The potential of 5G experimentation-as-a-service paradigm for operators and vertical industries: the case of 5G-VINNI facility

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Abstract—5G, in contrast to previous mobile network generations, has been conceived with vertical industries in mind. Vertical industry enterprises and other experts have identified a wide set of innovative use-cases that could take advantage of ample throughput, low network delay, widespread coverage and resilience promised by 5G technologies. However, the commercial success of an idea depends on a wide range of socio-economic factors that call for designers, engineers, business analysts and end-users to collaborate in setting-up, running and analysing a series of experiments. In this paper we describe the “Experimentation-as-a-Service” offering of 5G-VINNI facility, a collection of 5G testbeds, and analyse its potentials and shortcomings by combining online surveys with SWOT and TOWS analysis.

Keywords—5G, experimentation facility, experimentation-as-a-service, 5G infrastructure, vertical industries, verticals innovation, SWOT analysis, TOWS analysis, online survey

I. INTRODUCTION

Network infrastructures and new technologies such as cloud computing [1], Internet-of-Things (IoT) [2], artificial intelligence [3] and big data [4] have evolved into enablers for social security and cohesion, and business continuity and expansion. 5G can reshape many “vertical” industries, such as Industry 4.0, eHealth, Automotive and Utilities. The vision for 5G is to “become a stakeholder-driven, holistic environment for technical and business innovation integrating networking, computing and storage resources into one programmable and unified infrastructure” [5].

5G can dynamically configure the physical network to address different customers and different customer demands, support massive increase in traffic volume and provide highly resilient, secure and low latency communications. As a result, vertical industries will have enhanced technical capacity available to trigger the development of new products and services, or increased automation of business and operational processes.

The launch of commercial 5G services requires substantial investments by telecommunication operators and the Information and Communication Technology (ICT) industry in general. The latter will not invest in new infrastructures if they do not see clear prospects for a solid demand rendering the investment worthwhile. Equally, industry sectors interested in 5G for their digital transformation may want to wait until the 5G infrastructure is ready and tested.

We argue that in order to solve the “chicken and egg” problem that the 5G ecosystem currently faces (see Fig. 1), a staged approach for both the ICT industry and vertical industries’ enterprises is necessary. The former should gradually roll-out 5G infrastructures where demand is high (e.g. smart cities, industrial parks) and, especially for rural areas or individual campuses, deploy a shared small cell network jointly with other operators or vertical industries [6]. At the same time, vertical industries should not only check the technical feasibility of innovative use-cases, but validate their business potential by executing pilots with actual users.

In other words, Mobile Network Operators should broaden their product portfolio with a “5G experimentation-as-a-service” offering that can unleash the full potential of vertical industries. Pre-commercial activities can be isolated from the rest of the traffic and be scalable to cater for the experimenters’ needs. Such functional requirements are easier to meet through network slicing [7] and network softwarisation via SDN (Software-Defined Networking) and NFV (Network Function Virtualisation) technologies [8].

Experimenting throughout the service/product life-cycle is essential matching new services with real-user pain points and needs, and thus reducing costs and increasing revenues. Several methodologies, such as design thinking [9], emphasise the importance of multi-stakeholder engagement for effective innovation. Facilitating such experimentation processes is the main objective of 5G end-to-end facilities such as 5G-VINNI1, 5G EVE2 and 5GENESIS3 funded by the European Commission as part of Phase 3 of the 5G Public Private Partnership (PPP). With the same objectives in mind other leading economies besides the EU are also deploying experimentation infrastructures, as it is analysed in [10]. Some of these initiatives run in collaboration with their European peers4.

1 https://www.5g-vinni.eu/
2 https://www.5g-eve.eu/
3 https://5genesis.eu/
4 Prominent examples of such projects are EMPOWER (http://empowerproject.eu/) in USA, 5G-DRIVE (https://5g-drive.eu/) in China, 5G CONNI and 5G-DIVE in Taiwan,
This paper is structured as follows: Section 2 provides a short overview of the 5G-VINNI facility as the inter-working of several facility sites and its gradual change in focus from supporting technical trials to enabling full-blown business experiments. Section 3 provides a preliminary assessment of 5G impact on the innovative products/services and business processes of vertical industries, as the potential customers of “5G experimentation-as-a-service” offerings, while Section 4 provides a SWOT analysis for 5G-VINNI in order to understand the Strengths, Weaknesses, Opportunities and Threats. Section 5 suggests candidate strategies for unlocking the full potential of 5G-VINNI and we conclude with key observations and next steps in Section 6.

