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An Open Framework for the Assessment of 5G Business Cases and Investments

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***Abstract* — Beyond the technological advances, 5G aims to establish an open innovation ecosystem with a wide variety of stakeholders and a plethora of new business opportunities. Mobile Network Operators, Digital Service Providers, Communication Service Providers and Vertical Service Providers, are among the actor roles that co-create and deliver novel 5G-empowered applications. The variety of business relationships in the 5G ecosystem leads to multiple potential value network configurations and business models. In this paper, we introduce a framework that enables the assessment of 5G business cases through the techno-economic analysis of alternative value network configurations, business models, cost and revenue structures, infrastructure deployments, and market conditions. The implementation of the framework is enabled by the open 360 Business Model Evaluation tool, which allows the assessment of 5G business cases from different perspectives: *(i)* per actor business model evaluation, *(ii)* holistic cost-benefit evaluation, and *(iii)* upscaling and replication evaluation. We illustrated the use of our framework assessing the 5G Experimentation as a Service business case, motivated by the 5G-VINNI experimentation platform.**

I. Introduction and Background

The promise of 5G is to enable business opportunities for the different parties that either *consume* or *provide* the services and technology. Firms in vertical sectors such as health, automotive, and manufacturing may benefit from offering novel 5G-enabled applications to existing or new customers, which may in turn generate positive business cases for all the other stakeholders providing 5G-related capabilities. As 5G has been conceived as a service platform, none of the stakeholders will alone have full control of 5G-empowered value creation. Instead, they will be most likely interdependent both when co-creating and capturing value. Due to these characteristics, the 5G ecosystem can be modeled and analyzed as a value network [1]. However, 5G market is immature, i.e., the way the stakeholders arrange their business relationships in the 5G value network has not yet been settled.

The presence diverse stakeholders that seek profits foreshadows multiple potential configurations of the value network when investigating a specific 5G business case. Even for a given configuration of the value network, there may be multiple alternatives for stakeholders' business models, infrastructure deployments, cost/revenue models, etc. Given that different options may be viable under different market conditions, all "meaningful" configurations for a business case should be investigated, assessed, and applied when suitable. This will allow stakeholders to mitigate the perceived risk when investing in 5G infrastructure. In this paper, we address how the high complexity and uncertainty of business relationships in 5G markets can be handled in a systematic manner for assessing 5G business cases.

Our contribution is the definition and illustration of the first framework that allows complete systematic Techno-Economic Analysis (TEA) of 5G business cases under multiple configurations. The implementation of this framework is supported by the open 360 Business Model Evaluation (BME) tool [2]. The framework can be used for the design and conceptualization of alternative configurations (i.e., instances) of a business case and enables the quantitative assessment of these alternatives from different perspectives: the viability of per actor business models; the holistic cost-benefit analysis; and the potential of replication and upscaling of a business case instance. The framework is illustrated in the context of 5G Experimentation as a Service (EaaS) business case of 5G-VINNI platform [3].

In the remainder of this section, we present the background and existing studies on 5G TEA. In the following sections, we present our framework steps and its application to the EaaS business case, as well as our concluding remarks and future directions of work.

A. Techno-economic Analysis Background

TEA is a widely used method that applies economic principles to engineering decision-making. In communication networks, TEA has been applied to study the economic impact of deployment alternatives in terms of spectrum [4], network densification [5], network transport [6] and architectures.

Performing any TEA is challenging due to the complexities of the systems to be modeled and the inherent uncertainty associated with the input variables of these models, such as the future costs of network assets or the evolution of demand. For 5G networks, TEA becomes more challenging because the fully virtualized network architectures make the software deployment and maintenance costs harder to quantify, as they are increasingly associated with labor costs (as opposed to manufacturing costs). Furthermore, programmability allows network functions to be acquired as a service, transforming some capital expenditures (CAPEX) into operational expenditures (OPEX). Finally, the telco industry has shifted

