5G Programmable Infrastructure Converging disaggregated network and compUte Resources

D7.5 Commercial Exploitation and Market Impact

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Executive Summary

In the context of the 5G-PICTURE project, the activities aim at maximising the value from the project results technologies, and at paving the way to results'/technologies' sustainability, commercial exploitation and early deployment. These activities have been concretely performed under Task T7.3 "Commercial Exploitation". This deliverable reports on the work done and results obtained in the context of this task, from the beginning up to Month 30 of the project lifetime.

This document provides at first stage a detailed view of the principles and the methodology followed to identify 5G-PICTURE project exploitable outcomes and the ways to explore and foster their exploitation based on two well-structured business tools, namely the Value Proposition and the Lean Canvases.

At next stage a concrete identification of the project outcomes is performed. In practice, the nature of each outcome is specified; the particular value that each outcome brings to specific stakeholders is described in technical and business terms; the ownership of the associated Intellectual Property Rights (IPR) is identified; and considering the profile of the IPR owner in terms of business/academic activities and vision, the framework for the outcome's further business analysis and exploitation is set. To this end, the Technology Readiness Level (TRL) of each outcome as achieved in the context of 5G-PICTURE is presented, and it is compared against the initially expected TRL advancement.

This document further provides the business analysis for each 5G-PICTURE outcome, which is performed on a per target customer basis and is associated with the value that each outcome brings. This analysis constitutes the initial step of any exploitation activity. Concrete exploitation plans of the partners related to these outcomes are provided right after, allowing the reader to identify the direct association between the products and the partners' exploitation plans.

The deliverable includes also detailed analyses of the business perspectives of the integrated 5G-PICTURE solutions in the representative vertical sectors that the project has addressed; namely in the railway, the stadium/large venues and the smart city sectors. The current ecosystem and the changes to be incurred by the 5G-PICTURE solutions are identified, along with the current problems, the future challenges and opportunities. To this end, the primary steps/activities/licenses that are needed for a vertical to enter the vertical infrastructure providers' market have been presented. The business relations to be built are also recognized. Especially for the railway sector case the business analysis is accompanied by the associated, concrete exploitation plan of COMSA – a direct, relevant stakeholder involved in the 5G-PICTURE project.

Last but not least, further individual partners' exploitation plans are provided, mainly those being technology adopters (thus their business plans fall in the use case analysis) and/or owners of exploitable outcomes that are not of type "product".

This document outlines the main intention of the 5G-PICTURE consortium towards pursuing sustainability and exploitation of the project results.

1 Introduction

The aim of 5G-PICTURE is to develop and demonstrate a converged fronthaul (FH) and backhaul (BH) infrastructure integrating advanced wireless and novel optical network solutions. To address the limitations of the current Distributed Radio Access Network (D-RAN) and Cloud-RAN (C-RAN) approaches, 5G-PICTURE exploits flexible functional splits that can be dynamically selected, to optimise resource and energy efficiency. This results in a paradigm shift from RAN and C-RAN to "Dis-Aggregated RAN" (DA-RAN). DA-RAN is a novel concept where hardware (HW) and software (SW) components are disaggregated across the wireless, optical and compute/storage domains. "Resource disaggregation" allows decoupling these components, creating a common "pool of resources" that can be independently selected and allocated on demand to compose any infrastructure service. The whole solution is orchestrated by layers of technology and administrative domains orchestrators and multi-domain orchestrators, making use of the concepts of:

1. Network "softwarisation", migrating from the conventional closed networking model to an open reference platform, supported through HW programmability, as described in the following point.
2. HW programmability, where HW is configured directly by network functions, to provide the required performance. This enables provisioning of any service by flexibly mixing-and-matching network, compute and storage resources without sacrificing performance and efficiency as is the case in to-day's NFV-based solutions.

The 5G-PICTURE solution enables the overall 5G vision, supporting any service, including operational and end-user services for both Information and Communications Technology (ICT) and "vertical" industries. Proof of concept demonstrators are being showcased in realistic environments including:

- A 5G-railway testbed located in Barcelona, Spain comprising three tracks covering scenarios with the rolling stock, to be the first 5G railway experimental testbed to showcase support of seamless service provisioning and mobility management in high speed moving environments.
- A 5G-smart city testbed to experimentally validate the DA-RAN concept through the support of joint BH and FH services.
- A 5G-stadium testbed located in Bristol, UK to address scenarios with increased density and static-to-low mobility. In this environment media services associated with large venues will be demonstrated.

In this context a lot of effort has been put both on the development of individual technologies as SW/HW products/components, as well as on the integration together of these components in the testbeds towards demonstrating their capabilities along with the feasibility of their interworking.

From the business perspective, the 5G technologies evolution not only bring network performance enhancements to enable the delivery of new applications and services, but also it brings new business models involving multiple stakeholders from previous traditionally separated markets, and where also some business roles are changing due to the new paradigms. The latter are also realised through the extensive use of network softwarisation and programmability to provide integrated infrastructures consisting of telecommunication networks, computing resources and physical infrastructures making use of convergent technologies as addressed in the context of 5G-PICTURE vertical demonstrations. The latter are representative cases of the changing business environment and business roles.

At the same time, besides the research and technological advancements, EC is considering the timely deployment of 5G as a strategic opportunity for Europe [5], and is fostering activities towards the commercial exploitation and early deployment of 5G-related technologies/outcomes. In the context of the 5G-PICTURE project, the activities aiming at maximising value from the project results, and paving the way to results' sustainability and exploitation have been concretely performed under Task T7.3 "Commercial Exploitation". This deliverable reports on the work done and results obtained in the context of Task T7.3.

Organisation of the document

This document comprises eight (8) sections. Following the Executive Summary and Introduction sections:

- Section 2 sets the principles and the methodology followed to identify 5G-PICTURE project exploitable outcomes and the ways to explore and foster their exploitation based on two (2) well-structured business tools.
- Section 3 provides a concrete identification of the project outcomes, and considering each partner's business/academic activities and vision, sets the framework for the analysis of them in business terms.
- Section 4 provides the business analysis for the individual 5G-PICTURE outcomes on a per target customer basis and the value that these outcomes bring to them. It also provides concrete exploitation plans of the partners related to these outcomes.
- Section 5 analyses the business perspectives of the integrated 5G-PICTURE solutions in the representative vertical sectors that the project has addressed.
- Further individual partners' exploitation plans are provided in Section 6.
- Finally, in Section 7 the conclusions of the deliverable are summarised.

2 Project Exploitation Outcomes Classification and Methodology

2.1 Exploitation Outcomes Classification

Considering the diversity of the partners who may participate in a R&D EU funded project ranging from academic to industrial sectors, different and usually complementary expertise and prospects are reflected to their exploitation strategy and activities. More specifically, Universities and Research Centres usually focus on exploitation activities regarding research items, while large companies and SMEs are mainly interested in the commercial exploitation of the products. At the same time, partners representing the stakeholders which are the potential consumers/ users of the project outcomes mainly focus on the identification of the added value of the products/outcomes and the ways the latter can be adopted in their (usual) business processes, infrastructure, provided services and so on.

Regarding the exploitable outcomes of a project, they can be classified in four (4) major categories; each one usually associated with some type of partner as depicted in Figure 2-1:

- **Product development** which includes the development of new products/features (together with a roadmap definition) as well as the product validation that increases the technology readiness level (TRL) towards its commercial exploitation. This category is mostly related to companies (large companies and SMEs).
- **Business development** which includes enhancement of existing business services/activities and/or the creation of new ones. This category is also related mostly to companies.
- **Standardisation contribution** which constitutes a very concrete step towards products' / solutions'/ services' and (in general) outcomes' sustainability as it reflects the industry sector's consensus towards their development and commercial adoption. In the context of a project, partners that are actively involved in standardisation and regulatory activities may promote the results of the project as technical contributions to relevant Standards' bodies. Standardisation is not strictly associated with a certain type of outcome, but usually falls in the interest of commercial/industry entities.
- **Research achievements,** including theoretical studies and research prototypes, which can be further exploited/ extended by the research community (academic and industrial sectors) mainly when made available through publications and can be considered as the basis for further research/development. In general, academic and research entities focus on them.

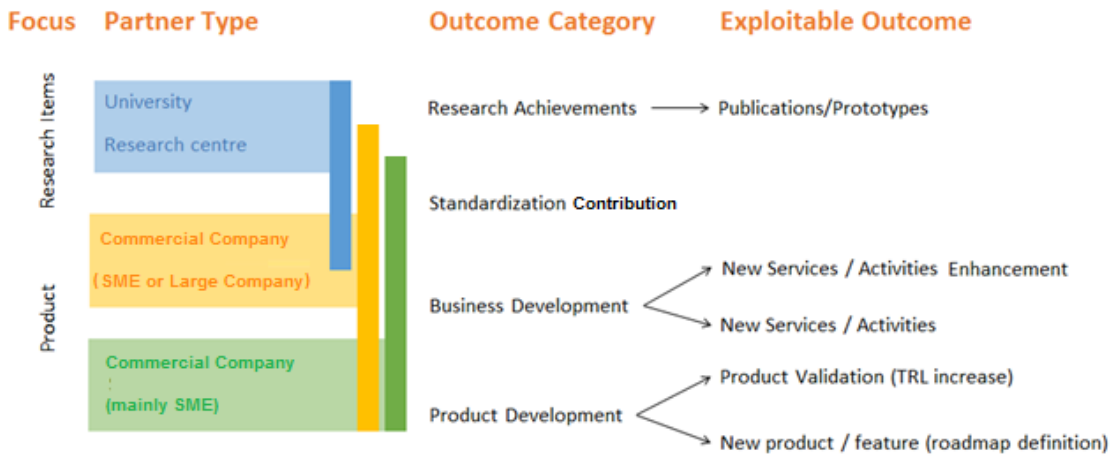


Figure 2-1: Potential Exploitation of a Project Outcomes.

In the 5G-PICTURE project, Universities, Research Centres, large companies and SMEs are involved, with various expertise and areas of interest, focusing on various aspects/ technologies/ outcomes of the project according to their strategic (profitable or non-profitable) goals. In particular, the 5G-PICTURE outcomes have been classified in the following categories:

- **Research Achievements:** The academic partners focus on the fields of propagation modelling as well as mobility support protocols/algorithms.
- **Contributions to standardisation and publications** – All partners (both academic and industrial) focus on generating exploitable results delivered to the industry through standardisation and dissemination paths (handled/analysed in the associated WP7 tasks).
- **Product Development:** In the context of the project, a number of industrial partners have focused on developing or enhancing specific products, by:
  - delivering them as **Prototypes** - Stand-alone products,
  - performing **Validation Activities** of the functionalities of specific products. These can be considered as exploitation activities aiming at increasing the TRL level of the associated products, and
  - accompanying the validation activities with **Demonstrators** in the field or in lab environment; either as Proof of Concept (PoC) or as Solutions addressing specific end-user needs.
- **Business Development:** For the partners representing the end-users/customers of the solution the exploitable outcomes fall in the following categories:
  - **Demonstrators**, through which partners (as end-users) can exploit testing results and identify issues related to the adoption of the associated solutions in their infrastructure at early stages, towards the enhancement of their business activities/services.
  - **Other Achievements,** namely Techno-economic Tools (developed by partners – end users) aiming at enhancing internal processes and assessment procedures related to the deployment of the 5G-PICTURE technologies.

2.2 Exploitation Strategy Methodology

There are two prevailing models in the market for customer centric identification of the exploitable potentials for a given product/result: (a) The Value Proposition Canvas and (b) the Lean Canvas, for more mature propositions; both presented in the following sections. Structured analysis of the 5G-PICTURE exploitation outcomes has been performed on the basis of these two commonly established business tools depending on the type of the exploitation outcome and the profile of the involved partner(s). The process to be followed encompasses the following steps:

1. As a first step information about each potential exploitable outcomes is associated with the Result Category, an Exploitation Type and the target Customer Segment, in a structured manner. The collected information is assessed and aligned across the project to offer a concrete final list of exploitable outcomes.
2. Depending on the type of the exploitation outcome, the profile of the involved partner(s), for the main Exploitable Outcomes and Customer Segments, the Value Proposition Canvas is filled. Through the identification of gains, pains and opportunities a clear and structured value proposition statement for the outcome is provided.
3. For the Outcomes with more promising (in the medium/short term) Value Propositions, the Lean Canvas methodology is used to further analyse the exploitation potential and identify the key parameters to build the related business case.

4. Concrete partners' exploitation plans have been devised associated with the exploitable outcomes of their focus/responsibility.

More specifically:

- **Prototypes/products developed by industrial partners** have been analysed using both the Value Proposition and the Lean Canvases for the specific products on a per customer basis.
- **Prototypes/products developed by research partners** (with no direct commercialization capability), have been analysed using the Value Proposition only.
- **Demonstrators** have been analysed using both the Value proposition and the Lean Canvases.
- **Validation Activities,** since aiming at increasing the TRL level of the associated products, have been incorporated in the analysis of the prototypes and demonstrators, and are further analysed in the context of the products' exploitation/partners plans.
- **Pure Research Outcomes and Other Achievements** have been analysed in terms of their value in the individual partners' exploitation plans that generated them.

2.2.1 Value Proposition Canvas Methodology

The Value Proposition Canvas [2] has two sides, the Customer Profile (on the right) and the Value Proposition (on the left) and is graphically depicted in Figure 2-2:

The Customer Segment describes the target customer profile and relevant key information to understand the expected value to be provided by 5G-PICTURE results. More specifically it includes the following information:

* **Customer Jobs**; the existing customer jobs and business processes executed by the prospect (corporate) users that are relevant to each or a set of 5G-PICTURE products.
* **Pains**; the risks, obstacles, problems related with the existing way (without the 5G-PICTURE product(s)) of performing the Customer Jobs.
* **Gains**; the outcome(s) customers want to achieve or concrete benefits they are seeking from their Jobs.

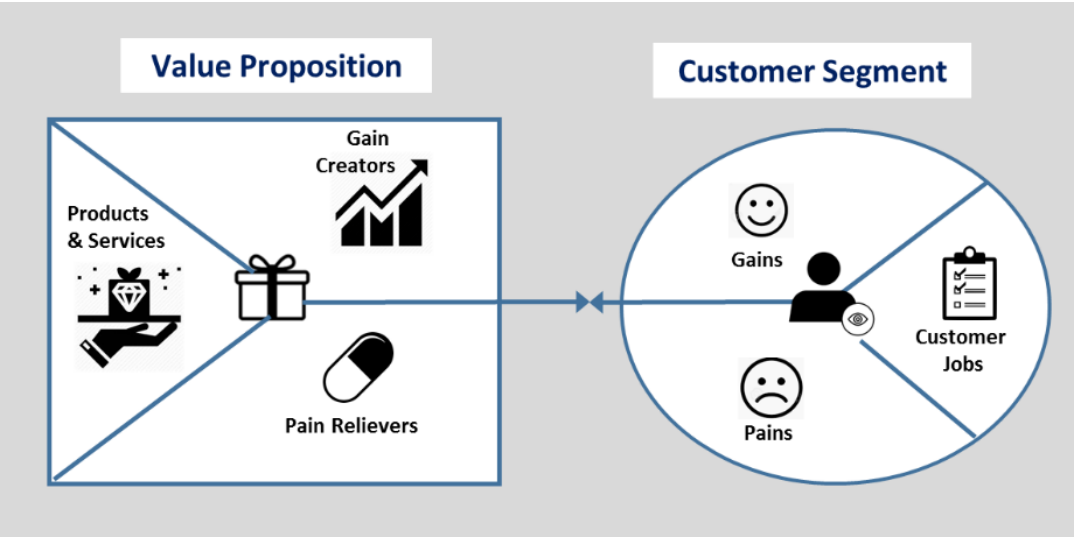


Figure 2-2: Value Proposition Canvas.

(a) The Value Proposition is used as a guide to depict and identify information regarding the features of a product or service targeting the specific Customer. The Value Proposition is broken down into:

* **Products and services**; the list of 5G-PICTURE products/services that are delivering a value proposition to the specific Customer Segment.
* **Pain relievers**; the ways in which the 5G-PICTURE products/services will alleviate specific Customer Pains.
* **Gain creators**; the ways in which these products/ services can create gains for the Customer.

2.2.2 Lean Canvas Methodology

The Lean Canvas Model (see Figure 2-3) is a business case development method that is based on the graphic representation of a number of variables that show the values of a business and/or organisation. Lean Canvas is adapted from The Business Model Canvas [3], [4] and can be applied for direct exploitable assets of a commercial initiative. The Canvas is presented in the figure below:

Figure 2-3: Lean Canvas Model.

The items foreseen in the Lean Canvas model are the following:

* **Problem:** The top problems that can be addressed from the product/service, addressing the jobs that are affected, why, how and who is concerned.
* **Existing Alternatives:** Other solutions solving the same or similar problem currently.
* **Solution:** A brief description of what the solution does and how, with special focus on the main features that differentiate it from the alternatives.
* **Key Metrics:** Key activities that will be measured to track the success (e.g., units sold, users registered)

* **Unique Value Proposition:** The critical success factors of the product(s) proposition towards satisfying customers' needs especially in comparison to the alternatives. The statement underlines the product's uniqueness and provide numbers to explain performance gains.
* **Unfair Advantage:** Advantages compared to the competition.
* **Channels:** Channels to be used to contact customers, promote and deliver the value promised.
* **Customer Segment:** The customer segment in focus, who has the problem and would be interested in buying the solution. The customer segment can be split in vertical segments to identify the strongest vertical to target for.
* **Early Adopters:** A small niche that is having the biggest problem, the ones who suffer the most, or who are most easily reachable and could become early adopters. In the process of identifying early adopters, geographic location, industry and connection to the problem are important aspects.
* **Cost Structure**: The main costs incurred so that the solution reaches the market and remains a sustainable product/business activity (e.g., customer acquisition costs, distribution costs, hosting, human resources costs, etc.).
* **Revenue Streams:** The main revenue streams generated from the commercialisation/ provision of the solution to the market.

3 Identification and Classification of 5G-PICTURE Exploitable Outcomes

3.1 5G-PICTURE Exploitable Outcomes and Owners

As aforementioned, the exploitable outcomes of the 5G-PICTURE project span pure research results, to individual products and further to integrated demonstrators tailored to specific end-users (verticals in 5G terminology). The exploitable outcomes list and classification is presented in Table 3-1 along with the corresponding owner.

Table 3-1: Identification and classification of exploitable results.

	Exploitable Outcome	Type	Owner
1	Rail use case demo	Demonstrator	COMSA/FGC/Others
2	Stadium use case demo	Demonstrator	Zeetta/Others
3	Smart city – 5G UK testbed demo	Demonstrator	UniB (HPN)/Others
4	Active massive MIMO radio unit	Prototype/Product	AIR
5	BWT Typhoon (& platforms synchronization support (IEEE 1588v2))	Prototype/Product	BWT
6	Flex-E Network Technology	Prototype/Product	HWDU
7	X-Ethernet Network technology	Prototype/Product	HWDU
8	IEEE TSN Network technology	Prototype/Product	HWDU
9	Time-sensitive 100G aggregator	Prototype/Product	ADVA
10	Layer 2 Network Slicing for Transport Networks	Prototype/Product	Zeetta
11	TSON Edge Node	Prototype/Product	UniB(HPN)
12	Slicing enabled WiFi controller and nodes	Prototype/Product	I2CAT
13	mmWave (60 GHz) beamsteering transport solution	Prototype/Product	IHP
14	Programmable data plane (Open Packet Processor - OPP)	Prototype/Product	CNIT
15	Mobility Server supporting handovers	Prototype/Product	CNIT
16	Multi-version service orchestration	Prototype/Product	UPB
17	Slicing enabled 4G/5G RAN controller and 4G/5G Node	Prototype/Product	EUR
18	Cross-technology MANO and SDN control	Prototype/Product	UTH
19	Validation of track-to-train mmWave system	Validation Activity	BWT
20	Validation of autotunable 10G Passive WDM TR6	Validation Activity	ADVA
21	Validation of SPC (Stanchion Power Cabinet) TR7	Validation Activity	COMSA
22	Propagation models & performance evaluation in a rail environment, for mmWave (26GHz, 60GHz) & mMIMO systems (3.5GHz)	Research Outcome	UniB (CSN)
23	Tools for 5G transport network dimensioning and cost analysis	Other Achievements	TIM, COS

It must be noted that due to the nature of the 5G-PICTURE work items and the work breakdown, practically due to the high expertise required for developing each of the required products/functionalities, each exploitable asset of type prototype/product is owned 100% by one partner/entity. Even though, significant gains have been generated for all partners and products through their participation in 5G-PICTURE, which otherwise would both have been achieved. In particular, in the context of 5G-PICTURE the products' features/functionalities have leveraged through the joint work of partners in the product/solution specification, design as well as in the demonstration phases. Especially, the leverage of the products' TRL to the level of test phase and demonstrator at

operational environment (i.e. mainly railway and stadium environment) is a major exploitation result of the project, which would be very difficultly achieved without the consortium/project partnerships. A brief description of the above exploitable outcomes follows in the next paragraphs.

3.2 5G-PICTURE Exploitable Outcomes of Type "Prototype/Product"

Table 3-2 presents the exploitable outcomes of the type "Prototype/Product" that stem from the 5G-PICTURE Consortium.

Table 3-2: Exploitable Outcomes of Type "Prototype/Product".

Prototypes/Products by Industrial Partners	Owner
Active massive MIMO radio unit	**XDE**
Xilinx Dresden (XDE) develops a proof-of-concept platform for a massive MIMO Radio Unit (RU), to be used in the access network of a Telecom operator. Together with a Distributed Unit and a Central Unit this forms what is traditionally known as a "Base Station". The RU implements massive MIMO, which promises a significant increase in cell capacity without requiring additional spectrum by utilizing spatial multiplexing. In addition, the RU features a new "functional split", in which additional signal processing is performed in the RU that in legacy networks is performed in a baseband unit. This has the benefit of reducing the required FH capacity dramatically.	
BWT Typhoon (and platforms synchronization support (IEEE 1588v2))	**BWT**
This is a prototype developed by BWT that consists of an IEEE 1588v2 development for the BWT Typhoon platform. This is new functionality which advances the state of the art and the TRL of the platform.	
Flex-Ethernet Network Technology	**HWDU**
This is a prototype developed by HWDU, Munich realizing the Flex-E technology, specified by Open Internetworking Forum (OIF) in the Flex Ethernet Implementation Agreement IA # OIF-FLEXE-01.0. Flex-E can run on top of an Optical Transport Network (OTN)-WDM and is able to provide Ethernet services, where multiplexing of users is done in time. Time multiplexing between client groups is performed in a layer between the MAC and the PCS.	
X-Ethernet Network technology	**HWDU**
Based on Flexible-Ethernet, a prototype was developed presenting a proprietary HWDU solution named X-Ethernet, where X stands for extended distance, expanded granularity and extremely low latency. X-Ethernet introduces Ethernet switching based on the interface offered by Flexible-Ethernet.	
IEEE TSN Network technology	**HWDU**
A HWDU prototype solution is exploited to demonstrate IEEE 802.1 TSN for the fronthaul network. The IEEE 802.1 TSN TG focuses mainly on the physical and link layer techniques to achieve guaranteed delivery of data with bounded low latency, low delay variation and low loss.	
Time-sensitive 100G aggregator	**ADVA**
This is a prototype developed by ADVA that follows IEEE802.1CM specification, providing low and bounded delay aggregation for synchronisation distribution and high-priority fronthaul traffic. This prototype can be exploited as the basis/input for a potential commercial product.	
Layer 2 Network Slicing for Transport Networks	**Zeetta**

Zeetta Networks are developing a Network Slicing Engine for Layer 2 and Layer 3 networks. The Virtualisation component of the Slicing Engine is based on the OpenDayLight framework. In this project we present a prototype of the Slicing Engine that creates Layer 2 Network Slices with different Quality of Service (QoS) to provide connectivity in a transport network.	
Prototypes/Products by Academic Partners	
TSON Edge Node	**UNIVBRIS-HPN**
TSON is proposed as a dynamic optical transport network solution to provide high bandwidth and low-latency connectivity in support of the 5G technology requirements. The TSON is extended to support 5G-PICTURE project. This prototype can be exploited as an input for a potential commercial product.	
Slicing enabled Wi-Fi controller and nodes	**I2CAT**
A Wireless access solution prototype developed by I2CAT composed of wireless nodes i) operating below 6 GHz (802.11ac) and the associated control and management software, ii) access and backhaul capabilities in the same node with backhaul application data rates up to 300 Mbps.	
mmWave (60 GHz) beamsteering transport solution including Hardware-programmable high speed, low latency point-to-multipoint (p2mp) MAC-processor	**IHP**
IHP has developed a Point-to-Multi-point (PTMP) Medium Access Control (MAC) processor for 60 GHz multi-gigabit single-hop wireless communication. This processor is characterized by a half-duplex communication, Master-slave configuration with up to 8 slaves, up to 1 Gbps throughput extendable to 4 Gbps, and it supports state-of-the-art beamforming Analogue Front-Ends (AFEs). IHP will make use of the Software Defined Radio (SDR) digibackboard to integrate the MAC processor and it will serve as the mmWave 60 GHz transport solution that will support the Smart City use case in Bristol.	
Programmable data plane (FlowBlaze)	**CNIT**
This is a prototype developed by CNIT. FlowBlaze is a programmable data plane designed to build stateful packet processing functions in hardware. The data plane implements Extended Finite State Machines and introduces explicit definition of flow state, allowing FlowBlaze to leverage flow-level parallelism. FlowBlaze can support a wide range of complex network functions and is easy to use since hides to the programmer low level hardware implementation issues.	
Mobility Server supporting handovers	**CNIT**
This is a set of network primitives developed by CNIT and implemented using the FlowBlaze platform. The functionalities allow fast and proactive handovers for mobility scenarios in which it is fundamental to minimize the off-time needed to reroute the traffic using the new network path, while providing a transparent handover. The use of this set of primitives permits to apply the mobility functionality to different network configuration, also supporting heterogeneous transport networks.	
Multi-version service orchestration	**UPB**
This is a prototype developed by UPB that consists of a Pishahang open-source MANO framework extension to support NFV multi-domain management and orchestration.	
Slicing enabled 4G/5G RAN controller and 4G/5G Node	**EUR**
This is a prototype developed by EUR that consists of an extension and validation of: (a) FlexRAN+:	

a SDN controller for heterogeneous RAN and (b) OAI-RAN: 4G RAN with multiple functional splits. FlexRAN+ is an SDN controller for a heterogeneous and disaggregated RAN with slicing support which has been exploited in the M5G open source communities (academia and industries) as well as a subject for master and Ph.D. programmes. (M5G members: https://mosaic-5g.io/members/). OAI-RAN is a prototype developed by EUR and UTH that consists of an extension and validation of OAI RAN to support flexible functional splits (3GPP option 8, 7.1, 6, and 2) and slicing. Exploited in the M5G open source communities (academia and industries) as well as for subject for master and Ph.D. programmes. (OAI members https://www.openairinterface.org/?page_id=83).	
Cross-technology MANO and SDN control	**UTH**
This is a prototype developed by UTH that consists of a development over Open Source MANO (OSM) platform. Special versions of VIM and SDN controllers (based on OpenDayLight) have been developed for enabling orchestration over heterogeneous networks integrating multiple wireless and wired technologies. In addition to the OSM support for the deployment of a network service over Ethernet-based networks, we extend OSM functionality over wireless networks that are either based on Wi-Fi, WiGig, etc.	

