 8 videos have been uploaded, with a total of views over 190. All the

videos have been uploaded to the video section at the website, and in some cases to the specific event entry to facilitate user navigation and make related content available in a more structured way. Moreover, the presentations' recordings at events that have been uploaded on external events' YouTube channels have been uploaded to the video section, but not to our YouTube account since we don't want to duplicate content.

6.3. Communication material

Between M1 and M11, TeraFlow has produced different types of communication material used at events to increase the project's visibility and position the project's visual identity.

D6.1 shows some of the material created:

- PPT Template
- Project Overview PPT
- Poster Template
- Virtual backgrounds
- Newsletter Template
- Social Media banners

On top of that material, the following images present a poster of the project created by CTTC for the European Researchers Night event, new banners for promoting specific activities of the project on social media, and the 1st newsletter of the project.

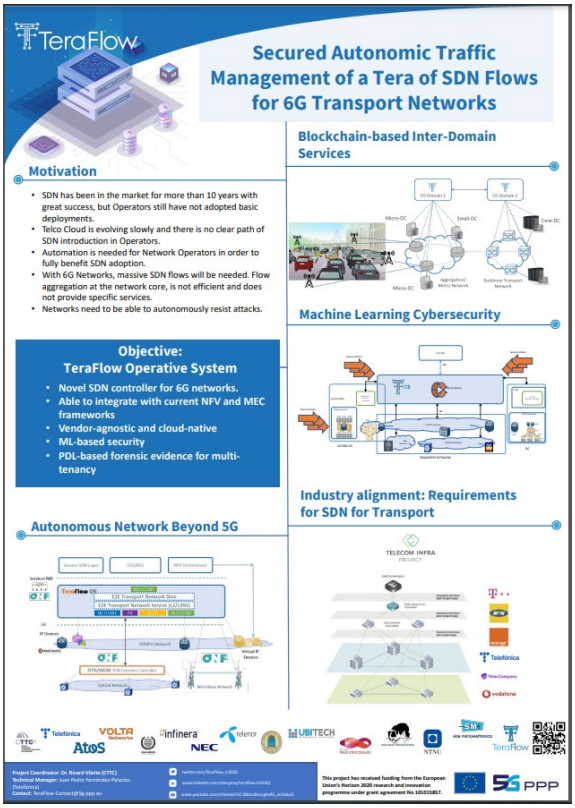


Figure 25: TeraFlow Poster

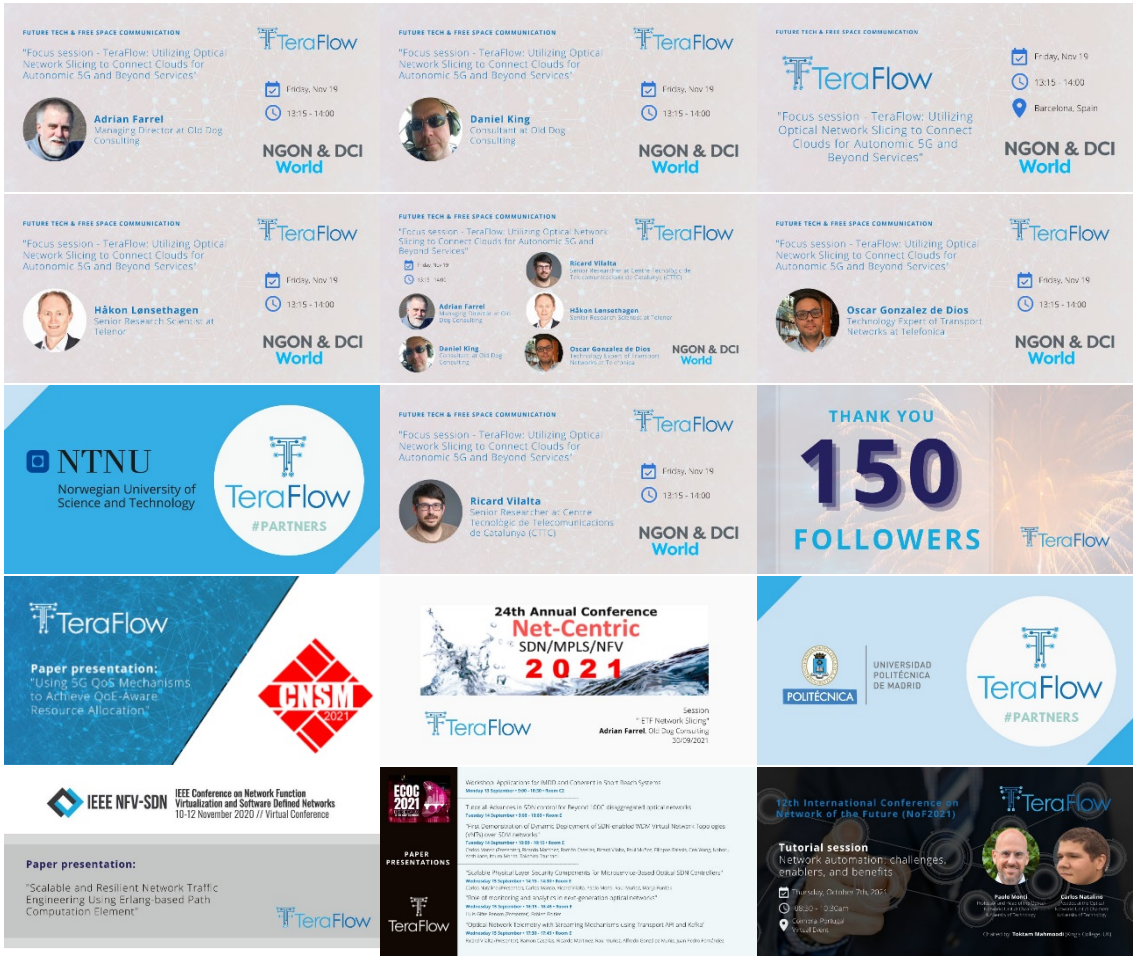


Figure 26: Social Media Banners

Figure 27: TeraFlow Newsletter #1

More communication material will be produced along with the project's life to support raising awareness about TeraFlow and provide useful content to external audiences in an attractive graphical way. Even though at the development of D6.1 we have foreseen the preparation of a flyer and a promotional video about the project's ambition, concept, and expected results, it was decided to focus this production and development effort to communicate one of the most important milestones of the project: the 1st release of the TeraFlow OS.

6.4. Journal Publications and Scientific Papers

Generating impact and disseminating the project's findings and results among research and academic communities has been mainly done through the active development of papers and its posterior presentation and publication at important conferences and journals.

All papers are uploaded to the project website and ZENODO Community whenever the PDF becomes available at the respective conferences' proceedings or publication of the journal. Moreover, this content is promoted through social media and included in the project's newsletter.

The following table presents the 20 scientific papers that have been submitted and published between at journals and conferences M1 and M11:

Table 1: TeraFlow Publications (M1-M11)

Type	Title	Authors	Title of the Journal/Proc./Book	Link
Conference	End-to-End Network Slice Stitching using Blockchain-based Peer-to-Peer Network Slice Managers and Transport SDN Controllers	Pol Alemany, Ricard Vilalta, Raul Muñoz, Ramon Casellas and Ricardo Martínez	OFC 2021 - The Optical Networking and Communication Conference & Exhibition	https://ieeexplore.ieee.org/document/9489482
Conference	First Scalable Machine Learning Based Architecture for Cloud-native Transport SDN Controller	Carlos Manso, Noboru Yoshikane, Ricard Vilalta, Raul Muñoz, Ramon Casellas, Ricardo Martínez, Cen Wang, Filippos Balasis, Takehiro Tsuritani, Itsuro Morita	OFC 2021 - The Optical Networking and Communication Conference & Exhibition	https://ieeexplore.ieee.org/abstract/document/9489435
Conference	Multi-layer Transport Network Slicing with Hard and Soft Isolation	A. Alcalá, S. Barguil, V. López, L.M. Contreras, C. Manso, P. Alemany, R. Casellas, R. Martínez, D. González-Pérez, X. Liu, J.M. Pulido, J.P. Fernández-Palacios, R. Muñz3, R. Vilalta	OFC 2021 - The Optical Networking and Communication Conference & Exhibition	https://zenodo.org/record/4756977#.YaUCd9DMJnK
Conference	TeraFlow: Secured Autonomic Traffic	Vilalta, Ricard; Muñoz, Raül; Casellas, Ramon;	European Conference on	https://zenodo.org/rec

	Management for a Tera of SDN Flows	Martínez, Ricardo; López, Víctor; González de Dios, Óscar; Pastor, Antonio; Katsikas, Georgios P.; Klaedtke, Felix; Monti, Paolo; Mozo, Alberto; Zinner, Thomas; Øverby, Harald; González-Díaz, Sergio; Lønsethagen, Hakon; Pulido, José-Miguel; King, Daniel	Networks and Communications & 6G Summit (EuCNC/6G Summit)	ord/5089970#.YaUCwtDMJnJ
Conference	Autonomous Security Management in Optical Networks	Carlos Natalino, Andrea Di Giglio, Marcho Schiano, Marija Furdek	OFC 2021 - The Optical Networking and Communication Conference & Exhibition	https://ieeexplore.ieee.org/document/9489575
Conference	Blockchain-Based Connectivity Provisioning in Multiple Transport SDN Domains	Pol Alemany, Ricard Vilalta, Raul Muñoz, Ramon Casellas, Ricardo Martínez	ONDM 2021 25th International Conference on Optical Network Design and Modelling	https://ieeexplore.ieee.org/document/9492411
Conference	Demo paper: Operationalizing partially disaggregated optical networks: An open standards-driven multi-vendor demonstration	E. Le Rouzic, A Lindgren, S. Melin, D. Provencher, R. Subramanian, R. Joyce, F. Moore, D. Reeves A. Rambaldi, P. Kaczmarek, K. Weeks, S. Neidlinger, G. Agrawal, S. Krishnamoha, B. Raszczyk, T. Uhlar, R. Casellas, O. Gonzalez de Dios, V. Lopez	OFC 2021 - The Optical Networking and Communication Conference & Exhibition	https://ieeexplore.ieee.org/document/9489763
Conference	Demo paper: Scalable for Cloud-native Transport SDN Controller Using GNPy and Machine Learning techniques for QoT estimation	Carlos Manso, Ricard Vilalta, Raul Muñoz, Ramon Casellas, Ricardo Martínez	OFC 2021 - The Optical Networking and Communication Conference & Exhibition	https://ieeexplore.ieee.org/document/9489436
Journal	Field trial of programmable L3 VPN service deployment using SDN-Based Multi-domain Service Provisioining over IP/Optical network	Samier Barguil, Victor Lopez, Cristyan Manta-Caro, Arturo Mayoral Lopez De Lerma, Oscar Gonzalez De Dios, Edward Echeverry, Juan Pedro Fernandez-Palacios, Janne Karvonen, Jutta Kemppainen, Natalia Maya, and Ricard Vilalta	IEEE networks	https://ieeexplore.ieee.org/document/9508928