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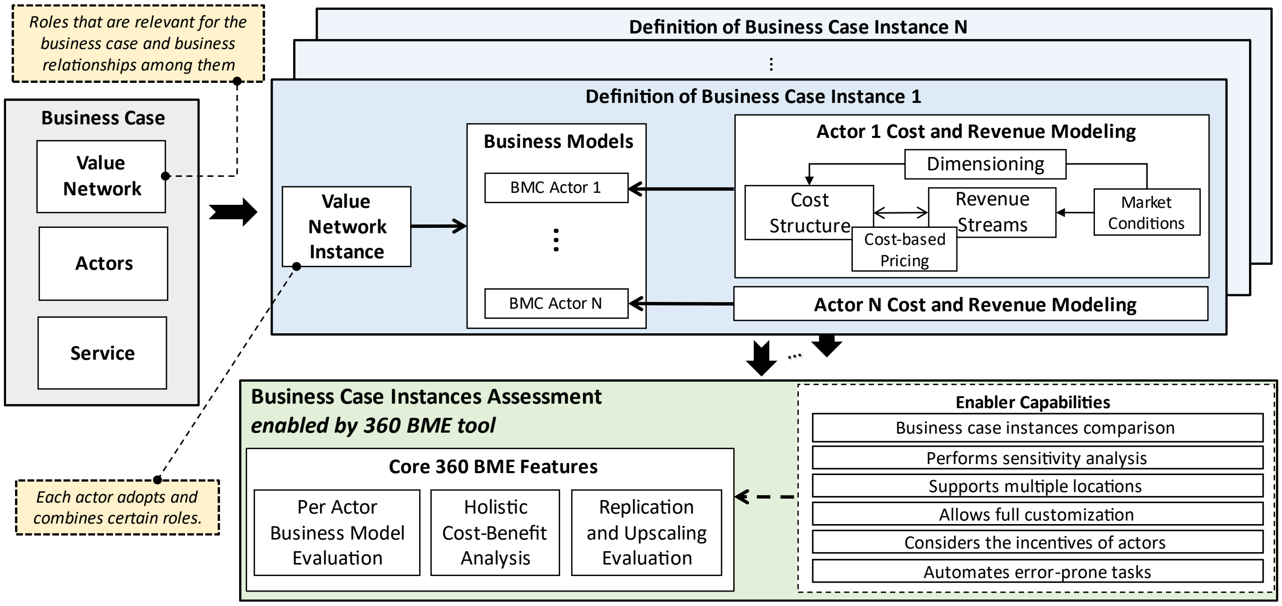


Figure 1: Our framework and its constituent steps.

from traditional value chain-based business models to platform-based ecosystems [7], where the value is co-created with a multitude of potential configurations which imposes additional challenges.

While there is a growing literature on TEA of 5G networks [8], almost all related works use purpose-built models not openly available to the scientific community [8], limiting the possibilities of TEA research to advance the frontiers of knowledge. Open frameworks and tools that allow the flexible customization and reuse of their features will be of great value to the community. There are very few openly available tools for 5G TEA (e.g., [9]). However, they do not capture the value networks' complexity or business model alternatives when multiple stakeholders contribute to the 5G service creation and delivery. In this paper, we present a novel framework for the TEA of 5G business cases, and we make available a tool (360 BME [2], along with a manual) to enable its implementation.

B. Key Business Modeling Terms

The following terms should be considered when defining and assessing 5G business cases.

Stakeholder: A part that holds an interest or concern in 5G.

Actor: A party that consumes and/or contributes to the provisioning of 5G services.

(Actor) Role: Each role contributes a certain type of service in the 5G ecosystem. An actor may hold multiple roles and a role may be adopted by multiple actors.

Business Relationship: It captures the association between two roles. It usually identifies a customer-provider relationship between two roles and the respective service and money flows.

Value Network [1]: A method to illustrate roles that appear in the 5G ecosystem and their business relationships for the co-creation of services. A value network *instance* maps each actor to a set of roles. One business case can be realized with multiple alternative instances of a value network.

Business Case: Identifies the business potential that is generated for a 5G market segment from the demand for a specific 5G service. Defines the value network of the necessary 5G roles for the co-creation and consumption of this service, and the actors that are involved by adopting these roles. Based on the set of roles that each actor adopts, different *business case instances* can be defined.

Business Model: A strategic plan of an actor for generating profit in the context of a business case. Business Model Canvas (BMC) [10] is the method applied for the definition of the business model of an actor. For a given value network instance, where *one* actor adopts and combines roles, the BMC identifies this *actor's* value proposition, key partners, customer segments, cost structure, revenue streams, key resources, key activities, customer relationships and channels.

II. 5G Techno-economic Analysis Framework

Our framework (Figure 1) consists of three steps for the assessment of any 5G business case. These steps are presented below in a linear fashion, but they may be subject to iterations.

