D6.5: 5G-IANA microprojects services report

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The 5G Infrastructure Public Private Partnership

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Control sheet

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Peer review		
	Reviewer name	**Date**
Reviewer 1	Thanos Xirofotos	27/11/2024
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Legal disclaimer

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ABBREVIATIONS

Abbreviation	Definition
AOEP	Automotive Open Experimental Platform
BMC	Business model Canvas
EEO	Extreme-Edge Orchestration
LTE	Long-Term Evolution
MANO	Management and Orchestration
MEC	Multi-Access Edge Computing
MEC	Multi-access Edge Computing
ML	Machine Learning
NF	Network Function
NOD	nApp Orchestration and Development (NOD) layer
OBU	On-Board Unit
OCx	Open Call x, where x refers to either 1 or 2
PU	Public Utility
RSU	Road-Side Unit
SACBT	Situational Awareness in Cross-Border Road Tunnel Accidents
SME	Small & Medium Enterprise
SWOT	Strengths, Weakness, Opportunities, Threats
TS	Telekom Slovenije
UCx	Use Case x, where x spans from 1 to 7
VNF	Virtualised Network Function
WG	Working Group
WPx	Work Package x, where x spans from 1 to 7

EXECUTIVE SUMMARY

The 5G-IANA project is dedicated to enabling third-party access to foster innovation and experimentation in the automotive sector. In this context, this deliverable outlines how the project conducted two Open Calls to attract third-party experimenters, specifically targeting SMEs and start-ups with innovative solutions, regardless of their prior expertise in telecoms or 5G. Through microprojects, the project provided access and support to these entities in a pragmatic 5G environment, leveraging automated tools and advanced testbed sites located in Germany (NOKIA, Ulm) and Slovenia (Telekom Slovenije, Ljubljana). Comprehensive mentoring and technical support were offered to help participants transform their automotive services into Network Applications (nApps) and deploy them effectively on the AOEP.

The current deliverable documents the detailed process and outcomes of the two Open Calls, with a focus on:

- The *objectives* and *goals* of both *Open Calls* and their alignment with the broader aims of 5G-IANA.
- The detailed *eligibility criteria* and selection processes employed to ensure transparency and fairness.
- The extensive mentoring and technical *support* provided, including access to 5G network resources, coaching, and tools such as the Business Model Canvas and SWOT Analysis.
- The **results** and **impact** of **funded microprojects**, showcasing how participants utilized 5G-IANA resources to advance their innovations.

Key outcomes from the Open Calls include the successful development and deployment of nApps, the demonstration of their functionality in real-world 5G environments, and the facilitation of SME-driven innovation in automotive services. The report further highlights the substantial contributions of the microprojects toward exploring and leveraging 5G technologies, underscoring the potential of 5G-IANA to support the digital transformation of the automotive sector.

1 Introduction

1.1 5G-IANA Concept and Approach

5G-IANA aims at providing an open 5G experimentation platform, on top of which third-party experimenters, i.e., SMEs in the Automotive vertical sector will have the opportunity to develop, deploy and test their services. The provided Automotive Open Experimentation Platform (AOEP) is a set of hardware and software resources that provides the computational and communication/transport infrastructure as well as the management and orchestration components, coupled with an enhanced nApp Toolkit tailored to the Automotive sector, for simplifying the design and onboarding of new nApps. 5G-IANA exposes to experimenters secured and standardized Application Programming Interfaces (APIs) for facilitating all the different steps towards the production stage of a new service. 5G-IANA targets different virtualization technologies integrating different Management and Orchestration (MANO) frameworks for enabling the deployment of end-to-end network services across different segments (vehicles, road infrastructure, Multi-access Edge Computing (MEC) nodes and cloud resources). 5G-IANA nApp toolkit is linked with an Automotive Virtual Network Functions (VNFs) Repository including an extensive portfolio of ready-to-use and openly accessible Automotive-related VNFs and nApp templates, that are available for SMEs to use and develop new applications. Finally, 5G-IANA develops a Distributed Machine Learning (DML) framework, that provides functionalities for simplified management and orchestration of collections of Machine Learning (ML) service components and thus, allows ML-based applications to penetrate the Automotive world, due to its inherent privacy-preserving nature. 5G-IANA will be demonstrated through seven Automotive-related use cases in two 5G Stand Alone (SA) testbeds. Moving beyond technological challenges, and exploiting input from the demonstration activities, 5G-IANA will identify and validate market conditions for innovative, yet sustainable business models for the AOEP platform, supporting a long-term roadmap towards the pan-European deployment of 5G as a key advanced Automotive services enabler.

1.2 Purpose of this deliverable

By advancing automotive nApps, 5G-IANA seeks to create new business opportunities and support the growth of Start-Ups and SMEs in the automotive sector. In this context, the project conducted two Open Call rounds to attract third-party experimenters, focusing on SMEs and start-ups in the automotive sector, even those without prior expertise in telecoms or 5G. These Open Calls offered participants the opportunity to develop, deploy, and test their services as nApps within a realistic 5G environment through supported microprojects.

In this context, the purpose of this report is to provide a *comprehensive account of the third-party microprojects* for the development and experimental trials of corresponding nApps hosted on the 5G-IANA platform and the support extended to the microprojects funded through the two 5G-IANA Open Calls, which facilitated the delivery of these services.

Also, this deliverable provides transparency information in the Open Call process, while showcasing the success and contributions of the microprojects to the broader 5G-IANA initiative. The report covers the particular objectives and goals of the two Open Calls, the *criteria* used to evaluate the projects for *funding*, and the *extensive mentoring* and *technical support* provided to the microprojects, including access to 5G network resources and coaching services. It also presents the outcomes of Open Calls, emphasizing the impact of the funded projects on advancing 5G technologies.

Last, the report sheds light upon the provided mentoring and technical support to help the participants of the Open Calls to understand the 5G landscape, convert their automotive-based services into nApps, and deploy them on the AOEP. This environment was enabled by the automated tools of the AOEP and two state-of-the-art testbed sites located at NOKIA, Ulm, Germany, and Telekom Slovenije, Ljubljana, Slovenia.

1.3 Intended Audience

This deliverable is designated as “public” (PU), hence it is accessible to a broad audience of any interested reader seeking information about the organisation, the outcomes of 5G-IANA Open Call microprojects, and any other information in compliance with the purpose of this deliverable discussed in Section 1.2.

1.4 Structure of the deliverable

The rest of this deliverable is structured as follows. Section 2 elaborates on the key aspects of the Open Calls, including eligibility criteria, objectives, timelines, and the funding selection process for microprojects. This section addresses the general and specific terms of eligibility, the goals of the initiative, and the processes for evaluating and selecting proposals. Next, section 3 details the resources and support provided to participants, including the 5G network resources, mentoring activities, and additional tools such as the Business Canvas and SWOT Analysis to enhance project development. Section 4 focuses on the participants' applications, evaluations, and outcomes. It covers the processes and results for both Open Call 1 and Open Call 2, detailing the steps towards final verdicts in accordance to the criteria, objectives, timelines, and the funding selection processes previously explain in Section 2. Finally, Section 5 summarises and concludes the deliverable. Last, the deliverable employs a comprehensive Annex section right after the References Section, including the proposed microproject application submissions by the participants, and the delivered written reports from participants that completed the Open Calls, in order to shed light on the progress and achievements of the 3rd party experimenters.

2 Overview of 5G-IANA Open Calls

The 5G-IANA Open Calls aimed to engage SMEs and start-ups from automotive-related sectors with participants being invited to use the 5G-IANA AOEP, which provided a comprehensive framework for designing, deploying, and validating automotive-related services in 5G.

Two Open Calls targeted a broad range of innovators with the goal of support them in integrating their ideas with the 5G-IANA platform, enhancing their position within the 5G ecosystem, and accelerating their innovation. The program also emphasized mentorship (a.k.a. coaching) and collaboration, offering guidance throughout the experimentation lifecycle to strengthen the SMEs' market readiness and contribution to 5G-driven mobility solutions.

In Open Call 1, funding was awarded to *only one microproject*, selected based on its evaluation as the best-performing project after the delivery and assessment of results in a final evaluation round. In contrast, Open Call 2 adopted the support of *four microproject proposals* with funding *from their beginning*. This change implied *two evaluation rounds*, one for pre-selecting and kicking off the microprojects, and one at the end for validating the delivered results by the microprojects. This difference aimed to provide SMEs with comprehensive support throughout their participation in the call, ensuring they had access to the necessary resources and guidance to successfully achieve their objectives. The funding in Open Call 2 was *conditional upon each SME delivering a results-driven* microproject that met 5G-IANA's criteria-based standards of quality and excellence. These criteria, established to maintain high expectations for the output by the microprojects are explained in further detail below in this section. This revised approach in Open Call 2 was designed to foster a more supportive environment, promoting innovation and development across multiple projects simultaneously.