Conference	Special Session: Autonomous Network Management towards 6G. Cloud-Native SDN Network Management for Beyond 5G Networks with TeraFlow	Ricard Vilalta, Raul Munoz, Ramon Casellas, Ricardo Martínez, Juan-Pedro Fernandez-Palacios, Georgios P. Katsikas, Thomas Zinner, Harald Øverby , Sergio Gonzalez-Diaz, Hakon Lønsethagenk , Jose-Miguel Pulido, Daniel King, Nicola Carapellese	European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit)	https://zenodo.org/record/5089908#.YaXXQtDMJnJ
Conference	Workshop: From 5G to 6G Automated and Intelligent SecuriTy: FAST. Cloud-Scale SDN Network Security in TeraFlow	Alberto Mozo, Antonio Pastor, Carlos Natalino, Marija Furdek, Rahul Bobba, Raul Muñoz, Ramon Casellas, Ricardo Martinez, Juan Pedro Fernández-Palacios, Ricard Vilalta, Stanislav Vakaruk	European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit)	https://zenodo.org/record/5089918#.YaXXtdDMJnJ
Conference	Optical Network Telemetry with Streaming Mechanisms using Transport API and Kafka	R. Vilalta, R. Casellas, R. Martínez, R. Munoz, A. Gonzalez-Muñiz, J.P. Fernandez-Palacios	2021 European Conference on Optical Communication (ECOC)	https://ieeexplore.ieee.org/document/9606002
Conference	Scalable Physical Layer Security Components for Microservice-Based Optical SDN Controllers	Carlos Natalino, Carlos Manso, Ricard Vilalta, Paolo Monti, Raul Muñoz, Marija Furd	2021 European Conference on Optical Communication (ECOC)	https://zenodo.org/record/5500101#.YaXYfdDMJnK
Conference	First Demonstration of Dynamic Deployment of SDN-enabled WDM Virtual Network Topologies (VNTs) over SDM networks	C. Manso, R. Muñoz, F. Balasis, R. Casellas, R. Vilalta, R. Martínez, C. Wang, N. Yoshikane, T. Tsuritani, I. Morita	2021 European Conference on Optical Communication (ECOC)	https://ieeexplore.ieee.org/document/9606167
Journal	Packet Optical Transport Network Slicing with Hard and Soft Isolation	S. Barguil, V. López, L.M. Contreras, O. González de Dios, A. Alcalá, C. Manso, P. Alemany, R. Casellas, R. Martínez, D. González-Pérez, X. Liu, J.M. Pulido, J.P. Fernández-Palacios, R. Muñoz, R. Vilalta	MDPI Photonics	https://www.mdpi.com/2076-3417/11/13/6219v

Conference	Using 5G QoS Mechanisms to Achieve QoE-Aware Resource Allocation	Marcin Bosk, Marija Gajic, Susanna Schwarzmann, Stanislav Lange, Riccardo Trivisonno, Clarissa Marquezan, Thomas Zinner	2021 17th International Conference on Network and Service Management (CNSM)	https://dl.ifip.org/db/conf/cnsm/cnsm2021/1570733570.pdf
Conference	Demo paper: Scalable and Resilient Network Traffic Engineering Using Erlang-based Path Computation Element	Sebastien Merle, Juan Pedro Fernández-Palacios, Oscar González de Dios, Lluís Gifre, Ricard Vilalta, Peer Stritzinger	VII IEEE Conference on Network Function Virtualization and Software Defined Networks (IEEE NFV-SDN 2021)	https://demossdn2021.github.io/#demonstrations (Not published yet)
Conference	Invited paper: Role of monitoring and analytics in next generation optical networks	Ll. Gifre, F. Boitier	2021 European Conference on Optical Communication (ECOC)	https://ieeexplore.ieee.org/document/9605997
Conference	HTBQueue: A Hierarchical Token Bucket Implementation for the OMNeT++/INET Framework	Marcin Bosk, Marija Gajic, Susanna Schwarzmann, Stanislav Lange and Thomas Zinner	8th OMNeT++ Community Summit, Virtual Summit	https://summit.omnetpp.org/2021/assets/pdf/OMNeT_2021_paper_8.pdf
Conference	SDN Control Architectures for WDM over SDM (WDMoSDM) Networks	R. Muñoz, N. Yoshikane, C. Manso, R. Casellas, R. Vilalta, R. Martínez, F. Balasis, C. Wang, T. Tsuritani, and I. Morita	Photonics in Switching and Computing 2021	https://zenodo.org/record/5520861#.YaXcndDMJnJ

As it is shown in the table, 18 publications were done at conferences being OFC 2021, EuCNC 2021, ECOC and PSC2021 some of the most important. Moreover, the type of publications varied from research paper to demo paper, workshop and in some cases, invited paper. Regarding Journals, 2 publications were published at IEEE Networks and MDPI Photonics.

The Consortium will continue developing relevant papers to share the work done within the project and demonstrate its progress and results at important venues targeting key stakeholders. Some of the conferences where TeraFlow aims to present papers and workshops next year are: EUCNC, OFC2022, ONDM, and ECOC2022.

To date, we can highlight the submission and acceptance of four papers to OFC2022, including a demo paper: “Demonstration of Zero-touch Device and L3-VPN Service Management using the TeraFlow Cloud-Native SDN Controller” which will demonstrate zero-touch device bootstrapping, monitoring, and L3-VPN service management using our novel OS SDN controller prototype.

Moreover, the partners' intention is to leverage potential opportunities arising from their involvement in other initiatives or H2020 projects as a way to raise awareness of the project and generate engagement/collaboration opportunities with 3rd parties.

6.5. Content strategy

The development of content targeting not only scientific and academic communities is essential to raise awareness about the project and connect with industrial stakeholders that could act as end-users of TeraFlow results.

Some non-technical content has been, and will be, produced to communicate the achievement of milestones and results to a wider audience. These include press releases, news entries at the project or partners' websites, and starting next year, blog posts.

Between M1 and M11 one press release was produced and issued by some of the Consortium partners. The press release communicated the beginning of the project and presented a short overview on the expected results.

The first press release was published on the project website and promoted through a dedicated social media campaign considering also external accounts from partners and related initiatives to maximise the impact and reach.

Other content on interesting news such as call for papers is frequently posted on the news section of the website although this is not considered press releases as they are not sent to media outlets for its posterior publication.

Moreover, the publication of information related to TeraFlow on external sites (media, partners website, event websites, etc) is an important part of the link building strategy that contributes to enhancing the website's organic positioning. Between M1 and M11, thirty-seven publications were done on different external websites reaching an estimated audience of more than 1 million people, as it is shown in the table below:

Table 2: TeraFlow publications @media, partners' websites, others

Type	Title	Source	Estimated Audience (Monthly Unique Visitors)[3]	Link
Partner	TeraFlow - Secured autonomic traffic management for a Tera of SDN flows	Atos Research and Innovation Website	1,860	https://booklet.atosresearch.eu/project/teraflow
Partner	UBITECH kicks off the TeraFlow Research and Innovation Action on	Ubitech Website	17,970	https://ubitech.eu/ubitech-kicks-off-the-teraflow-research-and-innovation-action-on-secured-

[3] The estimated audience reached has been calculated through the free online tool Siteworth Traffic (https://www.siteworthtraffic.com/) which provides data on the number of unique visitors of a website on a daily, monthly and yearly basis. The number presented in the tables for Estimated Audience Reached corresponds to the monthly unique visitors and it calculates all the people accessing the website. For estimating the number of people reading the news or article about TeraFlow we recommend considering only between 5% and 7% of the monthly views.

	Secured Autonomic Traffic Management for a Tera of SDN flows			autonomic-traffic-management-for-a-tera-of-sdn-flows/
External	EU-funded project TeraFlow to develop a novel and secure cloud-native SDN controller for beyond 5G networks	CORDIS	17,198.550	https://cordis.europa.eu/article/id/429114-eu-funded-project-teraflow-to-develop-a-novel-and-secure-cloud-native-sdn-controller-for-beyo
Partner	EU-funded project TeraFlow to develop a novel and secure cloud-native SDN controller for beyond 5G networks	Atos Research and Innovation Website	1,860	https://booklet.atosresearch.eu/press-releases/eu-funded-project-teraflow-develop-novel-and-secure-cloud-native-sdn-controller
Partner	CTTC leads a new project. Smart connectivity services to B5G networks	CTTC Website	24,210	http://www.cttc.es/teraflow/
External	TeraFlow Project page	5G PPP	24,780	https://5g-ppp.eu/teraflow/
Partner	Volta Networks joins TeraFlow to foster enhanced network management for large scale networks	VOLTA Website	19,950	https://voltanet.io/volta-networks-joins-teraflow/
Partner	TeraFlow Project page	CTTC Website	24,210	http://www.cttc.es/project/teraflow-secured-autonomic-traffic-management-for-a-tera-of-sdn-flows/
Media	TeraFlow project aims to foster a new generation of SDN controllers	Telecom TV	49,980	https://www.telecomtv.com/content/cloud-native/teraflow-project-aims-to-foster-a-new-generation-of-sdn-controllers-40829/
Partner	TeraFlow: next step in telecom operators' quest for open, virtual, and automated networks	VOLTA Website	19,950	https://voltanet.io/teraflow-next-step-in-telecom-operators-quest-for-open-virtual-and-automated-networks/
Media	EU Has Granted Over €95 Million in Funding for 6G Research	6G World	4,410	https://www.6gworld.com/exclusives/eu-has-granted-over-e95-million-in-funding-for-6g-research/
Partner	Networking Research Group	NTNU Website	251,070	https://www.ntnu.edu/iik/networking#/view/projects
Partner	Secured autonomic traffic management for a Tera of SDN flows (TeraFlow)	Chalmers Website	351,450	https://research.chalmers.se/en/project/10060