Step A - Business case definition: Define the value network, actors and service that are relevant to the business case.

Step B - Business case instances: Define "valid" alternatives (i.e., instances) for the realization of the business case. Each business case instance incorporates a value network instance, where each of the involved actors combines varying roles and develops relevant business models. Each actor also performs cost and revenue modeling considering the targeted market conditions (e.g., monopolistic vs competitive market).

Step C – Business case instances assessment: The business case instances, defined in the previous step, are fed into the 360 BME tool which can: assess the profitability of the alternative business models for the involved actors; perform a holistic comparative cost-benefit analysis across instances; and assess the upscaling/replication of business case instances under different conditions.

A. 5G Business Case Definition

A ***business case*** is defined by the demand for a specific 5G *service*, the roles involved in the relevant *value network* and the *actors* that may adopt one or several of these roles.

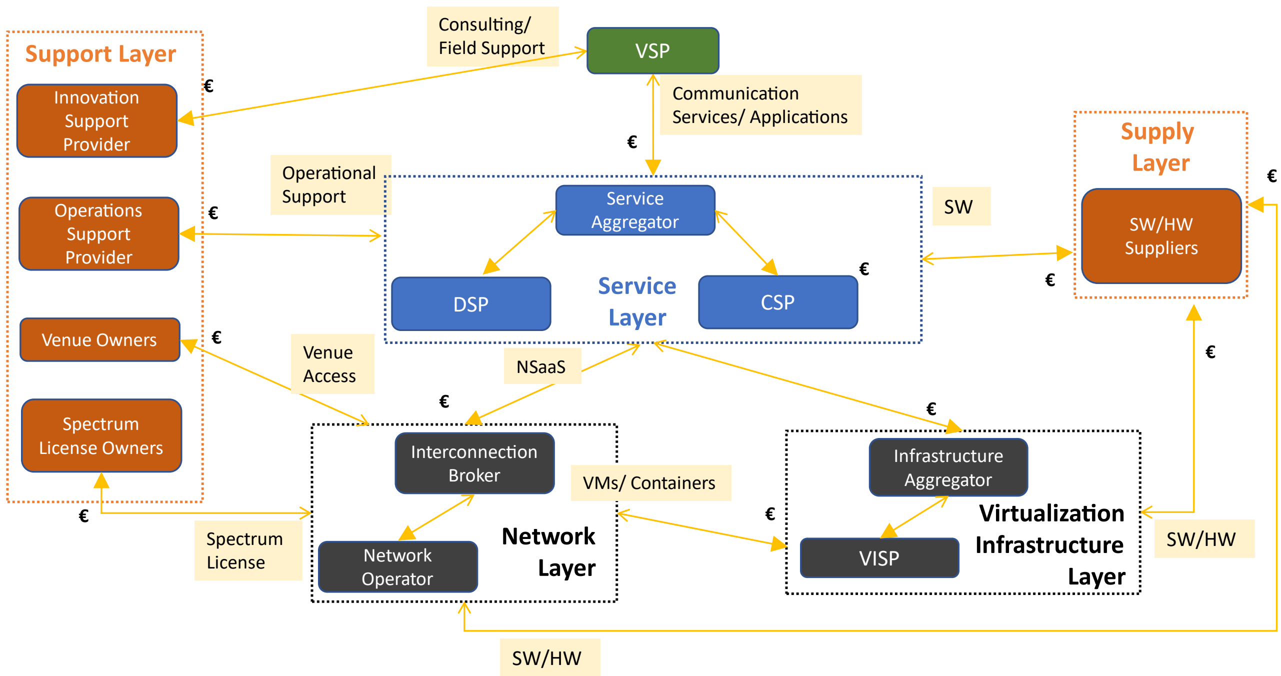


Figure 2: Generic 5G value network. Actor roles and business relationships among them.

The value network of any business case is a subset of a generic 5G value network that involves a variety of roles beyond the traditional telco networks, including the cloud, digital services, and vertical industry domains. An indicative list of the roles depicted in the *generic* 5G value network of Figure 2 is described below (a complete list is available in [11]).

Vertical Service Provider (VSP): A vertical enterprise (e.g., BMW) that buys and combines communication and digital services to deliver a vertical application (e.g., for connected automated mobility) to a set of vertical users.

Communication Service Provider (CSP): Delivers communication services to VSPs over own or leased network slice services.