2.1 Eligibility Criteria

2.1.1 General Eligibility Criteria

The 5G-IANA Open Call adhered to specific eligibility requirements to ensure fairness and alignment with European Union regulations. Participation was open exclusively to SMEs and start-ups legally established in eligible countries as defined under the Horizon Europe framework. Applicants were required to meet the criteria outlined in the *Commission Recommendation 2003/361/EC* and follow the guidelines provided in the *SME user guide* to qualify as an SME. Only individual entities were permitted to apply, as consortium-based proposals were not allowed under the call's rules.

Applicants also had to demonstrate independence from the 5G-IANA project partners, their affiliated entities, and any controlled companies. Institutions, organizations, or legal entities that received funding from or were otherwise affiliated with a 5G-IANA partner were considered ineligible. To uphold the integrity of the process, 5G-IANA reserved the right to disqualify any application that did not fully comply with these criteria.

Eligibility extended to legal entities established and operational in the *Member States of the European Union,* including their outermost regions, and the *Overseas Countries and Territories* linked to these Member States. Applicants from Horizon 2020 Associated Countries, as listed by the European Commission, were also eligible. Entities from the *United Kingdom* could apply, provided they met the conditions set by the European Commission for Horizon 2020 participation at the time of the call's deadline. These criteria ensured that all participants operated within a transparent and fair framework, contributing to the broader objectives of the 5G-IANA initiative.

2.1.2 Additional Funding Eligibility Terms to Open Call 2

Further to the general eligibility criteria, applicants to Open Call 2 were required to meet *additional eligibility criteria* regarding *funding* support. Organizations or individuals were *ineligible* to apply for *funding* if they were, or were *affiliated* with, an existing beneficiary involved in *any ICT-41 project*. Similarly, applicants who had previously received funding through an ICT-41 Open Call were also excluded from eligibility. Last, a strict application submission order was enforced for the limited funding budget available, allowing to fund *up to four* proposed microprojects with €20,000.

2.2 Summary of Objectives and Goals

The primary objective of the 5G-IANA Open Calls was to attract *Small and Medium-sized Enterprises (SMEs)* and *start-ups* from the automotive or other mobility-related vertical areas (e.g., automotive, Industry 4.0, aviation, robotics) to develop and test innovative products, services, or functionalities leveraging *5G capabilities*. The initiative aimed to foster experimentation on the 5G-IANA platform by providing technical and mentorship support to SMEs in designing, developing, deploying, and testing their solutions.

The Open Calls targeted three main profiles of participants:

(i) ***Service Creators***, i.e. Software developers creating services or applications requiring 5G connectivity;

(ii) ***Service Providers***, i.e. entities delivering end-user services (e.g., Intelligent Driving Mobility, HD maps, Localization) dependent on 5G; and finally,

(iii) ***Hardware Providers***, i.e. innovators offering new products that operate and communicate effectively within a 5G ecosystem.

The above targeted categories of participants enjoyed the following benefits from the Open Calls:

- **Canvas of advanced 5G resources.** Selected participants stood to benefit significantly from their involvement in the project. The 5G-IANA platform served as a "canvas" for SMEs to design and test new functions and services in the 5G-enabled automotive and mobility landscape. It enabled them to validate their existing products, services, or use cases in real-time using advanced 5G resources, such as vehicles, On-Board Units (OBUs), Road-Side Units (RSUs), MEC/Edge Servers, and 5G radio infrastructure.

- **Hands-on support.** Beyond technical access, the Open Calls also offered hands-on support. Participants were guided by automotive and network experts throughout their experimentation journey, with continuous mentorship, training, and technical assistance. They had the option to conduct live experiments at 5G-IANA's state-of-the-art testbeds in Nokia's facility in Ulm, Germany, or Telecom Slovenije's site in Ljubljana, Slovenia. Remote access to these resources was also provided for convenience.

- **Access to pre-built software functions and end-to-end service chains.** Additionally, participants gained access to a catalogue of pre-built software functions and end-to-end service chains, as well as tools to onboard their own functionalities and explore novel use case scenarios. This setup was designed to help them build and validate innovative business models within the 5G ecosystem. The project also supported Machine Learning (ML)-oriented services and provided technical resources such as GPUs, manuals, webinars, and video success stories to enhance the participants' experience.
- **Funding support & amplifying visibility.** Importantly, the 5G-IANA Open Calls aimed to amplify the visibility of participating SMEs and start-ups within the 5G and automotive communities, as well as across the broader EU innovation landscape. This exposure, coupled with direct *funding support* for some of the participant SMEs awarded after rigorous evaluation processes in both calls (see Section 2.4), helped SMEs strengthen their position in the 5G ecosystem, paving the way for future opportunities and growth.
- **Support without funding**. Notably, all participating SMEs were encouraged to leverage the 5G-IANA platform and the comprehensive support offered through both Open Call rounds, *regardless* of whether they were awarded with *funding or not*. This opportunity was extended to all SMEs with sound and meaningful microproject proposals that *aligned with the capabilities and objectives of the 5G-IANA* infrastructure.
- **Business Exploitation Plan Modelling.** Each participating SME was provided with a customized Business Model Canvas (BMC) and a detailed Strengths, Weakness, Opportunities, Threats (SWOT) Analysis, with individual reports shared per 3rd party as detailed in Section 0. SWOT analysis [3][1] is a frequently employed strategic tool to reveal competitive advantages and to assist decision-making by evaluating an entity's strategic position in order to pinpoint internal and external factors that may facilitate or impede the attainment of its objectives. The BMC, on the other, is a strategic tool designed to support the development of new business models and the improvement of existing ones, i.e. it is ideal for the context of this Open Call to SMEs and start-ups. It visually outlines key elements of a business, including its value proposition, infrastructure, customer relationships, and financial structure, in a clear

and accessible way. It is based on nine foundational components that simplify the representation of business operations without requiring detailed exploration of complex strategies [3] [5]. As a tool, the BMC is appreciated for helping organizations align their activities by identifying and managing trade-offs among different functions [4]. It is also recognized for its effectiveness in enabling creative sessions aimed at designing innovative business models [6].

2.3 Timelines

2.3.1 Open Call 1

Table 1 below overviews the timeline followed during Open Call 1, including key milestones and activities of Open Call 1. The reader may refer to details already documented in Section 3.2.3 of deliverable D6.3 [7].

Table 1. Overview of the timeline followed during Open Call 1.

Date	Activity
February 2023	Launch of Open Call 1: Applications are accepted from this date.
June 9th, 2023	Deadline for Submissions: Applications must be submitted by this date.
June 2023	Pre-testing phase begins.
July 2023	Pre-testing phase ends (end of July). Validation phase begins immediately thereafter.
October 2023	Validation phase concludes.
November 2023	Reporting period begins: Participants prepare and submit detailed reports on their results and activities.
December 2023	Award phase: Final evaluation and announcement of the awarded microproject based on delivered results.

2.3.2 Open Call 2

Table 2 summarises the timeline of Open Call 2. Notice that the "Step-wise Rolling Basis Process" begins after January 20th and continues until four proposed microprojects are approved to start with funding support. This process is not tied to specific deadline dates but follows a sequential order of application evaluation, ensuring that four eligible and high-quality applications are selected for funding. It is important to note that excellent applications submitted later in the timeline can still participate in the call and receive technical and mentoring support; however, they will not be eligible for funding support.

Table 2. General Timeline of Open Call 2.

Date	Activity
January 20th, 2024	Launch of Open Call 2.
March 19th, 2024	Info Day online [1] to promote Open Call 2 to interested SMEs and start-ups.
January 20th, 2024 onwards	Step-wise Rolling Basis Process: A strict application submission order enforced until four eligible and excellent applications are accepted for funding.
	• Step 1: Submission of applications.
	• Step 2: Applications evaluation.
	• Step 3: Notification of application acceptance or rejection.
	• Step 4: Preparation and signing of the microproject agreement, followed by the release of funding installment 1.
	• Step 5: Start of the experimentation phase with mentorship support.
October 2024	• Deadline for the conclusion of experiments: October 18th, 2024
	• Submission of the final written report and video-recording of demonstration/experimentation: October 31st, 2024; possible extension until November 18th, 2024 upon request by experimenters or resubmission requested by technical evaluation committee.
	• Evaluation of final deliverables (Written Report and Video-recorded demo), and decision to release funding installment 2 upon acceptance of deliverables: November 2024.

2.4 Funding Selection Process and Criteria for Microprojects

2.4.1 Open Call 1

The selection process for Open Call 1 was meticulously designed to evaluate microprojects with the goal of funding *a single microproject*, specifically the one demonstrating the highest-scored results as per the recommendations of a technical evaluation committee. This rigorous evaluation process emphasized three key criteria: *Excellence*, *Implementation*, and *Impact*. Each criterion was carefully weighted to ensure a comprehensive and balanced assessment of the proposed microprojects. A detailed discussion and analysis of this evaluation methodology can be found in Sections 3.4.2 and 3.4.3 of deliverable D6.3 [7].