3.3 5G-PICTURE Exploitable Outcomes of Type "Validation Activities"

Table 3-3 presents the exploitable outcomes of the type "Validation Activity" that stem from the 5G-PICTURE Consortium.

Table 3-3: Exploitable Outcomes of Type "Validation Activity"

Validation Activities	Owner
Validation of track-to-train mmWave system	**BWT / COMSA**
This is a validation activity undertaken by BWT and COMSA regarding the BWT track to train mmWave system that has been utilised in the railway demonstration in Barcelona. The demo deployment and the enhancements introduced to attain high performance will increase the TRL of the BWT system.	
Validation of autotunable 10G Passive WDM TR6	**ADVA**
This is a validation activity undertaken by ADVA and COMSA regarding the passive optical WDM link deployed in the Barcelona railway demo. The optical transceiver plugged in the BWT mmWave radio unit can be automatically tuned to the corresponding wavelength, which is paired to the head-end transceiver at the central office.	
Validation of SPC (Stanchion Power Cabinet) TR7	**COMSA**
This is a validation activity undertaken by COMSA to validate the deployment of network equipment on stanchions of the railway infrastructure. The SPC is a cabinet that holds and protect the following components of the mmWave solution for outdoor installation: • The DWDM passives. • Remote power switch (Controlled by SMS). • Power supplies for the mmWave modems on the track. • Power breakers and dischargers. • Fiber patch panel. • Power splitter.	

3.4 5G-PICTURE Exploitable Outcomes of Type "Demonstrator"

Table 3-4 presents the exploitable outcomes of the type "Validation Activity" that stem from the 5G-PICTURE Consortium.

Table 3-4: Exploitable Outcomes of Type "Demonstrator".

Demonstrator	Participants
Railway Use Case Demo	COMSA / FGC, ADVA, BWT, CNIT, others
The Railway use case demo will showcase the potential of the 5G-PICTURE solution to deliver business and performance operation services over a single infrastructure, integrated with the railway infrastructure; in line with the newly specified Future Railway Mobile Communication System (FRMCS). The railway demonstration was showcased in Barcelona and the partners involved are ADVA, BWT, CNIT, COMSA, FGC. This demo shows two services that have benefited from the capabilities of 5G-PICTURE innovations: Internet access for passengers and on-board CCTV, while different tools will be used for measuring the performance of the on-board solution. The section of the demonstration spans along a 1.5 km section of the demonstration track, located next to Olesa de Monserrat station. The speed of commercial trains up to 90 km/h and the services demonstrated will be of two categories: performance operation and business services. This demonstration in a railway operational environment leverages the TRL level of the particular involved technologies/products.	
Stadium Use Case Demo	Zeetta, I2CAT, UTH, UNIVBRIS-CSN others
The Stadium use case demo will showcase the potential of the 5G-PICTURE solution to deliver highly demanding (mainly multimedia) applications/services over a single infrastructure, integrated with the stadium infrastructure. An incremental approach is planned for this demo: 1) Demonstration over existing access network technologies, 2) Demonstration over 5G network using high capacity wireless access technologies (Massive MIMO), an application aware network with differentiated service slices for applications, and a network aware application using programmable network features. The traffic type most suited for this demonstration is high definition video stream which requires low jitter and low latency variations. This demonstration in a stadium operational environment leverages the TRL level of the particular involved technologies/products.	
Smart City Use Case (5G UK Testbed) Demo	UNIVBRIS-HPN, IHP, XDE, others

The Smart City use case demo will showcase the potential of the 5G-PICTURE solution to deliver highly demanding multimedia and critical applications/services over a single infrastructure at smart city locations. The Smart City demo will be based on the Bristol 5G UK test-bed and will be showcase the overall 5G-PICTURE architecture. This includes Mobile Edge Computing (MEC) capabilities located both at the HPN lab and at the "We The Curious" site. The optical transport network will exploit the installed fibre connecting the HPN lab with the "We the Curious" and the "Millennium Square" sites across the city of Bristol leveraging the TSON technology developed by UNIVBRIS-HPN in the framework of 5G-PICTURE. In the "Millennium Square" the IHP mmWave technology will be exploited to support the wireless access network requirements of the use cases as well as end user equipment that HPN will provide. In addition, an active massive MIMO Antenna Proof-of-Concept platform available through XDE will be also installed at the "Millennium Square" and will be interconnected to the overall 5G-PICTURE test-bed to support the FH services to be demonstrated. This demonstration in a smart city demo environment leverages the TRL level of the particular involved technologies/products.

3.5 5G-PICTURE Exploitable Outcomes of Type "Research Outcome" & "Other Achievements"

Table 3-5 presents the exploitable outcomes of the type "Research Outcome" & "Other Achievements" that stem from the 5G-PICTURE Consortium.

Table 3-5: Exploitable Outcomes of Type "Research Outcome".

Research Outcome	Owner
Propagation models and performance evaluation in a rail environment, both for mmWave systems (26 GHz, 60 GHz) and Massive MIMO systems (3.5 GHz)	**UNIVBRIS-CSN**
Under the scope of the 5G-PICTURE project, **UNIVBRIS-CSN** has been, and will keep, investigating propagation models (ray-tracer tool) and performance evaluation (Matlab simulators) in a rail environment, since it is one of the use cases that 5G-PICTURE targets, both for mmWave systems (26 GHz, 60 GHz) and Massive MIMO systems (3.5 GHz). Work includes comparison of the theoretical results with those of the real-time Rail Demo, with exploitation potential in the field of mmWave technology in rail environments research.	

Table 3-6: Exploitable Outcomes of Type "Other Achievements".

Other Achievements	Owner
A tool for 5G transport network dimensioning and cost analysis	**TIM / COS**
COS and **TIM** have cooperated for the development of two fully parameterized tools for (a) dimensioning of transport access/aggregation/core of 5G network deployments using 5G-PICTURE technologies and (b) cost and performance analysis of various 5G deployment scenarios; at early deployment phases for large scale 5G networks, and at deployment phases for short-scale, vertical 5G networks.	

3.6 5G Stakeholders, Business Roles and Business Models in 5G-PICTURE

To facilitate the analysis of the exploitable outcomes (that will follow in the next Sections) and to enable their association to the potential customers' segments, a brief introduction regarding the 5G ecosystem value chain is provided in this paragraph to the convenience of the reader.

In general, the business roles that usually appear in the value chain of the future 5G business ecosystem have been drafted in a number of industry white papers [10], [11], [12], which mainly adhere to existing business roles and stakeholders. Leveraging these initial definitions, [13], [14] focus on the refinement and extension of these business roles, which can be generalized for any 5G business ecosystem. These business roles definitions are described in the following paragraphs.

At first, a principal role in the 5G ecosystem is that of the Telecommunication Service Provider (TSP) – undertaken by Mobile and/or Fixed-network infrastructure providers – operating a programmable (5G) network infrastructure spanning from the radio and/or fixed access to the edge, transport and core network. The network infrastructure can be either owned by the TSP or network resources can be leased (partly or completely) as a Network Service (NaaS) from an Infrastructure Provider.

The latter reveals another significant role: that of the Infrastructure Providers (IPs), putting infrastructure resources (network resources, storage space, compute resources) in place for the 5G-ready applications deployment. Depending on the nature of the required infrastructure resources and the assets of the stakeholders, this role can be split to further roles, performed by one or more stakeholders; namely:

- Network Infrastructure Providers (NPs) operating telecommunication infrastructures and offering network resources and services to end-users, verticals and/or (other) TSPs;
- Cloud Infrastructure Providers (CPs), operating centralized or distributed (in more than one location) cloud/edge deployments and offering compute and storage resources in a programmable way.

The Equipment Vendors' role traditionally providing hardware equipment, now is extended to providing software telecom equipment (i.e. VNFs), thus implementing programmable network layer functions and delivering these components/ functions to the stakeholders in charge of their operation.

System integrators undertake the role of supporting the design and development of end-to-end orchestration platforms, at network and application level.

The role of software developers is key in the 5G ecosystem, and includes:

- VNF developers, designing and developing Virtual Network Functions.
- Cloud application developers, designing and developing cloud-applications (e.g. micro services-based applications based on cloud-native principles).
- (Vertical) application developers, designing and developing any type of application combining cloud and network concepts (e.g. Mobile Edge Computing-oriented functionalities).

(Vertical) Application/Service Providers (AP/SP) provide applications/ services to end users and aim at enhancing their portfolio and optimising service provisioning.

Finally, Service Consumers/ End Users are the individuals or corporate users to consume the 5G applications/ services while being static and/or on the move. Vertical industries usually fall into this category.

In practice, in future 5G business environment a stakeholder may undertake more than one role, or a stakeholder's role may be assigned to more than one stakeholder, depending on the nature of the 5G application/service and the resources that it requires. For instance:

- The NPs may also undertake the role of the CPs depending on their infrastructure assets, or in some cases even the role of the AP/SP.
- The Application Developers' and AP/SP's roles could be played by the same stakeholder.
- The SP role can be undertaken by a vertical or by a software house providing, while
- Many stakeholders can be considered as Service Consumers, depending on the nature of the applications, e.g. customers of the verticals or the verticals themselves can be Service Consumers, and so on.

Moreover, the advent of 5G, although does not extend significantly the existing business roles per se compared to existing network deployments, it facilitates the evolution of smaller telecom operators industry and it empowers stakeholders far from the traditional industries to engage into the ICT industry, through deploying and/or operating a 5G infrastructure and/or leasing resources and/or providing service to a 3rd party over it. The vertical industries sector is the primary such case and the specificities of these business cases are detailed in Chapter 5. From this perspective, 5G-PICTURE further advances [13], [14] can enable verticals to become "vertical infrastructure providers" – to be considered as a subset of the forthcoming "Small Telcos" stakeholder segment. The modified value chain is shown in Figure 3-1:

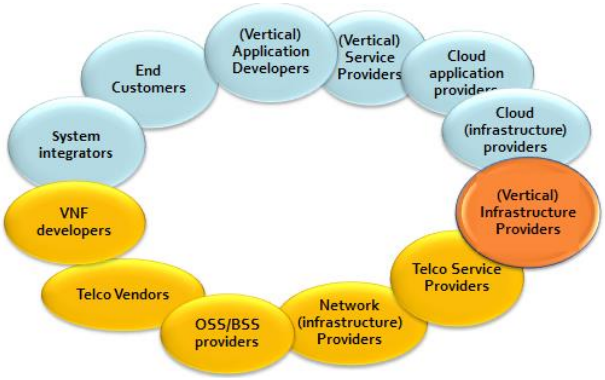


Figure 3-1: 5G-PICTURE Stakeholders' Overview.

3.7 Exploitable Outcomes Analysis

Taking into account the 5G-PICTURE exploitable outcomes and the 5G business roles and business models identified in the context of the project, a mapping between the exploitable outcomes and the stakeholders/business roles has been performed. The latter constitutes the first step towards the identification of the 5G-PICTURE exploitable outcomes value for key market segments, thus their exploitability and sustainability potential. Next to this mapping, and depending on the type of the exploitation outcome and the profile of the involved partner(s), different exploitation methodologies have been selected for further analysis of the outcomes exploitation potential. More specifically:

- **Prototypes/products developed by commercial partners** have been analysed using both the Value Proposition and the Lean Canvases for the specific products on a per customer basis.
- **Prototypes/products developed by research partners** (with no direct commercialization capability), have been analysed using the Value Proposition.
- **Demonstrators** have been analysed using the Lean Canvases.

- **Validation Activities** actually serve the purpose of increasing the TRL level of the associated products thus have been incorporated in the analysis of the prototypes and demonstrators and are further analysed in the context of the products' exploitation/partners plans.
- **Pure Research Outcomes and Other Achievements** have been analysed in terms of their value in the individual partners' exploitation plans that generated them.

It shall be mentioned that, throughout the course of the project, the maturity level of each outcome has been continuously monitored, and the project's exit TRL level has been identified. In general, the provisioning of operational environments for testing and demonstrating the 5G-PICTURE technologies, operating both in standalone operations and as an integrated solution, has been the most significant benefit obtained by all partners from the project, and a strong advantage that is difficult to be copied by competitive/similar companies with activities in similar fields. In this respect, in line with the general TRL definitions, technologies that have been included in the railway and stadium Use Case demonstrators have reached TRL 5/6, as they have been tested in operational environments, while technologies which have been demonstrated through individual standalone demonstrations have been considered reaching TRL 4. It shall be noted that, for all exploitable outcomes, the exit TRL level equals and, in most cases, even exceeds the expected TRL advancement to be fulfilled by the work in the context of 5G-PICTURE project. The 5G-PICTURE Exploitable Outcomes Analysis results are summarised in Table 3-7.

Table 3-7. Exploitation Analysis Methodology per Outcome

Exploitation Analysis Methodology per Outcome							
#	Exploitable Outcome	Type	Methodology	Stakeholder Addressed	TRL Advancement		
					From	Expected	Reached
1	**Rail use case demo**	Demonstrator	Lean Canvas	(Vertical) Railway / Company providing telecom services to railways	TRL1	TRL6	TRL6
2	**Stadium use case demo**	Demonstrator	Lean Canvas	(Vertical) Stadium owner / Company providing telecom services to Stadium, Other Services (e.g. Broadcasters, Emergency etc.) and/or fans	TRL1	TRL6	TRL6
3	**Smart city – 5G UK testbed demo**	Demonstrator	Lean Canvas	(Vertical) Municipality / Small Telco/ other Company providing telecom services to City	TRL1	TRL6	TRL6
4	**Active massive MIMO radio unit**	Prototype/Product	VP/Lean Canvas	Telco (or Vertical owning telecom Infrastructure)	TRL4	TRL5/6	TRL5/6
5	**BWT Typhoon (& platforms synchronization support (IEEE 1588v2))**	Prototype/Product	VP/Lean Canvas	Telco (or Vertical owning telecom Infrastructure)	TRL3	TRL4	TRL6
6	**Flex-E Network Technology**	Prototype/Product	VP/Lean Canvas	Telecom Operator	TRL2	TRL4	TRL4
7	**X-Ethernet Network technology**	Prototype/Product	VP/Lean Canvas	Telecom Operator	TRL2	TRL4	TRL4
8	**IEEE TSN Network technology**	Prototype/Product	VP/Lean Canvas	Telecom Operator	TRL2	TRL4	TRL4
9	**Time-sensitive 100G aggregator**	Prototype/Product	VP/Lean Canvas	Telecom Operator	TRL3		TRL6
10	**Layer 2 Network Slicing for Transport Networks**	Prototype/Product	VP/Lean Canvas	Telco (or other Stakeholder owning telecom Infrastructure)	TRL2	TRL5	TRL5/6
11	**TSON Edge Node**	Prototype/Product	VP Canvas	Telecom Operator	TRL4	TRL5	TRL5*
12	**Slicing enabled Wi-Fi controller and nodes**	Prototype/Product	VP/Lean Canvas	Telco (or Vertical owning telecom Infrastructure)	TRL2	TRL3	TRL5*
13	**mmWave (60 GHz) Beamsteering Transport solution**	Prototype/Product	VP Canvas	Telco (or Vertical owning telecom Infrastructure)	TRL3	TRL5	TRL5*
14	**Programmable data plane (FlowBlaze)**	Prototype/Product	VP Canvas	Telco (or Vertical owning telecom Infrastructure)	TRL0/ 1	TRL4	TRL6

Exploitation Analysis Methodology per Outcome							
#	Exploitable Outcome	Type	Methodology	Stakeholder Addressed	TRL Advancement		
					From	Expected	Reached
15	**Mobility Server supporting handovers**	Prototype/Product	CNIT exploitation plan	Telco (or Vertical owning telecom Infrastructure)	TRL0		TRL6
16	**Multi-version service orchestration**	Prototype/Product	UPB exploitation plan	Telco (or Vertical owning telecom Infrastructure)	TRL1	TRL5	TRL5*
17	**Slicing enabled 4G/5G RAN controller and 4G/5G Node**	Prototype/Product	VP/Lean Canvas	Telco (or Vertical owning telecom Infrastructure)/ Academic Institutes	TRL2	TRL4	TRL4
18	**Cross-technology MANO and SDN control**	Prototype/Product	UTH exploitation plan	Telco Or Vertical as Telecom Service Provider	TRL3	TRL4	TRL5*
19	**Validation of track-to-train mmWave system**	Validation Activity	BWT exploitation plan	As associated product	n/a	n/a	n/a
20	**Validation of autotunable 10G Passive WDM TR6**	Validation Activity	ADVA exploitation plan	As associated product	n/a	n/a	n/a
21	**Validation of SPC (Stanchion Power Cabinet) TR7**	Validation Activity	COMSA exploitation plan	As associated product	n/a	n/a	n/a
22	**Propagation models & performance evaluation in a rail environment, for mmWave & mMIMO systems**	Research Outcome	UNIVBRIS-CSN exploitation plan	Network Planner	n/a	n/a	n/a
23	**Tools for 5G transport network dimensioning and cost analysis**	Other Achievements	TIM & COS exploitation plan	Telecom Operator, Vertical	n/a	n/a	n/a

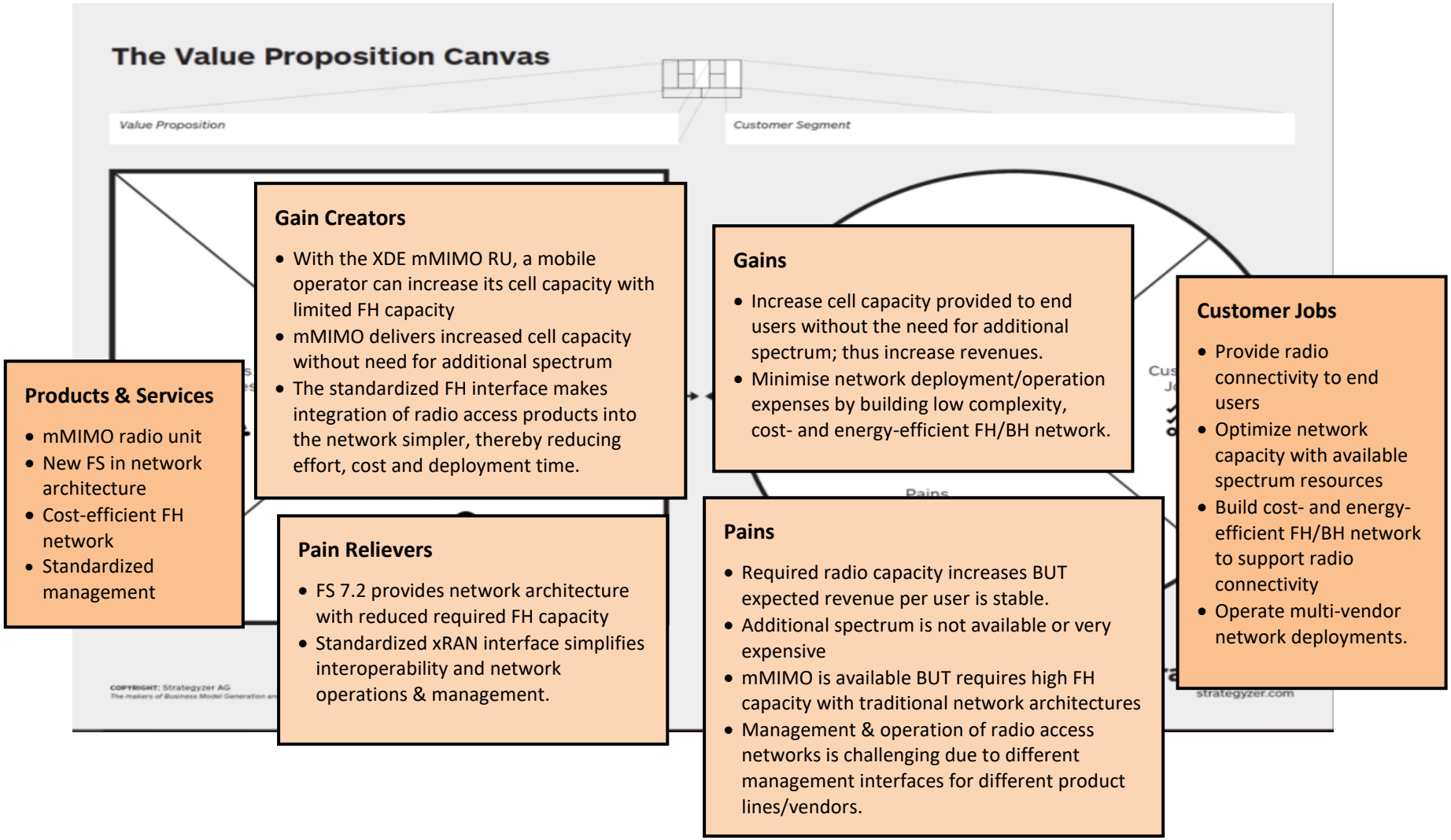
* These technologies are part of the “Stadium” and “Smart City” demonstrators, so currently the reached TRL level is 5, but will advance to 6 with the completion of the testing and demonstrations by the end of the project.

4 Prototypes/Products Business Analysis

This chapter extends the detailed business analysis for each 5G-PICTURE outcome of type prototype/product, on a per target customer basis, using as reference the 5G value chain as revised by 5G-PICTURE. It shall be noted that concrete exploitation plans of the partners related to these outcomes are provided right after, which reveal the high engagement of partners to pursuing sustainability, and further exploitation of these outcomes; this structure also helps the reader in identifying the direct association between the products and the partners' exploitation plans.

4.1 Active massive MIMO Radio Unit

The target customer segment of the Active massive MIMO radio unit product from Xilinx Dresden **XDE** is Telecom Operators or Verticals/Small Telcos owning radio network infrastructure. The value proposition delivered by this product to Telecom Operators is analysed in the following VP & Lean Canvases.


The Value Proposition Canvas
Value Proposition
Customer Segment
Gain Creators
• With the XDE mMIMO RU, a mobile operator can increase its cell capacity with limited FH capacity
• mMIMO delivers increased cell capacity without need for additional spectrum
• The standardized FH interface makes integration of radio access products into the network simpler, thereby reducing effort, cost and deployment time.
Gains
• Increase cell capacity provided to end users without the need for additional spectrum; thus increase revenues.
• Minimise network deployment/operation expenses by building low complexity, cost- and energy-efficient FH/BH network.
Customer Jobs
• Provide radio connectivity to end users
• Optimize network capacity with available spectrum resources
• Build cost- and energy-efficient FH/BH network to support radio connectivity
• Operate multi-vendor network deployments.
Products & Services
• mMIMO radio unit
• New FS in network architecture
• Cost-efficient FH network
• Standardized management
Pain Relievers
• FS 7.2 provides network architecture with reduced required FH capacity
• Standardized xRAN interface simplifies interoperability and network operations & management.
Pains
• Required radio capacity increases BUT expected revenue per user is stable.
• Additional spectrum is not available or very expensive
• mMIMO is available BUT requires high FH capacity with traditional network architectures
• Management & operation of radio access networks is challenging due to different management interfaces for different product lines/vendors.
strategyzer.com

Problem

- Required radio capacity is increasing but expected revenue per user is stable
- Additional spectrum is not available or very expensive
- mMIMO is available to increase radio capacity but requires very large FH capacity when using traditional network architectures
- Management and operation of radio access networks is challenging due to different management interfaces for different product lines/vendors.

Alternatives

- Acquire new spectrum
- Increase FH capacity by deploying more fiber or more expensive transceiver modules

Solution

- mMIMO radio unit
- New FS in network architecture
- Cost-efficient FH network
- Standardized management interface.

Key Metrics

- Volumes of sales of units
- Number of Customers
- Customers' loyalty in terms of number of orders through years.

Unique Value Proposition

Access network solution providing:

- Significantly Increased spectral efficiency (thus capacity without need for additional spectrum)
- While having moderate FH capacity requirements,
- With Standardized FH and management interface (ensuring interoperability with various vendors' equipment).