Digital Service Provider (DSP): Offers industry-specific online applications and services to VSPs.

Service Aggregator (SA): bundles multiple services and applications coming from CSPs and DSPs.

Innovation Support Provider: Offers technical, business, and legal consultancy services to VSPs or DSPs.

Operation Support Provider: Offers ancillary operational services such as performance monitoring and testing.

Network Operator: Operates a 5G network and offers Network Slice as a Service (NSaaS) to DSPs, CSPs and SAs.

Interconnection Broker: Combines network sub-slices from multiple Network Operators to build end-to-end network slices for CSPs, DSPs and SAs, with extended geographic reach.

Virtualization Infrastructure Service Provider (VISP): Offers virtualized cloud infrastructure services to Network Operators, as well as to CSPs, DSPs and SAs.

Software/Hardware (SW/HW) supplier: This role includes suppliers of Virtual Network Functions (VNFs), Management and Orchestration Systems, and Hardware.

Note that for a given business case, some roles may be of low relevance and can be omitted.

B. *Business Case Instances*

A business case can be realized in multiple ways, depending on how actors adopt different roles and business models. Hence, it is wise for an actor to assess and compare multiple “valid” business case instances. A ***business case instance*** is composed of a value network instance populated with varying business models per actor, as well as modeling and quantification of their costs and revenues.

An example of a value network instance, with three actors combining different roles for the business case of 5G EaaS is in Figure 3. Note that there is no need to illustrate the “internal” business relationships, that is the ones between roles adopted by the same actor. The BMC template is applied per actor to define its ***business model*** for the roles adopted/combined. The *cost structure and revenue streams are* essential business model elements. Thus, to perform a full-blown TEA of the different business case instances, we need to detail the magnitude of different costs and revenue streams, and their evolution over time. A business case instance is *viable* if the total revenues of all actors involved exceed their total costs. The viability of each actor can be achieved by leveraging revenue-sharing mechanisms and inter-actor price determination. The cost and revenue modeling aspects are further discussed in the next section.

C. *Business Case Instances Assessment*

The assessment of the alternative business case instances is implemented by the 360 BME tool, which is fully customizable and takes one or multiple instances of a business case as input and automatically carries out their assessment and comparison. The evaluation of the different instances is performed based on financial metrics, such as Internal Rate of Return (IRR), Total Cost of Ownership, etc. New metrics can be added by the user. The tool can also perform a sensitivity analysis of the different parameter values, for example, of cost items, revenue streams and demand drivers. This is relevant for parameters whose exact value may not be known a priori due to the market's immaturity. The tool can also perform simultaneous evaluations of multiple locations, such as regions, countries, etc. The incentives of the different actors involved in a business case can be captured by allowing the introduction of revenue-sharing rules and charging mechanisms when defining money flows. The tool allows the automation of error-prone tasks, full customization, flexibility, and transparency since it is based on Microsoft Excel spreadsheets. The tool can perform the evaluation of business cases from the following different angles:

- Evaluates and compares the viability/profitability of the **business models** considered for each actor across business case instances. *(Per actor view)*
- Evaluates and compares the holistic (i.e., the overall) **cost and benefit** of business case instances or a technology solution in general. (*Holistic view)*
- Evaluates the **replication/upscaling** of a business case instance or technology solution in general. (*Holistic view)*

To minimize the number of input values required by the user, the tool makes use of *scaling factors*, which associate the cost items and revenue streams for each of the locations compared to the values for a "default" location. By providing values to these location-dependent scaling factors, the effort required to analyze business models for alternative business case instances is significantly reduced. For example, if the examined business case includes 30 cost items and revenue streams under 5 business case instances, and the replicability the 5 instances must be evaluated in 4 locations, the user of a traditional tool would have to supply $30 \cdot 5 \cdot 4 = 600$ input values. In the case of 360 BME tool, the user only needs to provide $30 \cdot 5$ values for the cost and revenue items at the "default" location and $30 \cdot 4$ values for the scaling factors, thus 270 in total.

Note that 360 BME tool is not restricted to the evaluation of 5G business cases, but it can be used to evaluate business models in other domains, such as the smart grid domain [12].

III. The 5G Experimentation as a Service Business Case

To demonstrate our framework, we next describe a business case for 5G EaaS, motivated by the 5G-VINNI platform [3]. Our objective is to assess the viability of the commercial 5G-VINNI platform EaaS offerings for 5 years beyond the lifetime of the project, where EU funding is no longer available. Following our framework, we:

(A) Define the 5G EaaS business case by identifying a specific value network with the relevant roles and services, and the main actors that are expected to adopt/combine these roles for delivering the EaaS.