The technical evaluation committee for Open Call 1 was tasked with conducting an in-depth review of the submitted microproject outcomes after the conclusion of the call in December 2023, ensuring that the funding decision process upheld the highest standards of fairness, transparency, and technical rigor.

2.4.1.1 Technical Evaluation Committee

The technical evaluation committee consisted of experts from 5G-IANA member organizations, as well as two external experts. The members of the committee were as follows:

(i) Eirini Liotou (Institute of Communication and Computer Systems)
(ii) Konstantinos Katsaros (Institute of Communication and Computer Systems)
(iii) Dimitris Klonidis (UBITECH)
(iv) Gabriele Scivoletto (Nextworks)
(v) Edoardo Bonetto (LINKS Foundation)
(vi) Theodoros Rokkas (INCITES Consulting)
(vii) Markus Wimmer (Nokia)
(viii) Peter Zidar (Telekom Slovenije)
(ix) Richard Bishop (Bishop Consulting) – *external member*
(x) Tomasz Mach (Samsung) – *external member*

2.4.2 Open Call 2

Open Call 2 followed a *two-round evaluation process* to funding awards *compared to the single-round evaluation at the end of Open Call*. Based on the accumulated experience from Open Call 2, this change in approaching evaluation served to award *30%* of their awarded *funding in advance* after Evaluation Round 1, under the provision of completing their corresponding microproject service. This initial payment aimed to enable the awarded SME or start-ups to begin implementation activities, including deployment, testing, and conducting demonstrations and experiments. Evaluation Round 2 recommended the release of the remaining 70% of the funding award, with the provision that the initial instalment could be retracted in the event of failure to deliver or the submission of unacceptable deliverables.

While the results of evaluation round 1 and 2 are discussed in Section 4.2.1 and Section 0, respectively, the procedural details of both evaluation rounds are discussed below in Section 2.4.2.1 and Section 2.4.2.2, respectively.

2.4.2.1 ***Evaluation Round 1 –*** *granting 30% of awarded funding in advance*

In the first round, *four proposals were pre-selected for funding* among the submitted proposals by ensuring (i) fairness and alignment with the 5G-IANA objectives; and compliance to (ii) the *general eligibility criteria* (see Section 2.1.1) (iii) the *additional funding terms* applied to Open Call 2 (see Section 2.1.2).

(A) <u>Strict application submission order applied</u>

As outlined in the Open Call 2 public announcement on the 5G-IANA website [8], and in accordance to the terms arrayed in Section 2.1.2, a *strict application submission order was enforced* for the *limited funding* available. Applications submitted by 3rd parties later than others were deemed ineligible for funding. However, these applicants:

(i) were placed on a reserve list with respect to their application submisison order — provided they met the funding eligibility criteria and passed the application evaluation criteria— to be considered if any of the initially selected funding recipients withdrew or failed to meet intermediate milestones during the open call;

(ii) were encouraged to participate from the begining of the call without funding by utilizing the 5G-IANA platform and taking advantage of the available mentoring opportunities.

(B) Funding Exclusion Criteria

Further to the general eligibility criteria, applicants to Open Call 2 were required to meet *additional eligibility criteria* regarding *funding* support. Organizations or individuals were *ineligible* to apply for *funding* if they were, or were *affiliated* with, an existing ICT-41 beneficiary. Similarly, applicants who had previously received funding through a 5G PPP Open Call were also excluded from eligibility. However, third-party entities restricted from receiving funding under these criteria *were eligible to participate without funding* to utilize the 5G-IANA platform and benefit from the mentoring opportunities provided, although no financial support was available to them under Open Call 2.

(C) **Application Evaluation Criteria**

The Round One Pre-selection Evaluation Criteria focused on three main areas: **Feasibility**, **Application Objectives**, and **5G Connectivity & Impact**, ensuring a comprehensive assessment of the proposed microprojects.

- **Feasibility:** regards the practicality of the ideas presented in the application, assessing how realistic and achievable the proposed service, product, or use case was. This included identifying potential risks that could hinder successful implementation and evaluating the soundness of the approach, particularly its alignment with the capabilities of the 5G-IANA platform. An important aspect was the interoperability between the applicant's components and the infrastructure provided by 5G-IANA, which was critical for ensuring seamless integration.
- **Application Objectives**: the degree of alignment between the proposed project's goals and the overarching objectives of the 5G-IANA initiative was a key consideration. The quality and effectiveness of the experimental process outlined in the application were also assessed, along with the extent to which

the project leveraged the 5G-IANA platform's tools, such as nApps and virtual functions. Additionally, the quality of the report accompanying the application was reviewed as an indicator of the applicant's ability to deliver clear and structured outcomes.

- **5G Connectivity & Impact:** criteria evaluated the extent to which the project exploited 5G capabilities and demonstrated the added value that 5G technology could bring to the proposed experiment. The business and market potential, as well as the industrial impact for the SME, were critical factors, along with the anticipated benefits for the 5G-IANA platform itself, such as increased visibility or showcasing high potential. The expected outcomes were also analyzed to ensure that the project could contribute meaningfully to the goals of 5G-IANA and the broader 5G ecosystem.

(D) **Microproject agreement and releasing/retracting 30% of awarded funding in advance**

Selected SMEs were required to sign a microproject agreement and received 30% of their awarded funding in advance from ICCS. This initial payment allowed them to commence implementation activities, such as deployment, testing, and conducting demonstrations and experiments. It is important to note that *failure* to deliver the required outcomes or to successfully pass Evaluation Round 2 would result in the *retraction of the previously released 30% of funding in advance*, as stipulated in the microproject agreement.

2.4.2.2 ***Evaluation Round 2*** *– releasing the remaining 70% of awarded funding*

The second round focused on validating the final deliverables, which included:

1. A video recording of a live demonstration of running their service over the 5G-IANA infrastructure.
2. A written report following a specific template.

Both deliverables were thoroughly evaluated to ensure they met the required standards.

- **Upon successful validation**: the committee would recommend to the General Assembly the release of the remaining 70% of the funding.
- **Upon unsuccessful** validation or failure to deliver: in cases of unsuccessful validation or failure to deliver either the video demonstration or the written report, the committee would recommend to the General Assembly the retraction of the previously released 30% of the funding award and advised against releasing the remaining 70%. This decision was made in accordance with the relevant terms outlined in the signed microproject agreement.

Final deliverables

The final deliverables for 5G-IANA Open Call participants were assessed by technical experts based on two key components: **(i) a Video-Recorded Demonstration** and **(ii) a Written Report**. Both deliverables were expected to meet specific quality standards and align with the objectives of the 5G-IANA project.

1. **Video-Recorded Demonstration:**

The video-recorded demonstration served as tangible proof of the solution's implementation, testing, and demonstration. The evaluation focused on several key criteria to ensure the video met the required standards. Firstly, the video needed to clearly present *(i) a scenario* relevant to the solution and the use case being delivered. It was expected to showcase how 5G capabilities were exploited, highlighting the unique value that 5G brought to the experiment.

The approach demonstrated in the video had to *(ii) be sound* and *(iii) effectively built on the 5G-IANA platform*. Furthermore, the video needed to provide evidence of (iv) interoperability between the experimenters' own components and the elements provided by 5G-IANA. The content was also evaluated for its alignment with the commitments made by the SME in their original proposal, ensuring consistency between what was planned and what was achieved.

Depending on the nature of the implemented solution and the specific requirements of the demonstration, the video could include (v) various forms of content such as graphics or animations, execution console recordings, real-life footage, or any other relevant materials that matched the scope of the solution. This flexibility aimed to allow the SMEs to adapt their presentation style to best reflect the nature of their innovation.

2. Written Report:

The written report followed a *specific template* distributed to SMEs and was assessed based on its structure and the depth of information provided. The report template along with bullet-pointed hints to the authors is arrayed below. Note that numbered items must be mapped to corresponding report sections, hence the following poses a table of contents for the template along billet-pointed clarifying hints or comments:

1. **Introduction**:
    - Use case overview and testbed choice.
    - High-level and technical objectives.
2. **Project Timeline**:
    - Detailed milestones, phases, and a Gantt chart or relevant graphic representation.
3. **Demonstration**:
    - Setup details, including the demo setup, 5G-IANA components used, and relevant dates.
    - A description of the demonstration, along with a qualitative analysis.
4. **Exploitation of Results**:
    - Business impact of the solution and its integration with 5G-IANA.
    - Assessment of the value provided by the Open Call, coaching, and platform.
    - Challenges encountered and suggestions for future improvements.
5. **Conclusion and Future Plans**:
    - Insights gained during the Open Call and the envisioned direction for further development.

6. **Multimedia References**:
    - Links to video recordings related to demos or promotional materials.