Internet-Draft	Challenges for the Internet Routing Infrastructure Introduced by Semantic Routing – Old Dog Consulting	IETF Watersprings	1,579.740 8,370	https://datatracker.ietf.org/doc/draft-king-irtf-challenges-in-routing/ http://www.watersprings.org/pub/id/draft-king-irtf-challenges-in-routing-02.html
External	TeraFlow Project page	Cyberwatching	2,250	https://www.cyberwatching.eu/projects/2810/teraflow
Event	Focus Session - TeraFlow: Utilizing Optical Network Slicing to Connect Clouds for Autonomic 5G and Beyond Services	NGON DCI	519,600	https://app.swapcard.com/event/ngon-and-dci-world-1/planning/UGxhbm5pbmdfNzI2NTM2 https://tmt.knect365.com/next-generation-optical-networking/agendasc/
Event	TeraFlow Posters European Corner 2021	La Nit de la Recerca	574	https://lanitdelarecerca.cat/teraflow/
Partner	TeraFlow presents advances in Scalable and Resilient Network Traffic Engineering at IEEE NFV-SDN	CTTC Website	24,210	http://www.cttc.es/teraflow-presents-advances-in-scalable-and-resilient-network-traffic-engineering-at-ieee-nfv-sdn/
Partner	TeraFlow workshop at ONDM 2021	CTTC Website	24,210	http://www.cttc.es/teraflow-workshop-at-ondm-2021/
Partner	CTTC participates again in the Mobile World Congress as an exhibitor	CTTC Website	24,210	http://www.cttc.es/cttc-participates-again-in-the-mobile-world-congress-as-an-exhibitor-3/
Partner	Building the nervous system of our society	CTTC Website	24,210	http://www.cttc.es/building-the-nervous-system-of-our-society/
External	Communication Networks - CTTC	Xafir	No info	https://xafir.cat/es/communication-networks/
Event	Full Program - WS1: Micro-service based autonomic traffic control in 5G and beyond	ONDM Event	351,450	https://ondm2021.chalmers.se/full-program/
External	TeraFlow – Startup page	Innospot	4,110	https://innospot.de/profiles/teraflow/
Event	5G-PPP Webinar: Europe accelerates towards 6G	H2020 NARD	No info	http://www.h2020.md/en/5g-ppp-webinar-europe-accelerates-towards-6g

External	1 April 2021 5G-PPP Webinar: Europe accelerates towards 6G	AI@Edge Website	No info	https://aiatedge.eu/5g-ppp-webinar-europe-accelerates-towards-6g/
Partner	What's Next for SDN Control?	INFINERA Website	27,120	https://www.infinera.com/blog/whats-next-for-sdn-control/tag/software-and-automation/
Event	EuCNC 6G Summit – Virtual Conference. Final Programme	EuCNC Website	10,740	https://www.eucnc.eu/wp-content/uploads/2021/06/Programa-EUCNC-Summit2021_V2i.pdf
External	Workshop on Automated and Intelligent Security at EuCNC 2021	INSPIRE 5GPlus Website	3,480	https://www.inspire-5gplus.eu/workshop-on-automated-and-intelligent-security-at-eucnc-2021/
Partner	Old Dog Consulting is a partner in the EU's Horizon 2020-funded TeraFlow	Old Dog Consulting Website	No info	http://www.olddog.co.uk/
External	OSM Research	OSM Website	145,560	https://osm.etsi.org/wikipub/index.php/Research
Internet Draft	Framework for IETF Network Slices	Funet.fi	286,590	https://www.funet.fi/pub/netinfo/internet-drafts/draft-ietf-teas-ietf-network-slices-05.txt
Event	2nd IFIP/IEEE International workshop on Fully-Flexible Internet Architectures and Protocols for the Next-Generation Tactile Internet (FlexNGIA 2022)	FlexNGIa Website	No info	https://www.flexngia.net/workshop-flexngia-2022
External	TeraFlow 1st newsletter	5G PPP	24,780	https://5g-ppp.eu/teraflow-1st-newsletter/
External	PHASE 3.6: 5G INNOVATIONS AND BEYOND 5G	5G PPP	24,780	https://5g-ppp.eu/5g-ppp-phase-3-6-projects/
External	5G PPP Phase 3, Part 6 projects started in January 2021	5G PPP Newsflash	24,780	https://5g-ppp.eu/newsflash-january-2021/
External	5G-PPP Webinar: Europe accelerates towards 6G	5G PPP	24,780	https://5g-ppp.eu/event/5g-ppp-webinar-europe-accelerates-towards-6g/
Partner	New H2020 project on Smart Connectivity beyond 5G	Chalmers Newsletter	32,160	https://ui.ungpd.com/Issues/1e6e2ab8-934a-40e4-aba0-252388e40e57
External	Implemented engagement activities	NGINO Newsletter / NTNU	251,070	https://www.ntnu.edu/documents/1274239018/0/Newsletter+NGINO+October+-

				2020.pdf/c82218b2-a9d7-1fce-9bd7-dd1a7386d9d9?t=1602766316404
External	5G PPP Webinar: Europe accelerates towards 6G	5G PPP Newsflash	24,780	https://5g-ppp.eu/newsflash-march-2021/#lien2
External	5G PPP Projects – Phase 3 - Brochure	5G PPP Website	24,780	https://5g-ppp.eu/the-5g-ppp-phase-3-brochure-is-out/

Joined to this non-technical/scientific content presented in the table, the project newsletter is a powerful marketing tool that allows us to gather leads of people interested in the project and send them a newsletter informing of the progress of the project every 6 months. The newsletter is sent to the subscribers list on Mailchimp using a tailored template that contains the titles and short summary of the complete newsletter which is made on a PDF document which published on the website and promoted on social media channels. By doing so multiple benefits have been identified:

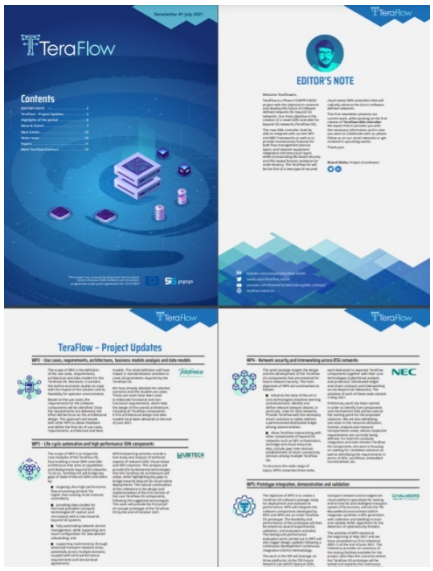


Figure 28: TeraFlow Newsletter #1 (Page 1-4)

- Collection of data of interested people respecting GPRD and data privacy requirements
- Possibility to send direct emails to contacts that have indicated that they would like to receive other type of communications about TeraFlow
- Increase of unique visitors to the project website by redirecting traffic from HTML template to the PDF version uploaded
- Monitoring of clicks and traffic reading the newsletter by creating a dedicated link using Bit.ly

The first issue was launched during the Summer and presented the main progress of each one of the technical WPs along with information related to the publication of papers and participation in events. According to data collected, the newsletter was sent to 8 subscribers on Mailchimp. The link shared by social media was clicked more than 50 times. The information on the website confirms that the PDF was seen/downloaded more than 38 times. Moreover, the newsletter was promoted by the 5G PPP on their website and social media accounts which contributed to reach a wider audience.

The newsletter's next issue will be launched on January 2022, presenting once again the progress of technical WPs, new publications on conferences and journals, events where the project was featured, partners, and a special article dedicated to the launch of TeraFlow OS. The results and content produced will be reported on upcoming deliverables.

Finally, the blog hosted on the website will be launched next year to strengthen the project's thought leadership on various topics and technologies the partners are contributing to within the project. The schedule created foresees the creation of at least 20 posts until the end of the project also including the involvement of other projects and experts to boost collaboration.

6.6. Events, workshops and demos

The participation in external events and the organisation of TeraFlow's own events/workshops in collaboration with other initiatives and projects or co-located within bigger and renowned venues has contributed to raising awareness of the project, increasing visibility of the work that is being done, and potentially engage with key stakeholders. The latter is a key benefit that so far, we haven't had the chance to experience at its fullest since most of the events where the project has been presented have been online.

Figure 29: TeraFlow at CTTC Booth @MWC2021

Online events are great in terms of reaching a wide audience located anywhere in the world, which normally during a physical event is limited to the attendees. Moreover, the availability of the recording of the sessions allows us to reuse these contents to promote them on the website and social media channels to increase the impact and reach posterior to the participation of the event. However, online events don't foster great engagement as people are more used to joining them to receive a talk on a specific topic, rather than connecting to establish meaningful connections on virtual booths. For this purpose, TeraFlow aims to boost its participation in physical events whenever it becomes safe again to foster new and relevant connections with participants and attendees that could be interested in the project's results.