Unfair Advantage

- "fresh start": no legacy product lines, no existing deployments, fast time to market
- No "vendor lock-in": solution is interoperable with standardized interfaces *(customers are tired of missing interoperability, demand for mix-and-match deployments involving different vendors)*

Channels

- Direct contact (requests for products etc.)
- Partner vendors
- Trade fairs
- Conferences

Customer segment

- Telecom Operators
- (Verticals/Small Telcos owning radio network infrastructure)

Early adopters:

- Network operators in markets with low average revenue per user and/or very high capacity demand (high user density or high data rates per user), e.g. China, India, Japan

Cost Structure

- High development cost (person-hours, measurement equipment, prototype hardware)
- Cost related to field trials with customers
- Final production cost (depends heavily of number of manufactured units)
- Marketing/advertisement costs (Relatively low)

Revenue Streams

- Direct sale of manufactured units
- Royalties-based if manufactured by third party or as part of larger system (partnering with baseband vendors)
- Licensing of product IP possible (certain algorithms, building blocks, etc…)
- Software licenses for enabling specific features possible
- Non-Recurring Engineering for specific new features / adaptation possible

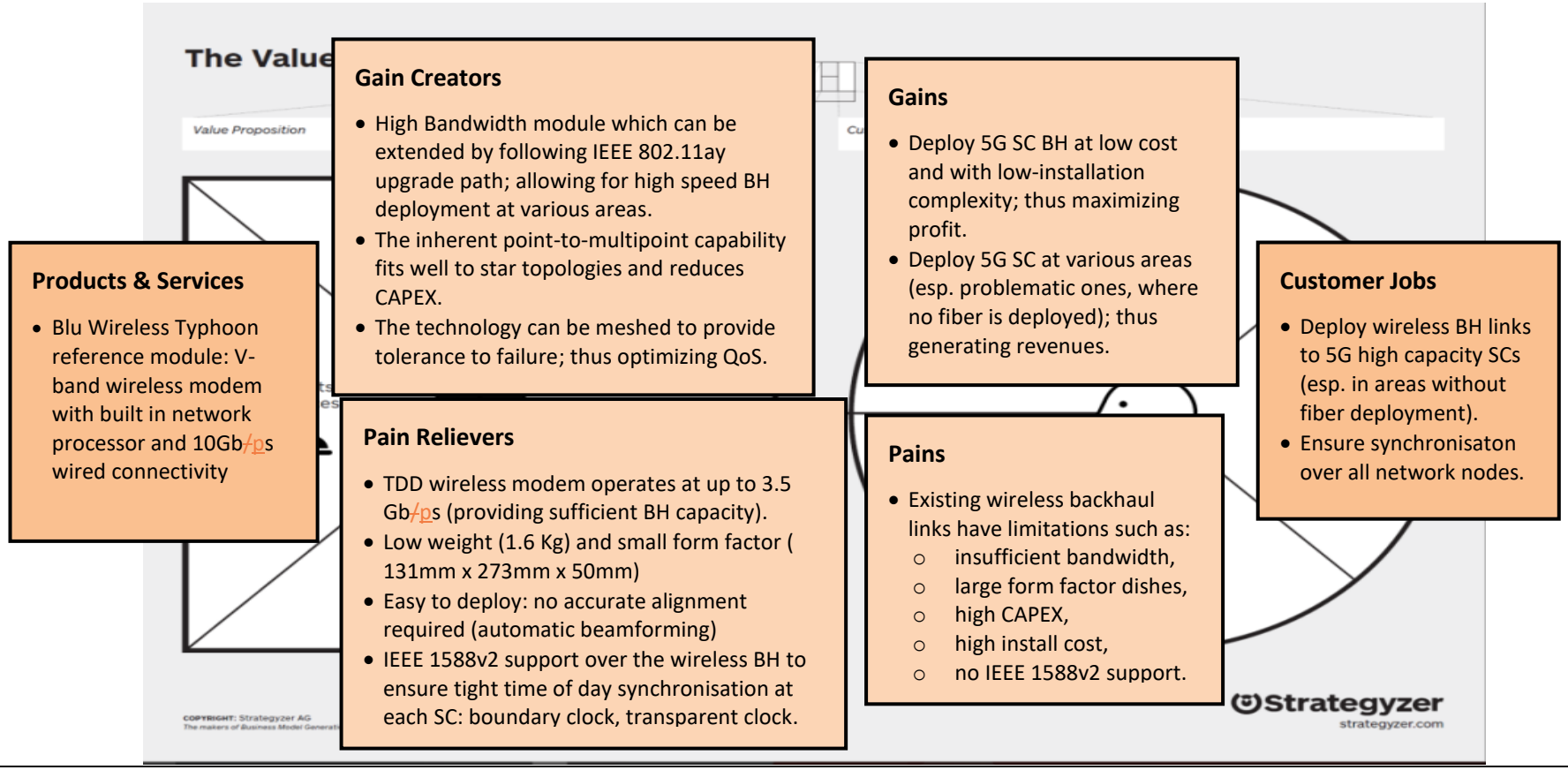
4.1.1 XDE Exploitation Plan for Active massive MIMO Radio Unit

As afore mentioned, the active massive MIMO radio unit is of 100% of ownership of AIR, therefore further exploitation of this product is tightly linked with individual AIR exploitation plans. In particular, within 5G-PICTURE, AIR developed a proof-of concept platform for an active massive MIMO radio unit (RU). Such RUs are in general purchased by Mobile Network Operators in large quantities to provide radio access within nation-wide networks. The focus within the project is on the configurability of the functional split of the RU, the corresponding FH interface, optimized beamforming and the configurability of the RU via a control interface. The product achieved an exit TRL level of 5-6, as these products will be “validated in relevant environment” as part of the smart city Use Case validation and testing activities.

The proof-of-concept platform will be the basis to develop a commercial-grade RU that can be enter the market within approximately one year after the end of the project. Furthermore, the results from the investigation can be also partially used for the development of next generation RUs, which are planned to enter the market approximately 2 to 3 years after the end of the project. The proof-of-concept will be also a valuable means to demonstrate the feasibility of the developed concepts to potential customers, thereby greatly contributing to the commercial promotion of the final product.

4.2 BWT Typhoon Platforms (with Synchronization Support (IEEE 1588v2 Development)

The customer considered for BWT Typhoon platform is a Telecom Operator that is employing mmWave backhaul in the V-band using IEEE 802.11ad technology. Furthermore, the BH connects small cells (SCs) that require accurate time-of-day synchronisation and this is enabled using the IEEE 1588v2 precision time protocol running from a master clock to the SC, via the mmWave BH. The IEEE 1588v2 method has been implemented in the Blu Wireless Typhoon mmWave module as part of 5G-PICTURE work. The value proposition to Telecom Operator delivered by this product is analysed as follows:



4.2.1 BWT Exploitation Plan for Typhoon Platform

The Typhoon platform is of 100% of ownership of Blu Wireless Technology (BWT), therefore further exploitation of this product is tightly linked with individual BWT exploitation plans. In the context of 5G-PICTURE, BWT focused on leveraging on its existing product the BWT Typhoon platform, and on further advancing its features and TRL.

In particular, the Blu Wireless Typhoon platform may find application in the following use-cases:

- 4G/5G SC backhaul
- Fixed wireless access (internet to home or building)
- Backhaul to moving vehicles

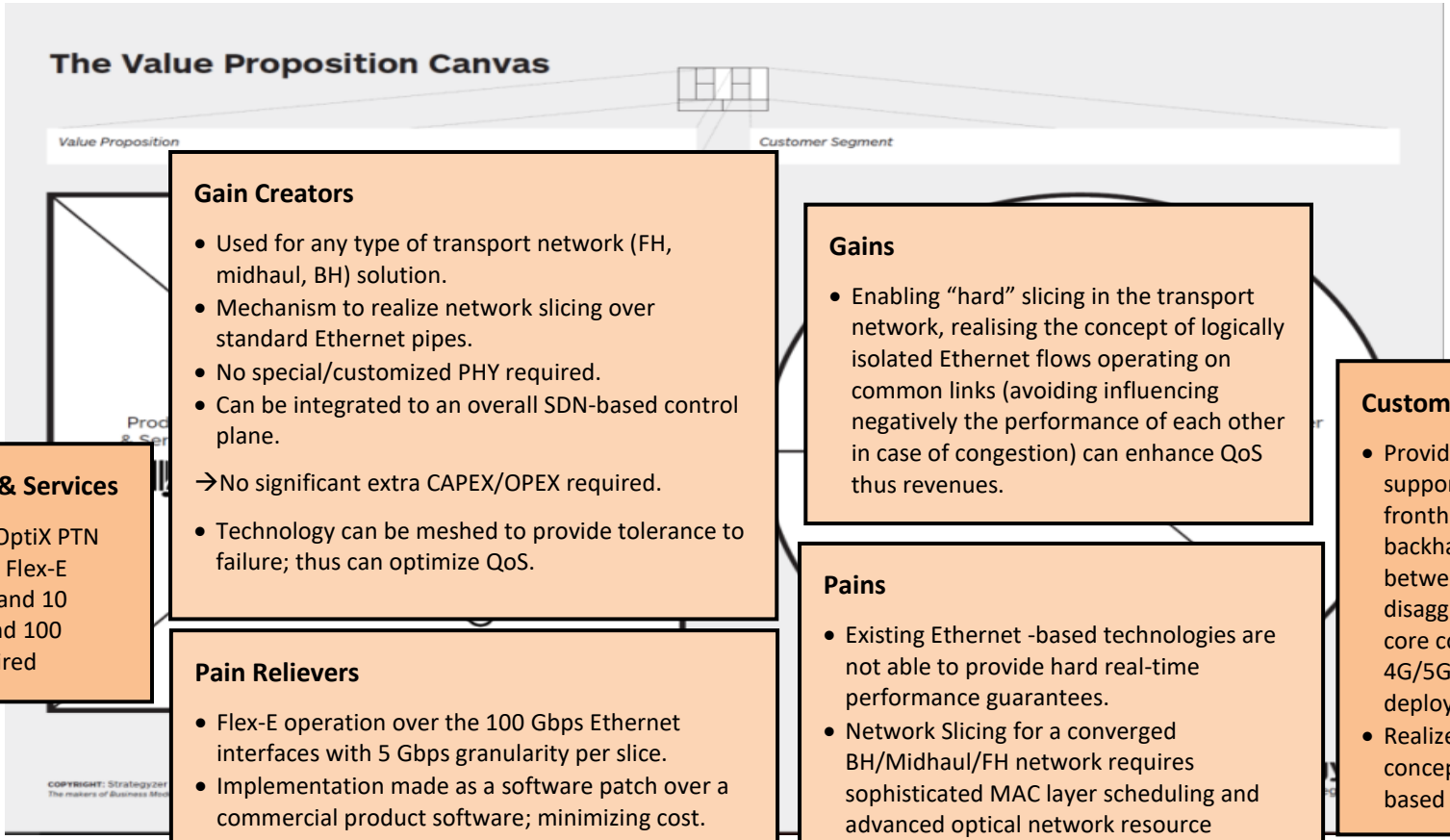
The IEEE 1588v2 implementation adds value to the offering when the customer requires the wireless access to have tight time (aka phase) synchronisation. This is expected for the SC backhaul case as well as in the future case of having access network nodes on-board moving vehicle (as in the case of the railway demo). These could be 3GPP LTE or 5G NR SCs, or Wi-Fi access points that benefit from tight synchronisation.

The product achieved an exit TRL level of 6, as it has been “demonstrated in relevant environment” as part of the Railway city Use Case Demonstration activities; this work has been considerably valuable in the sense that it verifies the BWT product in delivering a track-to-train wireless connectivity solution (and increases its TRL). This work is aligned with BWT commercial plans of the product as also verified through its further exploitation in similar use cases in the UK, i.e. with First Group (“FirstGroup and Blu Wireless partnering to provide superfast 5G Wi-Fi on trains” https://www.firstgroupplc.com/news-and-media/latest-news/2019/25-02-19.aspx). Obviously BWT has already devised internal lean canvas plans, addressing specific customers (going beyond the generic customer segment plans), which cannot be shared as they are strictly confidential.

At this point it shall be mentioned that the Barcelona Railway demonstrator deployment provided more value than a simple leverage of the TRL of the product. The work exploited existing infrastructure to mount the trackside units – stanchions which are typical of electrified lines using OLE (overhead line equipment). The impact of the stanchions on the wireless link performance is under study in the context of 5G-PICTURE WP6 activities and the results will be reported in the relevant deliverables. The demonstrator results may also reveal the need for new improvements in response to issues identified and addressed during the trial –prior to similar operational/commercial deployments. Furthermore, the integration with the aggregation solution from CNIT and the advanced WDM PON fibre connectivity to the trackside units further increased the TRL of the product. Such exploitable results would not have been possible without the joint partners’ work in the context of 5G-PICTURE. TRL improvements from the demo will be fed into the commercial work on-going with First Group in the UK.

4.3 Flex-E Network Technology

Potential customers for **HWDU**'s Flex-E technology are 3G and 4G Mobile Communication, and VIP Synthetical Bearer Solutions providers. The solution could be also exploited by group customer service providers including the following three types Inter-provincial backbone network (PBN) services, Provincial inter-metropolitan area network (MAN) services, and Intra-MAN services. Flex-E implementation is made as a SW patch in the commercial Huawei PTN optical while the environment of operation is exploiting the LTE solutions supported by PTN devices. The value proposition delivered by this product is analysed as follows:



Products & Services

- Huawei OptiX PTN 990 with Flex-E support and 10 Gb/ps and 100 Gb/ps wired

Gain Creators

- Used for any type of transport network (FH, midhaul, BH) solution.
- Mechanism to realize network slicing over standard Ethernet pipes.
- No special/customized PHY required.
- Can be integrated to an overall SDN-based control plane.

→No significant extra CAPEX/OPEX required.

- Technology can be meshed to provide tolerance to failure; thus can optimize QoS.

Pain Relievers

- Flex-E operation over the 100 Gbps Ethernet interfaces with 5 Gbps granularity per slice.
- Implementation made as a software patch over a commercial product software; minimizing cost.
- Easy to deploy, easy to configure.
- Interoperable with normal Ethernet solutions, no new format Ethertype required, standard Ethernet frames pass smoothly over the Flex-E link.

Gains

- Enabling "hard" slicing in the transport network, realising the concept of logically isolated Ethernet flows operating on common links (avoiding influencing negatively the performance of each other in case of congestion) can enhance QoS thus revenues.

Pains

- Existing Ethernet -based technologies are not able to provide hard real-time performance guarantees.
- Network Slicing for a converged BH/Midhaul/FH network requires sophisticated MAC layer scheduling and advanced optical network resource allocation mechanisms → high cost & complexity.
- Proprietary solutions do not ensure interoperability with existing systems.

Customer Jobs

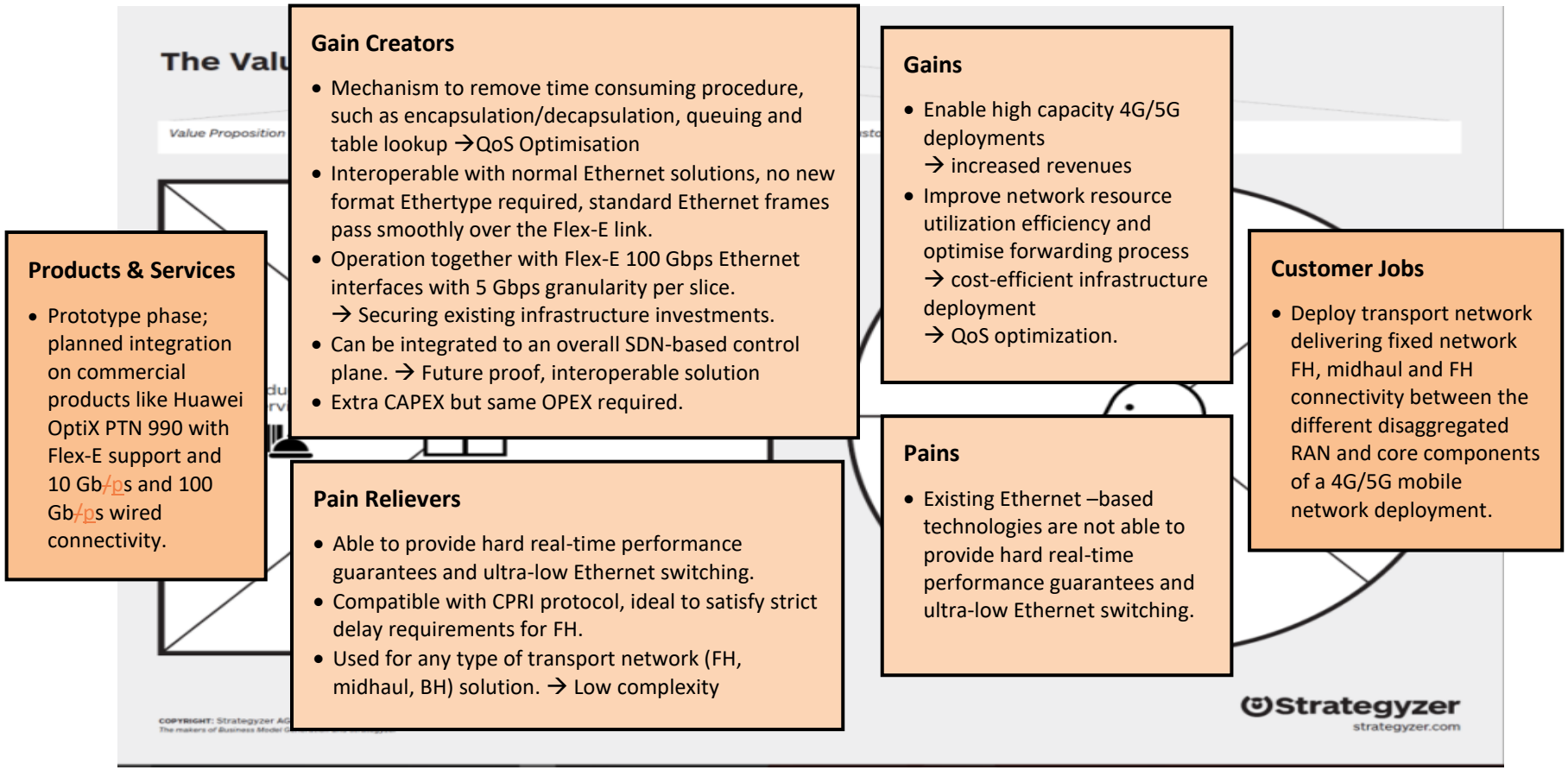
- Provide transport network support for fixed network fronthaul, midhaul and backhaul connectivity between the different disaggregated RAN and core components of a 4G/5G mobile network deployment.
- Realize Network slicing concepts over an X-Haul based network fabric.

Problem	Solution	Unique Value Proposition	Unfair Advantage	Customer segment
• Difficulty to handle efficiently optical transport network bandwidth in flexible ways. • No available mechanism to perform network slicing for transport networks below L2/L3 <u>Alternatives</u> • Deploy new high capacity networks • Investigate more efficient MAC layer scheduling algorithms	• adding a time-division multiplexing calendar that interacts with the existing Ethernet 64b66b mechanism, allowing dynamic bandwidth allocation • Perform efficient link aggregation • Exploit standards-defined physical lanes, namely the various forms of 25 Gbps Ethernet lanes. • Decouple MAC speed from PHY layer speed. **Key Metrics** • Isolation between Flex-E Ethernet clients • Simplicity of configuration • Ability to perform Channelization, sub-rating and Bonding • Guarantee throughput performance per client	Access network solution providing: • interface solution implementing ”hard” slicing in transport networks • Flex-E can utilize fully the capacity of Network Processing Units (NPU) without waiting for future Ethernet rates to be standardized. • Supports a variety of Ethernet MAC rates independently of the Ethernet PHY rate being utilized.	• “fresh start”: no legacy product lines, no existing deployments, fast time to market • No “vendor lock-in”: solution is proposed by OIF and control plane topics are investigated by IETF **Channels** • Direct contact (requests for products etc.) • Partner vendors • Trade fairs • Conferences	• Telecom Operators • Network Service Network operators. • Data Center providers <u>Early adopters:</u> • Data Center providers • Telecom operators

Cost Structure	Revenue Streams
• Low development cost (person-hours, measurement equipment, prototype hardware) • Cost related to field trials with customers • Final production cost (depends heavily of number of manufactured units) • Marketing/advertisement costs (Relatively high)	• Direct sale of manufactured units • Licensing of product IP possible (certain algorithms, building blocks, etc…) • Software licenses for enabling specific features possible • Non-Recurring Engineering for specific new features / adaptation possible

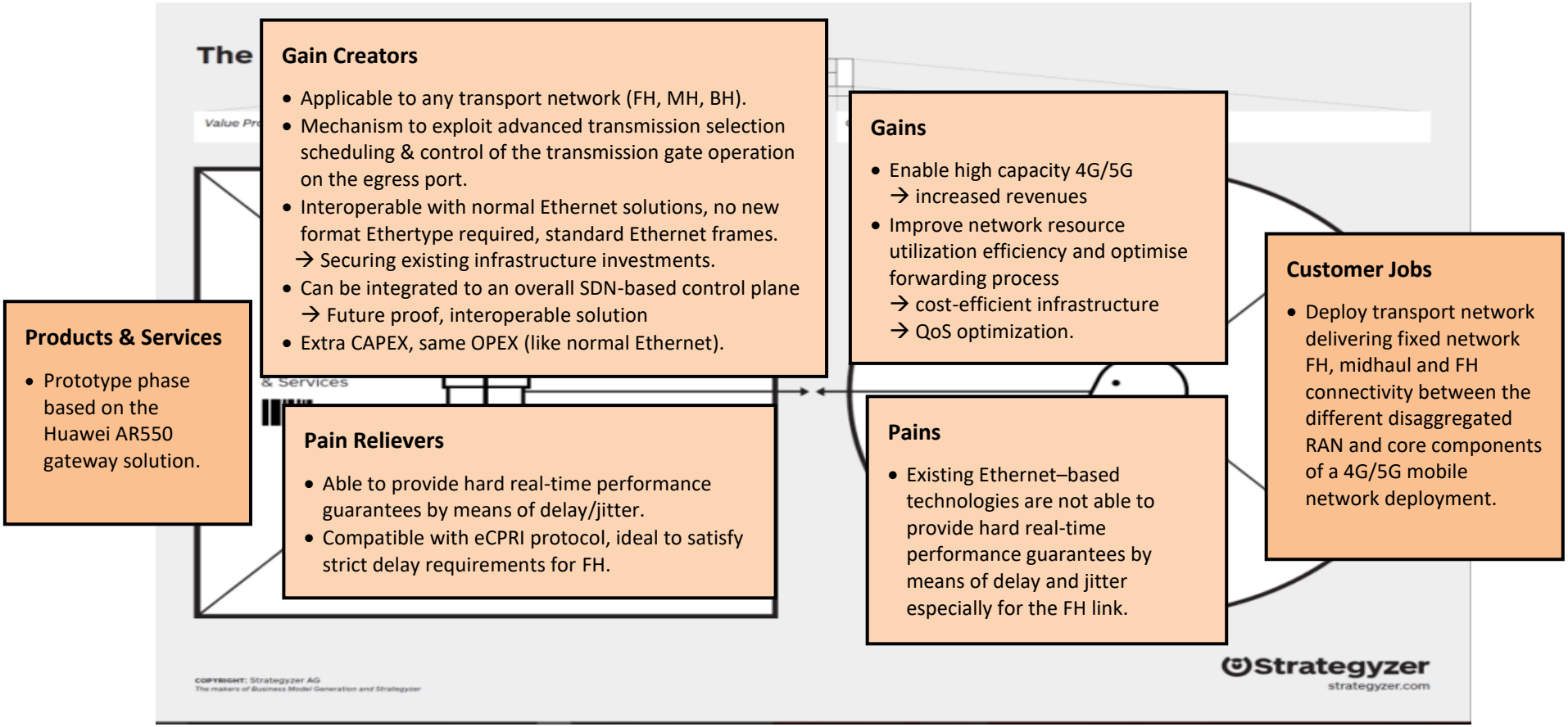
4.4 X-Ethernet Network technology

Potential customers for **HWDU's** X-Ethernet technology are 3G and 4G Mobile Communication, and VIP Synthetical Bearer Solutions providers. The solution could be also exploited by group customer service providers including the following three types Inter-provincial backbone network (PBN) services, Provincial inter-metropolitan area network (MAN) services, and Intra-MAN services. The value proposition delivered by this product is analysed as follows:



4.5 IEEE TSN Network technology

Potential customers for HWDU's TSN technology span from 3G and 4G Mobile Communication providers, to Audio-Video Bridging(AVB) networks providers (802.1BA profile), Industrial Automation (IEC/IEEE 60802 TSN Profile), Automotive In-Vehicle Ethernet Communications (P802.1DG profile). For the FH network IEEE has devised the 802.1CM TSN profile. The value proposition to Telecom Operators delivered by this product is analysed as follows:



Problem

- No performance guarantees by means of delay & jitter in Ethernet-based networks.
- Difficulty to guarantee high availability
- Difficulty to exploit a converged networks with real time Audio/Video Streaming and real-time control streams (as in automotive or industrial control facilities).

Alternatives

- Investigate more efficient MAC layer scheduling algorithms.
- Exploit customized deterministic network protocols like CAN or Ethernet based protocols like Profinet or Ethernet/IP or SERCOS

Solution

For all devices participating in real-time communication it delivers:

- Time synchronization: as common understanding of time
- Scheduling and traffic shaping: by adhering to the same rules in processing and forwarding packets
- Selection of communication paths, path reservations and fault-tolerance: by adhering to the same rules in selecting paths and in reserving bandwidth and time slots, possibly utilizing more than one simultaneous path for fault-tolerance

Key Metrics

- Guaranteed delay and jitter performance for Ethernet flows.

Unique Value Proposition

Network solution providing:

- Low operational cost
- Standard Ethernet frames
- Network Convergence for time critical and non-time critical traffic.
- Simplification of network infrastructure

Unfair Advantage

- No “vendor lock-in”: overall solution devised and hosted by IEEE

Channels

- Direct contact (requests for products etc.)
- Partner vendors
- Trade fairs
- Conferences

Customer segment

- Telecom Operators
- Industrial manufacturers
- Automotive manufacturers

Early adopters:

- Industrial manufacturers

Cost Structure

- High development cost (person-hours, measurement equipment, prototype hardware)
- Cost related to field trials with customers
- Final production cost (depends heavily of number of manufactured units)
- Marketing/advertisement costs (Relatively low)

Revenue Streams

- Direct sale of manufactured units
- Licensing of product IP possible (certain algorithms, building blocks, etc…)
- Software licenses for enabling specific features possible
- Non-Recurring Engineering for specific new features / adaptation possible

4.5.1 HWDU Exploitation Plan for Flex-E, X-Ethernet and IEEE TSN Network Technologies

As afore mentioned, X-Ethernet Technologies are of 100% of ownership of HWDU, therefore further exploitation of this product is tightly linked with individual HWDU exploitation plans. Flex-E solution is based on Optical Internetworking Forum (OIF) Flex Ethernet Implementation Agreement IA # OIF-FLEXE-01.0 published on March 2016. IEEE TSN Network implementation solution is based on 802.1Qbv, 802.1Qbu and 802.1Qci amendments and is targeting the 802.1CM profile for the fronthaul network. Within 5G-PICTURE HWDU developed the associated proof-of concept platforms/demonstrators:

- **Flex-Ethernet:** Decouples the actual PHY layer speed from the MAC layer speed of a client, i.e. being able to support multiple MAC clients over multiple PHY layers. Flex-E is based on a TDM mechanism that is able to drive the asynchronous Ethernet flows over a synchronous schedule over multiple PHY layers. A Flex-E testbed was used to perform channelisation, allocating a specific channel and protecting the end-to-end flow per network slice.
- **X-Ethernet:** X-Ethernet introduces Ethernet switching based on the interface offered by Flexible-Ethernet. The switch device will redirect FlexE Clients (64B/66B block streams) from its inbound port to its outbound port without waiting for the arrival of the whole Ethernet frame for FCS checksum and forwarding decision with table lookup. Three X-Ethernet prototypes were connected to each other and formed a network, while CPRI tester was used to generate CPRI option 7 traffic. As demonstrated X-Ethernet exhibits its ultra-low latency forwarding capability at around 0.5 µs.
- **IEEE TSN:** In a joint work with EURECOM, FRANCE Huawei evaluated the performance of Ethernet TSN networks based on IEEE 802.1Qbv and IEEE 802.1Qbu for carrying real fronthaul traffic and benchmark it against Ethernet with Strict priority and Round Robin scheduling. We demonstrated that both 802.1Qbv and 802.1Qbu can be well used to protect high-priority traffic flows even in overload conditions.