II. THE 5G-VINNI FACILITY

5G-VINNI is an end-to-end (E2E) 5G facility comprising multiple interworking 5G Radio Access Network (RAN) and core infrastructures, and zero-touch E2E service orchestration, which will facilitate the rapid on-boarding of verticals by exposing network slice life-cycle management functions through an open Application Programming Interface (API) [11]. The 5G-VINNI facility is composed of several facility sites spanning seven European countries, with the deployment of the 5G-VINNI architecture in several administrative domains. The Main Facility sites offer services to customers with well-defined Service Level Agreements, while there are also the Experimental/Research Facility sites which provide project internal environments for early technical experimentation and testing of prototype components and systems.

We have identified several maturity levels (ML) of the 5G-VINNI facility capturing its evolution over the life time of the project, foreseeing that the operation of the facility during the project will significantly differ from the one after the project’s completion, considering also the long-term vision of 5G-VINNI facility experimentation as a service. These MLs are described below and in Fig. 2:

1. ML1 focuses on running conformance tests for validating technical KPIs.
2. ML2 refers to a mature facility that will allow a restricted set of vertical “customers” to integrate their applications and run stress tests in order to assess the technical merits and feasibility of innovative use-cases.
3. ML3 refers to the same facility as in ML2 but for a 1-year period after the contracted duration of 5G-VINNI. In order to guarantee its sustainability, vertical organisations will have to compensate 5G-VINNI members for any additional capital or operational expenses incurred. Accordingly, we expect that some business-level experiments will be performed during this phase.
4. ML4 captures the long-term vision for 5G-VINNI experimentation as a service toward vertical customers. This could involve individual 5G-VINNI facility sites, multiple 5G-VINNI facility sites or even interworking with other external facilities. This will imply broadening the European footprint and governance structure. Experimenters, such as vertical customers and vertical application providers, are asked to pay competitive prices for using the infrastructure to get valuable feedback, considering various levels of public funding and support.

III. THE 5G-VINNI MATURITY LEVELS AND EXPECTED USE-CASE (UC) SCOPE

A. Methodology

In order to evaluate the innovation potential of 5G-VINNI, and 5G in general, the methodology followed was the one presented in the Oslo Manual 2018 [12], according to which there are two types of business innovations; product innovations (new or improved good or service) and business process innovations related to business functions. Product innovations must provide significant improvements to one or more product characteristics or performance specifications. Relevant functional characteristics include: quality, technical specifications, reliability, durability, economic efficiency during use, affordability, convenience, usability, and user friendliness. Business Process Innovations cover the following aspects: production of goods or services, distribution and logistics, marketing and sales, infrastructure provision and maintenance, administration and management (such as strategic decision-making), product and business process development.

B. Innovative products and business processes from selected vertical industries

In order to identify innovative products and business processes from selected vertical industries, in 5G-VINNI we performed a qualitative analysis on the expected potential of 5G to nine different industries, and consequently users and society [13]. The approach followed is based on [14] and appears in Fig. 3.

By interacting with representatives from each of the nine vertical industries we identified families of innovative use-cases that could benefit from 5G-VINNI capabilities and classified them into either product or business process innovation. Then, the latter ones were decomposed further according to the most relevant business process types, following the taxonomy described above. Note that each family of use-cases can have multiple instances; for instance, different services requiring high-quality video streaming could target distinct customer groups like entertainment, or immersive video conferencing. Thus the true innovation potential is even higher than estimated.

We identified 58 families of use-cases in total for the nine vertical industries. These innovative outputs, while not meant to be exhaustive, are not limited to a few vertical domains only. It was found that at least three interesting families of use-cases can be identified for each of the nine industries: 5G impact on the innovative products/services and business processes. Section 3 provides a preliminary assessment of 5G impact on the innovative products/services and business processes of vertical industries, as the potential customers of “5G experimentation-as-a-service” offerings, while Section 4 provides a SWOT analysis for 5G-VINNI in order to understand the Strengths, Weaknesses, Opportunities and Threats. Section 5 suggests candidate strategies for unlocking the full potential of 5G-VINNI and we conclude with key observations and next steps in Section 6.

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cases can be identified for each vertical domain; the average was more than six. The exact figures per vertical sector appear on the bottom of Fig. 3. This demonstrates that a wide range of actors are interested in trials and pre-commercial experiments - a big opportunity for 5G-VINNI (as will be discussed in the next section).