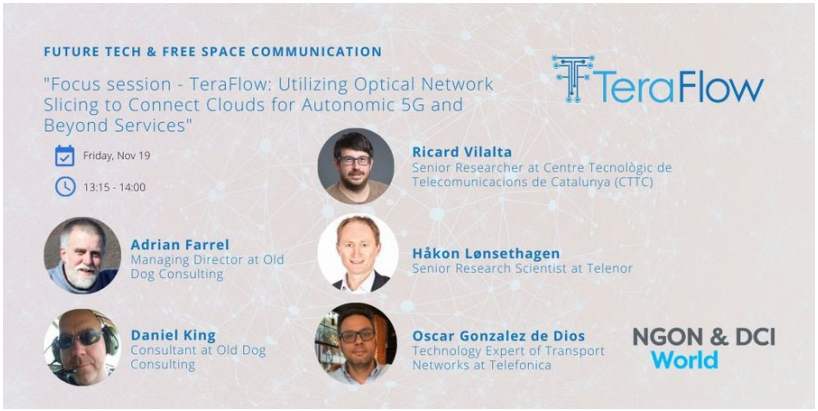


Figure 30: TeraFlow at NGON & DCI

The following table presents a list of the 21 events where TeraFlow has participated and/or organised between M1 and M11, reaching over 3000 persons of different role and background such as researchers, academics, industry, standardisation, among others. Participation and format have varied from presentations, invited talks, booth, demo sessions, workshops, webinars, etc. All events have been uploaded to the website and highly promoted on social media channels. Whenever possible, the recording of virtual presentations and the slides have been uploaded to each event entry to provide added content to visitors.

Table 3: TeraFlow events from M1 to M11

Event Name	Venue	Date	Type of participation	Description	Estimated # of persons reached	Link
3rd ONFIRE Symposium	Virtual	24/02/2021	Presentation	Victor Lopez from Telefónica held the presentation "Optical white boxes design and programmability using GNPy".	30	https://www.teraflow-h2020.eu/events/3rd-onfire-symposium
TIP OOPT MUST: Operators Driving SDN for Transport Adoption and Acceleration	Virtual	03/03/2021	Presentation	Presentation of work related to TeraFlow by Victor Lopez. This event will formally introduce the TIP OOPT MUST subgroup, providing a view to the optical industry what this subgroup will achieve.	50	https://www.teraflow-h2020.eu/events/tip-oopt-must-operators-driving-sdn-transport-adoption-and-acceleration
OSM Ecosystem Day	Virtual	10/03/2021	Presentation	TeraFlow in the OSM ecosystem by Dr. Ricardo Martínez, Senior Researcher, CTTC This presentation tackles the adoption and integration of the OSM within the TeraFlow project solution.	50	https://www.teraflow-h2020.eu/events/osm-ecosystem-day
5G-PPP Webinar: Europe accelerates towards 6G	Virtual	16/03/2021	Webinar	The webinar is held in two parts, where all projects will present their vision of 6G in the first part as the motivation for their projects and the technical challenges they are addressing to move towards 6G in the second part. TeraFlow is one of the participating projects, represented by Ricard Vilalta, Project Coordinator and Senior Researcher at CTTC. Recordings of the webinar are available at TeraFlow's YouTube channel and website: • https://youtu.be/YjASBzEcKCg https://youtu.be/xg9HQNczjhc	400	https://www.teraflow-h2020.eu/events/5g-ppp-webinar-europe-accelerates-towards-6g

MASTEAM Seminar: Software define control of optical networks	Virtual	18/03/2021	Presentation	Ricard Vilalta presented TeraFlow at a talk to the master's students in Applied Telecommunications and Engineering Management from Universidad Politecnica de Catalunya - Castelldefels School of Telecommunications and Aerospace Engineering (EETAC).	50	https://www.teraflow-h2020.eu/events/presentation-software-define-control-optical-networks-upc-eetac
CodeBeam STO 2021	Virtual	20/05/2021	Invited Tech Talk + Demo	After an overview of what is Software Defined Networking, Traffic Engineering, and the protocols involved, Sebastian Merle from Peer Stritzinger introduced the project's architecture, concerns, constraints, and challenges. Then a live demo showed the progress so far. Finally, he presented the open-source projects created or improved as part of the development.	350	https://www.teraflow-h2020.eu/events/codebeam-sto-2021
The Optical Networking and Communication Conference & Exhibition (OFC 2021)	Virtual	06-11/06/2021	Paper presentations / Demo papers	TeraFlow was featured through the presentation of 4 papers and 2 demo papers: 1. End-to-End Network Slice Stitching using Blockchain-based Peer-to-Peer Network Slice Managers and Transport SDN Controllers 2. First Scalable Machine Learning Based Architecture for Cloud-native Transport SDN Controller 3. Multi-layer Transport Network Slicing with Hard and Soft Isolation 4. Autonomous Security Management in Optical Networks 5. Operationalizing partially disaggregated optical networks: An open standards-driven multi-vendor demonstration 6. Scalable for Cloud-native Transport SDN Controller Using GNPy and Machine Learning techniques for QoT estimation	200	https://www.teraflow-h2020.eu/events/optical-networking-and-communication-conference-exhibition-ofc-2021

EuCNC | 6G Summit	Virtual	8-11/06/2021	Paper presentation + Special Session + Workshop	TeraFlow was featured through the following: • Paper presentation "TeraFlow: Secured Autonomic Traffic Management for a Tera of SDN Flows" – Recording available at YouTube Channel and website: https://youtu.be/ZuSIW0aVMmY • Special session: "Autonomous Network Management towards 6G. Cloud-native SDN Network Management for Beyond 5G Networks with TeraFlow" – Recording available at YouTube Channel and website: https://www.youtube.com/watch?v=I9paWb_nhXI&t=91s Workshop: "From 5G to 6G Automated and Intelligent SecuriTy: FAST. Cloud-Scale SDN Network Security in TeraFlow"	500	https://www.teraflow-h2020.eu/events/teraflow-participating-eucnc
25th International Conference on Optical Network Design and Modelling (ONDM 2021)	Virtual	28-06/01/07-2021	Workshop	TeraFlow organized a 2-hour workshop titled: "Micro-service based autonomic traffic control in 5G and beyond". The recording is available at the project's YouTube Channel and website: https://youtu.be/3XFojZUepsQ	100	https://www.teraflow-h2020.eu/events/ondm-2021
MWC21	Barcelona, Spain	28/06 – 01/07 - 2021	Booth + Demo	TeraFlow was featured at the CTTC booth, represented by our Project coordinator Ricard Vilalta, who could demonstrate the main concepts of the TeraFlow SDN controller to the interested audience through the demo TeraFlow: A scalable Cloud-Native SDN Controller for Transport Networks.	300	https://www.teraflow-h2020.eu/events/mobile-world-congress

IETF-111 side meeting	Virtual	28/07/2021	Workshop	TeraFlow participated at the "Evolving and Revitalizing the Internet" side-meeting co-located within the IETF-111. IETF participants occasionally organize side meetings to discuss topics of interest to some portion of the IETF community. In this case, Adrian Farrel from Old Dog Consulting and a member of TeraFlow Consortium hosted and moderated the 90-minute meeting.	30	https://www.teraflow-h2020.eu/events/public-side-meetings-ietf-111
OMNET++ Community Summit	Virtual	8-10/09/2021	Paper Presentation	The paper "HTBQueue: A Hierarchical Token Bucket Implementation for the OMNeT++/INET Framework" written by Marcin Bosk, Marija Gajic, Susanna Schwarzmann, Stanislav Lange and Thomas Zinner, was presented on September 8th. The recording of the presentation is available at the project website.	100	https://www.teraflow-h2020.eu/events/omnet-community-summit-2021
Photonics in Switching and Computing 2021 (PSC 2021)	Virtual	27-29/09/21	Paper Presentation	Raul Muñoz from CTTC presented the paper "SDN Control Architectures for WDM over SDM (WDMoSDM) Networks" within the Session Network Control and Management II that took place on September 29 from 11:30 to 13:30 EDT.	80	https://www.teraflow-h2020.eu/events/photonics-switching-and-computing-2021
Nit Europea de la Recerca	Barcelona, Spain	21/09/2021	Poster presentation	TeraFlow was showcased through a poster at the European Corner.	100	https://www.teraflow-h2020.eu/events/nit-europea-de-la-recerca
ECOC 2021	Bordeaux, France + Virtual	13-15/09/2021	Workshop + Paper presentations	TeraFlow participated with various activities during the event: • Workshop: “Applications for IMDD and Coherent in Short Reach Systems” • Paper presentations: “First demonstration of dynamic deployment of SDN-enabled WDM Virtual Network Topologies (VNTs) over SDM networks” – “Scalable physical layer security components for	400	https://www.teraflow-h2020.eu/events/ecoc21

				Microservice-based Optical SDN controllers" – "Role of monitoring and analytics in next-generation optical networks"		
17th International Conference on Network and Service Management (CNSM 2021)	Virtual	25-29/10/2021	Paper presentation	TeraFlow was featured at the presentation of the paper "Using 5G QoS Mechanisms to Achieve QoE-Aware Resource Allocation", where our partners from NTNU participated in the development. The complete list of authors include: Marcin Bosk, Marija Gajic, Susanna Schwarzmann, Stanislav Lange, Riccardo Trivisonno, Clarissa Marquezan, and Thomas Zinner. The presentation was held on October 26th at 14:45. Recording is available at the project website.	150	https://www.teraflow-h2020.eu/events/17th-international-conference-network-and-service-management
NetCentric 2021	Virtual	30/09 - 01/10 - 2021	Presentation	Adrian Farrel held a presentation on "IETF Network Slicing" mentioning TeraFlow within the discussion of solution architectures	50	https://www.teraflow-h2020.eu/events/net-centric-2021-conference
12th International Conference on Network of the Future (NoF2021)	Virtual	06-08/10/2021	Tutorial session	Paolo Monti and Carlos Natalino from Chalmers held the Tutorial Session: Network automation - challenges, enablers and benefits, where TeraFlow was mentioned	80	https://www.teraflow-h2020.eu/events/12th-international-conference-network-future-nof-2021
TIP OOPT MUST H2 Public Webinar	Virtual	27/10/2021	Presentation	A panel of expert speakers, including our partner Oscar Gonzalez de Dios from Telefonica as leading operators, presented updates in Q1-Q3 as well as the main project metrics to date, including the green-lighting of the TIP Test & Validation framework around defined use cases implementations, a key step in awarding the TIP Ribbons and Badges that will play a critical role in accelerating the pace of commercial deployments.	50	https://www.teraflow-h2020.eu/events/tip-oopt-must-h2-2021-public-webinar

				The recording of the session is available at the project's website.		
IEEE Conference on Network Function Virtualization and Software Defined Networks 2021	Hybrid - Heraklion, Greece	9-11/11/2021	Demo paper	Within this conference, the paper "Scalable and Resilient Network Traffic Engineering Using Erland-based Path Computation Element" was presented by Sebastien Merle from Peer Stritzinger at the Demo Track on November 11th between 12:00 and 14:00CET.	50	https://www.teraflow-h2020.eu/events/ieee-conference-network-function-virtualization-and-software-defined-networks
NGON DCI 2021	Virtual	19/11/2021	Workshop	TeraFlow organised the workshop "TeraFlow: Utilizing Optical Network Slicing to Connect Clouds for Autonomic 5G and Beyond Services". The session took place on November 19th between 13:15 and 14:00 and consisted of three presentations and a panel session with our partners from Old Dog Consulting, Telefónica, Telenor and CTTC	150	https://www.teraflow-h2020.eu/events/ngon-dci-world-2021

6.7. Summary of dissemination and communication activities

Dissemination and communication activities performed by TeraFlow and its Consortium partners have been successful within M1 and M11 of the project. The different set of activities established, the participation on events, the submission of papers, and the increasing digital visibility that the project has gotten are perfect indicators that we are reaching the objectives set and we are successfully raising awareness of the project.