(B) We construct a "valid" instance of this business case by identifying which are certain roles in the value network that each actor may adopt and combine. We elaborate on the business model of each actor, and we model their costs and revenues.

(C) We feed the data into the 360 BME tool and assess the viability of each actor individually, performing a sensitivity analysis on different parameters. In this paper, we assess only one *business case instances*. A comparison of different business case instances for 5G EaaS is available in [13] and [14].

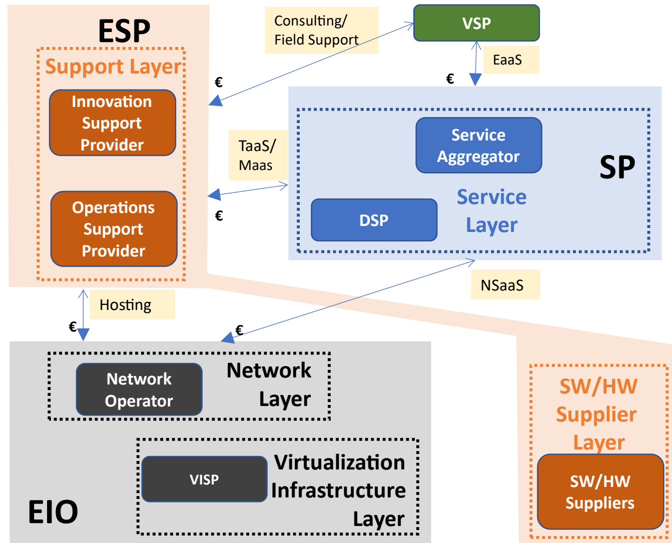


Figure 3: An instance of the 5G-VINNI EaaS business case.

A. 5G EaaS Business Case Definition

Service. To offer 5G EaaS the bundling of the following *complementary/enabler* services is necessary.

Network Slice as a Service (NSaaS) is the core service, and it is classified into three standard network slice types, namely the enhanced Mobile Broadband (eMBB), ultra-Reliable Low Latency Communications (uRLLC) and massive Machine-type Communications (mMTC) network slice types.

Testing as a Service (TaaS) offers automated performance, functional and quality assurance testing of SW/HW components and applications.

Monitoring as a Service (MaaS) allows the real-time data collection and performance monitoring of the infrastructure, services and applications when experiments are performed.

Field Support/Consulting supports the EaaS customers to design, develop and set up high-quality experiments, and to analyze and exploit the extracted results.

Value network. The EaaS-specific value network is built for the generic value network of Figure 2, by considering only the roles contributing the services defined above. The relevant roles are presented in the small rectangles of Figure 3.

Actors. The roles that appear in the relevant value network are adopted and combined by the three actors presented below.

Solution Provider (SP). A SP develops vertical applications for the targeted vertical market (e.g., automotive solutions).

Experimentation Infrastructure Operator (EIO). An EIO focuses on operating the 5G experimentation infrastructure and offers NSaaS for 5G-empowered solutions.

Experimentation Support Provider (ESP). The ESP offers TaaS/MaaS capabilities, by providing the necessary framework and support during the experimentation of the customers.

B. Selected 5G EaaS Business Case Instance

In different instances of the 5G EaaS business case, the actors presented above may consider alternative roles when they get