Fig. 3: Our approach to assessing innovation potential

Fig. 4 presents a high-level overview of these results. More than half of candidate innovations were classified as product innovations that meet candidate customers’ requirements while serving the vertical enterprises’ needs for improved goods or services, new offers for establishing new markets or entering to existing ones. The rest of the innovations were associated to improved business processes, for upgrading outdated processes, technology or methods, reducing operational costs and waste per unit of output, reducing time to market by improving capabilities for absorbing and analysing knowledge, as well as integrating processes with other organisations. Due to space constraints, the reader is redirected to [13] for more details and examples.

Fig. 4: Number of Candidate innovative outputs per innovation type

IV. SWOT ANALYSIS OF THE 5G-VINNI FACILITY

In this section we perform a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis focusing on the 5G-VINNI facility as a whole, under the concept of experiment-as-a-service. By means of this SWOT analysis, we aim to assess the value proposition of 5G-VINNI facility for all the involved stakeholders (internal and external), identifying both potential benefits and shortcomings.

A. Methodology

For the SWOT analysis we identified 19 qualitative criteria that, we believe, will determine the value proposition of 5G-VINNI facility. These aspects can be out of 5G-VINNI direct control (external), or within (internal). Each aspect, regardless of its external/internal nature, has a dual nature; it can be negative or positive. In the case of internal aspects, positive ones are considered as “Strengths”, while negative ones are “Weaknesses”. Similarly, positive external aspects are named “Opportunities”, while negative ones are recognised as “Threats”.

In order to assess the positive or negative effect of each aspect, we decided to compute a single value that ranges from -5 to 5. Note that the value of a criterion should identify the overall effect taking into account the impact on all actor roles in the ecosystem. It is quite possible the overall effect to be close to neutral (0), as some factors under the same aspect are promising while others pose concerns.

In order to compute values for the internal aspects we followed an approach where 5G-VINNI partners were considered ideal candidates to do the assessment. We acknowledge that the values may be a bit high for a maturity level 2, however, the strategic implications and discussion are still highly relevant. To determine the impact of external aspects we ran an online survey for better understanding the pain points that vertical industries’ representatives face today, their propensity to experiment during product/service life-cycle and how the 5G ecosystem could help them innovate in a mutually beneficial way.

Due to space constraints we will briefly describe the approach followed for collecting inputs on the external aspects. We prepared a questionnaire that included a set of 17 statements expressing a negative statement about 5G and invited a core group of 125 participants from different European organisations and several vertical industries to participate. They were allowed to further disseminate it, which means that we used the snowball sampling technique. Eventually 31 respondents filled in the survey, conducted between 1st and 31st of April 2019.

Respondents could select one of the following six possible Likert-type answers: “Strongly disagree”, “Partly disagree”, “Not sure”, “Not relevant”, “Partly agree” and “Strongly agree”. Each answer was associated with a value ranging from -5 to 5. The values selected were 5, 2.5, 0, 0.0001, -0.0001, -2.5 and -5, respectively. Note that the values of “Not sure” and “Not relevant”, due to their neutral nature, have received a low value which is close to zero. Furthermore, one or more questions were mapped to a single external aspect and a single value for each aspect was calculated as the weighted average of the related answers.

B. Results for Maturity Level 2 (ML2)

Due to space constraints, and in order to maximise room to discuss the effects of the strategies to be subsequently identified, we perform the strategic analysis only for the second maturity level (ML2) of 5G-VINNI. Note that the different maturity levels affect the internal characteristic of 5G-VINNI facilities, thus each level would exhibit different strengths and weaknesses. On the other hand, the external

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5 The online questionnaire can be found at: https://www.5g-vinni.eu/5g-vinni-questionnaire-on-the-pain-points-that-european-industries-face-today_allin1/
aspects refer to pain points that vertical industries face and we expect that these remain the same for all maturity levels. Similar results as for ML2, but slightly improved, were obtained for ML 3-4. Note that analysis for ML1 was skipped due to its internal nature. The results are reported below, and also graphically represented in Fig. 5. Furthermore, we expect that similar results will be obtained for other 5G facility sites, i.e., 5G-EVE and 5GENESIS, as these have similar objectives, structure and deal with the same external aspects.

1) Analysis of Internal aspects (Strengths/Weaknesses)

11. Performance (value = 4). 5G-VINNI virtualised environment is characterised by high-quality automation with respect to end-to-end service instantiation (network slice instantiation) and testing, online adaptation to the vertical customers’ needs and recovery from potential failures. 5G-VINNI architecture and implementation promises the efficient operation of the facility respecting the customers’ QoS requirements. This must be achieved while satisfying the customer SLAs and the targeted values on certain Key Performance Indicators (KPIs), with respect to capacity, ubiquity, latency, reliability, service creation time, etc.