The latter will be essential on upcoming phases of the strategy where we intend to actively engage with key stakeholders by reaching out to potentially interested end-users/adopters of the results of the project and involve them in activities that will be necessary to support exploitation and business modelling activities.

Table 4 presents the KPIs established to measure the success and effectiveness of the strategy presented on D6.1, which have been closely monitored monthly to timely identify any deviations or determine if any other actions should be executed to guarantee the effective accomplishment of these.

Table 4: TeraFlow Dissemination and Communication KPIs by M11

Type	KPI	Total Target by M30	Achieved by M11
Website	Unique Visitors	5.000	2.834
	Average Time	2:00	0:54
	Page Views	10.000	5.019
	Blog and News entries	20	4
Twitter	Tweets	360	93
	Retweets	800	199
	Likes	1.500	451
	Followers	250	144
	Engagement Rate	≥ 1.2%	1.7%
	Impressions	100.000	54.200
LinkedIn	Page Views	2.000	408
	Visitors	400	250
	Reactions	≥ 1.2%	4%
	Followers	100	69
Marketing Material	PPT – Scientific/Technical Dissemination Material	3	2
	Brochure	3	0
	Videos	2	0
	Press Releases	3	1
	Newsletters	5	1
Scientific Dissemination	Scientific Publications	25	20
	Articles in specialised magazines/journals	10	Specialised Magazines (2) Journals (2)
	Posters	5	1

Events	Workshops organised	2	3
	Attendees to the project workshops	25	+50
	Demo events	10	5
	Events and presentations where the project will be presented	20	21
Others	Liaisons and joint activities with other projects, communities, initiatives, etc. (e.g., website links, workshops, newsletters, social media, etc.)	20	15

As it can be seen, all of the KPIs are on a good track for their successful accomplishment by the end of the project. Therefore, no deviations have been foreseen until now. As a summary and conclusion of this chapter, we highlight some of the essential activities that will take place in the following phase:

- Website:
  - Revamp of content and structure giving maximum visibility to the TeraFlow OS release
  - Launch of the Blog with relevant content covering the different topics addressed by the project to strengthen our digital positioning and increase some of the metrics, including average time on site and number of posts on LinkedIn, through establishing thought leadership of TeraFlow.
- Social Media:
  - Increase the frequency of publication to at least 2 tweets per week and 3 LinkedIn posts per month.
  - Continue identifying relevant accounts to interact and enhance collaboration for cross-project promotion in these channels.
- Marketing Material:
  - Support the launch of the TeraFlow OS with the development of a PPT presentation, a brochure, a video, and a press release to be issued on local media outlets and specialized magazines. All this material will be uploaded to the website and promoted via social media accounts from the project, partners' and 3rd parties such as 5G PPP.
  - Continue delivering updates on the progress of the project via the newsletter.
- Scientific Dissemination:
  - Continue developing and submitting scientific publications to relevant conferences and specialised journals.
- Events:
  - Leverage collaboration opportunities with other H2020 projects for the organisation of workshops and events.
  - Continue participating in various events to raise awareness about the project
  - If the COVID-19 situation gets better, participating in physical events to better engage with key stakeholders and build strong relationships with potential adopters of the project results.

7. Standardisation Activities and Open-Source Contributions

This section covers the specific plans (presented in D6.1), and the actions realized during Year 1 to generate impact in Standardisation and open-source communities. Figure 31 shows the addressed Standard Defining Organizations (SDO) and Open-Source Software (OSS) communities and highlights potential overlap and strategy between these communities.

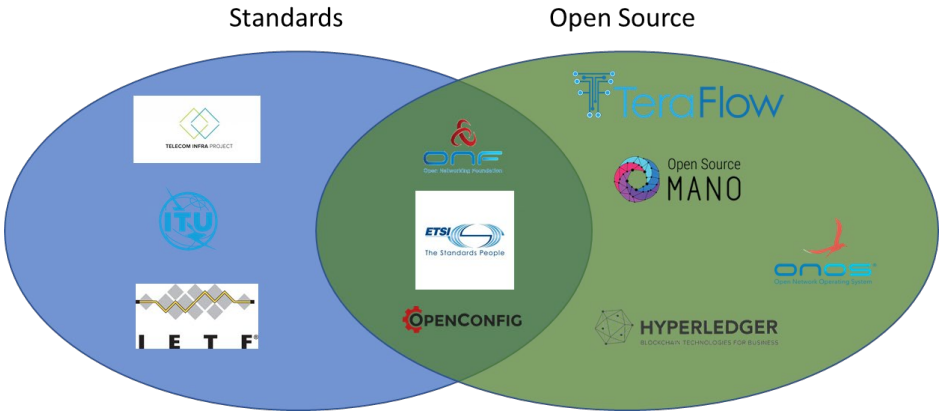


Figure 31: TeraFlow SDO and OSS ecosystem

7.1. Standards

Besides fostering collaboration with the standardisation bodies, TeraFlow takes part in relevant working groups, and other relevant industry fora, putting effort into contributing with relevant documentation and research results. Active partners have been identified and led by TID in T6.2: Standardization and open source software activities. This report presents the current performed activities.

7.1.1. ETSI ISG PDL

Members: NEC Europe Ltd. (Brigitta Lange), TID (Diego Lopez), ODC (Daniel King).

NEC and Telefónica are a founding member of ETSI ISG PDL (Industry Specification Group Permissioned Distributed Ledger), a group that targets the utilization of blockchain technologies for the creation of open and trustworthy ecosystems of industrial digital solutions, and contributing to the group's working items and reports on challenges, concepts, and features related to the operation of permissioned distributed ledgers.

TeraFlow project is already part of the PDL work items **MI/PDL007 Research Landscape** and **GR/PDL-008 Research and Innovation Landscape** where NEC is rapporteur.

TID chairs the group and plans to contribute to smart contract applicability to network management and auditability and to the issues related to multi-ledger interactions.

ODC will support the activities of NEC and TID with reviews and discussions of the work and will assist with forming strategies to ensure that TeraFlow objectives are met.

NEC and Telefónica will closely monitor standardization activities in ISG PDL and actively connect TeraFlow project research results related to DLT with PDL work items.

7.1.2. ETSI ISG ZSM

Members: TID (Diego Lopez), CTTC (Ricard Vilalta), ODC (Daniel King), TNOR (Min Xie).

The ETSI Zero-touch network and Service Management (ZSM) Industry Specification Group (ISG) applies modern principles in its low-touch management framework for 5G end-to-end automation.

The ISG ZSM is currently working on the specification of solutions and management interfaces for the orchestration and automation of the emerging end-to-end network slicing technology (GS ZSM 003) as well as of the end-to-end, cross-domain service orchestration and automation (GS ZSM 008). TeraFlow plans to bring results in transport network automation based on the work in scenario 1 Beyond 5G networks. We are studying the feasibility to run a Proof-of-Concept based on ZSM006-PoC Framework. Results from Automation component might be of interest to be presented.

TNOR contributed to **ETSI ZSM-011** based on the Automotive scenario and inter-domain module. The contribution has been approved and included in ETSI ZSM-011 draft (Section 4.3.1. Automotive use case).

7.1.3. ETSI ISG mWT

Members**:** SIAE

SIAE is member of ETSI, as part of the "ISG mWT" (Industry Specification Group on Millimitre Wave Transmission). In particular, with regard to the SDN activity, SIAE collaborates to the activities of the following Work Items: WI#24 and WI#25.

WI#24 Wireless Transport Profile for Standard SDN Northbound Interfaces

The purpose of this WI is to produce a Group Specification defining a Wireless Transport NBI Profile to be used in conjunction with the IETF Data Models used to implement SDN. This Profile will not only recommend which models to use from the vast library available from IETF, but also the selection of YANG sub-trees within such models, that are necessary to manage MW and mmW networks.

It is not in the scope of this WI to define any YANG module or to define or recommend any specific SDN architecture. The ultimate goal of this Profile is to simplify and promote interoperability of SDN solutions based on the IETF NBI standards.

In this context, SIAE participated in the following ETSI Plugtests™ activities:

- 1st mWT Plugtests™ (January 2019 - Sophia Antipolis, France)
- 2nd mWT Plugtests™ (March 2020 - Sophia Antipolis, France)
- 3rd mWT Plugtests™ (November 2020 - Remote activities due to COVID-19)

WI#25 Wireless Backhaul Network and Services Automation: SDN SBI YANG models
The key objective of this WI is to interact with industry and SDOs towards a widely acceptable and implementable SDN model profile for Wireless Backhaul systems.

The WI will produce a Group Report of detailed use cases, driven by service providers and jointly developed with system vendors to be implemented by standard data models (e.g. IETF, ONF), whilst ensuring interoperability among different vendors. The WI will also identify gaps in existing MW node-related YANG models (based on the identified use cases) and propose methods to improve the situation.