Besides the mandatory template, the written deliverable reports were carefully assessed to ensure they met completed and reported microproject *(i) aligned with the overall objectives of the 5G-IANA* project, ensuring consistency and relevance to the project's mission. The *(ii) quality and effectiveness* of the *experimental process* were also scrutinized, along with the degree to which the SMEs leveraged the 5G-IANA platform. This included the use of its nApps and AOEP functions, demonstrating the platform's utility in supporting innovation. Additionally, evaluators considered *(iii) the extent to which 5G capabilities were exploited* in the experiment and the unique value these technologies brought to the proposed solution.

Another critical factor was the *(iv) business and market potential* of the delivered service, along with their industrial impact for the SME. The ability of the solution to *(v) add value to the 5G-IANA platform itself,* whether through increased visibility or showcasing high potential, was also a significant part of the evaluation.

Lastly, the assessment included *(vi) verifying the alignment between the proposed solution and the final implementation outcomes*, ensuring that the deliverables were consistent with the original commitments made by the SME.

2.4.2.3 Technical Evaluation Committee

The evaluation committee consisted of experts from 5G-IANA member organizations, as well as two external experts. The members of the committee were as follows:

(i) Thanos Xirofotos (UBITECH)

(ii) Gabriele Scivoletto (Nextworks)

(iii) Edoardo Bonetto (LINKS Foundation)

(iv) Markus Wimmer (Nokia)

3 5G-IANA Support to Microprojects

3.1 5G network resources and platforms

To support third-party microprojects by the external experimenter SMEs or start-ups, the 5G-IANA project made AOEP available to Open Call participants. This open and flexible framework, designed for creating and deploying innovative 5G-based automotive services, was accompanied by coaching sessions provided by 5G-IANA to help participants understand how to use the platform effectively and leverage its automation advantages for developing, deploying, and testing their nApp services.

The AOEP [9] features a modular architecture comprising two primary layers: the *nApp Orchestration and Development (**NOD**) layer* and the *Slice Management and Resource Orchestration layer*. These layers provide a structured separation of roles and responsibilities, ensuring seamless integration [12] of software and hardware components by the experimenters. Through the NOD layer, Open Call participants were guided in real-time application deployment and management using the *5G-IANA Toolkit*, which empowers developers to create, configure, and manage network-driven services. This toolkit includes the *Network Application Catalogue,* hosting 63 network functions and application functions (NFs/AFs) used in the final use case service chain, as detailed in deliverable D4.3 [10]. Additionally, participants received support in leveraging custom-developed NFs/AFs, further elaborated deliverable D4.4 [11].

The AOEP also provides runtime features like telemetry for collecting real-time metrics and the *Extreme-Edge Orchestration (EEO)* framework, which manages distributed tasks on edge devices such as OBUs and RSUs. These edge nodes, equipped with 5G communication hardware and computing resources, were crucial for enabling edge-based computation and real-time application management. The hardware, including RAN components, 5G modems, edge servers, and network slicing infrastructure, was made accessible to participants via testbeds hosted at Nokia (Ulm) and Telekom Slovenije (Ljubljana), as outlined in deliverable D3.4 [12].

This combination of advanced software and robust hardware ensured that the AOEP provided a scalable, adaptable environment for cutting-edge automotive and edge computing innovation. Participants were coached on the platform's capabilities, as thoroughly documented in documents D3.1 [13] and D3.3 [14] , ensuring they could effectively utilize the AOEP to achieve their objectives.

3.2 Mentoring

The mentoring scheme involved individual calls, webinars and direct communication with the 3rd parties. The support details for each open call, including the mentors and a briefed background for each mentor, are arrayed in the following subsections.

3.2.1 Open Call 1

This section provides additional information to deliverable D6.3 [7] regarding Open Call 1 mentoring, covering activities and outcomes from December 2023 until its completion in April 2024. The four participants that declared their interest in Open Call 1: **roadsAI**; **Link Robotics**; **Level 7** and **RFSAT**. **RoadsAI** engaged in regular discussions but had to suspend all activities due to the ongoing war in Israel. Also, **RFSAT** filed an application but did not move forward with further engagement.

As a result, the 3rd parties benefiting from the mentoring scheme during Open Call 2 were Link Robotics and Level 7. The coaching support was carefully structured to ensure comprehensive assistance throughout the process.

1. One *webinar* was conducted to introduce participants to the deployment process on the 5G-IANA platform. This session included guidance on GitLab processes and instructions for collecting and preparing the requirements necessary for software onboarding.

2. *Peer-to-peer coaching sessions* with the mentors (see Table 3) were held per request by the 3rd parties that continued in the open call, providing direct support to the companies that continued up until the end of the call (Link Robotics and Level7).

3. Technical support based on a ticketing system, according to which users could send an e-mail to helpdesk@5g-iana.eu, to be handled by the 5G-IANA helpdesk as soon as possible.

4. Additionally, on-site technical support was made available at NOKIA testbeds for Link Robotics, facilitating their experimentation and testing activities. Unfortunately, Level 7 did not progress to the on-site experimentation stage within the given timeline until December 2023, while roadsAI and RFSAT had already withdrawn from the process.

Table 3. Open Call 1 Mentors.

Mentor Name	Role	Background
Eirini Liotou	Scientific Project Manager, ICCS	Senior researcher and Deputy Project Coordinator for 5G-IANA, expert in Quality of Service management, Federated Learning, and SDN.
Konstantinos V. Katsaros	Scientific Project Manager, Head of Intelligent Networks & Services, I-SENSE / ICCS	Specializes in Federated Learning management and Beyond 5G network orchestration, with experience in NFV, MEC, and SDN for 5G networks.
Dimitris Klonidis	Head of Network Softwarization & IoT Unit, UBITECH	Has over 160 publications and expertise in 5G/6G network automation and edge computing.
Matteo Andolfi	R&D Senior Software Engineer, Nextworks S.R.L.	Experienced in Big Data, DevOps tools, and tailored solutions for complex requirements using diverse technologies.
Edoardo Bonetto	Researcher, LINKS Foundation	Focuses on mobile network evolution and connected vehicle safety applications, with expertise in V2X and MEC solutions.
Theodoros Rokkas	CTO, InCites Consulting SA	Specialist in techno-economic evaluations, network planning, and business modeling for next-generation networks.
Markus Wimmer	System Specification Engineer, Nokia Solutions and Networks	25+ years in cellular radio technology, focusing on low-latency V2X communications.
Peter Zidar	Specialist, Telekom Slovenije	Led several successful EU projects with expertise in telecommunications research and project coordination.
Richard Bishop	Principal, Automated Driving Strategy & Partnership, Bishop Consulting	Pioneer in automated vehicle strategies, with over 25 years of experience advising global automotive and government stakeholders.
Tomasz Mach	Chief Engineer, Samsung R&D Institute UK	Thought leader in mobile communications standards and Beyond 5G systems, with numerous patents and research contributions.

3.2.2 Open Call 2

The coaching scheme for Open Call 2 was designed to provide comprehensive guidance and support to participating SMEs throughout their engagement with the project's Open Call. A series of tailored activities and resources were implemented and reserved, respectively, to ensure participants received the mentorship and technical support necessary via getting equipped with the knowledge, tools, and support required to achieve their objectives and maximize the success of their microprojects:

- **Communication support.** Asynchronous communication support was provided through a purpose-built dedicated email list (open-call-2-coaching-team@lists.5g-iana.eu), while synchronous though individual Slack channels for instant messaging. Each participant had access to a dedicated Slack channel (oc2-coaching-<SME_name>) within the 5G-IANA Slack workspace, ensuring immediate and direct communication with mentors.
- **Online mentoring sessions (6x).** Six individual online mentoring sessions were held with each Open Call 2 participant SME with the with the mentors. (see Table 4) These sessions were interactive, with coaches facilitating active Q&A discussions to address specific participant needs and challenges.
- **Webinars (3x).** To supplement individual mentoring, three targeted webinars were conducted. The first webinar introduced participants to the 5G-IANA platform, providing essential information on its features and functionalities. The second webinar focused on onboarding to the AOEP platform, equipping participants with the knowledge needed for effective utilization. The third webinar addressed business exploitation planning, helping participants align their project goals with market opportunities.
- **Business Canvas & SWOT Analysis:** Each participant SME was provided with tools to enhance their strategic planning. This included access to a tailored Business Canvas and SWOT Analysis, as outlined in Section 0.

Table 4. Open Call 2 Mentors.