HWDU is using concrete ways to maximize the exploitation of the integrated 5G-PICTURE solution. The project results, especially those associated with the HWDU owned exploitable outcomes, are further protected at IPR level, adopted in the HWDU product lines and are also promoted in standardisation bodies, towards achieving broader consensus by the industry; thus further ensuring sustainability and exploitability of the results.

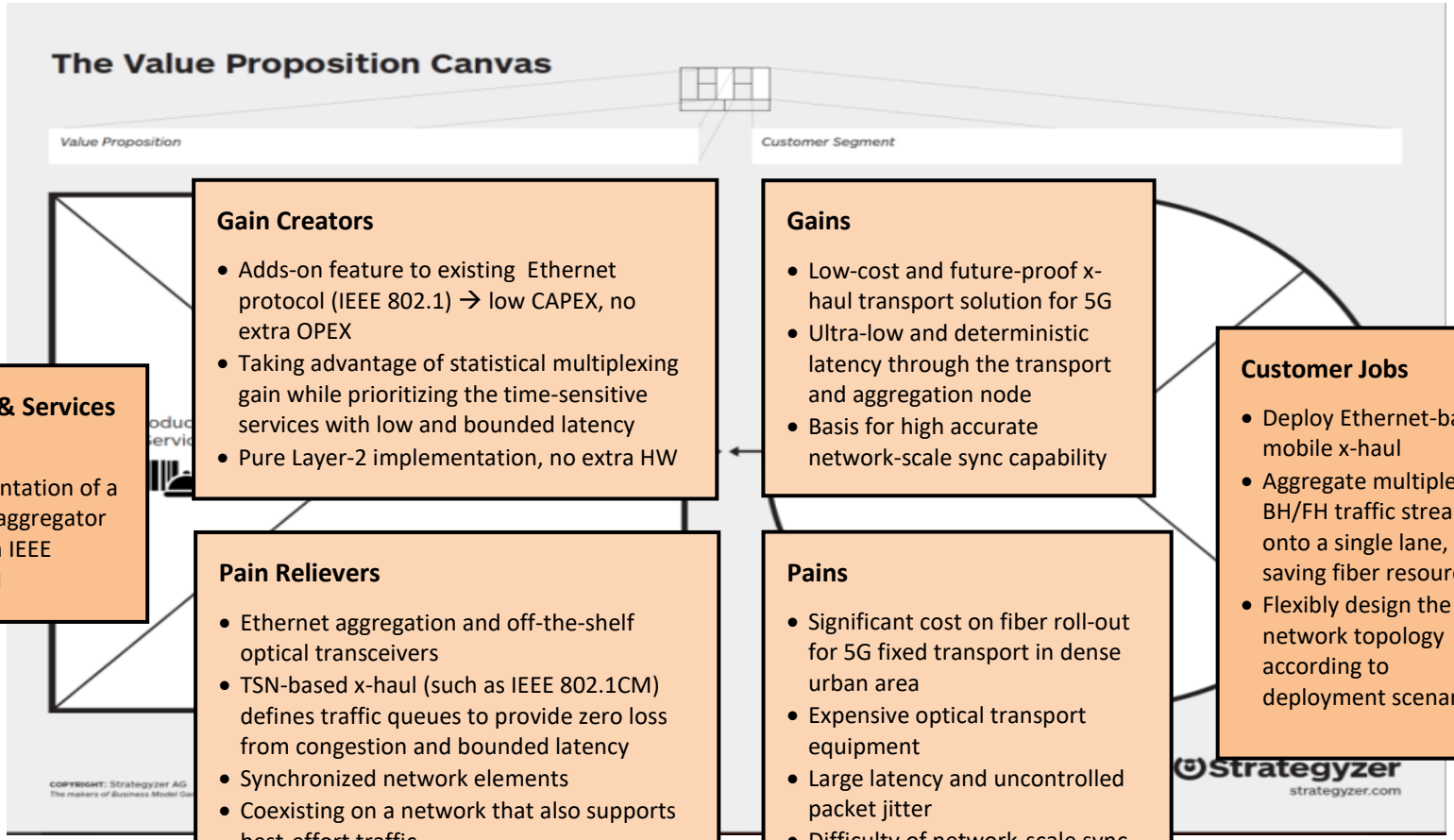
In particular, for the aforementioned exploitable outcomes/products, an IPR portfolio in the areas of X-haul and SDN control plane is generated to accommodate the 5G-PICTURE innovations on these areas. At present, one patent has been submitted/filed regarding realizing network slicing in the transport network. The patent disclosure relates to techniques for managing access rights to shared network slice instances and network slice subnetwork instances, particularly to a Network Slice Management Function (NSMF) entity and a Network Slice Subnet Management Function (NSSMF) entity according to 3GPP terminology. In particular, the disclosure relates to methods and devices for protection of shared network functions and resources under network slicing. A detailed technical analysis of the patent idea was submitted in the EU patent office with Application number PCT/EP2019/084659.

Moreover, the project results have been promoted in standardization bodies like IEEE TSN and BBF. In particular HWDU contributed technical content and interacted for the topic of BH-FH integration via the means of network slicing in a BBF study on Network Slicing (SD-406) at Wired-Wireless convergence WG. Valuable discussions were triggered and feedback received, as presented in more detail in 5G-PICTURE deliverable D7.2 [16].

At the same time, the technical results for both data plane and control plane innovations while also the x-haul integration novelties of the project are transferred to the company's product lines (EU/overseas) for integration into final products. It shall be noted, that similar to the case of other products, the validation/testing results obtained through the 5G-PICTURE validation/testing work have contributed significantly to the advancement of the products' features –besides their TRL level- as such feedback/ results would not have been possible without the joint partners' work in the context of 5G-PICTURE.

4.6 Time-sensitive 100G Aggregator

The targeted customers of **ADVA**'s Time-sensitive 100G aggregator are mobile operators and service providers. The typical application will be mobile FH with stringent timing requirement. The value proposition delivered by this product is analysed as follows:



Products & Services

- FPGA implementation of a 100GbE aggregator based on IEEE 802.1CM

Gain Creators

- Adds-on feature to existing Ethernet protocol (IEEE 802.1) → low CAPEX, no extra OPEX
- Taking advantage of statistical multiplexing gain while prioritizing the time-sensitive services with low and bounded latency
- Pure Layer-2 implementation, no extra HW

Pain Relievers

- Ethernet aggregation and off-the-shelf optical transceivers
- TSN-based x-haul (such as IEEE 802.1CM) defines traffic queues to provide zero loss from congestion and bounded latency
- Synchronized network elements
- Coexisting on a network that also supports best-effort traffic

Gains

- Low-cost and future-proof x-haul transport solution for 5G
- Ultra-low and deterministic latency through the transport and aggregation node
- Basis for high accurate network-scale sync capability

Pains

- Significant cost on fiber roll-out for 5G fixed transport in dense urban area
- Expensive optical transport equipment
- Large latency and uncontrolled packet jitter
- Difficulty of network-scale sync

Customer Jobs

- Deploy Ethernet-based mobile x-haul
- Aggregate multiple BH/FH traffic streams onto a single lane, saving fiber resources
- Flexibly design the network topology according to deployment scenarios

Problem	Solution	Unique Value Proposition	Unfair Advantage	Customer segment
• 5G driven by diverse set of services • Need for higher capacity, lower latency, and better reliability • Today's x-haul networks lack capacity and do not scale • Different technologies in fronthaul & backhaul • Missing tools for operation & optimization <u>Alternatives</u> • Live with bottlenecks, deploy point-to-point solutions wherever necessary	• Converged x-haul solution for 5G and legacy services • Time-sensitive Ethernet, precision timing, and open SDN control • Network probes for assured delivery of data, control, and timing information **Key Metrics** • Market share • Revenue and profit • Number of customers	• TSN based transport solution for fiber-based x-haul deployments • High resource efficiency at low operational costs • Guaranteed latency performance • Flexible adaptation to changing traffic patterns and services • Additional monetization opportunities by service assurance and optimization	• No.1 in Ethernet access devices • No.2 in precision timing solutions • Cross-selling opportunities to 250 operators and 10,000 enterprises **Channels** • Direct sales • OEM partners • Value added resellers	• Service providers • Mobile equipment vendors • System integrators • Enterprises <u>Early adopters:</u> • 5G test-beds and pilots

Cost Structure	Revenue Streams
• Costs of goods sold (COGS), • R&D cost, • G&A cost, • S&M cost (c.f. ADVA's annual report).	• Equipment, software licenses, cost. • Customer services provisioning (support, maintenance, etc.), • System integration and consultancy services to customers

4.6.1 ADVA's Exploitation Plan for Time-sensitive 100G Aggregator and G.metro Passive WDM Access

The Time-sensitive 100G Aggregator is of 100% of ownership of **ADVA**, and it is well aligned with ADVA's product strategy. ADVA is a company founded on innovation and driven to help our customers succeed. ADVA technology is the foundation of a shared digital future and empowers networks across the globe. They are continually developing breakthrough hardware and software that leads the networking industry and creates new business opportunities. It's these open connectivity solutions that enable their customers to deliver the cloud and mobile services that are vital to today's society and for imagining new tomorrows.

In the context of 5G-PICTURE, ADVA focused on developing the TSN implementation based on IEEE 802.1CM as well as FUSION, and further advancing its TRL to migrate the features into ADVA's FSP150 product portfolio. In particular, ADVA has implemented and demonstrated IEEE 802.1Qbu and 802.3br on the FPGA platform to evaluate the performance of best-effort frame preemption and interspersing time-sensitive traffic. The results show a significant improvement on PDV of the time-sensitive traffic, compared to the best-effort one.

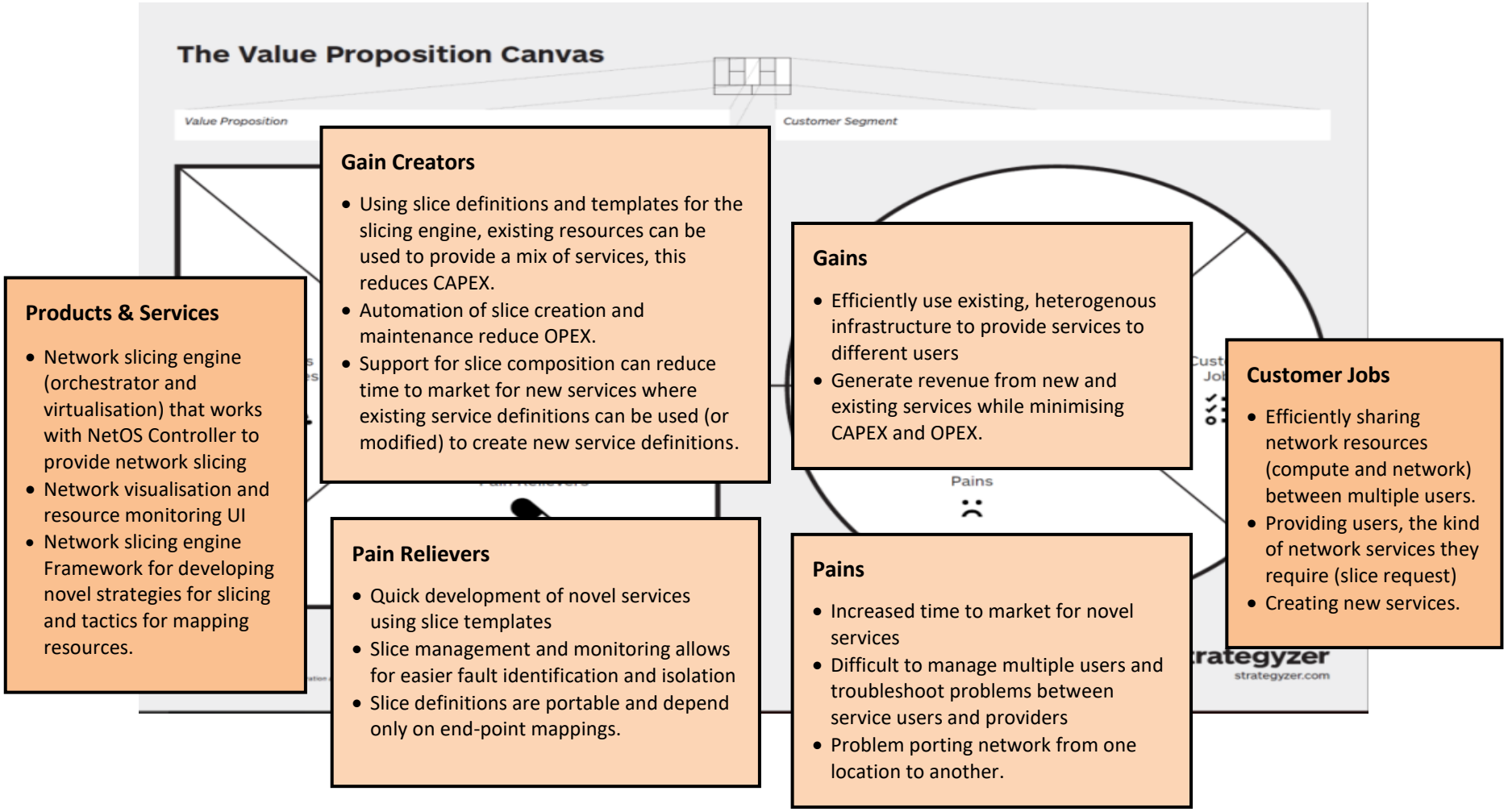
In addition, ADVA further leveraged its G.metro passive WDM technology in the project, where the relevant results have been promoted to ITU-T Study Group 15, Question 6. In particular ADVA along with TIM contributed technical content reflecting ADVA's G.metro optical solutions, towards achieving industry consensus, thus further fostering sustainability and exploitability of the solution. Valuable discussion were triggered and feedback received, as presented in more detail in 5G-PICTURE Deliverable D7.2 [16].

The ADVA's G.metro solution has achieved an exit TRL level of 6, as it has been "demonstrated in relevant environment" as part of the Railway Use Case Demonstration activities; this work has been considerably valuable in the sense that it verifies the ADVA's G.metro solution for delivering optical network connectivity in railway environments. This work initiates ADVA's business development plans to promote this solution and further exploitation in similar use cases.

The Barcelona railway demonstrator deployment provided more value than a simple leverage of the TRL of the product. Since the operation environment of the railway is harsher than the traditional telecom, the solution has to meet much stricter requirements in terms of reliability and redundancy, which will be addressed in the future product development. The TRL improvements from the demo will be also fed into the on-going commercial engagements. Such exploitable results would not have been possible without the joint partners' work in the context of 5G-PICTURE.

4.7 Layer 2 Network Slicing for Transport Networks

The target customer segment of **ZN**'s Layer 2 Network Slicing for Transport Networks product is Telecom Operators or Verticals/Small Telcos owning radio network infrastructure. The value proposition delivered by this product is analysed in the following VP & Lean Canvases.


The Value Proposition Canvas
Value Proposition
Customer Segment
Pains
strategyzer
strategyzer.com
Products & Services
• Network slicing engine (orchestrator and virtualisation) that works with NetOS Controller to provide network slicing
• Network visualisation and resource monitoring UI
• Network slicing engine Framework for developing novel strategies for slicing and tactics for mapping resources.
Gain Creators
• Using slice definitions and templates for the slicing engine, existing resources can be used to provide a mix of services, this reduces CAPEX.
• Automation of slice creation and maintenance reduce OPEX.
• Support for slice composition can reduce time to market for new services where existing service definitions can be used (or modified) to create new service definitions.
Pain Relievers
• Quick development of novel services using slice templates
• Slice management and monitoring allows for easier fault identification and isolation
• Slice definitions are portable and depend only on end-point mappings.
Gains
• Efficiently use existing, heterogenous infrastructure to provide services to different users
• Generate revenue from new and existing services while minimising CAPEX and OPEX.
Pains
• Increased time to market for novel services
• Difficult to manage multiple users and troubleshoot problems between service users and providers
• Problem porting network from one location to another.
Customer Jobs
• Efficiently sharing network resources (compute and network) between multiple users.
• Providing users, the kind of network services they require (slice request)
• Creating new services.

Problem	Solution	Unique Value Proposition	Unfair Advantage	Customer segment

• 5G brings a new set of opportunities in terms of technology but also increased complexity related to network management and rollout of new services
• Service design is not portable, it becomes tied to the infrastructure vendors
• 5G involves creating end-to-end service slices that may use resources from different providers, there is no agreed mechanism for achieving this
 	
Alternatives
 	
• Put effort in building bespoke integrations between infrastructure to provide the end-to-end view of the network
	• Orchestration based on Topology Mapping
	• Plugin-based network control
	• Network virtualization tactics that allow service creation via layering and composition.
	
	Key Metrics
	
	• IPR/Patents
	• Number of deployments
	• Variety of deployments
	• CAPEX/OPEX savings
		• Efficiently use existing, heterogenous infrastructure to provide services to different users
		• Generate revenue from new and existing services while minimising CAPEX and OPEX.
			• Breaks out from vendor lock in
			• Can work around existing deployments and can provide more information about the network as further plugins are developed – no need to 'throw away' current infrastructure
			• Ability to inter-work with existing deployments
			• Product occupies a unique 'grey area' between established product lines (OSS and NMS)
			
			Channels
			
			• Sale via:
			  ○ Channel Partners
			  ○ Partner Vendors
			  ○ Managed Service Providers (MSP)
			• PoC and Catalysts
				• Telecom Operators
				• (Verticals/Small Telcos owning multi-technology infrastructure, especially with Layer 2/connectivity products)
				
				Early adopters:
				
				• MVNO
				• Smaller providers of network infrastructure to bigger operators and carriers
				• Large scale enterprise networks

Cost Structure	Revenue Streams
• High development cost (person-hours, measurement equipment, prototype hardware). • Cost related to field trials with customers. • Costs related to R&D, market survey and business case development to target development effectively. • Marketing/advertisement costs (Relatively low).	• Sale via Channel Partners, MSPs and Vendors. • Suitable licensing scheme targeting smaller customers tied with network support services. • Licensing of product IP possible (certain algorithms, building blocks, etc.). • Software licenses for enabling specific features possible.

4.7.1 ZN's Exploitation Plan for Layer 2 Network Slicing for Transport Networks

In the context of 5G-PICTURE, **ZN** focuses the exploitation plans on the Zeetta Slicing Engine (as related to the work done for the Project) (100% of ownership of ZN). This work is aligned with ZN commercial plans of the product. In particular, towards ensuring sustainability and exploitability of the product, the company has already made steps to preserve their IPR through patents. In particular, there is no conflicting IPR, since this component is of 100% of ownership of Zeetta, and parts of it filed under to following Patents:

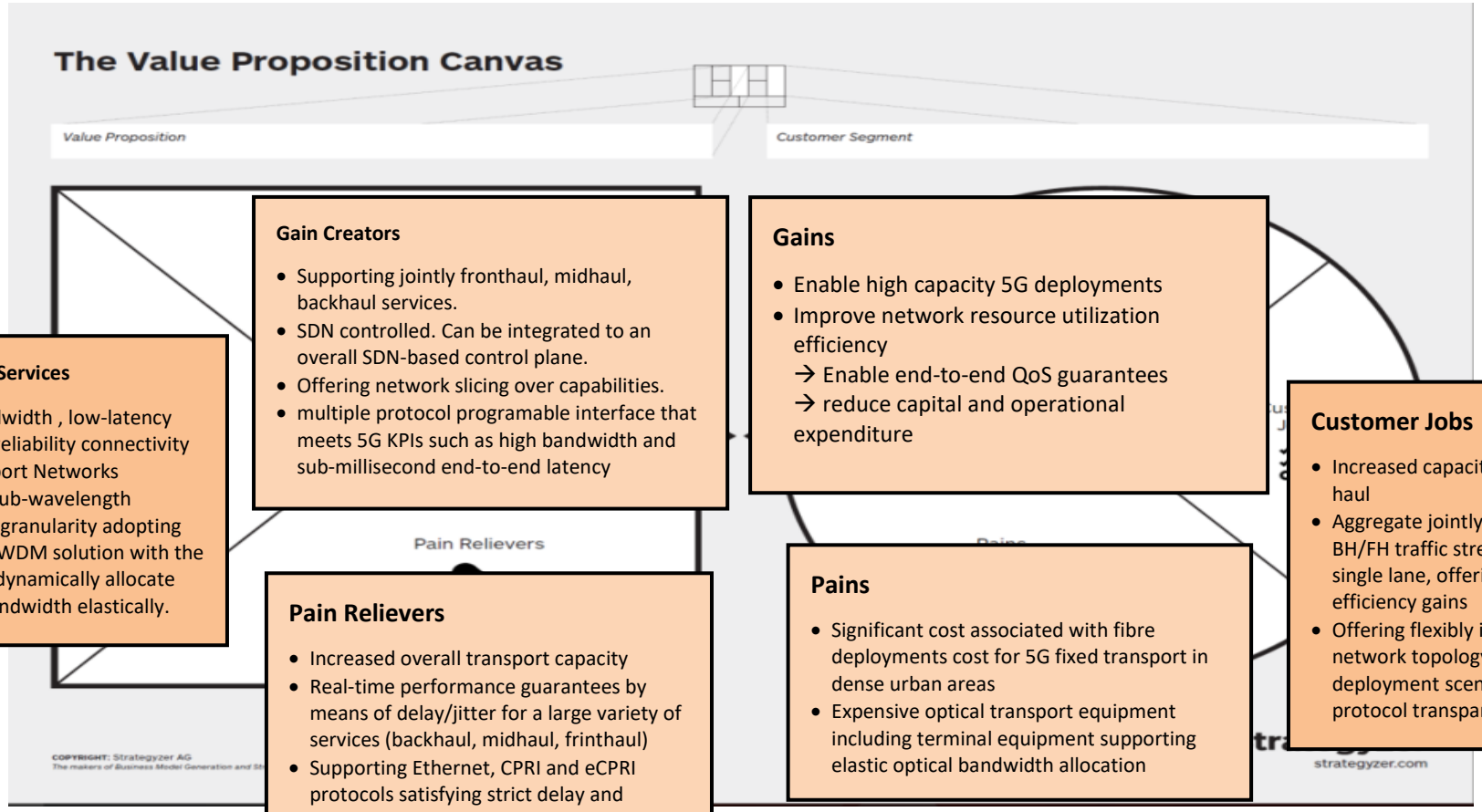
- GB2550844 Network abstraction and topology aggregation
- GB2546569 Network virtualisation: slicing and splicing
- GB1719556 Network slicing automation based on smart contracts and distributed ledger.

The TRL Level of the product has increased from 2 to 6 by the end of the project, as the product is part of the solution to be "demonstrated in relevant environment" as part of the Stadium Use Case Demonstration activities. The results and artefacts produced by these activities will be exploited in further product development after the project ends; as they may reveal reveal the need for new improvements prior to similar operational/commercial deployments. So beside the product features developed in the context of the project, the results to be obtained through the Stadium demonstration activities constitute a valuable exploitable outcome, not easily achievable out of the context of 5G-PICTURE.

Exploitation potential is estimated to be quite high. Time to market is expected to be 2-3 years (considering the TRL advancement achieved in the context of 5G-PICTURE) with the target market being (as specified in the afore-presented canvases): Telecom infrastructure providers, Telecom Service Providers and Telecom Operators. In line with the VP and lean canvases analyses, ZN will seek and create opportunities to promote and offer the Slicing Engine solution through partners and integrators.

4.8 TSON Edge Node

Potential customers for the TSON Edge Node, developed by **UNIVBRIS-HPN**, are mainly Telecom Operators. The value proposition delivered by this product is analysed as follows:



Products & Services

- High bandwidth , low-latency and high reliability connectivity 5G Transport Networks
- Variable sub-wavelength switching granularity adopting an active WDM solution with the ability to dynamically allocate optical bandwidth elastically.

Gain Creators

- Supporting jointly fronthaul, midhaul, backhaul services.
- SDN controlled. Can be integrated to an overall SDN-based control plane.
- Offering network slicing over capabilities.
- multiple protocol programable interface that meets 5G KPIs such as high bandwidth and sub-millisecond end-to-end latency

Pain Relievers

- Increased overall transport capacity
- Real-time performance guarantees by means of delay/jitter for a large variety of services (backhaul, midhaul, frinthaul)
- Supporting Ethernet, CPRI and eCPRI protocols satisfying strict delay and synchronization requirements.

Gains

- Enable high capacity 5G deployments
- Improve network resource utilization efficiency
  → Enable end-to-end QoS guarantees
  → reduce capital and operational expenditure

Pains

- Significant cost associated with fibre deployments cost for 5G fixed transport in dense urban areas
- Expensive optical transport equipment including terminal equipment supporting elastic optical bandwidth allocation

Customer Jobs

- Increased capacity mobile x-haul
- Aggregate jointly multiple BH/FH traffic streams onto a single lane, offering efficiency gains
- Offering flexibly in terms of network topology to deployment scenarios and protocol transparency

4.8.1 UNIVBRIS Exploitation Plan for TSON Edge Node

The HPN group of the University of Bristol (**UNIVBRIS**) will leverage on the architectural designs it has developed in the framework of 5G-PICTURE and the TSON extensions in order to further enhance TSON's suitability, performance and efficiency as a 5G transport solution. The architectural work will continue including also computation/storage requirements in the context of 5G. TSON that was extended in the framework of 5G-PICTURE in order to support multiple functional splits as defined by the eCPRI standard and also offer resilient C-RAN capabilities at line rate through the adoption of Network Coding and the implementation of coding splitting and decoding functions at the TSON edge nodes.