Within these activities, SIAE will actively promote relevant outcomes from TeraFlow for a possible standardization roadmap.

7.1.4. ETSI ISG SAI

TID and UPM are members of ISG "Securing AI". TID and UPM plan to contribute in some work items and potential PoC from the cybersecurity scenario. Some possible topics might include: Securing AI problem statement (ETSI GR SAI 004), AI threat ontology, Data supply chain report, Mitigation strategy report, and Security testing of AI. In particular, TID and UPM plan to align the research activities on the development of resilient ML components to adversarial attacks, that were planned in T4.1 for the second year, with their potential contributions to SAI.

7.1.5. Telecom Infra Project

Members: Telefónica (Oscar González-de-Dios, Victor López, Juan-Pedro Fernández-Palacios)

The Open Optical & Packet Transport (OOPT) project of TIP works on the definition of open technologies, architectures and interfaces in Transport Networks. Telefonica and SIAE are key members of TIP and active contributors in multiple OOPT subgroups.

The MUST (Mandatory Use Case Requirements for SDN for Transport), co-chaired by Telefonica, has the main goal of driving the adoption of SDN standards for IP/MPLS, Optical and Microwave technologies. MUST has defined an open SDN architecture, which is followed by TeraFlow. Each MUST track defines the requirements that the devices have to support. There is a close relation between TIP MUST and TeraFlow. The gaps found in the data mode.

Telecom Infra Project: TIP OOPT MUST subgroup – IP track

Telefonica is leading the activities of the IP track of the MUST subgroup. The subgroup is delivering the specification of the Openconfig and IETF Yang based data modes that need to be used in controllers and devices. In that regards, TeraFlow is directly contributing to complete the gaps of the Yang models that are used in the specification. In that regards, the contribution of TeraFlow is Key to have the required functionalities in the standards. Note that TIP MUST does not produce new standards, but point to the relevant IETF/Openconfig models.

Telecom Infra Project: TIP OOPT MUST subgroup - Wireless Backhaul

SIAE is following the activities of this working group and is participating in meetings to ensure the compatibility of its products with the required requirements and providing feedbacks to the operators, based on many years of experience in the field of wireless backhaul.

The goal of this project group is to create an ecosystem to further advance wireless backhaul technology to help overcome traditional delays in deployment and meet critical time-to-market requirements with effective use of resources.

This group will work towards providing improvements to overall system performance with reliability and proactive capacity adjustments. The Wireless Backhaul solution will address ease of site configuration and turn up by reducing configuration overlap.

7.1.6. ONF

Members: TID (Oscar González-de-Dios), SIAE (Roberto Servadio, Danilo Pala), CTTC (Ramon Casellas, Ricard Vilalta), ODC (Daniel King).

With a key objective of developing a cloud native and scalable SDN controller, standardization efforts related to the development of data models and interfaces enabling a hierarchy of controllers are clearly in scope of TeraFlow research and standardization work. In this sense, the Optical Networking Foundation (ONF) Open Transport Configuration & Control (OTCC) project aims to promote common configuration and control interfaces for transport networks in SDN. One of the project work items is the specification of the Transport Application Programming Interfaces (TAPI) data models, publishing open standard interfaces, whose main application domain is the controllers North Bound Interfaces (NBI).

The contributions from TeraFlow members CTTC and Telefonica are related to the refinement of data models enabling "clients" (such as parent controllers, orchestrators, operators' OSS/BSS) to request connectivity services with focus on the optical transport networks (OTN) and the so called "photonic media layer". In particular, the contributions are related to: i) the specification of use cases covering fundamental operations such as (constrained) provisioning of Digital Signal Rate (DSR), or OTN services – both for the digital (ODU/OTU) as well as the optical (OTSi / Media channel) layers, path computation, OAM or fault management; ii) the definition of workflows and model usages to subsequently solve such use cases; iii) the refinement of data models to take into account additional requirements or gaps identified by the aforementioned use cases, resulting in a continuous evolution towards future TAPI releases, and iv) the editing and publication of the TAPI Reference Implementation Agreement (RIA) v1.1 [25] (both for the RESTCONF based NBI as well as for Streaming), which constitutes a self-contained document providing guidelines, model usage examples and practical considerations.

Considering the "network layering" that TeraFlow envisions, such standard API (along with the implementation guidelines and sample model usage) becomes a target interface in view of the integration of the transport layers (L0/L1) into the network orchestration functions of the TeraFlow controller (for example, as a controller South Bound Interface, SBI, to consume the services provided by dedicated per-domain optical controllers).

It is worth noting that more specific technical contributions related to the technology specific aspects (such as physical impairments, optical performance monitoring, or extensions to support multi-band networking) will be addressed by the companion project H2020 B5G-OPEN, while TeraFlow will address additional work items from a client perspective. It is expected that both projects will continue with a fruitful collaboration in this regard.

SIAE is member of the ONF and participates to the standardization activities in the Open Transport Configuration & Control (OTCC) carried on by the "5G xHaul" working group, which mainly involves the definition and upgrade of interfaces/models for microwave transport. In this context, SIAE participated to several Proof of Concepts (PoC), focused on demonstrating the capabilities and benefits of utilizing a common Information Model for multi-vendor control of wireless network elements through open management interfaces, as documented in the technical report TR-532.

As a result of the TeraFlow efforts, some of the existing interfaces/models might be improved or new ones might be created. In case such outcomes get considered by the Consortium for a possible standardization, SIAE will actively promote them to the ONF standardization roadmap.

7.1.7. IETF

Members: ODC (Adrian Farrel and Daniel King), TID (Oscar González-de-Dios), CTTC (Ramon Casellas and Ricard Vilalta), TNOR (Håkon Lønsethagen).

The Internet Engineering Task Force (IETF) is a critical Standards Development Organisation (SDO) that invents, develops and creates Internet standards, focusing on the architectures protocols that facilitate the Internet.

TeraFlow partners (Telefonica and ODC) are actively contributing to the network operation in OPSA (Operations and Management Area) Working Group. The participation has led to contributions of Yang models to the management and control of several types of VPNs, including Layer-3 (L3) VPNs, Virtual Private Wires (VPWs) and Ethernet-VPNs (EVPNs), considering aspects of topology, management of client routes and security parameters.

Key technology areas of TeraFlow include Network Slicing (NS) and Traffic Engineering (TE). Within the IETF, the TEAS (Traffic Engineering and Signaling) working group (WG) is responsible for defining the TE architecture and the associated protocols and data models. In addition, TeraFlow partners (Telefonica and ODC) are contributing in multiple drafts acknowledged to the project.

The IETF internet-drafts (working documents) that have direct contributions from TeraFlow partners is provided below:

- "**Challenges for the Internet Routing Infrastructure Introduced by Changes in Address Semantics**"
  URL: https://datatracker.ietf.org/doc/draft-king-irtf-challenges-in-routing/
- **"A Survey of Semantic Internet Routing Techniques",**
  URL: https://datatracker.ietf.org/doc/draft-king-irtf-semantic-routing-survey/
- "**Framework for Use of ECA (Event Condition Action) in Network Self-Management",**
  URL: https://datatracker.ietf.org/doc/draft-bwd-netmod-eca-framework/
- "**A YANG Data model for ECA Policy Management",**
  URL: https://datatracker.ietf.org/doc/draft-ietf-netmod-eca-policy/
- "**Instantiation of IETF Network Slices in Service Providers Networks**"
  URL: https://datatracker.ietf.org/doc/draft-barguil-teas-network-slices-instantation/
- **"A Layer 2 VPN Network YANG Model",** URL: https://datatracker.ietf.org/doc/draft-ietf-opsawg-l2nm/
- **"A Layer 3 VPN Network YANG Model",** URL: https://datatracker.ietf.org/doc/draft-ietf-opsawg-l3sm-l3nm/

- **A YANG Model for Network and VPN Service Performance Monitoring,** URL: https://datatracker.ietf.org/doc/draft-ietf-opsawg-yang-vpn-service-pm
- "**A Layer 2/3 VPN Common YANG Model",** URL: https://datatracker.ietf.org/doc/draft-ietf-opsawg-vpn-common
- **"IETF Network Slices",** URL: https://datatracker.ietf.org/doc/draft-ietf-teas-ietf-network-slices/
- **"Applicability of Abstraction and Control of Traffic Engineered Networks (ACTN) to Network Slicing",** URL: https://datatracker.ietf.org/doc/draft-ietf-teas-applicability-actn-slicing/
- **"Extensions to the Access Control Lists (ACLs) YANG Model",** URL: https://datatracker.ietf.org/doc/html/draft-dbb-netmod-acl-00

Several Internet-Drafts (I-Ds) exist which are of interest to TeraFlow but are not directly worked on currently by project principles; however, this may change over time as the work becomes more relevant for TeraFlow. The IETF "drafts-of-interest" include:

- "**YANG Data Model for Slice Policy**", URL: https://datatracker.ietf.org/doc/draft-bestbar-teas-yang-slice-policy/
- **IETF Network Slice Controller and its associated data models**" URL: https://datatracker.ietf.org/doc/draft-contreras-teas-slice-controller-models/
- "**IETF Network Slice Use Cases and Attributes for Northbound Interface of IETF Network Slice Controllers**"
  URL: https://datatracker.ietf.org/doc/draft-contreras-teas-slice-nbi/
- "**IETF Network Slice YANG Data Model**" URL: https://datatracker.ietf.org/doc/draft-liu-teas-transport-network-slice-yang/
- **"Framework for Use of ECA (Event Condition Action) in Network Self Management"** URL: https://datatracker.ietf.org/doc/draft-bwd-netmod-eca-framework/
- **"Overview and Principles of Internet Traffic Engineering",** URL: https://datatracker.ietf.org/doc/draft-ietf-teas-rfc3272bis

We expect several of these documents to progress throughout the project. In addition, individual documents and working group documents will be published as Internet Standards (RFC status), highlighting the project's leading technology and industry impact.