12. Deployment Cost (value = 1). Capital Expenditures (CapEx) for deploying 5G-VINNI system are low compared to green field 4G setups (and in some cases incremental ones), since the network functions are running on general-purpose commodity servers. However, at this early stage of 5G deployments, the cost of RAN equipment is not considered as low.

13. Operational Cost (value = 2). One of the main 5G-VINNI architecture design principle is the E2E virtualisation of resource taking advantage of NFV technology. This allows for a low-cost automated network management, thus a low Operational Expenditures (OpEx) for on-boarding services and testing. However, at the early stage of the project the development of E2E Management And Network Orchestration (MANO) framework that allows the interworking of facility sites implementing different MANO framework will impose a start-up cost.

14. Innovation potential (value = -1). In operation level ML2, 5G-VINNI is not available for any interested vertical customer to experiment. While openness and accessibility are two of the key design principles for 5G-VINNI, this limitation imposed on serving other customers will also limit the innovation potential of the platform. However, assuming that 5G-VINNI consortium members (Network Operators, vendors, etc.), and those granted access to 5G-VINNI facility can take advantage of the facility to innovate, the innovation cannot be considered as strongly unsustainable.

15. Brand Name (value = 1). 5G-VINNI consortium includes well-known vendors and operators, which helps in establishing a brand name. On the other hand, due to the limitation on the customers groups during ML2, it is unlikely for 5G-VINNI to be able to establish a strong brand name at this stage. Nevertheless, other 5G facility sites will face similar issues and thus the outlook is positive.

16. Stakeholders’ collaboration (value = 4). The collaboration amongst the 5G-VINNI members is guaranteed during the project lifetime and ML2 due to the consortium agreement and the management plan for mitigating relevant risks. In this phase, 5G-VINNI is a not-for-profit partnership and its sustainability is secured by a combination of internal and external funds. To this end, we assume that collaboration among the stakeholders of the 5G-VINNI facility is safe.

17. Facility growth-geographical expansion (value = -4). In operation level ML2, the 5G-VINNI facility is not expected to grow, since none of the individual sites is expected to interconnect with external sites. It is quite possible that an EU-funded project may ask to interconnect an external facility site to 5G-VINNI but again this growth will be limited in ML2, but should improve in ML3 and especially ML4, where scope will expand to support international use-cases as well.

18. Ability of managing large scale networks (value = 5) The Network Operators present in the consortium have great experience in managing large scale networks of high complexity and critical applications. Furthermore, they are familiar with deploying new infrastructure and interacting with several market entities. Thus, we expect that this is a strong point for 5G-VINNI for all maturity levels.

19. Ability to exploit new technologies (value = 3). One of key design principles for 5G-VINNI facility is the ability for each site to evolve both during and beyond the project’s lifetime. In fact, ML2 involves three incremental releases of 5G-VINNI technologies, where each one of them will be backwards compatible while introducing additional functionalities and new technologies.

2) Analysis of External aspects (Opportunities /Threats)

E1. Capacity of existing solutions to meet verticals’ needs (value = 2.42). The majority of survey participants (77%) strongly or partly believe that the existing technologies cannot meet mid-term requirements or that the advanced network quality, coverage and flexibility promised by 5G will have a significant effect on their industry.

E2. Private networks (value = 2.42). The majority of participants (74%) strongly or partly believe that 5G technologies will meet their performance and security requirements, although some further validation is needed.

E3. Demand for advanced international networking services (value = 0.65). Some 42% of participants agree that the future candidate geographical markets will require only moderate or minimal adaptation to their service/product portfolio in order to comply with regulation (such as on data management). However, there are quite a few participants that are not sure (16%) or who believe that regulations (on digitalisation issues) hinder geographical expansion (29%).

Fig. 5: Graphical representation of SWOT analysis for Maturity Level 2 of 5G-VINNI
E4. Innovation and Regulation (value = 0.48). Like in the case of E3, responses were quite balanced. While 42% of participants, and especially small medium-sized industries, agree that there are no or only some regulatory constraints on the roles and business models they can adopt; 35% have different opinion (mainly those belonging to Manufacturing and Utilities industries).