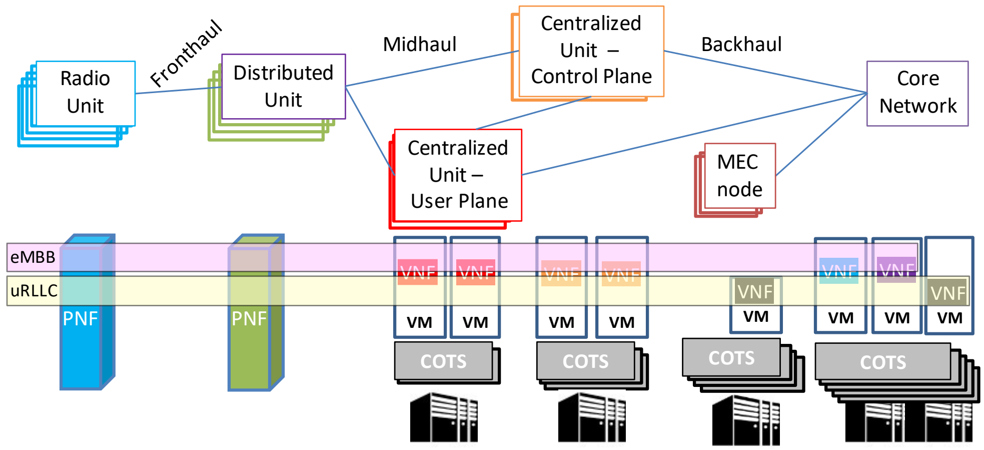


Figure 4: 5G Network topology and key network functions, with services sharing resources and cost.

involved in the co-creation of EaaS. In this paper, we study the *value network instance* in Figure 3, as it was the one eventually selected for the 5G-VINNI platform.

The *SP* adopts the DSP role to offer vertical market-specific applications and the Service Aggregator role for combining its applications with the NSaaS offered by the EIO and the TaaS/MaaS capabilities offered by the ESP. Eventually, the SP offers the EaaS directly to the targeted VSP market.

The *EIO* adopts and combines roles in the infrastructure and network layers, that is the Network Operator and VISP roles. Thus, it focuses on the operation of the experimentation infrastructure and offers NSaaS to the SP for a fee.

The *ESP* adopts roles in the Support and Supplier layers for offering the TaaS/MaaS service and the necessary framework, namely the Operations Support Provider and HW/SW supplier roles. The ESP services are delivered to/paid by the SP, while the EIO is paid by the ESP for hosting the necessary TaaS/MaaS equipment. The ESP also adopts the Innovation Support Provider role for consulting of the VSP.

Business Models. A BMC is developed for each of the three actors (as presented in [14]), complementing business relationships that appear in the value network instance of Figure 3. With this as a settled context, we set off to model the cost structure and revenue stream elements in the BMC for preparing data for analyses in the 360 BME tool.

1) Revenue model. The revenue estimation model for the EaaS business case instance presented in Figure 3 considers the revenue streams associated with EaaS, the enabler services and their demand-side drivers, such as the number of customers, the average number of sessions (per service type) per customer, etc. The main revenue streams and their mapping to the involved actors are discussed below.

SP - Revenues from EaaS offerings. This captures the revenue of the SP from the EaaS offerings, by considering the relevant demand drivers and their values in the specific markets. We estimate the *annual* revenues R_e of the SP from EaaS as a product of the price per hour $p_{e,u}$ that a VSP pays for the service in a certain use case u, the average hours $t_{e,u}$ per EaaS session required for use case u, the average number of sessions $s_{e,u}$ per year per VSP established for use case u and the average number of VSP $V_{e,u}$ been active in use case u. Note that the price of EaaS $p_{e,u}$ also includes the charge for the vertical application of the SP:

$$R_e = \sum_{u=1}^{U} p_{e,u}\, t_{e,u}\, s_{e,u}\, V_{e,u}. \quad (1)$$

EIO - Revenues from NSaaS offerings. This is an aggregation of revenue streams per network slice type, i.e., eMBB, uRLLC, etc. Each revenue stream can be computed by applying Equation (1) and setting values to the different parameters of the formula for the NSaaS offerings.

EIO - Revenues from hosting TaaS/MaaS framework. This revenue stream is calculated by a formula that accounts for the price p_h per hour for hosting the VNFs of the TaaS/MaaS framework for an ESP, the hours t_h that VNFs should be hosted in the span of a year and the number of ESPs C_h requesting a hosting service in the span of a year.

$$R_h = p_h\, t_h\, C_h. \quad (2)$$

ESP - Revenues from TaaS/MaaS offerings. This revenue stream can be estimated by applying Equation (1) for the TaaS/MaaS service.

ESP - Revenues from consulting VSPs. This revenue can be estimated by Equation (1) by adapting the parameters for the consulting service.

2) Cost Model. The OPEX and CAPEX items (non-exhaustive list) of the involved actors are elaborated below. Some of the cost items are not illustrated in Figure 3, but they can be validated in Figure 2.

SP - Digital Service Software. OPEX for vertical-specific software licenses, TaaS/MaaS services and personnel salaries for SW development and service integration.

EIO - 5G RAN and Transport. CAPEX for equipment and spectrum acquisition; OPEX for equipment maintenance, passive network rental, and backhauling cost.