7.1.8. ITU-T FG-AN

Members: ODC (Daniel King), TID (Oscar González-de-Dios)

The ITU-T Focus Group (FG) on Autonomous Networks (FG-AN) is a relatively recent work area. The intention for the Focus Group will be to draft technical reports and specifications for intelligent autonomous networks. This technology area includes use cases and requirements for real-time responsive experimentation and dynamic adaptation of network resources to changing demands.

TeraFlow project is designing and building several components relevant to FG-AN use cases in the future. However, the TeraFlow partner ODC is following the output from the FG-AN effort and will highlight potential FG-AN use cases to the TeraFlow partners that might be solved using the TeraFlow platform.

7.1.9. OpenConfig

Members: TID (Oscar González-de-Dios)

OpenConfig is a network operator led initiative to provide a consistent set of Yang based vendor-agnostic device data models. Even though it is an informal group and not a proper SDO, the models are being implemented in network devices as a "defacto" standard. TeraFlow IP/MPLS based use cases use Openconfig Yang data models in the southbound interface of the TeraFlow SDN controller (via the device driver). Telefonica is an active member of Openconfig and provides contributions with Yang code that completes the gaps found in TeraFlow to support the use cases. It is planned to submit contributions during the timeframe of the project.

Telefonica has made the following contributions

- Openconfig EVPN Yang model to provide Layer 2 connectivity, including the modeling of Ethernet segments. The contribution is documented in https://github.com/openconfig/public/blob/master/doc/evpn_use_cases.md , and covers the following technologies:
    - BGP MPLS-Based Ethernet VPNs RFC 7432 with VLAN based service.
    - Provider Backbone Bridging Combined with Ethernet VPN (PBB-EVPN) RFC 7263 with VLAN based service.
    - Network Virtualization Overlay (NVO) EVPN RFC 8365 with VLAN based service and symmetric IRB.
- Ethernet counters. These are ethernet related information that are read from the TeraFlow SDN controller.

Also, there are a set of contributions in progress:

1. Keychains and authentication of routing protocols. It is necessary for the network creation TeraFlow use cases.
2. Extensions of ACL yang model. Can be used for the Attack mitigator component

7.2. Open-Source Contributions

TeraFlow partners recognise open-source communities as important pillars to ensure the sustainability of the project results and uptake by third parties. Preliminary synergies with active open-source projects are identified below, indicating the contributing partners.

7.2.1. TeraFlow SDN Controller

Members: ALL

One of the key objectives of TeraFlow SDN Controller is to design and develop a new generation of SDN Controller and contribute it to the open-source Community. A release of a basic version of a fully functional SDN controller using Apache 2 License is expected for January 2022. This release will have support for transport connectivity services, topology and inventory. Other features will be included.

To have a successful release, we have prepared a set of guidelines showing how to configure a computer or use a VM to run the TeraFlow OS.

The guidelines are available here: https://gitlab.com/teraflow-h2020/controller/-/wikis/home

7.2.2. ETSI OpenSource MANO

Members: TID (Diego Lopez), ATOS, NTNU (Katina Kravleska), CTTC (Ricard Vilalta), TNOR (Pål Grønsund).

ETSI OpenSource MANO (OSM) is an initiative developing an open source Management and Orchestration (MANO) stack which is compliant with the information models being defined within the ETSI ISG NFV standardization activities. To this end, the OSM project is being developed in a community fashion targeting the MANO implementation dealing with operators' requirements for delivering commercial and production NFV services. In this regard, the under-deployment TeraFlow OS leverages the current OSM solution with the aim to attain a tight integration with OSM acting as a WAN Infrastructure Manager (WIM) (i.e., SDN controller). This enables the OSM requesting to the TeraFlow OS the deployment of connectivity services between Virtual Network Functions (VNFs) hosted at remoted cloud facilities (NFVI-Pops).

In this regard, in the organized session OSM-MR#10 Ecosystem Day (March 10th, 2021)[24], the TeraFlow project uses cases and objectives were presented to OSM community to outline the interest of the project on using such a MANO solution as an external entity to interact with. Indeed, currently TeraFlow involved partners are closely discussing with OSM developers to accomplish a functional integration between the OSM latest release and a designed component of the TeraFlow OS architecture referred to as Compute component. By doing so, the Compute component will be the front-end of the whole TeraFlow OS enabling the incoming connectivity service operations (e.g., creation, deletion, and updating) triggered by the OSM. To this end, a defined API between the OSM and the Compute component is used targeting the lifecycle management of the connectivity services fulfilling the requirements (e.g., bandwidth, latency, etc.) needed to roll out the network services orchestrated by the OSM.

7.2.3. ONF ONOS and Stratum

Members: UBI (Georgios P. Katsikas)

UBITECH is leading the P4 activities within TeraFlow. The plan for providing P4 support to the TeraFlow SDN controller is through a device driver plugin (i.e., as an individual part of the device component) which will bridge the TeraFlow controller with ONF's Stratum OS[26]. Stratum is a minimal open-source OS distribution for white box switches, supporting popular next-generation SDN protocols, such as the P4Runtime, OpenConfig, gRPC, gNMI, gNOI, etc. Stratum has an active community of users and it has been broadly used in large ONF projects, such as Aether[27] and SD-Fabric[28].

Through the P4 device driver plugin P4 switches will be able to register to the TeraFlow SDN controller, thus allow the latter to program their parsers and in turn manage their match-action tables. For the needs of TeraFlow, UBI plans to first test the P4 device driver plugin with existing P4 software switches, such as the bmv2 switch [29] provided by ONF as a mininet [30] extension. When the device driver plugin becomes functional, then UBI will perform a similar testing procedure on a state-of-the-art hardware P4 device, namely the upcoming Tofino-2 [31] switch by Intel (former Barefoot networks). As this switch is currently in pre-production stage, there is no validated testing procedure so far. UBI

aims to use the TeraFlow P4 device driver to test this switch and share experiences with the P4 community (i.e., ONF Stratum and ONOS) in the form of testing reports, potential issues raised on Stratum's GitHub pages, and/or bug fixes in Stratum/ONOS network operating systems. Our goal is to exploit the active P4 channels by ONF to advertise the P4 activities within TeraFlow, thus attract P4 users that could leverage TeraFlow for research and innovation activities, while keeping backward compatibility with ONF Stratum and the ONF developments in general.

7.2.4. HyperLedger

Members: NEC (Ghassan Karame).

This project is hosted by the Linux Foundation and was created to advance cross-industry blockchain technologies.

The blockchain technology developed for the distributed ledger component of the TeraFlow OS (like improved consensus algorithms) will be of interest for Hyperledger Lab. Specifically the MinBFT project, which allows to achieve Byzantine fault-tolerant consensus with fewer consenting nodes and less communication rounds comparing to the conventional BFT protocols. NEC is a leading contributor to MinBFT. Insights gained from MinBFT also advance NEC´s own FastBFT consensus algorithm.

8. Liaison and 5G-PPP Relationship

In this section, we detail the participation and expected contributions to the 5G PPP Programme, including Working Groups (WG), meaning contribution to joint program publications, to Global 5G events and joint demos, workshops, etc. to be organized at relevant events.

Partners' current involvement and participation in existing WGs is presented in Table 5.

Table 5: 5G-PPP Working Groups

WG	Partner
5G Architecture	TNOR
SN WG	CTTC
SME	UBI
TMV	ODC
Security	CTTC, TID
Pre-Standards	ODC
VSC	TNOR
Steering Board	CTTC
Technical Board	TID

A particularly relevant contribution to the long-term impact of TeraFlow will be contribution of the project vision and results to the ongoing structuring activities of future research programmes on Smart Networks within NGI (Next Generation Internet). TID is a founding member of the Networld2020 ETP and the 5G IA and is currently taking part in the definition of a Strategic Research and Innovation Agenda 2021-27 for future network technologies. TID, as Technical Manager of TeraFlow, will foster the adoption of the TeraFlow vision and results regarding the further convergence of software network technologies, their applicability in much denser deployments and the requisites on security and privacy, to be consolidated as part of the aspects to become part of the future Smart Networks research.

8.1. Steering and Technical Boards

Steering and Technical Boards help the alignment of the multiple 5G PPP projects and their coordination. Apart from the regular meetings, TeraFlow has supported the following main activities:

- Ricard Vilalta participated in the 5G-PPP Webinar "Europe accelerates towards 6G" on 16/03/2021 (see for reference Figure 32).

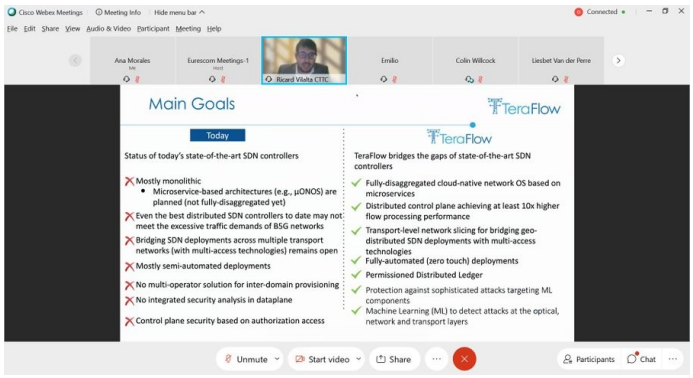


Figure 32: TeraFlow participation in 5G-PPP Webinar

- Participation in elaboration of material for ICT-52 projects dissemination (i.e., brochures, leaflets, websites). This content is well described in Section 6.
- EUCNC 2021 research paper on TeraFlow use cases:

TeraFlow: Secured Autonomic Traffic Management for a Tera of SDN Flows

Ricard Vilalta, Raul Muñoz, Ramon Casellas and Ricardo Martinez (Centre Tecnològic de Telecomunicacions de Catalunya (CTTC/CERCA), Spain); Victor Lopez (Telefonica, Spain); Oscar González de Dios (Telefonica I+D, Spain); Antonio Pastor (Telefonica I+D & Universidad Politécnica de Madrid, Spain); Georgios Katsikas (Ubitech, Greece); Felix Klaedtke (NEC Europe Ltd., Germany); Paolo Monti (Chalmers University of Technology, Sweden); Alberto Mozo (Universidad Politécnica de Madrid, Spain); Thomas Zinner (NTNU, Norway); Harald Øverby (Norwegian University of Science and Technology, Norway); Sergio González (Atos, Spain); Håkon Lønsethagen (Telenor Research, Norway); José-Miguel Pulido (Volta Networks, Spain); Daniel King (Old Dog Consulting, United Kingdom (Great Britain))

TeraFlow proposes a new type of secure, cloud-native Software Defined Networking (SDN) controller that will radically advance the state-of-the-art in beyond 5G networks by introducing novel micro-services architecture, and provide revolutionary features for both flow management (service layer) and optical/microwave network equipment integration (infrastructure layer) by adapting new data models. TeraFlow will also incorporate security using Machine Learning (ML) and forensic evidence for multi-tenancy based on Distributed Ledgers. Finally, this new SDN controller shall be able to integrate with the current Network Function Virtualization (NFV) and Multi-access Edge Computing (MEC) frameworks as well as to other networks. The target pool of TeraFlow stakeholders expands beyond the traditional telecom operators towards edge and hyperscale cloud providers.