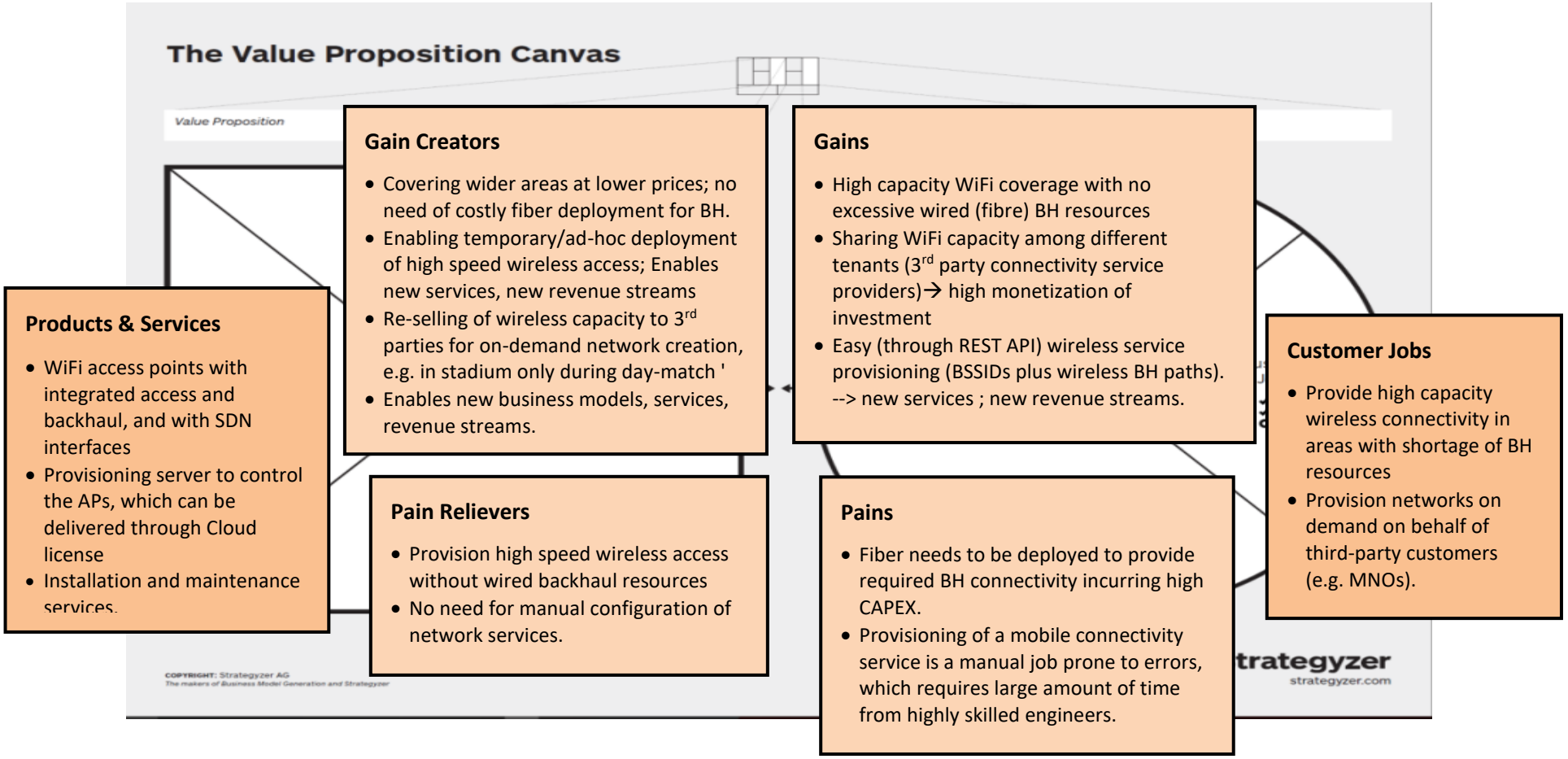
Beyond the TSON data plane work was also performed on the TSON control plane and higher layers. The TSON node is controlled by an SDN controller which together with an OpenFlow agent make it programmable. The SDN controller programs the TSON node in order to provide end to end network slicing traffic. This capability was extended in the framework of 5G-PICTURE in order to be provided as a function that can be exposed and combined together with other functions in support of a variety of services. Finally, the HPN group is/has been involved in a variety of integration activities including integration of heterogeneous optical technologies but also optical and wireless networking solutions as well as field trials in the framework of 5G-PICTURE. The relevant knowledge and experience will be exploited as integration and demonstration activities have become one of the main competences of the group that is currently leading and is involved in several other but relevant national and EU integration/demonstration activities involving advanced lab test-beds and field demonstrators such as the Phase 3 5G-PPP project 5G-VICTORI that UNIVBRIS has the technical coordination role.

Overall, through these activities UNIVBRIS will enhance and promote its know-how, foster innovation and improve industrial collaborations. PhD students and researchers will have the opportunity to participate in relevant research activities. Standardisation organisation and fora like ONF will be influenced. Through the 5G-PICTURE TSON related work, UNIVBRIS will:

- improve its ability to leverage additional investments, extending current national UK funds and expand towards other vertical industries such as rail, energy, etc.,
- use results of use case demonstration and showcases to promote adoption of programmable and open city infrastructures across UK and Europe in general, and
- utilise the technological developments of the project to influence local authorities on its road map for providing new services to the user communities with emphasis on vehicular industries and entrepreneurial community and technology start-ups.

4.9 Slicing enabled Wi-Fi Controller and Nodes

Potential customers for **I2CAT**'s Slicing enabled Wi-Fi controller are mainly Telecom Operators or Verticals/Small Telcos owning radio network infrastructure. The value proposition delivered by this product is analysed as follows:


The Value Proposition Canvas
Value Proposition
Gain Creators
• Covering wider areas at lower prices; no need of costly fiber deployment for BH.
• Enabling temporary/ad-hoc deployment of high speed wireless access; Enables new services, new revenue streams
• Re-selling of wireless capacity to 3rd parties for on-demand network creation, e.g. in stadium only during day-match '
• Enables new business models, services, revenue streams.
Gains
• High capacity WiFi coverage with no excessive wired (fibre) BH resources
• Sharing WiFi capacity among different tenants (3rd party connectivity service providers)→ high monetization of investment
• Easy (through REST API) wireless service provisioning (BSSIDs plus wireless BH paths). --> new services ; new revenue streams.
Products & Services
• WiFi access points with integrated access and backhaul, and with SDN interfaces
• Provisioning server to control the APs, which can be delivered through Cloud license
• Installation and maintenance services.
Pain Relievers
• Provision high speed wireless access without wired backhaul resources
• No need for manual configuration of network services.
Pains
• Fiber needs to be deployed to provide required BH connectivity incurring high CAPEX.
• Provisioning of a mobile connectivity service is a manual job prone to errors, which requires large amount of time from highly skilled engineers.
Customer Jobs
• Provide high capacity wireless connectivity in areas with shortage of BH resources
• Provision networks on demand on behalf of third-party customers (e.g. MNOs).
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strategyzer.com

Problem

- Deployment of wireless broadband in areas without wired backhaul
- Quick and easy provisioning of temporary/ad-hoc mobile network service
- Quick and easy provisioning of private mobile networks
- Re-sell mobile network capacity on demand to third parties.

Alternatives

- LTE in a box solutions for easy network provisioning, which can use satellite or similar backhaul
- Facebook Terragraph (https://terragraph.com/) as a solution to deploy SC with self-backhauling for urban coverage

Solution

- Wi-Fi access points with integrated access and backhaul, and with SDN interfaces
- Provisioning server to control the APs, which can be delivered through Cloud license
- Installation and maintenance services.

Key Metrics

- Volumes of sales of units
- Number of Customers
- Customers' loyalty in terms of number of orders through years.

Unique Value Proposition

- Self-backhauling
- One-click service provisioning
- Seggregating network resources on different slices to serve different 3rd-party tenants with a single infrastructure

Unfair Advantage

- "fresh start": no legacy product lines, no existing deployments, fast time to market
- No "vendor lock-in": solution is interoperable with … *(customers are tired of missing interoperability, demand for mix-and-match deployments involving different vendors)*

Channels

- Trade fairs
- Conferences

Customer segment

- Verticals owning telecom infrastructure
  - City administrator
  - Venue owner (stadium, transport hub, factory)
- Telecom Operator

Early adopters:

- Venue owners that want to resell network capacity to MNOs.

Cost Structure

- Medium development cost (person-hours, software testing and validation)
- Cost related to Field trials (on customers' request)
- Production cost for high volumes of HW units (Unclear (as of now) model to scale number of produced HW units, cost will depend heavily of number of manufactured units)

Revenue Streams

(Regarding I2CAT role in the value chain)

- Licensing of product IP/Royalties-based by solution transferring to commercial 3rd party

(Regarding commercial 3rd party undertaking manufacturing of products)

- Direct sale of manufactured units
- Software licenses for enabling specific features possible
- Non-Recurring Engineering for specific new features / adaptation possible

4.9.1 I2CAT Exploitation Plan for Slicing enabled Wi-Fi Controller and Nodes

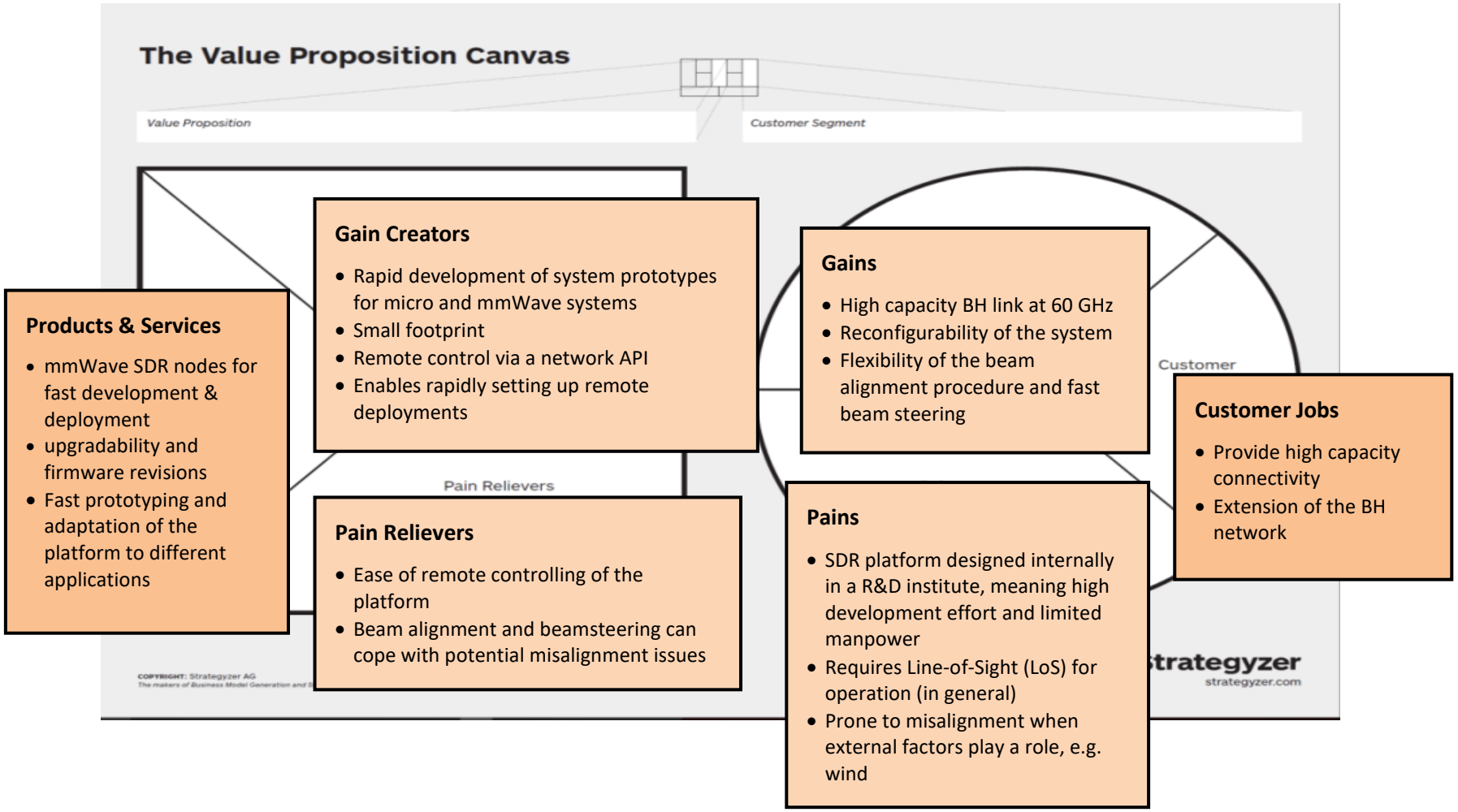
I2CAT plans to exploit the slicing enabled Wi-Fi controller and nodes in two different ways, which we describe next.

First, I2CAT will use this technology to position itself in new 5G related H2020 projects, in order to continue developing the technology. This has in fact already happened since I2CAT participates in two new ICT20 projects called 5G-CLARITY and 5G-ZORRO. In the 5G-CLARITY project I2CAT will integrate the RAN Controller with 5GNR access devices provided by Accelleran, an SME offering Small Cell solutions, and Pure LiFi, another SME offering Li-Fi based access points. In the 5G-ZORRO project, I2CAT will extend this technology to demonstrate how spectrum can be negotiated dynamically if the I2CAT RAN Controller is linked with a Blockchain based spectrum market. Besides the aforementioned two projects that are already granted, I2CAT has also submitted another bid for the call ICT53 dealing with cross-border corridors, where the multi-tenant wireless access and backhaul nodes will be used to provide V2X services across highways in an inexpensive manner.

Second, besides R&D exploitation, I2CAT is also analysing a potential commercial exploitation for this technology. In this regard i2CAT is discussing with a start-up company that is currently participating in a 5G accelerator program named The Collider (https://thecollider.tech/). If the start-up project moves forward this company would be in charge of exploiting the developed technology through an IP transfer agreement with I2CAT. At the time of this writing though these negotiations are still ongoing.

4.10 mmWave (60 GHz) Beamsteering Transport Solution

The target customers of IHP's mmWave (60 GHz) beamsteering transport solution are Telecom Operators or Verticals/Small Telcos owning radio network infrastructure. The value proposition delivered by this product is analysed as follows:


The Value Proposition Canvas
Value Proposition
Customer Segment
Products & Services
• mmWave SDR nodes for fast development & deployment
• upgradability and firmware revisions
• Fast prototyping and adaptation of the platform to different applications
Gain Creators
• Rapid development of system prototypes for micro and mmWave systems
• Small footprint
• Remote control via a network API
• Enables rapidly setting up remote deployments
Pain Relievers
• Ease of remote controlling of the platform
• Beam alignment and beamsteering can cope with potential misalignment issues
Gains
• High capacity BH link at 60 GHz
• Reconfigurability of the system
• Flexibility of the beam alignment procedure and fast beam steering
Pains
• SDR platform designed internally in a R&D institute, meaning high development effort and limited manpower
• Requires Line-of-Sight (LoS) for operation (in general)
• Prone to misalignment when external factors play a role, e.g. wind
Customer
Customer Jobs
• Provide high capacity connectivity
• Extension of the BH network
strategyzer
strategyzer.com

<table>
<tr>
<td rowspan="2">Problem
• Deployment of wireless broadband in areas without wired backhaul
• Quick and easy provisioning of temporary/ad-hoc mobile network services
• Fast prototyping and adaptation of the platform to different applications
<u>Alternatives</u>
• Sub-6 backhaul for communications in Non-Line-of-Sight (NLoS) environments</td>
<td>Solution
• Small footprint
• Rapid prototyping and the possibility of using it real-time or in Software Defined Radio mode
• Possibility of use in wired communication systems
• Availability of easy-to-use SW an example designs
• Installation and maintenance services.</td>
<td rowspan="2">Unique Value Proposition
• Fast development times due to the SDR nature of the platform
• Allowance of multiple applications using the SDR, from radar to localization.</td>
<td>Unfair Advantage
• Flexibility compared with product solutions in the market, performance achieved is higher than that of available evaluation boards</td>
<td rowspan="2">Customer segment
• Verticals owning telecom infrastructure
○ City administrator
○ Venue owner (stadium, transport hub, factory)
• Telecom Operator
<u>Early adopters:</u>
• Venue owners</td>
</tr>
<tr>
<td>Key Metrics
• Volumes of sales of units
• Number of Customers
• Customers' loyalty in terms of number of orders through years.</td>
<td>Channels
• Exhibitions
• Conferences</td>
</tr>
<tr>
<td colspan="3">Cost Structure
• Medium development cost (person-hours, software testing and validation)
• Production cost for high volumes of HW units. Need of a model to scale number of produced HW units, cost will depend heavily of number of manufactured units)</td>
<td colspan="3">Revenue Streams
• Sale via daughter company IHP Solutions
• Suitable licensing schemes
• Licensing of product IP possible (certain algorithms, building blocks, etc…)
• Software licenses for enabling specific features possible.</td>
</tr>
</table>

4.10.1 IHP Exploitation Plan for mmWave (60 GHz) Beamsteering Transport Solution

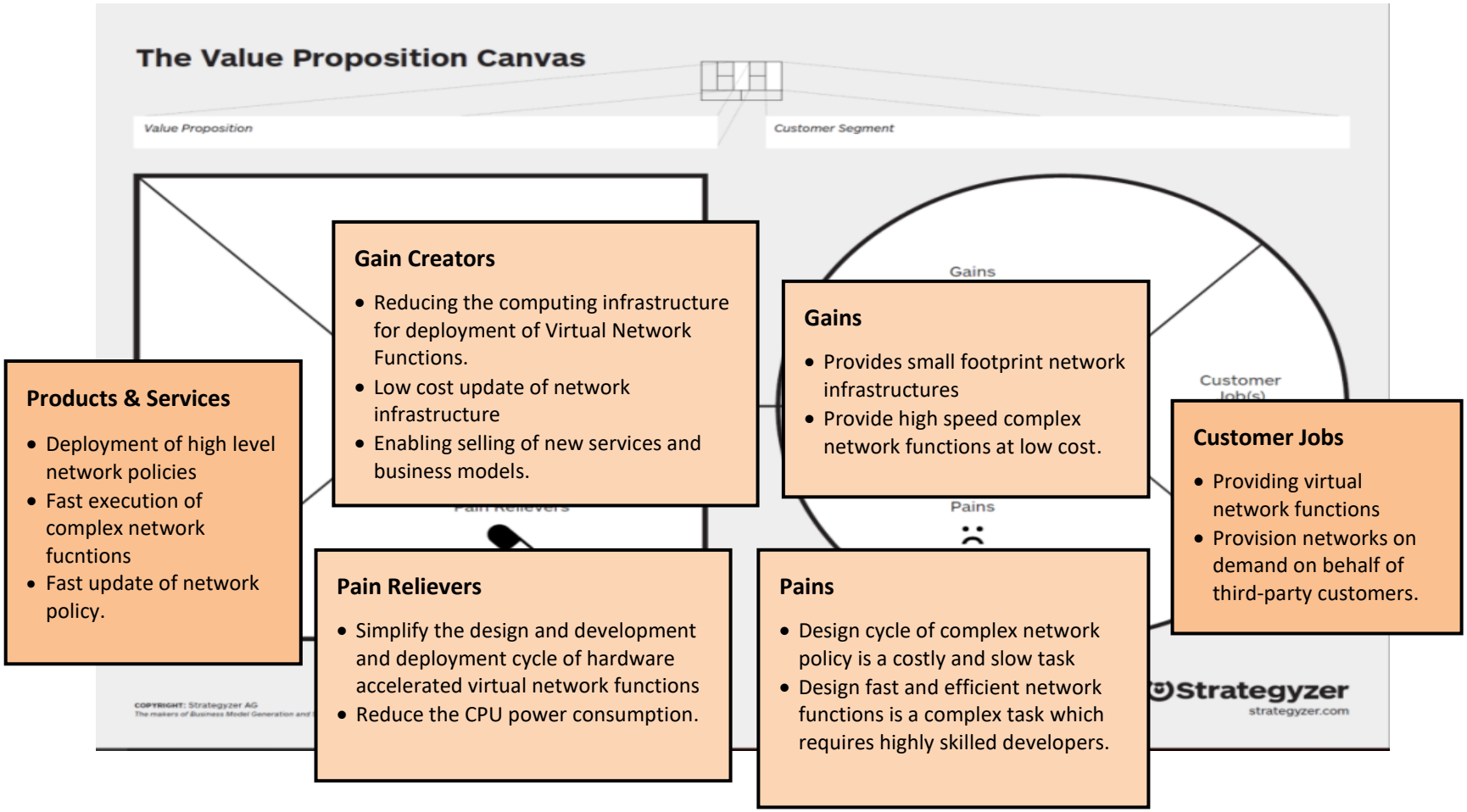
IHP focuses on developing innovative solutions for wireless communications. Its expertise ranges from the system and circuit design to the implementation and optimisation of protocol stacks and the development of system-enabling CMOS compatible technology modules. IHP has a long experience in the wireless systems research especially in design and implementation of the PHY and MAC layers. IHP participated in three key EU FP7 projects in the field of wireless broadband communications: MIMAX and OMEGA, as well as being Project Coordinator and contributing with mmWave point-to-multipoint beamforming chipsets, localization algorithms and system integration and prototyping in the 5G-PPP Phase-1 project 5G-XHaul. IHP is currently bringing as well its expertise in development and deployment of mmWave systems to the Phase-3 Projects 5GENESIS and 5G-VICTORI and including novel developments in the ICT-20 Projects 5G-CLARITY and 5G-COMPLETE.

During the 5G-PICTURE Project, IHP has been working in the development of the digibackboard SDR platform, being designed to accommodate SoTA Analogue Front-Ends, e.g. Sivers IMA 60 GHz transceiver solution, by the design and fabrication of a tailored adapter board. Additionally, this board has been designed in view of habilitating yet more additional interfaces (SFP+) for interconnection with other platforms. The digibackboard SDR platform is being upgraded with additional developments, such as the hardware-programmable high speed, low latency point to multi-point (p2mp) MAC-processor, which facilitates the potential exploitation plan of the system, and allows a plethora of applications to be running on top. The product constitutes the mmWave (60 GHz) Beamsteering Transport Solution.

The product is 100% of ownership of IHP and will achieve TRL 5/6 by the end of the project as it is part of the solution to be demonstrated at the Smart City Use Case Demonstration in Bristol. Given the nature of IHP as a public research institution, the digibackboard, together with its associated developments, will be exploited by IHP Solutions (https://www.ihp-solutions.com), a daughter company of IHP playing the role of the technology transfer unit of IHP.

4.11 Programmable Data Plane (FlowBlaze)

Potential customers for the **CNIT**'s FlowBlaze programmable dataplanes are mainly Telecom Operators or Verticals/Small Telcos interested in the management of the core/edge network infrastructure. The value proposition delivered by this product is analysed as follows:


The Value Proposition Canvas
Value Proposition
Customer Segment
Gains
Customer Jobs
Pains
Strategyzer
strategyzer.com
Products & Services
• Deployment of high level network policies
• Fast execution of complex network fucntions
• Fast update of network policy.
Gain Creators
• Reducing the computing infrastructure for deployment of Virtual Network Functions.
• Low cost update of network infrastructure
• Enabling selling of new services and business models.
Gains
• Provides small footprint network infrastructures
• Provide high speed complex network functions at low cost.
Customer Jobs
• Providing virtual network functions
• Provision networks on demand on behalf of third-party customers.
Pain Relievers
• Simplify the design and development and deployment cycle of hardware accelerated virtual network functions
• Reduce the CPU power consumption.
Pains
• Design cycle of complex network policy is a costly and slow task
• Design fast and efficient network functions is a complex task which requires highly skilled developers.

4.11.1 CNITs' Exploitation Plan for Programmable Data Plane (FlowBlaze)

CNIT (National Inter-University Consortium for Telecommunications) is a non-profit Consortium, bringing together 37 Italian Universities to foster research activity in the field of telecommunications, and provide facilities and clustering support to the Italian academic ICT research community. CNIT participated in hundreds of research projects, including EU coordinated projects, ERC grants and Italian nation-wide initiatives. It comprises three national laboratories (Photonic Networks and Radar & Surveillance Systems, in Pisa, Multimedia Communications, in Naples) and 37 Research Units, one for each participating university.

In the context of 5G-PICTURE, CNIT developed two main technologies: (i) FlowBlaze, which is a programmable data plane designed to build stateful packet processing functions in hardware and (ii) a set of primitives for mobility server supporting handovers; thus these two technologies are considered as 100% of CNIT's ownership.

The FlowBlaze programmable dataplane has reached a good maturity level (at least TRL6) and CNIT has received a considerable interest when FlowBlaze was presented. Therefore CNIT is planning to contact/discuss with possible customers (Big Telecom Operators or Verticals/Small Telcos interested in the management of the core/edge network infrastructure) and investors to understand if there is the opportunity to starting the commercialization of a product based on the FlowBlaze prototype.

As first step, a patent with title "Method of handling data packets through a conditional state transition table and apparatus using the same", related to the FlowBlaze abstraction has been submitted to both the European and the US patent offices.