EIO - 5G Core and Cloud Infrastructure. CAPEX for physical cloud infrastructure acquisition and perpetual licenses for virtualization SW; OPEX for 5G Core licenses (annual or pay-per-use) and the maintenance of owned infrastructure.

EIO - Network Slicing. OPEX for SW licenses for the management and orchestration framework.

EIO - Other Costs. CAPEX as land acquisition fees for the placement of equipment (e.g., lampposts); OPEX for personnel salaries, land rental and electricity bills.

ESP - TaaS/MaaS Software. OPEX as a fee to EIO for hosting the TaaS/MaaS framework, as well as OPEX as personnel salaries for the development and maintenance of the framework and consulting of VSPs.

The *total cost* of each actor is affected by the *unit costs* of the relevant items presented above and the *number of units per item* that needs to be deployed to satisfy the demand. The number of units per item is determined by the *dimensioning* process discussed later in this section. The unit cost values that are used in this analysis are retrieved from the related literature (Table 2-2 of [12]).

3) Cost-Revenue Association. 5G assets (e.g., equipment, software, etc.) and personnel can be shared across several services offered by an actor. Figure 4 presents an exemplary 5G network topology where two network slice types, (i.e., uRLLC and eMBB) share VNFs/PNFs (Physical Network Functions), hosted in shared Virtual Machines (VMs). Thus, computing prices for services of an actor in a transparent manner suggests that the common costs are split into the respective services in a "reasonable" way. There are multiple alternative methodologies in the literature [15] for computing *cost-based prices* for services that share common costs. The Fully Distributed Costs is a suitable method to determine the price for services in immature markets like the 5G EaaS market. By applying this method, the price of each service is determined by the individually generated cost and a portion of common costs with other services. The eventual price of the service is adjusted by a proper markup (e.g., multiplied by 1.1). The assignment of costs to services is straightforward when an item is utilized by a single service. When an item is utilized by multiple services, we split the generated cost among them proportionally to their load.

4) Market Conditions. In the instance under study, the *demand* for experimentation originates from 8 vertical domains. In each domain, there are two active VSPs that offer 5G-enabled services to retail customers, while they continuously update and test their services before their roll-out. A VSP receives 15,000€ per year from offering services. VSPs are symmetric in terms of load injected into the 5G experimentation platform. Regarding the SP market, there are two competing providers per vertical domain of equal size. Both follow the same *pricing strategy*, under which a 200% markup is added on the hourly price that the EIO charges for eMBB, uRLLC and mMTC network slices (i.e., *Revenues from NSaaS offerings*). Finally, the (single) ESP receives 4,000€ for the TaaS/MaaS offerings, while paying 0.36 €/hour to the EIO for hosting its VNFs.

5) Dimensioning. We *dimension* the infrastructure (e.g., number of Base Stations required, number of VNFs to be activated, cloud vCPUs, etc.), volume of SW licenses to be acquired, personnel to be employed, etc., as in Equation (3), which estimates the number of units N_i for an item i.

$$N_i = \sum_{\tau \in T_i} \frac{l_\tau \hat{S}_\tau}{L_i} \quad , \qquad (3)$$

where T_i is the set of different services that item i enables, l_τ is the average load that an instance of service τ generates, $\hat{S}_\tau$ is the average number of active instances for this service at any given time and L_i is the maximum load that a unit of item i can support. Driven by site deployments of 5G-VINNI [3], we assume that some items in the *hypothetical* platform of our case

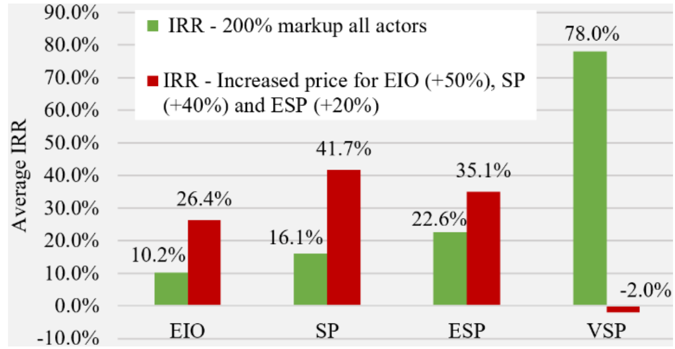
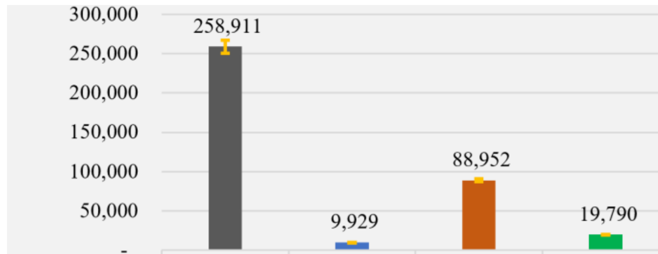