Mentor Name	Role	Background
Xenofon Vasilakos	Scientific Project Manager and Senior Researcher, i-Sense, ICCS	Specializes in 6G MEC architectures, applied ML intelligence, and Zero-touch Self-Managed networking.
Konstantinos V. Katsaros	Scientific Project Manager, Head of Intelligent Networks & Services, i-SENSE / ICCS	Leads projects on Federated Learning management, B5G/6G networks, and orchestration in automotive environments.
Dimitris Klonidis	Head of Network Softwarization & IoT Unit, UBITECH	Expert in 5G/6G network automation and cloud-edge computing with 160+ publications.
Thanos Xirofotos	Researcher, Network Softwarization and IoT Unit, UBITECH	Expert in 5G/6G network automation, edge computing, mobile edge computing, network slicing, and virtual network functions.
Gabriele Scivoletto	R&D Senior Software Engineer, Nextworks S.R.L.	Specialist in embedded systems and software solutions for Industry 4.0/5.0 and 5G projects.
Edoardo Bonetto	Researcher, LINKS Foundation	Focuses on V2X communication solutions and safety applications for connected vehicles.
Theodoros Rokkas	CTO, InCites Consulting SA	Expert in techno-economic evaluations, next-generation access networks, and network planning.
Markus Wimmer	System Specification Engineer, Nokia Solutions and Networks	Over 25 years of expertise in cellular radio technologies with a focus on V2X communications.
Peter Zidar	Specialist, Telekom Slovenije	Led multiple successful EU projects in telecommunications research and project coordination.
Richard Bishop	Principal, Automated Driving Strategy & Partnership, Bishop Consulting	Pioneer in intelligent, connected, and automated vehicle strategies with 25+ years of global experience.

3.2.3 BMC & SWOT Analysis

Each participating SME was provided with a customized BMC and a detailed SWOT Analysis as instrumental tools in guiding the participants through a structured evaluation of their strengths, weaknesses, opportunities, and threats. The Business Canvas facilitated a comprehensive overview of their value proposition, customer segments, key resources, and revenue streams, enabling a systematic approach to refining their business models.

Additionally, the SWOT Analysis provided actionable insights into competitive positioning and market dynamics, helping participants identify areas for improvement and capitalize on emerging opportunities. For example, in the case of Diamantis's "5G-STREAM," the modeling process emphasized scalability, energy independence, and sustainability as core value propositions. It also highlighted the importance of leveraging early adopters, such as municipalities and transport providers, for pilot projects to demonstrate real-world applicability.

All in all, the 5G-IANA business report submitted to the participants (see subsections below) helped them clarify their value proposition, supported them in articulating the market gaps they can penetrate, supported them in the articulation of a unique selling point, helped them identify specific customer segments, provided insights on the target market size, growth trends and drivers, suggested collaboration strategies and helped them design a marketing plan.

3.2.3.1 SWOT Analysis per 3rd party

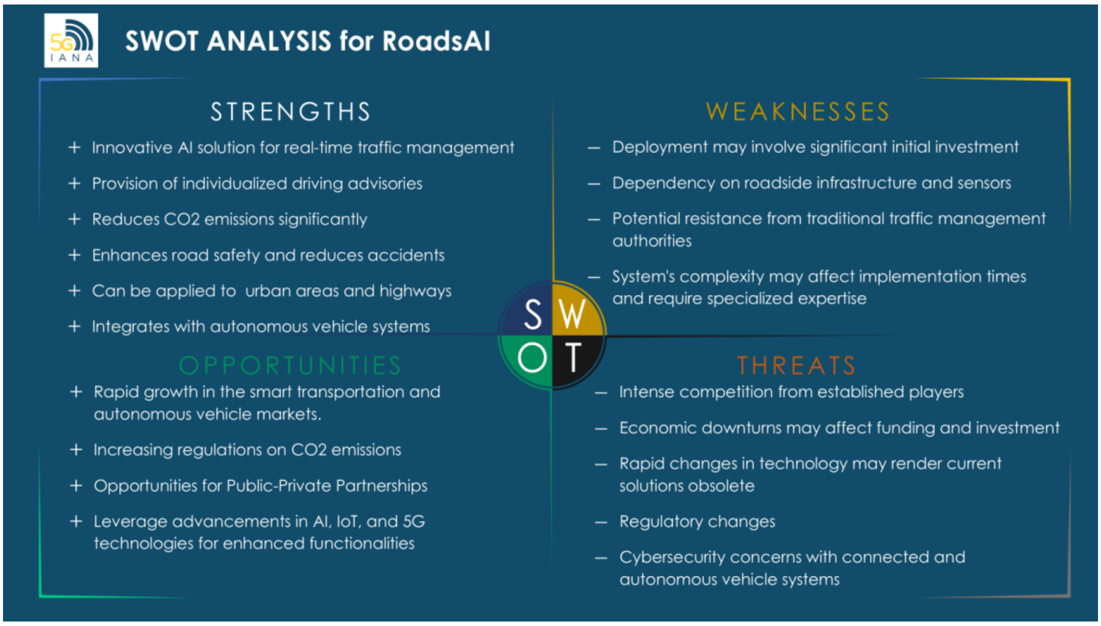

Figure 1. SWOT Analysis for roadsAI

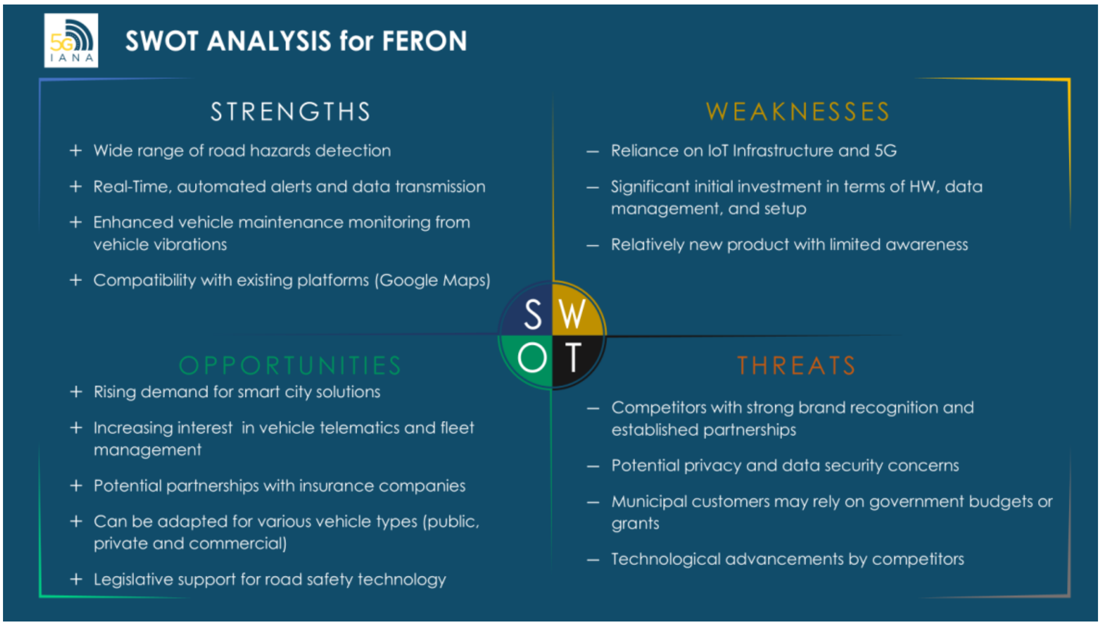

Figure 2. SWOT Analysis for FERON.

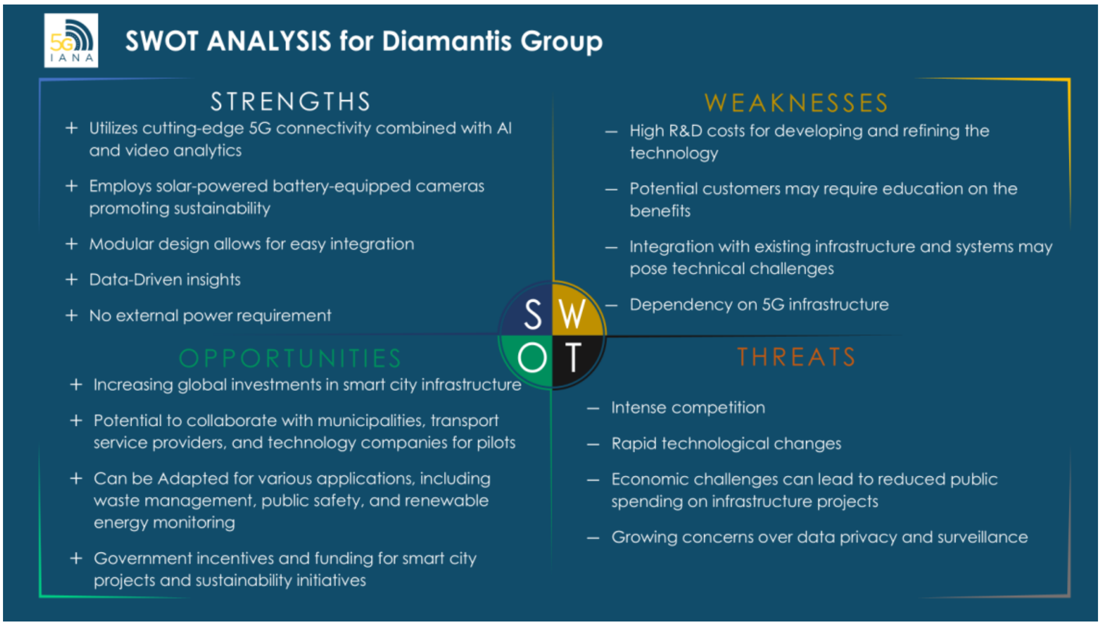

Figure 3. SWOT Analysis for Diamantis.