- Workshops:
  - From 5G to 6G Automated and Intelligent SecuriTy: FAST (see for reference Figure 33).

Cloud-Scale SDN Network Security in TeraFlow, Alberto Mozo (UPM, Spain); Antonio Pastor (Telefonica I+D & Universidad Politécnica de Madrid, Spain); Carlos Natalino and Marija Furdek (Chalmers University of Technology, Sweden); Rahul Bobba (NEC, Germany); Raul Muñoz, Ramon Casellas and Ricardo Martinez (Centre Tecnològic de Telecomunicacions de Catalunya (CTTC/CERCA), Spain); Juan Pedro Fernández-Palacios (Telefónica I+D, Spain); Ricard Vilalta (Centre Tecnològic de Telecomunicacions de Catalunya (CTTC/CERCA), Spain); Stanislav Vakaruk (Universidad Politécnica de Madrid, Spain)

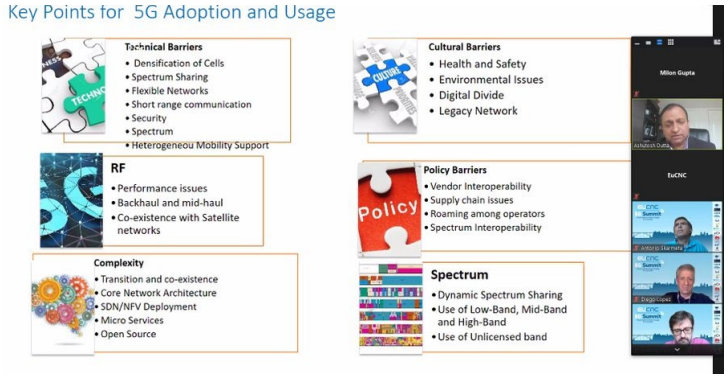


Figure 33: FAST workshop at EUCNC 2021 with TeraFlow participants

- Special Sessions:
    - Special Session 8: Autonomous Network Management towards 6G

Cloud-Native SDN Network Management for Beyond 5G Networks with TeraFlow Ricard Vilalta, Raul Munoz, Ramon Casellas, Ricardo Martínez, Juan-Pedro Fernandez-Palacios, Georgios P. Katsikas, Thomas Zinner , Harald Øverby , Sergio Gonzalez-Diaz, Hakon Lønsethagenk , Jose-Miguel Pulido, Daniel King, Nicola Carapellese TERAFLOW Project

An ICT-52 Workshop on 6G organized by flagship project Hexa-X is planned for 12 hours on:

- Feb 3rd 9-12 CET & 14-17 CET
- Feb 4th 9-12 CET & 14-17 CET

8.2. Architecture WG

TNOR, with support from CTTC, has followed the Architecture WG. TeraFlow was presented to the WG by CTTC. In the period, the WG has developed and delivered a new Whitepaper (5G PPP – View on 5G Architecture V4.0). This was the main activity. TeraFlow contributed to sections addressing new (transport) network concepts (Logical Network as a Service, Transport Network as a Service) and anticipated provisioning, deployment, configuration and management topics.

- Architecture WG Whitepaper 4.0 Section: Overall Architecture [32].

8.3. Software Networks WG

5G-PPP Software Network Working Group has the objective to analyse and address unification and applicability of key research topics related to Software Networking including software defined concepts, infrastructures, systems and components for Wire and- Wireless Networks, including Networked Clouds, IoT and Services, i.e. Software Defined Networks (SDN) and Network Function Virtualization (NFV) as developed and promoted by the 5G PPP projects.

To this end, TeraFlow is closely monitoring and contributing to this WG activities. Firstly, the project was introduced to the group, and currently contributions have been made to the white paper regarding network API.

- From VNF to API: Opening up 5G and beyond networks

8.4. SME WG

UBITECH closely follows the activities of the SME WG during the last two years. Currently, there is no relevant activity for TeraFlow to report., however UBITECH is actively trying to identify opportunities for further engagement and collaboration.

8.5. TMV WG

A requirement for 5G and related technologies is testing the complex infrastructure via the validation and performance monitoring of the architecture, functional components, and end-to-end services. The 5G PPP Test, Measurement, and KPIs Validation Working Group (TMV WG) will bring experiences and requirements across concurrent 5G PPP projects to develop measurement and assessment methods, use cases, procedures and performance indicator validation. This is a relatively new 5G PPP WG, and the current focus is to agree set of use cases and coordinate discussion. The project member ODC participates in this activity and will report status as progress is made.

8.6. Security WG

TeraFlow participates in the 5G IA Security Working Group in order to be updated with the latest trends and actions done by 5G PPP projects that focus on security aspects. Currently this working group is working on a set of four whitepapers in which TeraFlow aims to contribute in two of them that focuses on aspects such as Network Slicing and Distributed Ledger Technologies (DLT) with Blockchain as its most known example:

- Access control mechanisms in distributed 5G environments
- SDN/NFV virtualisation, 5G Slicing and Security Considerations

8.7. Pre-Standards WG

The 5G PPP Pre-Standardisation working group is developing a pertinent standardisation roadmap and highlighting regulatory topics for 5G. TeraFlow has several active efforts on standardisation, including ETSI, 3GPP, IETF and other relevant standards bodies. The project partner ODC is attending and participating in this WG and providing updates on TeraFlow standardisation activity to other WG participants. In addition, there may be standards collaboration between 5G PPP projects in the future.

8.8. VSC WG

TNOR has been very active in the Vison and Societal Challenges working group, and its sub-groups over several years.

VSC vicechair: Håkon Lønsethagen (TNOR)

- BVME SG (Business validation, models and ecosystems.
    - Hanne Stine Hallingby (TNOR), chair
    - Esther Garrido (ATOS), participant
        - Ideas and concepts from TeraFlow shared: ecosystem approach to markets, enabling interoperability and market attractivity

    - Recent white paper published: 5G ecosystems
- Horizon Europe Vision SG, aka. Smart Network Vision subgroup
    - Contributors: Lønsethagen and Hallingby (TNOR)
        - Ideas and concepts shared: Full interoperability with open interfaces, enabling (new) cross-domain concepts and services, which in turn unleash business opportunities and ecosystem evolution
    - Recent white paper: European vision for the 6G Network vision Ecosystem

8.9. New WGs and SG to be considered for TeraFlow

- New VSC sub-group: Societal needs and value creation
- New 6G IA WG: Open SNS

8.10. Plans for EUCNC 2022

TeraFlow is preparing its contribution to annual EUCNC conference. This year a booth will be requested in order to perform the latest demo of TeraFlow OS, with the objective of disseminating project results among the rest of 5G PPP projects. Moreover, a scientific paper and a special session (joint with B5G-Open) will also be submitted in order to foster 5G PPP inter-project collaboration.

9. Conclusions and next steps

This deliverable has offered an overview of the WP6 activities of the project in its first year. As outlined within the document, we have made excellent dissemination progress and achieved several important KPIs (see Table 4 in section 6.7 for a summary). Ultimately, we have been successfully raising awareness of the project on several fronts and are excited about the overall response and interest we have received.

The impact achieved with these activities has been recently presented to the TeraFlow Advisory Board[1] (17th December 2021), whose members gave very positive feedback and some guidance for future work on how to ensure the sustainability of the TeraFlow SDN controller after the H2020 TeraFlow project ends. This future effort aims to maintain the momentum of the standardisation efforts, seek touchpoints with ETSI, and study the possibility of performing a PoC (Proof of Concept).

Significant next steps include the first release of TeraFlow OS, planned for the beginning of next year (2022). From WP6, we will work to support the launch of this first release by developing a presentation, a brochure, a video, and a press release to be issued on local media outlets and specialized magazines. In addition, all this material will be uploaded to the website and disseminated widely via social media accounts from the project partners, European Commission portals such as 5G PPP, and, where possible wider industry and academic channels.

Participation in relevant conferences and workshops is already planned for next year. On the 3rd of February 22, TeraFlow will be presented at the ICT-52 Workshop on 6G organised by the European 6G Flagship project Hexa-X. We can also highlight the submission and acceptance of four papers to OFC2022, including a demo paper: “Demonstration of Zero-touch Device and L3-VPN Service Management using the TeraFlow Cloud-Native SDN Controller”, which will demonstrate zero-touch device bootstrapping, monitoring, and L3-VPN service management using our novel OS SDN controller prototype. Besides, TeraFlow is preparing its contribution to the EUCNC 22 conference. This year, a booth will be requested to perform the latest demo of TeraFlow OS to disseminate project results among the rest of 5G PPP projects. Moreover, a scientific paper and a special session (joint with B5G-Open) will also be submitted to foster 5G PPP inter-project collaboration.

The following step activities and milestones outlined will be essential for our overall dissemination strategy, key phases and ongoing success. In addition, we intend to continue and actively engage with key stakeholders by reaching out to potentially interested end-users/adopters of the project's results and involving them in activities that will be necessary to support the exploitation and business modelling activities.

[1] TeraFlow Advisory Board members are: Noboru Yoshikane (KDDI Research), Silvia Almagia (ETSI) and Diego Marí (TIP OOPT)

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