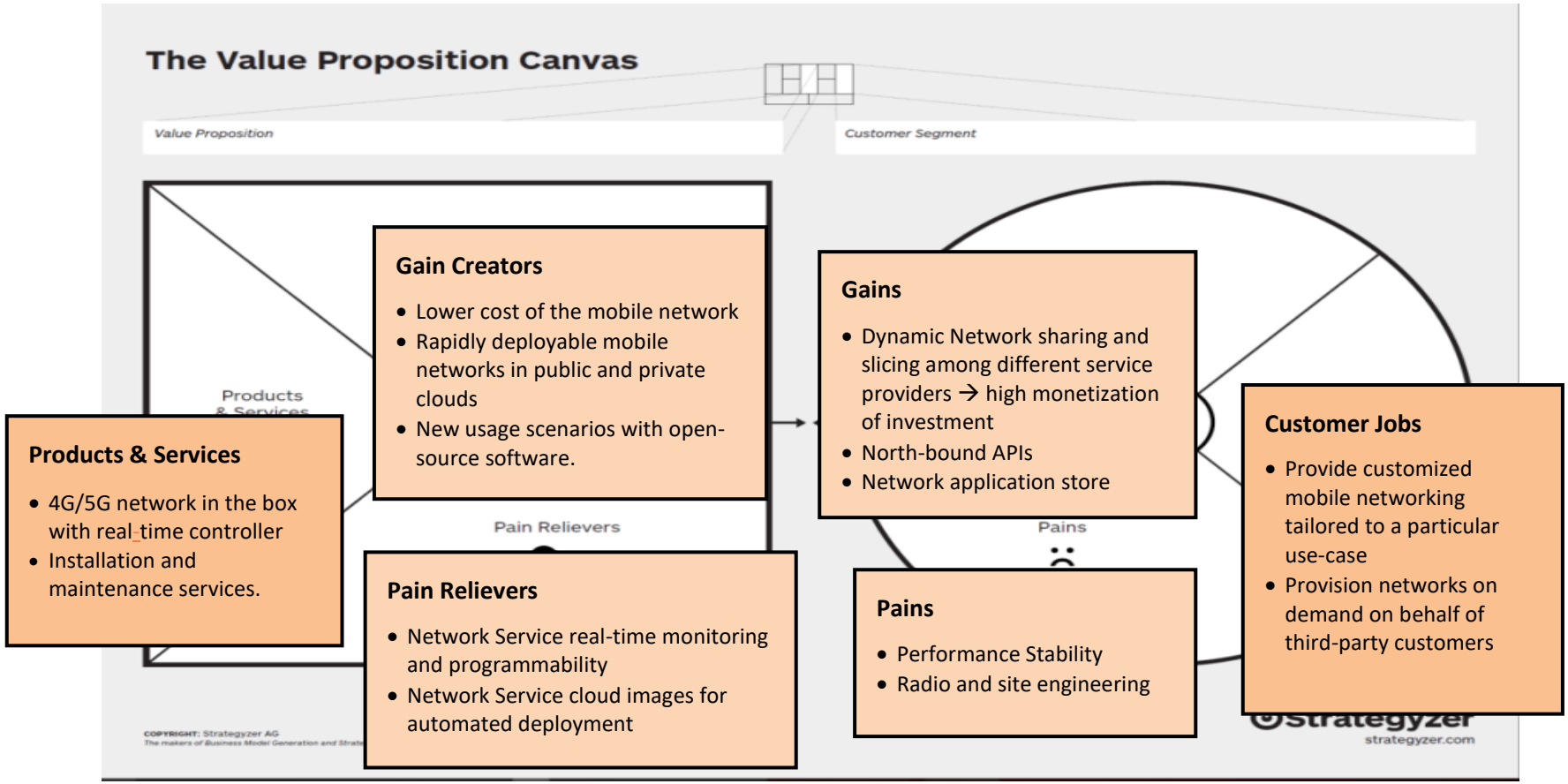
- The US patent US20190158388A1 has been published 2019-05-23 and is currently in pending state.
- The EP patent EP3440809A1 has been published 2019-02-13 and CNIT has received a communication that the patent has been granted the 2019-09-16.

As next step, given the fact that commercialization requires to open a specific company (a startup) and to transfer the technology and the knowledge acquired by CNIT during the 5G-PICTURE project to this entity, the senior CNIT personnel recently opened a start-up company (named AXBRYD) which aims to commercialize the FlowBlaze abstraction also acquiring the US20190158388A1 patent currently hold by CNIT, which has been developed and finalized among the project activities.

Secondarily, it has been identified that the mobility server functionalities will be of interest only for specific companies (railways, industries, etc.). CNIT plans to leverage the credibility acquired during the project with other 5G-PICTURE partners which focus on the railways use case (such as COMSA and FGC) to further develop the mobility functionalities and to discuss possible common exploitation.

4.12 Slicing enabled 4G/5G RAN controller and 4G/5G Node

Potential customers for **EUR**'s Slicing enabled 4G/5G RAN controller and 4G/5G node are mainly Telecom Operators, service providers, and verticals/Small Telcos owning mobile network infrastructure. The value proposition delivered by this product is analysed as follows:


The Value Proposition Canvas
Value Proposition
Customer Segment
Products & Services
Pain Relievers
Pains
Gain Creators
Lower cost of the mobile network
Rapidly deployable mobile networks in public and private clouds
New usage scenarios with open-source software.
Gains
Dynamic Network sharing and slicing among different service providers → high monetization of investment
North-bound APIs
Network application store
Products & Services
4G/5G network in the box with real-time controller
Installation and maintenance services.
Pain Relievers
Network Service real-time monitoring and programmability
Network Service cloud images for automated deployment
Pains
Performance Stability
Radio and site engineering
Customer Jobs
Provide customized mobile networking tailored to a particular use-case
Provision networks on demand on behalf of third-party customers
strategyzer.com

<table>
<tr>
<td rowspan="2">Problem
• Low-cost modular 4G/5G networking
• Quick and easy provisioning of 4G/5G network services
• Quick and easy provisioning of private and customized 4G/5G networks

<u>Alternatives</u>
• Wi-Fi-in-a-box solutions for easy network provisioning
• Facebook 4G system (Magma)</td>
<td>Solution
• Turnkey 4G/5G network in the box based on open-source technology
• Installation and maintenance services.</td>
<td rowspan="2">Unique Value Proposition
• Low cost 4G/5G network service
• Real-time monitoring and Programmability
• Support of network slicing</td>
<td>Unfair Advantage
• Open source technology
• No “vendor lock-in”
• Lowering the cost</td>
<td rowspan="2">Customer segment
• R&D centers

Upon commercialization:
• Verticals owning telecom infrastructure
○ City administrator
○ Venue owner (stadium, transport hub, factory)
• Telecom Operators

<u>Early adopters:</u>
• R&D centers</td>
</tr>
<tr>
<td>Key Metrics
• Volumes of sales of units
• Number of Customers
• Customers' loyalty in terms of number of orders through years.</td>
<td>Channels
• Open-source communities
• Conferences, demos
• Research-oriented projects (5GPPP, industry projects)</td>
</tr>
<tr>
<td colspan="3">Cost Structure
• Man power for software development, testing and packaging
• Hardware cost for compute and RF
• Production cost for low volumes and high volumes of HW units</td>
<td colspan="2">Revenue Streams
• Licensing software stack and cloud images
• Direct sale of turnkey solution
• Customized solution for private networking
• Support and services</td>
</tr>
</table>

4.12.1 EUR's Exploitation Plan for Slicing enabled 4G/5G RAN controller and 4G/5G Node

Slicing enabled 4G/5G RAN controller and 4G/5G Node are of 100% **EUR**'s ownership. However, currently sustainability and exploitability of these products are tightly linked to EUR's activities as a research institute. In line with this, EUR will exploit the results of the 5G-PICTURE project to enrich their education offer with the novel concepts of network slicing and orchestration for 5G verticals. Young researchers and students will come closer to the fascinating new world of service-oriented 5G gaining practical experience through the Eurecom 4G/5G infrastructure facility enriched by 5G-PICTURE. Some of the use-case trials related to train and stadium tackled in the project will become part of master courses, as well as topic for master and PhD thesis. The impact of the project will be on the (a) experimentation and validation of OpenAirInterface.org and Mosaic5G platforms in realistic use-cases, (b) evolution towards reference prototyping platforms for current and future service-oriented mobile networks, and (c) adoption and democratization of the tools by academic and industrial communities.

5 Vertical Industries Use Case Analysis

5.1 Vertical Industries in 5G Networks and in 5G-PICTURE

With the eminent advent of 5G networks, and the forthcoming introduction of full 5G network capabilities to market, the whole ICT ecosystem will move from technology-driven approaches to service-driven ones. In practice, this means that, unlike current network deployments, based on the satisfaction of service-agnostic, abstract and (network-wide) cumulative requirements, next-generation network deployments will need to satisfy more flexible and varied requirements which will be dictated by the specific stakeholders/ applications/ services. Technology-wise this implies moving from existing closed, static and inelastic network infrastructures/ technologies which can satisfy these service-level advancements, to the transformation of traditional network infrastructures into open, scalable and elastic ecosystems that can support a large variety of dynamically varying applications and services.

From the business perspective, this technology shift will not only bring network performance enhancements to enable the delivery of new applications and services, but also it will trigger the development of new business models involving multiple stakeholders from traditionally separated markets where also some business roles are changing due to the new paradigms. The latter are also realised through the extensive use of network softwarisation and programmability to provide integrated infrastructures, in which telecommunication networks, computing resources and physical infrastructures are integrated making use of convergent technologies as addressed in the context of 5G-PICTURE vertical demonstrations.

In particular, contrary to the legacy network technologies (including 4G), for which all the activities related to technology development and commercialisation, including requirements and specifications definition, design, standardisation and deployment activities, were based on an abstract, application/service agnostic definition of the network QoS requirements, the respective 5G development activities are based on a more stakeholder/application/service requirements aware approach. Practically this means that besides the general technical QoS Key Performance Indicators (KPIs) and target values for 5G technologies, the actual 5G network deployments and operation will be tailored (automatically) to support the requirements of a range of stakeholders and services in a holistic manner, and to an extend will be deployed and integrated with their existing business infrastructures. For this purpose, technical activities around 5G are tightly coupled with activities related to the analysis of stakeholders and their service and business requirements and strategies. The ultimate goal worldwide is to deliver “a stakeholder driven, holistic ecosystem for technical and business innovation integrating networking, computing and storage resources into one programmable and unified infrastructure”, “enabling the transport of software to the data rather than the other way round, i.e. executing software on the device where the data is produced instead of sending all data to a centralised data centre [6].

To this end, 5G-related activities are converging to address the following major Vertical industries [6], [7], [8]:

- Automotive, especially focusing on services provided in high mobility scenarios, Internet of Things (IoT) applications/services, etc.
- eHealth, especially focusing on remotely provided health services with high latency and reliability requirements,
- Energy, especially focusing on IoT based energy monitoring, management, and network control scenarios,

- Media & Entertainment, especially focusing on next generation applications/services provisioning such as UHD content, Crowdsourced/multi-user created content, highly interactive services, etc., as well as,
- Factories of the future, referring to Industry 4.0 setups.

It becomes obvious that these vertical industries involve large service groups, which can be provided by various business stakeholders depending on the specific market/social environment, and can include various applications/services.

5G-PICTURE aims at providing a stakeholder/service-driven approach towards optimal infrastructure resource utilisation for the traditionally established Telecom Operators, as well as at empowering verticals towards deploying and/or operating smaller scale 5G infrastructures for their specific telecommunication needs thus expanding and/or optimising their business activities. The main verticals addressed through 5G-PICTURE proof of concept demonstrators (showcased in realistic environments) are the following:

- The “railway industry” through the 5G-railways testbed located in Barcelona (representing the automotive and Media & Entertainment industry).
- The “large venue (stadium) owners’ industry” (representing the Media & Entertainment industry), through the 5G-stadium testbed located in Bristol, UK addressing scenarios with increased density and static-to-low mobility. In this environment media services associated with large venues will be demonstrated.
- The “smart cities vertical”, through the 5G-smart city testbed in Bristol, UK.

The latter are representative cases of the changing business environment and business roles. The business impact of 5G (starting with 5G-PICTURE technologies’ drive) on these use cases has been further analysed in this chapter.

5.2 Railway Use Case Analysis

5.2.1 Railway Ecosystem Overview and Prerequisites towards Commercialisation

The railway industry constitutes a major vertical sector addressed in the context of 5G-PICTURE. In the current landscape, the main stakeholders involved in the value chain of telecommunication services provisioned both to railway operators’ (internal) and to passengers (external) are the following:

- Railway & Transport operators that require multiple/versatile network services for performing their own critical communication, performance & business services.
- Infrastructure Engineering companies, which along with Telecom Operators/Carriers deliver network infrastructure solutions and possibly, depending on the agreements also services to Railway & Transport operators.
- The Telecommunication Services’ end-users:
    - Railway & Transport operators served both by Telecom Operators/Carriers and by their own overlay network infrastructures (if any);
    - Passengers usually served directly by Telecom Operators/Carriers.

In this framework, from the business model perspective, high complexity is incurred as multiple bilateral agreements are needed to arrange these relationships, while from the technical perspective, different networks are deployed for different communications services, leading to slow service deployment, low performance for premium services, high TCO for all stakeholders.

In the envisioned, future ecosystem it is sought (in line with FRMCS standards/reports) a shared neutral network capable to support effectively critical/ operational/ business communication services over a communication infrastructure integrated with the railway infrastructures providing lower TCO, service flexibility & deployment speed.

In technical terms, a set of 5G-PICTURE technologies (analysed in the aforementioned chapter) integrated, interoperating and deployed together can be considered as a holistic solution for railway communications addressing this vision of Future Railway Mobile Communication System (FRMCS), and supporting from the technical perspective the business model. In this context, the railway use case demo performed in Barcelona with the railway sector/industry being represented by COMSA and FGC, constitutes a key exploitable asset not only for COMSA and FGC but also for the complete railway sector. The use case demo constitutes a key exploitable asset also for the partners delivering the specific products/components for the solution, since this demo at operational environment directly leverages their TRL level. In particular, the technical solution has been described in the deliverables of **WP6**, and spans along a 1.5 km section of the demonstration track, located next to Olesa de Monserrat station. The speed of commercial trains up to 90 km/h and the services demonstrated will be of two categories: performance operation and business services.

However, besides, the technical feasibility of the envisioned ecosystem, the business potential, prerequisites and steps to be followed have been explored in the context of the project. To this end a swift has been identified for both the Engineering companies (such as COMSA) providing the infrastructure deployment of the 5G-PICTURE solution to their customers, for the Railway operators (such as FGC), and for future railway telecommunication infrastructure providers (being COMSA or FGC or a 3rd company). In particular, in this future environment, the main stakeholders and their roles would change as follows:

- Railway & Transport operators, still requiring the same multiple/versatile network services.
- Infrastructure Engineering Companies, in this case delivering a single network solution to Railway & Transport operators which can be of ownership of the Railway or Transport operators' or of an external stakeholder (e.g. a Telecom Operator or 3rd party (Small Telecom Operator) depending on the business case).
- The owner of the network deployment (possibly being the Railway Operator or a 3rd party/company e.g. a spinout/daughter company of the railway operator/ engineering company), which can lease/provide network resources to multiple Service Providers e.g. Telecom Operators, Content Providers, (Transport Operators if not the owner of the network), passengers (depending on the business model), etc.
- The Telecommunication Services' end-users, being again Railway & Transport operators & passengers, all served by the single network infrastructure.

In particular, in order for the business swift to be achieved specific regulatory aspects need to be handled, as a set of licenses need to be held by different players based on their role. Considering the current regulatory environment which is almost common in most EU Countries, in such future business case, in order for the railway operator/ engineering company/ or separate 3rd party to undertake the role of vertical infrastructure provider and telecommunication services provider, the following licenses and agreements need to be acquired before any initiation of business activities (see indicatively [17] and [18] for detailed information about the Spanish and Greek regulatory framework):

- Related to Telecommunication Services Provisioning
    - License to provide Telecommunication Services from the national Telecommunications Commission/Agency; the fee (if any) is usually negligible.

  - The respective commercial license to perform such business activities from the national commercial chamber; the fee (if any) is usually negligible.
  - License to obtain specific range from the national numbering plan – if the services include also telephony communications, not just data. The fee (if any) is usually negligible.
- Related to Infrastructure Deployment and Operation:
  - If the wireless access network frequencies to be used are part of the licensed spectrum bands a frequency license is needed (usually acquired through public spectrum allocation contests); the fee is usually non-negligible, and very time-, market-, service-, competition- specific. It is also needed to declare the infrastructure deployment including location, air interface characteristics, etc., of each access network node to the Telecommunications Commission/Agency.
  - If the equipment is operated on unlicensed spectrum bands, usually only the simple declaration of the infrastructure deployment is needed. The fee (if any) is usually negligible.

Afterwards, the business activities can be launched, and business models can take effect.

5.2.2 Railway 5G-PICTURE Solution Lean Canvas Analysis

The business value and tentative business model of the aforementioned 5G-PICTURE solution for railways is analysed in this section by means of Lean Canvas Analysis, from the perspective of engineering companies such as **COMSA**, primarily targeting the rail operators as their direct customers.

PROBLEM

Currently in the railways sector/environment different networks are deployed each providing different communications services: critical communication, performance & business services.

Critical communications refer to communications between railways personnel or to train control, both performed over reserved spectrum bands. Performance services aim at railway operational improvement, and business services support the railway passenger experience, usually relying on multiple commercial mobile or satellite networks.

The multiple technology deployment leads to a slow reaction to communication needs (i.e. with regard to the offering of a new service) and incurs a high total cost of ownership (TCO) for the infrastructure providers and the rail operators.

ALTERNATIVES

Telecom Operators currently share some of the required assets for the provision of services along the track and lease fibre capacity, building space and towers from rail administrations to reduce their TCO.

The vision of future railways mobile communications will be to be performed over an integrated communications infrastructure for stations, trains and along tracks, supporting all communications based on commercial 4/5G technologies. The infrastructure would be owned by railways administrations and would be shared with rail and Telecom Operator operators, in order to provide services by the most appropriate entity/stakeholder. However, currently no such deployments exist in the market.

CUSTOMER SEGMENT

The afore-described problem thus the solution proposed by 5G-PICTURE concerns primarily the railway communications' and railway infrastructure providers/operators and at an extended level any infrastructure operator requiring/seeking (1) the provision of critical services with large coverage requirements, (2) adopting operational improvements of the infrastructure to accommodate new communication services and (3) aiming at providing a better user experience for the end user.

Therefore, the adopters of the 5G-PICTURE solution would be the infrastructure providers/operators and their associated target customer segments to benefit/be provisioned with the solution (to be deployed by infrastructure providers) would be primarily:

- Terrestrial transportation industries with fixed routes: Railways, coaches/bus operators.
- Ports and airports.

COMSA as a representative of the railway infrastructure/systems industry/vertical is exploring the business viability for a railway communications solution comprised of the following building blocks: shared broadband connectivity (backbone/aggregation network, neutral 4/5G access, Wi-Fi access), new generation services core, and turnkey and maintenance services.

EARLY ADOPTERS

Early adopters (i.e. stakeholders deploying the solution or asking from infrastructure providers to deploy the solution) would be those infrastructure customers facing critical technology communications phase-out, or being forced by liberalisation pushing the need for new services, or seeking/planning deep operational improvement.

UNIQUE VALUE PROPOSITION

The unique value proposition of 5G-PICTURE solution for railway communications is the delivery of a shared neutral network capable to support effectively both critical and operational as well as business communication services over a communication infrastructure integrated with the railway infrastructures. The integrated solution provides lower TCO and service flexibility and velocity.

The benefit is maximized by using the promising G.Metro and mmWave technologies. G.metro provides very low TCO for 10G transparent services along the track and with potential in large stations. mmWave allows 4 Gbps connectivity into train, allowing the build of high performance Wi-Fi access and neutral 4/5G access inside trains.

SOLUTION

The solution comprises the following:

- Shared broadband connectivity
    - Optical/wireless interconnection network.
    - Wi-Fi access network
    - Neutral 4/5G access network for Telecom Operator and vertical
- Next Generation Cores and IP Services: Critical, Performance and Business Services
- Turnkey and maintenance.

Figure 5-1 shows how solution proposed applies for the railways case support to the different stakeholders: railways administrator, rail transport operators and public Telecom Operators.

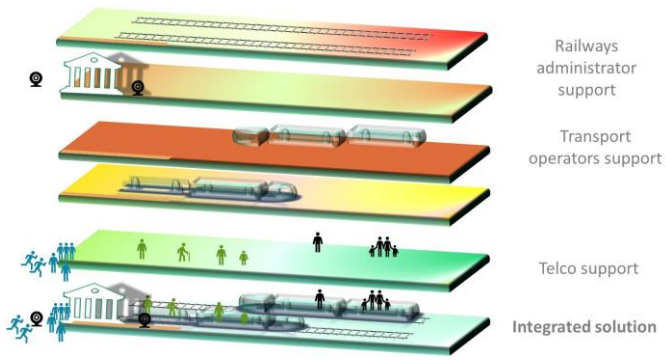


Figure 5-1: 5G-PICTURE Railway Communication Solution – Stakeholders.

The solution for the station is the following. It provides a common infrastructure for all critical, performance and business services in the station. Broadband infrastructure is shared between all stakeholders, providing service flexibility and velocity, and a common maintenance support from the infrastructure operator (such as COMSA) with distributed operations from each operator. The connectivity network is based on differentiating G.Metro technology for large stations.

A similar solution is built for the track. The optical aggregation network is based on G.Metro.

And finally, an alternative design for the track, combining the optical aggregation with differentiating mmWave connectivity to train. This brings 4 Gbps to trains up to 300 km/h and pushes the neutral 4/5G access into the train:

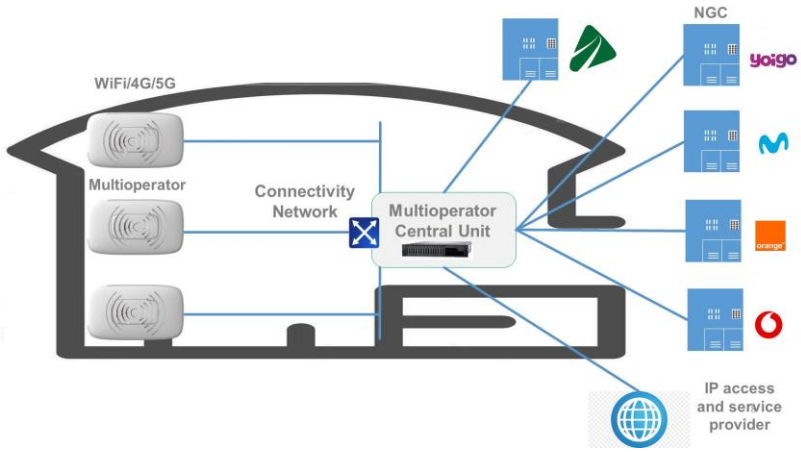


Figure 5-2: 5G-PICTURE Railway Communication Solution at Stations.

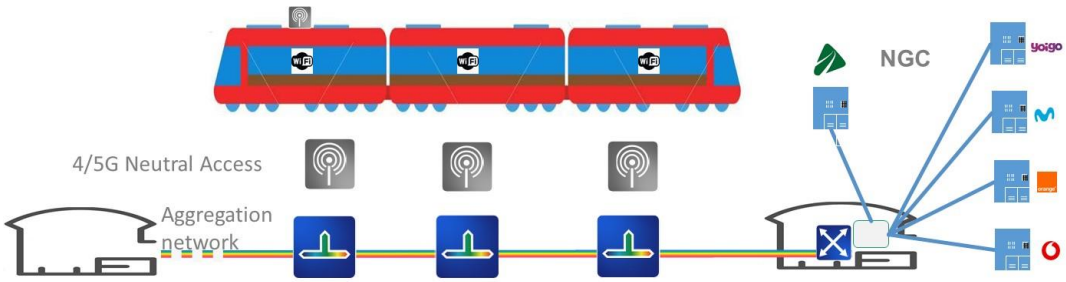


Figure 5-3: 5G-PICTURE Railway Communication Solution at track based on 4/5G radio access.

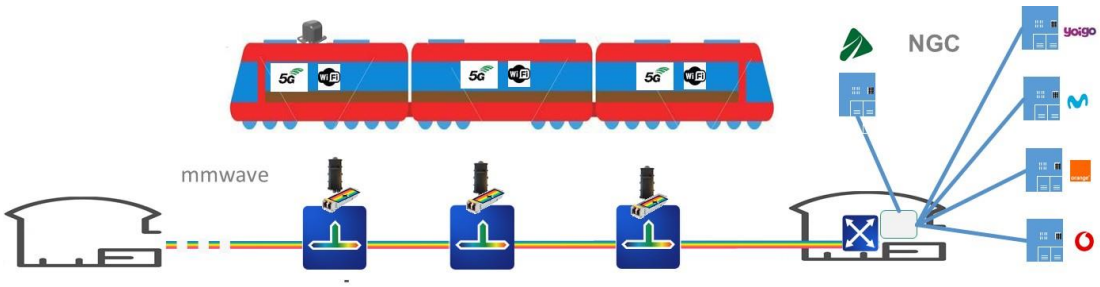


Figure 5-4: 5G-PICTURE Railway Communication Solution at Tracksides based on mmWave.

CHANNELS

Direct sales to Railways and other customers of infrastructure providers (e.g. other COMSA customers).

COMSA business is more than 50% in the railways sector. The role of Telecom Operator is key in this new scenario. Collaboration with a Telecom Operator is required e.g. for service continuity, for service bundling, for benefiting from the Telecom Operator customer base/expertise/ communication channels, etc. The latter would be valuable for both COMSA and Telecom Operator (e.g. for service portfolio enhancement, for sustaining market share etc.), given COMSA's footprint in railways market/industry.

Other customers

In join bidding with competitors with customer presence but without differentiating solution.

UNFAIR ADVANTAGE

From the present viewpoint, the "Unfair Advantages" of the solution are basically:

- Potential of early commercial deployment of the solution (before competition, and before similar products emerge).
- And above all, the fact that this solution has resulted from contributions of a number of partners (companies and research institutes) coming from versatile industries each providing valuable input (specific requirements, feedback, expertise, work, etc.), which is extremely difficult to be collected otherwise -than working together on a single project.

From the infrastructure providers' side, other unfair advantages can (and need) to be built. The latter will be based on the following:

- collaboration with Telecom Operators, in the form of
    - national roaming agreements in case telephony services are provided and are handled on a per end-user basis
    - capacity/ telecommunication services leasing agreements for bulk purchase of capacity over the infrastructure by Telecom Operators
    - bilateral agreements on special tariffs and charging schemes of users.
- combination of solution with differentiating products like mmWave,
- collaboration with COMSA critical application providers (Airbus, etc.), to enforce/ complement deployment with new efficient applications,
- collaboration with start-ups with new niche applications for the vertical to gain differentiation against other Airbus channels, or to attract adoption of e.g. infotainment services from passengers, etc.

It is also very important to leverage maintenance contracts and maintenance teams.

Existing TETRA customers provide also a potential advantage to COMSA due to relationship and existing presence (business volume or soft network phasing-service evolution).

KEY METRICS

Railways infrastructure providers' customers' key metrics of the performance of the solution will be the following:

- the faster response time and better performance due to the use of Telecom Operator 4/5G technology (for the customer), and
- lower TCO for the infrastructure supporting business, performance and critical communication services, due to infrastructure sharing.
- Moreover, sustainable earnings before interest, taxes, depreciation, and amortization (EBITDA) will be the financial metric for infrastructure providers like COMSA.

COST STRUCTURE

The resources by COMSA required for developing the market are: sales dedicated person, sales engineer, product engineer support, and incremental bid management activity for the total of one person year. Estimation 330 k€/year.

It is key to review the availability and training of the in service and specially the maintenance teams.

Assuming in services total 20% of project value, post sales 3 years, direct margin 20% and a 1 year delay from initial activity to business, this requires a minimum 4 M€ equipment and in service sales per year during two years for 0% earning or 5.6 M€ for 5%.