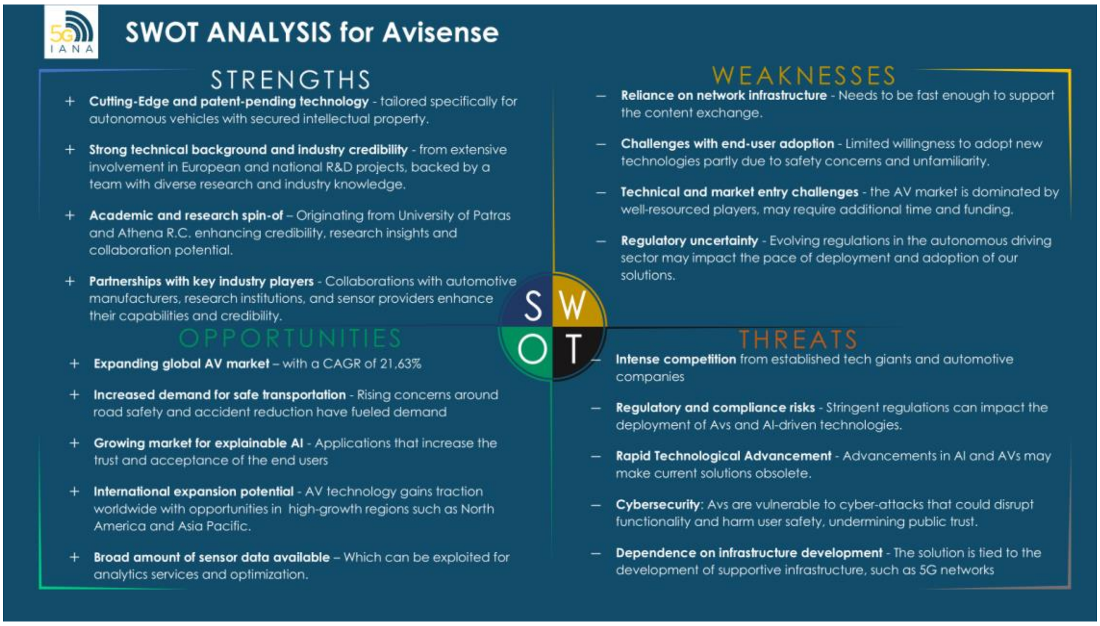

Figure 4. SWOT Analysis for AviSense

3.2.3.2 BMC per 3rd party

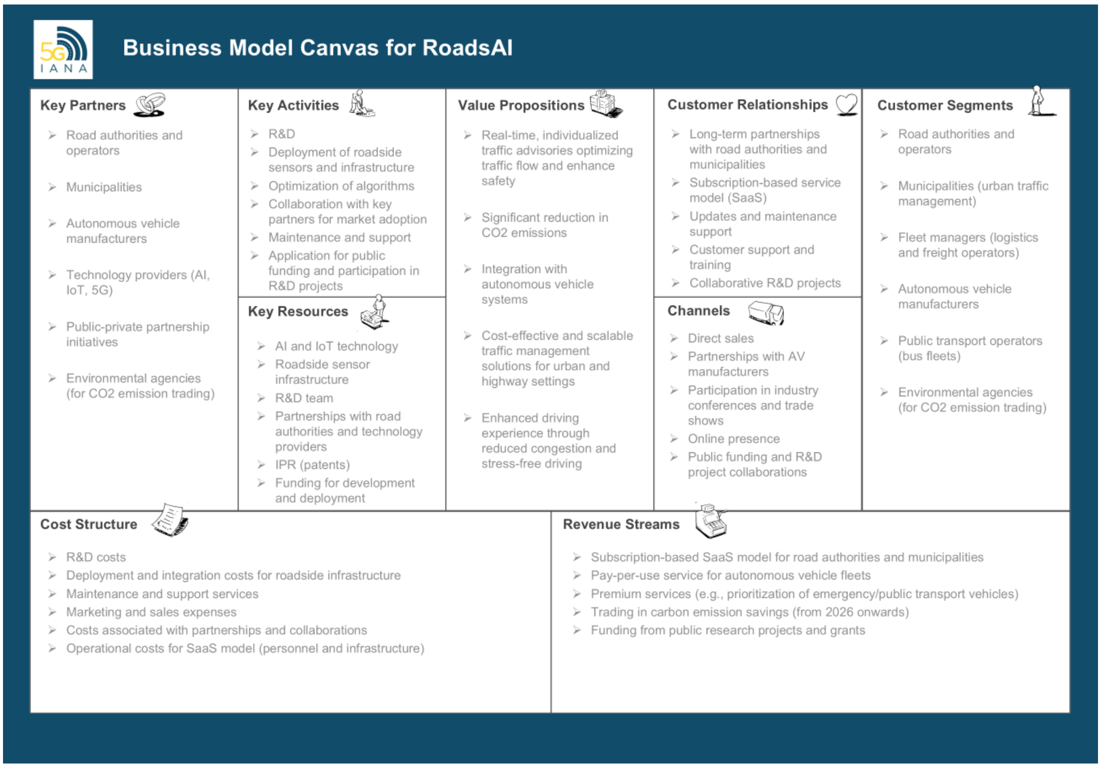

Figure 5. BMC for roadsAI.

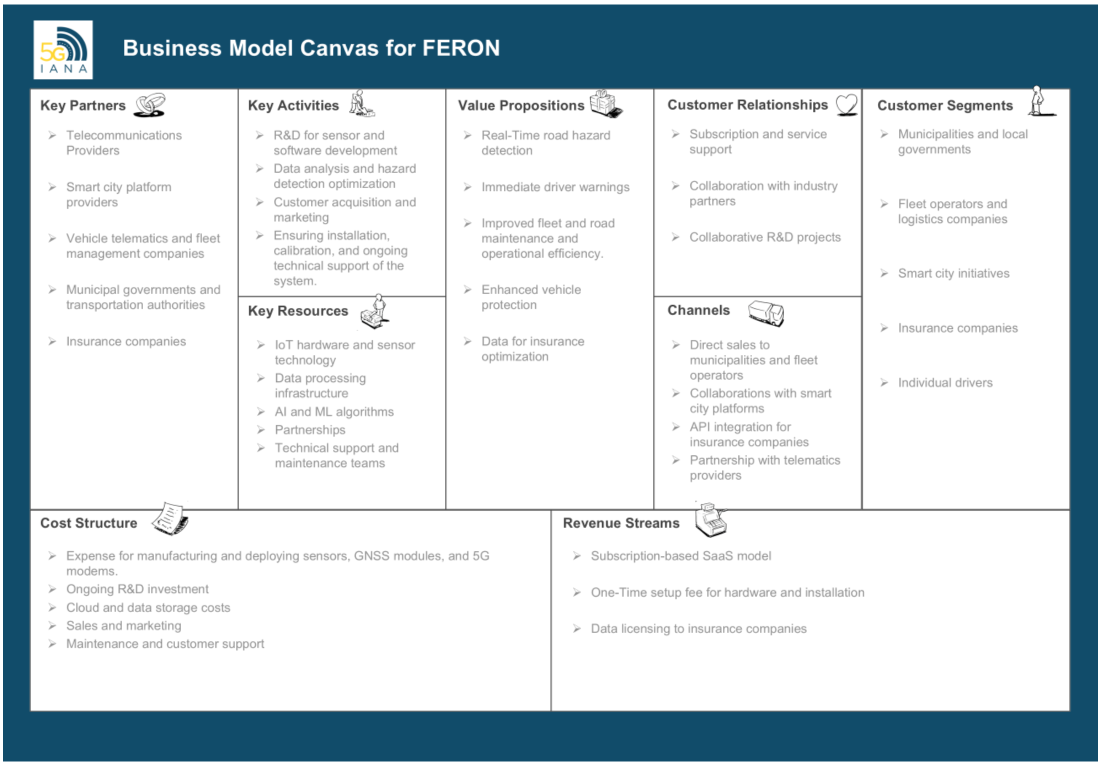

Figure 6. BMC for FERON.