Figure 5: The average IRR for each actor when running 100 iterations using the 360 BME tool.



	EIO	SP	ESP	VSP
Average balance	258,911	9,929	88,952	19,790
St. error	8,348	174	1,791	56

Figure 6: The sensitivity of the average balance at the end of the 5 years for each actor to the changes in cost item values.

are already dimensioned while others are determined by Equation (3).

In particular, the hypothetical platform includes 2 macro cells and each of them hosts an integrated Radio Unit with 3 sectors. Each Distributed Unit serves 2 Radio Units on average and thus a single Distributed Unit is required. A single Central Unit is needed that runs on a single Metro Data Centre, while the 5G core runs on a single Central Data Centre. The nodes above are connected using existing fiber links and no small cells or Multi-access Edge Computing (MEC) nodes exist. The EIO buys a perpetual license for 5G Core software and invests in its own cloud infrastructure. We assume that the dimensioning of the cloud infrastructure is performed based on Equation (3), while no extra 5G RAN infrastructure will be needed.

C. 5G EaaS Business Case Instance Assessment

Next, we assess the attractiveness of the selected 5G EaaS business case instance depicted in Figure 3, for all the actors that participate in 5G EaaS demand (i.e., VSP) and supply side (i.e., SP, EIO and ESP). Our analysis focuses on the *per-actor business model evaluation* angle of 360 BME. We perform a *sensitivity analysis* on the values of the cost items while investigating alternative markup values for cost-based pricing.

Figure 5 presents the IRR for each of the four actors for two different scenarios of cost-based pricing markup values. In the first scenario, EIO, SP and ESP adopt a 200% markup strategy, while in the second one, they increase further their prices to achieve an IRR>25%. We observe that the first scenario is viable since all business models have a positive outlook, while the second one is not viable due to the "aggressive" pricing of actors. The results were obtained by running 100 iterations of the business case instance while assuming an "uncertainty" for the values of cost items. Assuming a baseline cost value for each cost item, the cost value of each item in each iteration is determined by a *uniform* di*stribution* in the range [*80%, 120%*] of the *baseline cost.*

Error! Reference source not found. presents the *average b alance* for each actor, is defined as the actor's cumulative revenues subtracted from the cumulative expenditures and taxes. The *standard error* of the computed cost values (i.e., the variability of cost values across the 100 samples) is also presented. We observe that the standard error can be as high as 3.2% for the EIO and 2% for the ESP and that the EIO will extract most of the revenues despite carrying most of the costs, which places its IRR is on the lower end.

IV. Conclusions

We have introduced a framework for the analysis of complex 5G business cases, where multiple stakeholders interact and contribute to the co-creation of 5G-empowered services. Our framework handles the complexity of 5G business cases, stemming from the immaturity of business relationships in the 5G market, by allowing for the definition and simultaneous evaluation/comparison of alternative business case instances.

Framework use cases: Our framework can be used by any stakeholder to evaluate the attractiveness of alternative *business models* for a specific business case, before entering the market. Also, a stakeholder can utilize the framework to determine viable prices for its services. Our framework handles the uncertainty on different parameter values of a business case since 360 BME tool allows for their automated sensitivity analysis. From a holistic perspective, our framework can identify the need for cost/revenue sharing among the actors of a business case to render it viable, assess the overall cost-benefit of a 5G solution and evaluate the potential replication/upscaling of solutions.

Future work: A direction of future work is the continuous development of our framework and 360 BME tool to capture the advancement of 5G/6G technology that may result to addition of new roles, new business relationships, new equipment, etc. Our framework design is modular so that it can be extended or adapted towards this direction. Furthermore, we plan to further apply our framework to more commercial, pre-commercial and research 5G/6G business cases. Finally, an extended version of this paper, where the individual steps of our analysis are presented in detail, is another direction of future work.

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