REVENUE STREAMS

The revenue streams that will be generated or reinforced will depend highly on the specific business model to be adopted which includes the trackside/stations/trains' infrastructure ownership level and agreements, the sharing of responsibility for deployment and operation of the telecom infrastructure, the sharing of responsibility of operation of the communication services, the responsibility of delivering/provisioning/selling the business communication services to end-users etc. In general, the revenue streams could be:

For infrastructure engineering/providers (such as COMSA):

- Revenue from railways from equipment supply, turnkey project and maintenance.

For Telecom Operators:

- Lower cost for covering large areas (stations).

For railways:

- Revenue from Telecom Operators for usage of shared infrastructure (subject to the aforementioned agreements)
- Compensation with other services from Telecom Operator to railways (internet access, etc.).

Table 5-1: 5G-PICTURE Solution for Railway Use Case – Lean Canvas.

<table>
<tr>
<td rowspan="2">Problem
Currently different networks are deployed for different services: critical communication, performance & business services; incurring long service deployment times, high TCO and complexity for the infrastructure providers and rail operators.
<u>Alternatives</u>
• Current solutions are based on infrastructure sharing & communication services provisioning between Telcos & Railway Operators.
• Currently, no solution exists that is completely integrated with Reailway/Transport Operator assets (stations, trains and trackside infrastructure) supporting all railway communication services.</td>
<td>Solution
• Shared broadband connectivity
  ○ Optical/wireless transport
  ○ WiFi access
  ○ Neutral 4/5G access
• Next Generation Core & IP Services: Critical, Performance & Business Services
• Turnkey & maintenance</td>
<td rowspan="2">Unique Value Proposition
A shared neutral network capable to support effectively critical, operational and business communication services over a communication infrastructure integrated with the railway infrastructures;
providing lower TCO, service flexibility and deployment speed.</td>
<td rowspan="2">Unfair Advantage
• Early deployment before competition.
• Solution resulted from collaboration between partners from versatile industries/academia giving input that is difficult to be collected otherwise.
• (Esp. for COMSA) Existing customer base.
Others can (and need) to be built, such as:
• collaboration with Telcos,
• collaboration with COMSA critical application providers,
• collaboration with start-ups with new niche applications to achieve differentiation.</td>
<td rowspan="2">Customer segment
• Terrestrial transportation industries with fixed routes: Railways, coaches/bus operators.
<u>Early adopters</u>
Railway/Transport operators, facing critical technology phase-out, or seeking deep operational improvement & planning new services delivery.</td>
</tr>
<tr>
<td>Key Metrics
Railways customers' service delivery metrics:
• Better performance for services
• lower TCO
• Sustainable EBITDA for infrastructure providers (e.g. COMSA).</td>
</tr>
<tr>
<td colspan="2">Cost Structure
• Equipment purchase cost
• Equipment deployment cost
• Personnel costs (estimated at): sales representatives, sales engineer, product support, and incremental bid management activity (estimated at one person year).</td>
<td colspan="3">Revenue Streams
Depend on the specific business model, incl. trackside/stations/trains' infrastructure ownership, responsibility for deployment & operation of the telecom infrastructure, etc. In general:
For infrastructure providers & operators (e.g. COMSA):
• Revenue from railways from equipment supply, turnkey project and maintenance, etc.
For infrastructure operators (e.g. railway operators/3rd parties/ etc.):
• Revenues from Telcos for leasing capacity of the shared infrastructure.
• Revenues from end-users:
• Cost minimization for the support of critical communications etc.</td>
</tr>
<tr>
<td>Channels
• Direct sales to Railways & other existing customers (e.g. COMSA customers)
• Collaboration with Telcos (existing or new), for e.g. service continuity, service bundling, benefiting from the telco customer base/ expertise/ communication channels, etc.</td>
</tr>
</table>

5.2.3 COMSA Exploitation Plan related to Railway Use Case

As first step towards commercialization, **COMSA** explored the business potential of some applications based on a single large customer and few applications to validate the business case.

Case 1. Rail stations ADIF: Priority AVE and large stations: 42 of +100 stations case

Shared broadband connectivity:

- Wi-Fi access network.
- Optical network in station. Total 3.3 M €. Does not include fiber cable nor power deployment assuming deployed with Wi-Fi network.
- Neutral access network 4 / 5G for Telecom Operator and Rai. Total 2 M €. Integration with operators not to be included. Responsibility of each operator with support from COMSA and COMSA supplier.

Next Generation Cores and IP Services: Critical, Performance and Business Services. Railways Core will be key for COMSA in TETRA based railways. Too soon to evaluate.

Turnkey for the items costed included in prices above.

Maintenance (3 years in 3 regions) Total € 3.8M for the items evaluated above.

Case 2. Rail track and train in ADIF using mmWave. Priority AVE and main long lines: 1000 km of + 3100 km in Spain.

Shared broadband connectivity:

- Optical network in track Total € 21 million. It does not include fiber nor power.
- Network interconnection mmWave in track.
- Neutral access network 4 / 5G for Telco and Rail by train. Not to be evaluated.
- Wi-Fi access network in train. Not to be evaluated.

Next Generation Cores and IP Services: Critical, Performance and Business Services. Railways Core will key for COMSA in TETRA based railways. Too soon to evaluate.

Turnkey for the items costed included in prices above.

Maintenance (3 years) Total € 7.1M for the items evaluated above.

Case 1 and 2 currently include few items for a single customer. These cases confirm the existence of addressable business for COMSA above the minimum business required discussed in lean canvas cost structure.

It is still soon for a meaningful exploitation plan, due to the fact that technology is currently at technologically mature but pre-commercial stage and the very initial activity done with potential customers.

A list of customer engagement activities is included:

- March 2018 Value proposal to Telefónica for Red.es. Objective to promote sharing network between Telecom Operator and rail operators / emergencies.
- May 2018 Presentation to the technical direction of Metro Madrid.
- Oct. 2018 Presentation to the CTF (Railways Technology Center) of ADIF in Málaga.
- Dec. 2018 Presentation to RENFE.

- Dec. 2018 Bid Proposal for a neutral 4G / 5G network in stations integrable with Wi-Fi, to ADIF innovation.
- May 2019 Presentation for a neutral 4G / 5G network station to Telecom engineering ADIF.

The current plan under internal discussion in COMSA is as follows:

Innovation team:

- Agree business case to prioritise actions and coordinate efforts.
- Respond / propose new calls and innovation financing programs for PoC and operational demo, for track and station.
- Obtain support from Programs for obtaining financing.
- Facilitate alliances and client projects through Start-ups and joint ventures (JVs).
- Support commercial and business activity.

Sales and business operations:

- Agree business case to prioritise actions and coordinate efforts.
- Commercial action in ADIF.
- Wi-Fi opportunity in immediate stations (September 2019-2021).
- Validate the suitability between existing technologies and their provider.
- Close distribution agreements with selected commercial solution providers.
- Development of commercial plan for neutral connectivity in priority railway customers.
- Facilitate alliances and client projects through join bid for proposals.
- Support innovation activity.

5.3 Stadium Use Case Analysis

5.3.1 Stadium Use Case Ecosystem Overview and Prerequisites towards Commercialisation

The industry of media and entertainment in large venues constitutes a major vertical sector addressed in the context of 5G-PICTURE. In the current landscape, the main stakeholders involved in the value chain of telecommunication services provisioned both to stadium administration services (internal) and to end-users (fans) (external) are the following:

- Stadium Owners requiring multiple/versatile network services.
- Telecom Operators/Carriers delivering network solutions and services to Stadiums.
- Broadcasters/ Content/ Multimedia Application providers require high performance connectivity.
- Service end-users:
    - Stadium Administration services.
    - Stadium visitors/fans.
    - Safety/Emergency services (e.g. police, medical care).

In this framework, from the business model perspective, telecommunication infrastructure in large venues/stadiums deployed/ operated by Telecom Operators, with current technologies enabling static and inflexible infrastructure sharing for Telecom operators service providers; practically leading to separate infrastructure/equipment deployment from each Telecom operator, thus incurring high TCO. As a result, considering also the balance between TCO and expected revenues (as those are only generated during events) in most cases inadequate networks capacity is provided for fully crowded events and/or for highly demanding services.

In the envisioned, future ecosystem it is sought a shared neutral network capable to support effectively highly demanding media and entertainment (along with other) services from multiple providers over a communication infrastructure integrated with the stadium infrastructure; allowing for lower TCO, service flexibility and higher speed of deployment.

In technical terms, a set of 5G-PICTURE technologies (analysed in the aforementioned chapter) integrated, interoperating and deployed together can be considered as a holistic solution for delivering highly demanding telecommunication services at large venues/ stadiums, and under crowded conditions. In the stadium use case demo performed in Ashton Gate stadium (Bristol UK), the stadium owner vertical is represented by BRISTOL SPORT in collaboration with Zeetta. The demonstrator results will constitute a key exploitable asset not only for BRISTOL SPORT but also for the partners delivering the specific products/components for the solution, since this demo directly leverages their TRL level. In particular, the technical solution has been described in the deliverables of WP6, and is further elaborated with the stakeholders' involvement in the following paragraphs. The services will be based on I2CAT's Watchity Application (a crowdsourced video application as described in 5G-PICTURE deliverables of WP2 and WP6).

In addition to the technical feasibility of the envisioned ecosystem, the business potential, prerequisites and steps to be followed have been explored in the context of the project. To this end a business opportunity has been identified for the stadium owners. In particular, in this future environment, the main stakeholders and their roles would change as follows:

- Stadium Owners still require multiple/versatile network services, but can undertake the role of the vertical infrastructure provider by owning the telecommunication infrastructure integrated with the stadium infrastructure.
- Multi-Domain Orchestrators, expected to be represented by Telecom Operators/Carriers, which undertake the role to attach the Stadium infrastructure in the multi domain infrastructure of their responsibility.
- Broadcasters, Content/ Multimedia Applications/ Cloud providers, other Telecom Operators request and obtain edge compute/ network/etc. services with QoS guarantees, on a time-basis.
- Service end-users to be served over the common infrastructure:
    - Stadium Administration services.
    - Stadium visitors/fans.
    - Safety/Emergency services (e.g. police, medical care).

In order for the business swift to be achieved specific regulatory aspects need to be handled, as a set of licenses need to be held similarly to the railway case. Considering the current regulatory environment which is almost common in most EU Countries, in such future business case, in order for the stadium owner to undertake the role of vertical infrastructure provider and telecommunication services provider, the following licenses and agreements need to be acquired before any initiation of business activities (see indicatively [17] and [18] for detailed information about the Spanish and Greek regulatory framework):

- Related to Telecommunication Services Provisioning
    - License to provide Telecommunication Services from the national Telecommunications Commission/Agency; the fee (if any) is usually negligible.
    - The respective commercial license to perform such business activities from the national commercial chamber; the fee (if any) is usually negligible.
    - License to obtain specific range from the national numbering plan - if the services include also telephony communications, not just data. The fee (if any) is usually negligible.

- Related to Infrastructure Deployment and Operation:
    - If the wireless access network frequencies to be used are part of the licensed spectrum bands a frequency license is needed (usually acquired through public spectrum allocation contests); the fee is usually non-negligible, and very time-, market-, service-, competition- specific. It is also needed to declare the infrastructure deployment including location, air interface characteristics, etc. of each access network node to the Telecommunications Commission/Agency.

If the equipment is operated on unlicensed spectrum bands, usually only the simple declaration of the infrastructure deployment is needed and the fee (if any) is usually negligible. Of course this does not apply in the case of free of charge Wi-Fi data services.

5.3.2 Stadium 5G-PICTURE Solution Lean Canvas Analysis

The business value of the aforementioned 5G-PICTURE solution for large venues/ stadiums is analysed in this section by means of Lean Canvas Analysis, from the perspective of stadium infrastructure providers such as BRISTOL SPORT, targeting Telecom Operators and Service providers (corporate customers) as well as the fans/end users (direct retail customers) depending on the services definition and business case.

PROBLEM

Currently, the telecom infrastructure delivering services in large venues/stadiums is deployed/ operated and managed permanently or ad hoc by Telecom Operators using existing technologies. The infrastructure/ equipment deployments are also separate for each Telecom Operator over the same venue. Currently solutions such as MOCN (Multi-Operator Core Network) and RAN Sharing (Radio Access Network Sharing) allow sharing of 3G/4G access network nodes between customers of multiple Telecom Operators, but with no QoS guarantees. Moreover, sharing of access network infrastructure is not flexible to accommodate other Telecom Operators easily, service providers etc. and is not modifiable on a per time basis. Moreover, critical communications at these venues are also performed over separate network infrastructures; in some cases also in order to comply with regulation and directives.

These deployments are subject to various agreements between multiple Telecom Operators and the venue owners, usually entailing simple leasing of space for the deployment of the infrastructure. Moreover, they incur high TCO for Telecom Operators (depending on the frequency and attendance of the events) thus the dimensioning of network capacity takes into account cost and potential revenues, in many cases leading to not adequate capacity planning for cases of fully crowded events. Moreover, the complexity of agreements and contractual limitations restrict the massive integration of telecommunication equipment with the venue infrastructure. Next generation highly demanding services (media and entertainment as well as critical communications) can barely be delivered over these infrastructures, not to mention the fact that in cases of high congestion (e.g. in significantly crowded events) (a spike) the installed networks have no way of scaling up resources.

ALTERNATIVES

Currently solutions such as MOCN (Multi-Operator Core Network) and RAN Sharing (Radio Access Network Sharing) exist, and in some cases they are deployed in large venues. These imply the deployment of 3G/4G access network nodes that are shared between customers of multiple Telecom Operators. However, at access network level there is no controlled resources utilisation, nor QoS guarantees. At the same time, sharing of access network infrastructure is not flexible to accommodate other Telecom Operators, service providers etc. and is not modifiable on a per time basis. Moreover, these solutions are only operated by Telecom Operators and without any involvement from the venue/ stadium owner (vertical), the role of which is limited to space leasing.

Currently no neutral network infrastructure sharing solution exists that is at the same minimising TCO for Telecom Operators, maximising benefits for venue owners, and allowing high levels of multitenancy and flexibility over time.

CUSTOMER SEGMENT

The solution proposed by 5G-PICTURE to the afore-described problem concerns primarily the large venue/ stadium owners and at an extended level any infrastructure operator seeking the provision of highly demanding services to crowds. Therefore, associated target customer segment to deploy/adopt the 5G-PICTURE solution would be (depending on the individual business model) "Large venue owners including shopping malls, stadiums, concert halls, etc." The latters' customer segment that is addressed through the solution could be:

- Service providers aiming to deliver media and entertainment services to crowds/crowded areas (in this case to fans/audience of the stadium).
- Safety/Emergency service agencies (e.g. police, medical personnel) operating at crowded, large venues/ stadiums.

Telecom operators aiming to provide versatile telecommunication services to these venues.

EARLY ADOPTERS

The adoption of the solution/services/business model is dependent on the individual local/national market and specifically associated with the infrastructure deployment agreements and models followed by Telecom Operators and venues, as well as with the level of familiarity with high-end, new media and entertainment services from the public. From the initial estimations, with regard to the deployment of the solution early adopters would be large venues/large stadiums usually hosting massive numbers of spectators, thus having an existing customer base, and operating in markets that are accustomed with spectacles and high-end media and entertainment services. With regard to the adoption of the large venues/stadium's infrastructure as a service provisioning, early adopters would be spin offs in the media and entertainment as well as marketing services sectors, and potentially existing Telecom Operators.

UNIQUE VALUE PROPOSITION

The unique value proposition of 5G-PICTURE solution for large venue/stadium communications is the delivery of a shared neutral network capable to support effectively highly demanding media and entertainment (as well as other) services from multiple service providers over a communication infrastructure integrated with the stadium infrastructures. The integrated solution provides lower TCO and service flexibility and speed of deployment.

SOLUTION

The solution allows the delivery of highly demanding communication/application services over neutral, commodity infrastructure shared by multiple tenants. It comprises the following:

- A pool of hardware resources including:
    - Ethernet interconnection network.
    - Slicing enabled Wi-Fi controller and nodes (operating in mesh mode).
    - Edge Core Switches (OpenFlow based).
    - Compute nodes/ Servers (mini datacenters) for hosting network and application services.
- Multi-Domain Orchestrator
- Multi-version Orchestrator
- Cross-technology MANO and SDN control

- Layer 2 Network Slicing for Transport Networks Product
- Highly demanding media and entertainment applications (in the demo being the "Watchity" service by I2CAT).
- The integration of massive MIMO (mMIMO) technologies in the access network part further enhances the capabilities of the solution. At this point it shall be noted that delivering extremely high capacity density at access network connectivity level (i.e. high throughput/m^2) requires also physical layer solutions (mMIMO).

The solution deployment delivered by the Stadium Demonstrator in Ashton Gate Stadium, Bristol UK, is presented in Figure 5-5, along with the potential involvement of the various stakeholders.

In particular, a pool of infrastructure resources comprising Ethernet interconnections, Slicing enabled Wi-Fi controller and nodes (operating in mesh mode), Edge Core Switches (OpenFlow based) and Compute nodes/ Servers (mini datacenters as MEC servers) for hosting network and application services. The solution is deployed over the stadium Concourse, Bowl, separate rooms for dedicated events etc. and with respect to the 5G ecosystem it can be of ownership of the stadium owners/stakeholders (namely Principality Stadium, Ashton Gate). The interconnection to the internet can be established over a "transit slice" by agreement with a Telecom Operator (e.g. Vodafone, BT, colt, Orange) while cloud compute resources for hosting service components can be provided by a "core slice" from public or private cloud operators (e.g. AWS, MS Azure).

Considering the MANO part of the solution a multi-domain orchestrator (MDO) of ownership possibly of a large Telecom Operator or third party (e.g. COMCAST) allows the flexible, time-based request of slices (with specific QoS guarantees) over multiple domains to be allocated to Telecom Operators (e.g. Vodafone) and Service Providers (e.g. BT Sport, Sky). The MDO also allows the effective interworking/connection of the stadium infrastructure with the other/external networks. A Cross-technology MANO and SDN control layer allows the incorporation of multiple, versatile resources and the orchestration of them from a common MANO system.

In this business ecosystem, multiple bilateral or multilateral agreements will be needed between the various stakeholders, associated with the sharing of responsibilities and revenues, essentially forming the business model and business cases for all involved parties.

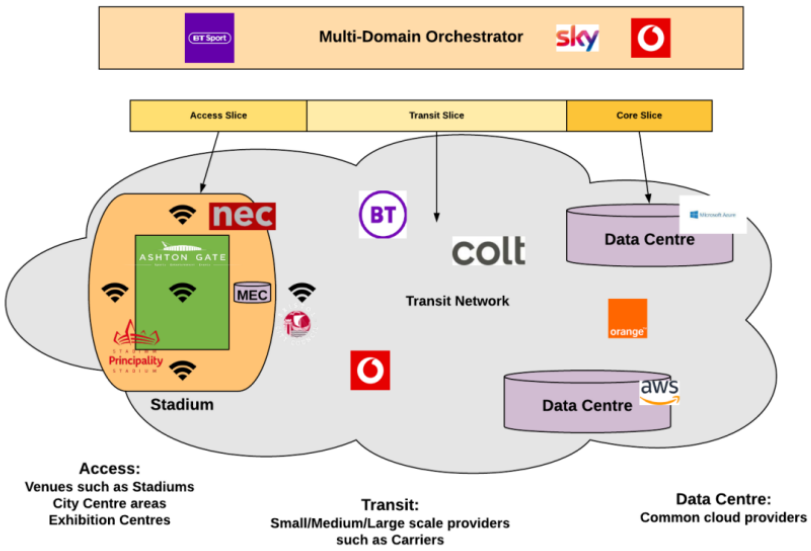


Figure 5-5: 5G-PICTURE Stadium Solution – Overview and Stakeholders.

CHANNELS

Existing communication channels of the large venue/stadium owner with:

- Telecom Operators to use of the stadium neutral, shared infrastructure. These channels can be also used to achieve service continuity with the Telecom Operators macro network (e.g. covering the surroundings of the venue), service bundling, benefiting from the Telecom Operator customer base/ expertise/ communication channels, etc.
- Emergency/safety services/agencies.
- End-users/fans for service sales.

Establishment of new channels with:

- Media and entertainment service providers through business to business (B2B) communication
- Telecom Operators' customer base/ end-users through agreements with Telecom Operators as aforementioned.

UNFAIR ADVANTAGE

From the present viewpoint, the "Unfair Advantages" of the solution (mainly that of the Ashton Gate Stadium Demonstrator) are basically:

- Potential of early commercial deployment of the solution (before competition, and before similar products emerge).
- And above all, the fact that this solution has resulted from contributions of a number of partners (companies and research institutes) coming from versatile industries each providing valuable input (specific requirements, feedback, expertise, work, etc.), which is extremely difficult to be collected otherwise -than working together on a single project.

From the infrastructure providers' side (expected to be the stadium owner in most cases), other unfair advantages can (and need) to be built. The latter will be based on the following:

- collaboration with Telecom Operators, at multiple levels e.g. for infrastructure sharing, for benefiting from Telecom Operators' existing customer base, for benefiting from Telecom Operators' existing channels with service providers, etc.,
- collaboration with service providers and start-ups with new niche applications for the vertical to gain differentiation against competition with regard to the provided media and entertainment services.

KEY METRICS

Key metrics of the success of the solution towards the end-users will be the network performance with regard to delivering highly demanding media and entertainment services.

For large venue/stadium owners key metrics of the success of the solution will be:

- lower TCO for deploying multiple telecommunication services/ hosting multiple service providers.
- number of agreements with externals' for using the infrastructure and for delivering services.
- number of end-users/fans making use/subscribing of the services.
- potential increase in the number of end-users/fans visiting the venue/stadium.

COST STRUCTURE

The resources that are required to be committed by the large venue/stadium owner for developing the market and sustaining the solution/service are the following (directly interpreted to cost factors):

- Solution Hardware/Software purchase.
- Operation and Maintenance personnel (1-2 persons full time).
- Sales engineer for dealing with agreements with Telecom Operators, app/service providers, etc.
- Marketing personnel for selling services to market or for establishing partnerships for common sales channels.

REVENUE STREAMS

The 5G-PICTURE solution for large venues/stadium owners allows for the generation of new revenue streams through the uptake of new activities. The actual revenue streams depend highly on the specific business model to be adopted which includes the infrastructure ownership level and agreements, the sharing of responsibility for deployment and operation of the telecom infrastructure, the sharing of responsibility of operation of the communication services, the responsibility of delivering/provisioning/selling the media and entertainment services to end-users etc. Indicative revenue streams generated for the stadium owner can be the following (not limited to):

- Revenues from Telecom Operators for the use of the stadium infrastructure.
- Collaboration with premium/special content service providers and sharing of revenues obtained from service sales to end-user/fans.
- Indirect revenues from enhancing user safety (thus making the stadium more attractive even in heavily crowded events) through efficient support of critical communication services.
- Minimisation of TCO through infrastructure sharing with other stakeholders.

Table 5-2: 5G-PICTURE Solution for Stadium Use Case – Lean Canvas.

<table>
<tr>
<td>Problem

Telecom infrastructure in large venues/stadiums is deployed & operated by Telcos leading to:
• No flexible Infrastructure sharing for Telcos/ service providers; not modifiable over time; separate Infrastructure/equipment for each Telco
• High TCO for Telcos,
• Inadequate capacity for fully crowded events & for highly demanding services.

<u>Alternatives</u>
MOCN & RAN Sharing but no QoS guarantees; no flexible infrastructure sharing; not modifiable on time basis.
No neutral network infrastructure sharing solution exists.</td>
<td>Solution
• A pool of HW resources:
  ○ Ethernet network
  ○ Slicing enabled Wi-Fi controller & nodes
  ○ Edge Core Switches
  ○ Compute nodes/ Servers
• Multi-Domain Orchestrator
• Multi-Version Orchestrator
• Cross-tech MANO & SDN control
• L2 Network Slicing for Transport
• Media & entertainment apps
• mMIMO @ access network.

Key Metrics
• Lower TCO for multiple Telcos/ services/ service providers
• # agreements with externals’ for using the infrastructure
• # end-users subscribing/ using the services
• increase in #end-users/fans visiting the venue/stadium.</td>
<td>Unique Value Proposition

A shared neutral network capable to support effectively highly demanding media & entertainment (as well as other) services from multiple service providers over a communication infrastructure integrated with the stadium infrastructures.
It provides lower TCO, service flexibility and speed of deployment.</td>
<td>Unfair Advantage
• Early deployment before competition
• Solution resulted from partners from versatile industries/academia giving input - difficult to be collected otherwise

Others can (and need) to be built, such as:
• Collaboration with Telcos, (for e.g. infra sharing, Telcos’ existing customer base/ channels to service providers, etc.
• Collaboration with start-ups with new niche apps to differentiate from competition.

Channels

Existing:
• Telcos'
• Emergency/safety services/agencies
• End-users/fans for service sales
New:
• Media & entertainment service providers through B2B communication
• Telcos' customer base.</td>
<td>Customer segment
• Media & entertainment services providers to crowds.
• Safety/Emergency service agencies (e.g. police, medical personnel) at large venues/stadiums
• Existing and emerging Telcos.

<u>Early adopters:</u>
• Large venues/ stadiums with massive # spectators, in markets accustomed to spectacles & high-end media & entertainment services
• Spin offs in the media/ entertainment/ marketing services sectors
• Existing Telcos’</td>
</tr>
<tr>
<td colspan="3">Cost Structure
• Solution Hardware/Software purchase
• Operation and Maintenance personnel (1-2 persons full time)
• Sales engineer for dealing with agreements with telcos, app/service providers, etc.
• Marketing personnel for selling services to market or for establishing partnerships for common sales channels</td>
<td colspan="3">Revenue Streams (Depend on the specific business mode)
• Revenues from Telcos for the use of the stadium infrastructure
• Collaboration with premium/special content service providers and sharing of revenues obtained from service sales to end-user/fans
• Indirect revenues from enhancing user safety (thus making the stadium more attractive even in heavily crowded events) through efficient support of critical communication services.
• Minimisation of TCO through infrastructure sharing with other stakeholders.</td>
</tr>
</table>

5.4 Smart City Use Case Analysis

5.4.1 Smart City Use Case Ecosystem Overview and Prerequisites towards Commercialisation

Another major vertical sector addressed in the context of 5G-PICTURE is the "smart city" one. In the current landscape, city administration services have no role in the value chain of telecommunication services, apart from -in very specific cases- the provisioning/leasing space to Telecom Operators to install telecommunication infrastructure. All telecommunication services consumed by the city administration services or other city agencies/services (e.g. safety, emergency etc.), are deployed and operated by Telecom Operators/Carriers. In some cases, existing "smart cities" have deployed overlay (island) data networks mainly for Internet of Things (IoT) services. In this environment, high TCO is incurred for Telecom Operators, and depending on the availability of the sites, in many cases the network performance can be inadequate for highly demanding services. Moreover, the complexity of agreements and contractual limitations restrict the extensive network rollout.