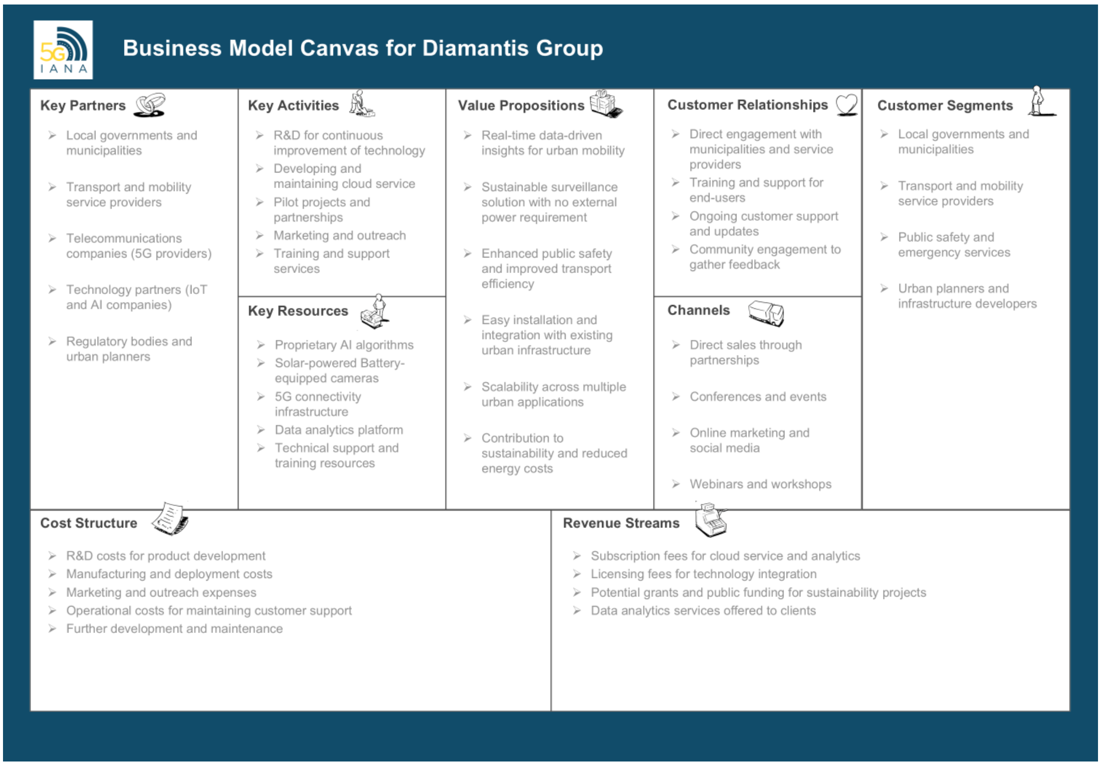

Figure 7. BMC for Diamantis.

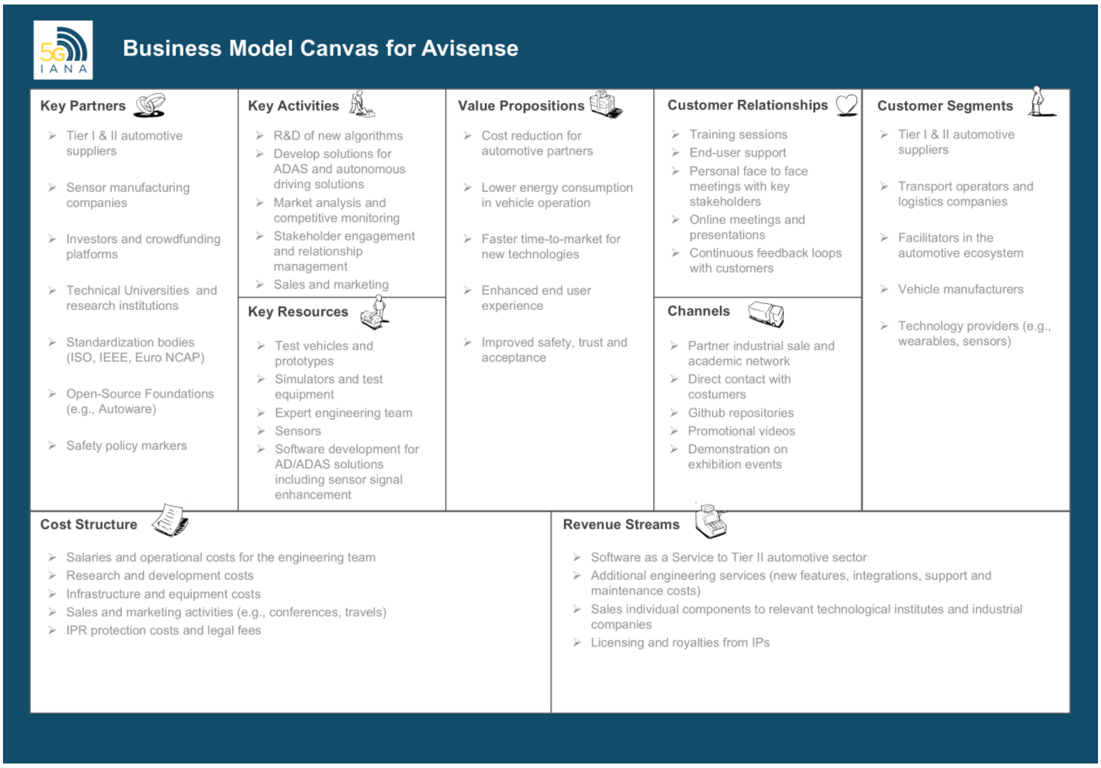

Figure 8. BMC for AviSense.

4 Microservices Proposed Applications and Reported Results

4.1 Open Call 1

4.1.1 Signed microproject agreements

Four participants declared their interest in Open Call 1, namely, roadsAI, Link Robotics, Level 7, RFSAT. However, only three actively engaged and RFSAT stopped engaging after applying. As a result, microproject agreements were signed only with **Level7**, **Link Robotics**, and **roadsAI**, with details summarized in Table 5. Coaching support was provided to all three participants, with continued support until December 2023 for Level7 and Link Robotics after roadsAI's withdrawal.

Table 5. SMEs with signed microproject agreements.

Company Legal Title	Representative	Country & Address
D.R roadsAI Ltd.	Roni Dulberg (CEO)	18 Hasivim Street, Petach Tikva, Israel
Link Robotik Teknolojileri Mak. San ve Tic A.S.	Berk TURANLI and Mert TURANLI	Sahrayicedit Mah. Ataturk Cad. Osman Nuri Ergin Sk. No:12/3, Kadikoy, Istanbul, Turkiye
Level7	Paolo DI FRANCESCO (CEO)	Largo Montalto 5, Palermo, Italy

Out of the three, *only* ***Link Robotics*** *successfully validated* their experiment and delivered their microproject results within the timeline of the Open Call outlined in deliverable D6.3 [7].

RoadsAI engaged in regular discussions but had to suspend all activities due to the ongoing war in Israel. Last, **Level7**, did not complete their effort within the timeline of the Open Call,

4.1.2 Final Evaluation

Table 6 contains the evaluation score results regarding the microproject completion and delivery by Link Robotics, as suggested by the Technical Evaluation Committee.

Table 6. Open Call 1 evaluation score results for Link Robotics.

Evaluation Committee Member / Criterion	Eirini Liotou (ICCS)	Konstantinos Katsaros (ICCS)	Dimitris Klonidis (UBITECH)	Gabriele Scivoletto (NXW)	Edoardo Bonetto (LINKS)	Theodoros Rokkas (INCITES)	Markus Wimmer (NOKIA)	Peter Zidar (TELECOM SLOVENIA	Richard Bishop (Bishop Consulting)	Tomasz Mach (Samsung)
Excellence	4	4	4	4	4	4	4	4	3	No longer in Samsung – could not contact
Implementation	4	4	4	4	4	4	4	4	4	
Impact	4	3	4	4	5	4	4	4	5	

The evaluation process for experiments in Open Call 1 utilized a standardized scoring framework to assess the quality and relevance of submissions. Each submission was evaluated against three criteria, with scores ranging from 0 to 5 for each criterion. As a result, the maximum possible score assigned by a reviewer was 15, with a minimum score of 0. The scoring framework applied above is defined below:

- **Fail (0):** The experiment failed to address the criterion or could not be assessed due to missing or incomplete information.
- **Poor (1):** The criterion was inadequately addressed, or the experiment exhibited serious inherent weaknesses.
- **Fair (2):** The experiment broadly addressed the criterion but had significant weaknesses.
- **Good (3):** The experiment addressed the criterion well, though a number of shortcomings were identified.
- **Very Good (4):** The experiment addressed the criterion very well, with only a small number of minor shortcomings.
- **Excellent (5):** The experiment successfully addressed all relevant aspects of the criterion, with any shortcomings being minor.

This scoring framework was applied to all participants at the conclusion of the Open Call to determine the experiment with the highest overall score. The highest-scoring experiment was awarded funding of €15,000 based on its performance.