E5. Innovation and collaboration (value = 0.32). This external aspect was very controversial as 33% of participants (mostly from Smart cities and transportation and Smart Agriculture industries) agree that they will have access and control to all new or existing infrastructure(s) or that the critical mass of required technologies will be reached, while 34% considered this as a bottleneck.

E6. Shared Vision (value = 1.17). 68% of the participants are either very confident or simply believe that industry forums and associations enable consensus building between industry members while setting future directions (including pre-standardisation, best practices). However, only 29% of the sample finds that 5G research and industry visions drive pre-standardisation, best practices. Thus, a fair share of respondents seems to put more trust in industry members’ views rather than external consultants.

E7. Standardisation process (value = -0.73). According to the survey findings, the narrow majority of the participants (52%), from varying industries and organisation size, believe that standardisation organisations are either good in identifying emerging needs but slow in addressing them, or slow in both identifying and addressing emerging needs, 29% believes the opposite. Although clear progress has been made during the last years, standardisation process is still slow, and it is considered to be a threat.

E8. Culture for trust and collaboration across 5G actors (value = -1.21). Most of the survey participants (61%), from a broad range of industries, believe that some additional mechanisms or new Service Level Agreements (SLAs) are needed for building trust between ecosystem actors (e.g., some commonly agreed operational policies and mechanisms should be in place for aligning the incentives of the rest of the entities), while only 29% find these unnecessary. The 5G value network involves multiple actors that implement traditional telecommunication roles, but also new ones that have emerged due to the digitalisation of vertical sector, virtualisation Network Infrastructure and softwarisation of Network Operations. Thus, the absence of trust-enabling mechanisms is considered as threat.

E9. Vertical experimentation with the service/product portfolio (value = 3.1). Based on the survey findings, the majority of the participants (82%) strongly and partly agree that their organisation (mainly from Utilities, Media/Entertainment and Smart Agriculture industries) is comfortable and interested in running technical trials and business experiments throughout service/product lifecycle, as well as, that these experiments are valuable e.g., in terms of reduced costs, increased revenues or new revenue sources.

E10. Strategic and operational concerns (value = 1.81). Most of the survey participants (60%) believe that strategic concerns will be reduced due to increased performance control by customers and isolation will be outweighed by new business opportunities, while their organisations (whose industry categories and sizes vary) will be ready to adopt 5G technologies and services when these are offered, even though facing some minor operational challenges. Only a few participants (19%) have an opposite opinion, while even fewer (16%) are not sure. This is considered as an opportunity for 5G-VINNI.

V. PROPOSED STRATEGIES FOR 5G-VINNI

The reason for performing the SWOT analysis above is to identify potential strategies for 5G-VINNI stakeholders, aiming to exploit strengths/opportunities and mitigate weaknesses/threats. This approach is known as TOWS [15] and involves the following pairs:

- **Strengths–Opportunities (Use internal strengths to take advantage of opportunities);**
- **Strengths–Threats (Use strengths to reduce the probability of a threat being materialised or its consequences);**
- **Weaknesses–Opportunities (Improve weaknesses by taking advantage of opportunities);**
- **Weaknesses–Threats (Work to eliminate weaknesses to avoid threats).**

Fig. 6 provides a graphical representation of some potential strategies identified in order to address or improve the weaknesses or threats. Even more are described below.

![Fig. 6: Graphical representation of selected strategies (S1, S3, S6 and S7) identified based on the SWOT analysis of 5G-VINNI (ML2)](image)

1) **Attack Strategies (Strengths & Opportunities)**

(S1: I1+E1+E4+E2): The technical performance superiority of 5G-VINNI facility, gives 5G-VINNI the potential to exploit the high interest of some vertical industry sectors for offering value-added/assured quality services to their customers. In fact, 5G-VINNI should collaborate with verticals in order to design technical solutions that are able to meet vertical-driven KPIs. In addition, 5G-VINNI can take advantage of the opportunity that small firms are adopting the “network as a service” model in order to design tailored end-to-end slice solutions.

(S2: I1+I8+I9+E2): The fact that private networks (defence, emergency) have become too expensive/challenging for non-ICT actors to handle, revitalise the traditional strength of high performance and professionalism of Mobile Network Operators (MNOs) and their ability to exploit new technologies.

2) **Reinforce Strategies (Weaknesses & Opportunities)**
Although the SWOT assessment can be disputed, the strategic implications are highly relevant.

The need for attractive business models and incentive-compatible governance models was identified as key for building and improving the culture for collaboration and trust between 5G actors and this finding will guide our next steps.

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