In the envisioned, future ecosystem it is sought a single shared network infrastructure deployed over a smart city (in our case deployed by the smart city vertical) capable to support effectively highly demanding media and entertainment (along with other) services from multiple providers; allowing for lower TCO, service flexibility and higher speed of deployment.

In particular, a set of 5G-PICTURE technologies (analysed in the aforementioned chapter) integrated, interoperating and deployed together can be considered as a holistic solution for delivering highly demanding telecommunication services as enablers for a plethora of smart city envisioned applications and public services. In the smart city use case demo performed in Bristol UK, the smart city selected is the Bristol city, which has granted access to University of Bristol to proceed with the installations at Bristols' Millennium Square. The demonstrator results will constitute a key exploitable asset not only for Bristol City and University of Bristol but also for the partners delivering the specific products/components for the solution, since this demo directly leverages their TRL level. In particular, the technical solution has been described in the deliverables of WP6, and is further elaborated with the stakeholders' involvement in the following paragraphs. Indicative Virtual Reality and Safety services will be demonstrated. The main differentiating points of this use case compared to the stadium one, are the technologies that are needed to deliver the network services in the versatile and geographically more extensive environment of a city, as well as the fact that the smart city business case would evolve more around infrastructure provisioning to 3rd parties, rather than service provisioning agreements with broadcasters/content providers; the latter being the case for the stadium business case.

Similar to the railway and stadium use cases a number of licenses may be required to be obtained. We foresee however that the smart city verticals will not go far with the telecommunications services provisioning, rather with the infrastructure provisioning, thus the main licenses that would need to be obtained (considering the current regulatory environment which is almost common in most EU Countries) would be (see indicatively [17] and [18] for detailed information about the Spanish and Greek regulatory framework):

- Related to Telecommunication Services Provisioning (depending on the level of engagement of the smart city with the provisioning of telecommunication services to other public sector services).
    - License to provide Telecommunication Services from the national Telecommunications Commission/Agency; the fee (if any) is usually negligible.
- Related to Infrastructure Deployment and Operation:
    - If the wireless access network frequencies to be used are part of the licensed spectrum bands a frequency license is needed (usually acquired through public

spectrum allocation contests); the fee is usually non-negligible, and very time-, market-, service-, competition- specific. It is also needed to declare the infrastructure deployment including location, air interface characteristics, etc. of each access network node to the Telecommunications Commission/Agency.

If the equipment is operated on unlicensed spectrum bands, usually only the simple declaration of the infrastructure deployment is needed and the fee (if any) is usually negligible.

5.4.2 Smart City 5G-PICTURE Solution Lean Canvas Analysis

The business value of the aforementioned 5G-PICTURE solution for smart cities is analysed in this section by means of Lean Canvas Analysis, from the perspective of smart cities operating also as infrastructure providers. The canvases reflect also the case that another entity undertakes the role of Infrastructure providers, being existing Telecom Operators or new small Telecom Operators/ infrastructure providers. Strictly considering the former case, Smart Cities are expected to provide the infrastructure to Telecom Operators', Service providers (corporate customers), other cities agencies as well as the end users (citizens), for their application/business services.

PROBLEM

Currently, the telecom infrastructure delivering services in cities is deployed/ operated and managed permanently or ad hoc by Telecom Operators using existing technologies. The infrastructure/ equipment deployments are also separate for each Telecom Operator over the same area. As also mentioned in Stadium Use Cases, currently solutions such as MOCN (Multi-Operator Core Network) and RAN Sharing (Radio Access Network Sharing) allow sharing of 3G/4G access network nodes between customers of multiple Telecom Operators, but with no QoS guarantees. Moreover, sharing of access network infrastructure is not flexible to accommodate other Telecom Operators easily etc. and is not modifiable on a per time basis.

In this landscape, city agencies and public services maintain agreements with Telecom Operators both for the leasing of city locations/sites to Telecom Operators for the deployment of infrastructure and (in the opposite direction) for obtaining telecommunication services over the Telecom Operators' networks. For the activities of specific public services (e.g. emergency/safety services, etc.) especially for critical communications separate network infrastructures are deployed and usually operated by these city services.

Therefore, high TCO is incurred for Telecom Operators, and depending on the availability of the sites, in many cases the network performance can be inadequate for highly demanding services. Moreover, the complexity of agreements and contractual limitations restrict the extensive network rollout. Next generation highly demanding services (media and entertainment as well as critical communications) can barely be delivered over these infrastructures.

ALTERNATIVES

Currently solutions such as MOCN (Multi-Operator Core Network) and RAN Sharing (Radio Access Network Sharing) exist, and in some cases they are deployed especially in cities with infrastructure deployment restrictions. These imply the deployment of 3G/4G access network nodes that are shared between customers of multiple Telecom Operators. However, at access network level there is no controlled resources utilisation, nor QoS guarantees. At the same time, sharing of access network infrastructure is not flexible to accommodate other Telecom Operators, service providers etc. and is not modifiable on a per time basis. Moreover, these solutions are only operated by Telecom Operators and without any involvement from the smart city, the role of which is limited to space leasing.

Currently no neutral network infrastructure sharing solution exists that is at the same minimising TCO for Telecom Operators, maximising benefits for smart cities, and allowing high performance applications and services.

CUSTOMER SEGMENT

The solution proposed by 5G-PICTURE to the afore-described problem concerns primarily the smart city entities (the later could be technological parks, large campuses etc.) and at an extended level any infrastructure operator seeking the provision of highly demanding services to versatile, city environments. Hence smart cities are considered the associated target customer segment for the specific 5G-PICTURE solution. The latters' "customer segment(s)" (practically end-users) addressed through the solution could be:

- Public Services aiming to deliver content services to citizens (e.g. could be the cultural services, or tourist information services),
- Safety/Emergency service agencies (e.g. police, medical personnel) benefiting from smart cities infrastructure,
- Telecom operators aiming to provide versatile telecommunication services without having to invest on telecom infrastructure.

EARLY ADOPTERS

The adoption of the solution/services/business model is highly dependent on the individual local/national market regulations and environment and is specifically associated with the infrastructure deployment agreements and models to be formulated between Telecom Operators, telecommunications infrastructure providers and cities agencies. Another critical factor of adoption is the level of familiarity of city agencies with telecommunication infrastructure operations. It also depends on the familiarity of citizens with new, highly demanding services (mainly critical and/or entertainment). Considering the current market environment, early adopters would be the traditional telecom operators or small telecom operators licensed to deploy and operate smart city infrastructure. A second group of early adopters would be cities (or/and technology parks, large campuses etc.) with existing, strongly engaged technology departments; such cases are city of Bristol in UK, city of Trikala in Greece, etc.

With regard to the adoption of the smart cities' infrastructure for service provisioning, early adopters would be spin offs in the media and entertainment as well as marketing services sectors, potentially existing Telecom Operators, and emergency services.

In this business ecosystem, multiple bilateral or multilateral agreements will be needed between the various stakeholders, associated with the sharing of responsibilities and revenues, essentially forming the business model and business cases for all involved parties.

UNIQUE VALUE PROPOSITION

The unique value proposition of 5G-PICTURE solution for the smart city vertical segment is the delivery of a shared, high performance network capable to support effectively highly demanding applications to be provided directly to citizens (e.g. media and entertainment) or through service providers, as well as to support city safety applications of various city public services (e.g. police, emergency services, etc.), over a singly communication infrastructure. The integrated solution is expected to provides lower TCO for Telecom Operators and to enable the provisioning of public services with considerably enhanced performance.

SOLUTION

The solution allows the delivery of highly demanding communication/application services over a smart city -wide telecommunications infrastructure shared by multiple tenants. It comprises the following (further details can be found in 5G-PICTURE deliverable **D6.3**):

- A pool of compute resources including:
  - Edge Compute nodes/ Servers for hosting network and application services.
  - Central Compute nodes/ Servers (mini datacenters) for hosting network and application services.
- A pool of wireless technologies' resources including:
  - mmWave nodes delivering mesh backhaul topology.
  - massive MIMO units configurable to deliver access and/or backhaul services.
  - 4G/5G/Wi-Fi access network nodes.
- High level transport network aggregation using TSON edge nodes.
- Orchestration enabling slicing for various tenants/services.

CHANNELS

Communication channels of the smart city with:

- Emergency/safety services/agencies,
- Citizens for service sales,
- As well as with Telecom Operators (these channels need to be created if not existing) to use of the smart city shared infrastructure. These channels can be also used to achieve service continuity with the Telecom Operators macro network (e.g. covering other locations/cities), service bundling, benefiting from the Telecom Operator customer base/ expertise/ communication channels, etc.

Optionally establishment of new channels with:

- Media/ entertainment service providers
- Advanced safety/security/emergency service developers/providers/etc.

UNFAIR ADVANTAGE

From the present viewpoint, the "Unfair Advantages" of the solution (mainly that of the Bristol city Demonstrator) are basically:

- Potential of early commercial deployment of the solution.
- The fact that this solution has resulted from contributions of a number of partners (companies and research institutes) coming from versatile industries each providing valuable input (specific requirements, feedback, expertise, work, etc.), which is extremely difficult to be collected otherwise -than working together on a single project.

From the smart cities' side, other unfair advantages can (and need) to be built. The latter will be based on the following:

- collaboration with Telecom Operators, at multiple levels e.g. for infrastructure sharing, for benefiting from Telecom Operators' existing customer base, for benefiting from Telecom Operators' existing channels with service providers, etc.
- collaboration with service providers and start-ups with new niche applications of the interest of the public sector.

KEY METRICS

Key metrics of the success of the solution towards the end-users will be the network performance with regard to delivering versatile highly demanding services across a smart city area.

For smart cities key metrics of the success of the solution will be:

- the number of agreements with externals' for using the infrastructure and for delivering services, and
- the number of citizens making use/subscribing of the services; depending on the level of engagement of the smart city with the service provisioning.

COST STRUCTURE

The resources that are required to be committed by a smart city entity for developing the market and sustaining the solution/service are the following (directly interpreted to cost factors):

- Solution Hardware/Software purchase
- Operation and Maintenance personnel
- Sales engineer for dealing with agreements with Telecom Operators, app/service providers, etc.
- Personnel for promoting services to citizens.

REVENUE STREAMS

The 5G-PICTURE solution for smart cities allows for the generation of new revenue streams through the uptake of new activities. The actual revenue streams depend highly on the specific business model to be adopted which includes the infrastructure ownership level and agreements, the sharing of responsibility for deployment and operation of the telecom infrastructure, the sharing of responsibility of operation of the communication services, the responsibility of delivering/provisioning/selling the media and entertainment services to citizens etc. Indicative revenue streams generated for the smart city can be the following (not limited to):

- Revenues from Telecom Operators for using the infrastructure.
- Collaboration with service providers and sharing of revenues obtained from services to citizens.
- Benefits (Indirect revenues) from enhancing citizens' quality of life through support of advanced emergency/safety/information services.

Table 5-3: 5G-PICTURE Solution for Stadium Use Case - Lean Canvas.

<table>
<tr>
<td rowspan="2">Problem
Currently, telecom infrastructure at cities is deployed/ operated by Telcos.
No flexible Infrastructure sharing for Telcos/ service providers; not modifiable over time; separate Infrastructure/equipment for each Telco.
High TCO for Telcos, and inadequate capacity for highly demanding services.

<u>Alternatives</u>
MOCN & RAN Sharing but no controlled resources utilisation; no QoS guarantees; no flexible infrastructure sharing; not modifiable on time basis.</td>
<td>Solution
• A pool of compute resources:
  ○ Edge Compute nodes/ Servers
  ○ Compute nodes/ Servers (mini datacenters)
• A pool of wireless access resources:
  ○ mmWave nodes delivering mesh backhaul topology
  ○ mMIMO units configurable for access or BH services
  ○ 4G/5G/WiFi access nodes
• Optical aggregation with TSON
• Orchestration enabling slicing.</td>
<td rowspan="2">Unique Value Proposition
A shared neutral network capable to support effectively highly demanding services of a number of Telecom Operators, and Service Providers over a Smart City area. The integrated solution provides lower TCO and service flexibility and speed of deployment as well as high performance.</td>
<td>Unfair Advantage
• Early deployment
• Solution resulted from partners from versatile industries/academia giving input - difficult to be collected otherwise

Others can (and need) to be built, such as:
• collaboration with Telcos, at multiple levels e.g. for infrastructure sharing, Telcos' existing customer base, existing channels with service providers, etc.
• collaboration with service providers and start-ups with new niche applications of the interest of the public sector.</td>
<td rowspan="2">Customer segment
• Media & entertainment services providers to city sights.
• Safety/Emergency service agencies (e.g. police, medical personnel)
• Existing and emerging Telcos.

<u>Early adopters:</u>
• Of the 5G-PICTURE solution: Cities (or/and technology parks, large campuses, etc.) with existing, strongly engaged technology departments
• Of the Smart City infrastructure: Existing telcos'</td>
</tr>
<tr>
<td>Key Metrics
• #agreements with externals' for using the infrastructure & delivering services
• # citizens making use/subscribing of the services; depending on the level of engagement of the smart city with the service provisioning.</td>
<td>Channels
Existing:
• Emergency/safety services/agencies
• Citizens for service sales
• Telcos
New, Optional:
• Media & entertainment service providers
• Advanced safety/security/emergency service developers/providers/etc.</td>
</tr>
<tr>
<td colspan="2">Cost Structure
• Solution Hardware/Software purchase
• Operation and Maintenance personnel
• Sales engineer for dealing with agreements with telcos, app/service providers, etc.
• Personnel for promoting services to citizens.</td>
<td colspan="3">Revenue Streams (Depend on the specific business model)
• Revenues from Telecom Operators for using the infrastructure
• Collaboration with service providers and sharing of revenues obtained from services to citizens.
• Benefits (Indirect revenues) from enhancing citizens' quality of life through support of advanced emergency/safety/information services.</td>
</tr>
</table>

6 Additional Individual Partners' Exploitation Plans

6.1 COS Exploitation Plan

Main Exploitable outcomes: Use Case Demonstrators' evaluation results, Techno-economic Analysis Tools

Plan:

COSMOTE (http://www.cosmote.gr) is a member of OTE Group and a member of Deutsche Telekom Group. The OTE Group is a pioneer in technological advances, by far the largest telecom provider (and investor) in telecommunications infrastructure in Greece and one of the leading telecom groups in SE Europe, offering a full range of telecommunications services from fixed-line and mobile telephony, broadband services, to pay television and ICT solutions. COSMOTE holds the leading market position in Greece since 2001, having an impressive record of very important firsts in Greek and/or European Market, the latest being the launch of 4G+/LTE-A services with speeds above 300 Mbps (Feb/15) and 500 Mbps (Dec/16), and the demonstration/participation in the 5G pilot conducted in the Municipality of Zografou, Athens (2019).

In line with its strategy and its business activities, and representing the 5G Telecom operator sector, in the context of 5G-PICTURE, significant benefits have been derived for COSMOTE to further exploit, mainly in the domains were special focus was put on by COSMOTE, namely:

a. Know-how/expertise obtained regarding the technical challenges underpinning a 5G-network and services' deployment, as well as the service and infrastructure provisioning to vertical markets across a 5G network infrastructure, through monitoring the technical developments of the project;
b. New architectures/deployment options towards addressing the verticals' markets' needs that were identified through closely monitoring the products/prototypes canvases and significant contribution to the formulation of the canvases of the vertical use cases/demonstrators while COSMOTE added value by offering the telecom operator's perspective to them;
c. The technical and business –related factors affecting the cost of real network deployments at early stages and later on, that were identified through the development of a fully parameterized techno-economic analysis tool by COSMOTE (as presented in detail in Deliverable D2.3); the outcomes of this work comprise valuable input to COSMOTE's forthcoming activities towards the 5G-network deployment and services provisioning, in order to minimize the deployment time, the problems' resolution time and eventually the time-to-market, and deployment cost;
d. Last but not least, the perspective obtained towards the expected 5G ecosystem, including not only the major technology related changes, but more importantly the major modifications regarding the 5G stakeholders and the adopted business models that seem to be leading to an inevitable disruption by a wide and yet unknown range of vertical industries to the telecommunications sector; the telecom operators need to be prepared to adjust their positioning in the new market environment to their benefit.

The acquired knowledge and work done in the context of the project has been (and will be further) channelled to the appropriate departments within COSMOTE/OTE (both Technology and Marketing ones), as well as to affiliating companies within the Group, towards achieving cost-savings at Group level. In addition, COSMOTE will pursue further opportunities to build upon the 5G-PICTURE technology background and maintain its technology superiority supported by EU funding in the context of following EU R&D projects.

6.2 TIM Exploitation Plan

Main Exploitable outcomes: Use Case Demonstrators' evaluation results, Techno-economic Analysis Tools

Plan:

TIM is the incumbent network operator in Italy. It owns access, regional and core network in Italy, and offers LTE connectivity and, under deployment phase also the 5G coverage in the major cities in Italy, as well as entertainment and a plethora of other services.

The results obtained in 5G-PICTURE are used as an input to the Group Technology Plan, an internal document that analyses the available technologies and that, together with the Strategy Plan, is the basis to develop the Investment Plan.

The outcomes of the Techno-economic analysis tools guarantee that the introduction of 5G for the scenarios envisaged in 5G-PICTURE (smart city, metropolitan train, mega event) are sustainable. Furthermore the tool itself will be exploited for internal use. The validation of the tool by both Industrial and Academic Partner is a guarantee of the validity of the result.

In addition, the technological features demonstrated in the use cases are the point of start for offering 5G services to TIM's customers. In more details, virtualisation of infrastructure functions and slices will be exploited in 5G TIM network to facilitate different RAN functional splits and tenants able to request and be assigned infrastructure slices for a set of FH and BH services.

6.1 UNIVBRIS-CSN Exploitation Plan

Main Exploitable outcome: Propagation models and performance evaluation in a rail environment, both for mmWave systems (26 GHz, 60 GHz) and Massive MIMO systems (3.5 GHz)

Plan:

Under the scope of the 5G-PICTURE project, University of Bristol (**UNIVBRIS-CSN**) has been delivering state-of-the-art research on mmWave and Massive MIMO, since both technologies constitute pioneers of 5G networks. Research has commenced with the investigation of propagation models (ray-tracer tool) and performance evaluation (Matlab simulators) in a rail environment, since it is one of the use cases that 5G-PICTURE targets, both for mmWave systems (26 GHz, 60 GHz) and Massive MIMO systems (3.5 GHz). Furthermore, UNIVBRIS-CSN will take part to the Stadium Demo, deploying the NI mMIMO kit, looking at achievable performance in such a scenario. Our work has been and will be exploited through conference and journal publications, attracting funding for future research projects based on the research of this project. Furthermore, work can be exploited for giving experience to PhD student and attracting new PhD students in the future. Results from the project will be part of an improved teaching program within the Doctoral Training in Communications and will thus contribute to maintaining a competitive academic programme.

6.2 UPB Exploitation Plan for Multi-version service orchestration

Main Exploitable outcome: Multi-version service orchestration

Plan:

In line with its academic profile, Paderborn University (**UPB**) will exploit 5G-PICTURE outcomes along two axes including:

(i) **Education for students and academics,** by

a. integrating 5G-PICTURE's results in ongoing classes, e.g., an MSc-level lecture on future Internet,

b. engaging students in practical implementations in the form of 1-year projects for 8-16 MSc students, working on orchestration support for multi-version services as well as support for service chaining in multi-domain structures,

c. using 5G-PICTURE's findings in tutorials, presentations, and hands-on sessions on NFV and SDN high-presence events, such as summer schools

(ii) **Providing advancements to open-source software,** through Pishahang [1]. The latter is an NFV multi-domain management and orchestration framework implemented by **UPB**. It supports the orchestration of services that need to be deployed across OpenStack and Kubernetes domains. This functionality allows service providers to exploit network services that consist of VM- and container-based VNFs. Pishahang is extended in 5G-PICTURE to support the orchestration of multi-version services. To maximise the uptake and use of the results, the source code of Pishahang is published under Apache v2.0 license in a public Github Repository[1] . It is freely available for download and is ready to be installed with the related technical documentation[2], and installation guide.

6.3 UTH Exploitation Plan for Cross-technology MANO and SDN control

Main Exploitable outcome: Cross-technology MANO and SDN control

Plan:

The Department of Electrical and Computer Engineering of the University of Thessaly (**UTH**) is a well-known institute for higher education in Greece. The Networks and Telecommunications laboratory focuses its activities in the areas of wireless networks, optical networks, mobile communications, security of telecommunications, Information centric networks and applications and services for smart cities. The lab members' research profiles show a complementary background expertise in different areas in networking, including wireless networks and protocols, signal processing, distributed computing, sensors, video and media transmission, network security and energy-efficient networking. International collaborations strengthen ties with prestigious scientific and industrial institutions from abroad.

UTH will exploit 5G-PICTURE outcomes for providing hands-on experience to graduate students, since significant development and experimentation work related to the orchestration and implementation of NFV-based RAN and transport network functions takes place at NITOS testbed. Researchers and students will be educated through research conducted along the lines of 5G-PICTURE in the form of theses, fellowships or research internships in industrial or other academic partners. The knowledge and experience acquired by students will provide them with better job opportunities and will be the driving force for distilling know-how to industry. Furthermore, establishment of fundamental knowledge and understanding on advanced and novel techniques to address the next generation RAN challenges will be achieved.

[1] https://github.com/CN-UPB/Pishahang

[2] https://github.com/CN-UPB/Pishahang/wiki

7 Summary and Conclusions

In the context of the 5G-PICTURE project, the activities aim at maximising value from the project results/technologies, and at paving the way to results'/technologies' sustainability, commercial exploitation and early deployment. These activities have been concretely performed under Task T7.3 "Commercial Exploitation". This deliverable reports on the work done and results obtained in the context of this task, from the beginning up to Month 30 of the project lifetime.

At first stage the document provides a detailed view of the principles and the methodology followed to identify 5G-PICTURE project exploitable outcomes and the ways to explore and foster their exploitation based on two well-structured business tools, namely the Value Proposition and the Lean Canvases.

At next stage a concrete identification of the project outcomes is performed. In practice, the nature of each outcome is specified; the particular value that each outcome brings to specific stakeholders is described in technical and business terms; the ownership of the associated Intellectual Property Rights (IPR) is identified; and considering the profile of the IPR owner in terms of business/academic activities and vision, the framework for the outcome's further business analysis and exploitation is set. As identified, no cases of conflicting IPRs occur, mainly because of (1) the nature of the exploitable outcomes/products, (2) the fact that they require high expertise available by partners highly engaged to these products/technologies, (3) the fact that most of them leverage on existing high technology products. To this end, the TRL level of each outcome as achieved in the context of 5G-PICTURE is presented, and it is compared against the initially expected TRL advancement. In all cases, the TRL advancement has been greater or at least equal to the expected one -in most cases being TRL 5-6; given the fact that almost all technologies have been validated and demonstrated in the railway operational environments, or will be validated and demonstrated in the stadium and smart city environments available to the project.

This document further provides the business analysis for each 5G-PICTURE outcome. For this purpose the 5G value chain is visited and also revised based on the enablements that 5G-PICTURE technologies bring. As identified, in the forthcoming 5G business landscape, existing business roles and activities would be undertaken by stakeholders that are currently far from the traditional industries and the small telecom operators industry will be fostered. To this end, 5G-PICTURE provides the technological means to further advance the future 5G ecosystem through the enablement of verticals to become "vertical infrastructure providers" - to be considered as a subset of the forthcoming "Small Telcos" stakeholder segment. With this regard, the business analysis for each 5G-PICTURE outcome is performed on a per target customer (of the revised value chain) basis and is associated with the value that each outcome brings.

Concrete exploitation plans of the partners related to these outcomes are provided right after, which reveal the high engagement of partners to pursuing sustainability, and further exploitation of these outcomes; this structure also helps the reader in identifying the direct association between the products and the partners' exploitation plans. In general terms, it has been shown the products/advancements/enhancements generated by industry partners in 5G-PICTURE are in line with their individual business plans, thus these 5G-PICTURE outcomes will be directly fused in the partners' product lines. At the same time, we shall highlight the effort of specific academic partners namely CNIT and IHP which have put significant effort to introduce their products/outcomes to the market, through start up or daughter companies.

The deliverable includes also detailed analyses of the business perspectives of the integrated 5G-PICTURE solutions in the representative vertical sectors that the project has addressed; namely in the railway, the stadium/large venues and the smart city sectors. The current ecosystem and the

changes to be incurred by the 5G-PICTURE solutions are identified, along with the current problems, the future challenges and opportunities. To this end, the primary steps/activities/licenses that are needed for a vertical to enter the vertical infrastructure providers' market have been explored, using as reference the current national (especially in Spain and Greece) and European regulatory environment. The business relations to be formed in order to provide the channels for exploitation and to build significant unfair/competitive advantages are also recognized. Especially for the railway sector case the business analysis is accompanied by the associated, concrete exploitation plan of COMSA – a direct, relevant stakeholder involved in the 5G-PICTURE project.

Last but not least, further individual partners' exploitation plans are provided, mainly those being technology adopters (thus their business plans fall in the use case analysis) and/or owners of exploitable outcomes that are not of type "product".

This document outlines the main intention of the 5G-PICTURE consortium towards pursuing sustainability and exploitation of the project results.

8 References

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9 Acronyms

Acronym	Description
B2B	business to business
BH	Backhaul
CPs	Cloud Infrastructure Providers
DA-RAN	Dis-Aggregated RAN
EBITDA	earnings before interest, taxes, depreciation, and amortization
FH	Fronthaul
FRMCS	Future Railway Mobile Communication System
HW	Hardware
IPR	Intellectual Property Right
JVs	joint ventures
MOCN	Multi-Operator Core Network
NaaS	Network as a Service
NPs	Network Infrastructure Providers
NSMF	Network Slice Management Function
NSSMF	Network Slice Subnet Management Function
PoC	Proof of Concept
PTMP	Point-to-Multi-point
QoS	Quality of Service
SDR	Software Defined Radio
TCO	Total Cost of Ownership
TRL	Technology Readiness Level
TSON	Time Shared Optical Network
TSP	Telecommunication Service Provider
XDE	Xilinx Dresden (former Airrays)