4.1.3 Final Verdict

Among the participants, **Link Robotics** successfully delivered their report and video demonstration within the prescribed deadline for Open Call 1, which concluded in December 2023. Based on the evaluation conducted using the framework described above, Link Robotics achieved the highest score and **was awarded the funding of €15,000.**

For completeness, **Level 7** submitted reporting documents via email on **July 11, 2024**, i.e. *over six months* after the December 2023 deadline. While their effort to report results is acknowledged, it was not evaluated nor considered for funding due to violating the established deadline.

4.2 Open Call 2

Open Call 2 received applications by the following *eight (8) SMEs* of Table 7. The table also includes submission dates and the recorded order of submission per applicant, ensuring compliance with the requirement for a *strict submission sequence* followed to identify the first four eligible and high-quality proposals for funding.

Table 7. Third party companies that applied for Open Cal 2.

Applicant	Submission Date	Submission
RFSAT	2024-03-08	1
Diamantis	2024-03-20	2
Feron	2024-03-23	3
RoadsAI	2024-04-01	4
Neobility	2024-04-08	5
Infolysis	2024-04-12	6
AviSense	2024-04-26	7
Wings	2024-05-01	8

Table 8. Preselection of four companies for funding support.

Applicant Company	Final Verdict
RFSAT	Rejected based on evaluation
Diamantis	Accepted
Feron	Accepted
roadsAI	Accepted
Neobility	Without funding: Already an ICT-41 beneficiary based on CORDIS.
INFOLYSIS	Without funding: Already an ICT-41 beneficiary based on CORDIS.
AviSense	Accepted
Wings	Without funding: (i) submitted later than other applicants; and (ii) already an ICT-41 beneficiary based on CORDIS.

The results of evaluation round 1 and 2 are discussed next in Section 1 and Section 0, respectively. Note that the procedural details of both evaluation rounds are discussed earlier in Section 2.4.2.1 and Section 2.4.2.2, respectively.

4.2.1 Evaluation Round 1 Results

Whereas all original submitted applications can be found in the Table 10, a summary of technical reviews per application, as conducted by the technical evaluation committee is provided in Section 4.2.1.1. The reviews, along with the recommended verdict of the technical evaluation committee, were presented to the General Assembly on **June 10th, 2024**. The **General Assembly approved** the recommendation according to which (i) *Diamantis*, *Feron*, *roadsAI* and *INFOLYSIS* where proposed for funding; (ii) Neobility and Wings were *not* proposed for funding due to their engagement with other ICT-41 projects; (iii) with *AviSense designated as the first alternate* in case any of the selected companies needed to withdraw from the Open Call for any reason; (iv) RFSAT's proposal was rejected due to concerns regarding quality and technical feasibility.

Subsequently, *AviSense replaced INFOLYSIS:* INFOLYSIS *withdrew from funding* due to an eligibility issue related to its involvement as an ICT-41 beneficiary in project. Therefore, the release of the first installment of the **awarded funding** equal to **30%** of **the total** of €20,000, equating to **€7,000**, was **authorized** for Diamantis, Feron, roadsAI and AviSense.

Irrespective of funding, all companies but RFSAT (due to proposal rejection) were encouraged and invited to participate and benefit from coaching and access to the AOEP platform and 5G infrastructure, albeit without funding. Specifically, INFOLYSIS, Neobility, and Wings had filed sound proposals, hence were deemed acceptable, but were excluded from funding due to their association with other ICT-41 as verified through the CORDIS[1] database.

4.2.1.1 Summary of evaluations

The summary of evaluations for Open Call 2 proposals by the technical evaluation committee is arrayed per applicant below.

RFSAT evaluation summary

Feasibility: RFSAT's proposal raises several feasibility concerns. Integration of the RTK transceiver and satellite communication into the testbed requires further clarification. Additionally, the proposal lacks specifics about the intended network application, focusing instead on testing radar sensors and RTK receivers. Hardware usage also poses challenges, particularly with the connection of radar and RTK receivers to LINKS devices, adding complexity within the 5G-IANA timelines.

5G Connectivity: The necessity of 5G connectivity remains unclear due to the lack of application details. While the proposal acknowledges 5G's potential to sustain RTK-aided GNSS positioning, the absence of 5G positioning solutions in the testbeds limits its alignment with RFSAT's objectives.

Objectives: The lack of clarity regarding the intended network application complicates the evaluation of the proposal’s objectives. Despite some alignment, further details are required to confirm coherence with the 5G-IANA initiative.

[1] https://cordis.europa.eu/

DIAMANTIS evaluation summary

Feasibility: The proposal appears feasible but requires clarification regarding specific elements. Integration of required VNFs seems achievable, though timelines for extending Solar-powered Battery-equipped cameras (SB-CAMs) with 5G connectivity must be confirmed. Privacy concerns related to EU GDPR compliance also need to be explicitly addressed.

5G Connectivity: Video streaming demands a 20 Mbps UL capacity, which may limit test execution to specific testbeds, such as the TS testbed. The feasibility of video streaming depends on managing bandwidth requirements effectively.

Objectives: The proposal by Diamantis strongly aligns with 5G-IANA objectives, leveraging the platform's capabilities effectively. Collaboration with testbed owners will be key to ensuring feasibility and alignment with initiative goals.

FERON evaluation summary

Feasibility: FERON's proposal faces challenges, particularly in accessing IMU sensor data from connected vehicles. If LINKS OBUs, which lack IMUs, are utilized, integration with LPMS-U2 Sensors could address this issue but would require compatibility modifications. Alternatively, a laptop-based setup previously used in Nokia testbeds may offer a viable solution.

5G Connectivity: FERON's expectations for 5G align with the testbeds' capabilities, but legacy 4G connections may suffice for the latency requirements of IMU sensor data sharing. Vehicle availability for testing remains uncertain, and clarification on early warning mechanisms is needed.

Objectives: FERON's proposal aligns well with 5G-IANA's objectives, focusing on sensor integration compatible with OBUs. Additional clarification regarding sensor compatibility and mounting is necessary to ensure seamless execution.

roadsAI evaluation summary

Feasibility: The proposal from roadsAI presents a promising concept, though it faces significant challenges within the 5G-IANA framework due to its complexity. Testing large-scale scenarios using an emulator appears difficult, raising doubts about the feasibility of performance verification within the designated testbeds. Furthermore, the proposal's focus on performance verification does not fully align with the objectives of 5G-IANA. Implementation would require 2–3 vehicles equipped with OBUs (likely only achievable virtually) and potentially RTK, which raises concerns about the availability of RTK from NOKIA or TS, and the requirement for an RSU equipped with LiDAR/Camera sensors.

5G Connectivity: The proposal emphasizes the need for 5G connectivity to enable large bandwidth for sensor data sharing and low latency for maneuver coordination.

Objectives: While the proposed objectives have theoretical alignment with the 5G-IANA initiative, the primary focus seems to be on testing 5G networks rather than directly addressing the platform's objectives.

Neobility evaluation summary

Feasibility: Key concerns arise regarding the provision of two phones for connection and the type of monitoring required from NEF, which typically exposes 5G core data. Clarity is also needed on whether the network application will be deployed on user devices (Android phones) or solely on the edge/cloud side. Despite limited information, feasibility could improve if these issues are addressed.

5G Connectivity: The necessity for 5G connectivity appears low. Neither ultra-low latency nor MEC capabilities are essential for the proposal, as it does not involve safety-critical functions typical in CCAM scenarios.

Objectives: The proposal aligns moderately with 5G-IANA objectives but lacks detailed explanations. The necessity of 5G connectivity is questionable, requiring further clarification to establish its indispensability.

Note: The proposal was flagged due to Neobility’s previous funding under the ICT-42 initiative, making it ineligible for funding.

INFOLISYS evaluation summary

Feasibility: The proposal presents minor challenges related to Qualcomm Snapdragon X55 modem compatibility in Nokia testbeds. These can be resolved by using alternative tested modems connected via USB. However, the lack of specific maximum UL/DL rates and QoS requirements complicates the evaluation of test feasibility.

5G Connectivity: Questions arise regarding the necessity of 5G for deploying the application, which requires further clarification.

Objectives: INFOLISYS's proposal demonstrates strong alignment with 5G-IANA's goals. However, more details are needed to clarify the deployment strategy and the essential role of 5G in the proposed use case.

AviSense evaluation summary

Feasibility: AviSense's proposal is promising but hinges on critical factors such as the complexity of its three trial phases, which raises concerns about feasibility within the timeframe. Additionally, AviSense lacks experience in developing VNFs, and practical implementation requires a vehicle equipped with sensors and an RSU installed at the testbed, raising privacy considerations. A more focused scope with achievable objectives is recommended.

5G Connectivity: The proposal relies on robust 5G connectivity to handle sensor data exchange, particularly for real-time applications. However, current testbed limitations, such as the inability to meet the 40 Mbps uplink throughput requirement, present challenges. AviSense should recalibrate its expectations to align with testbed capabilities.

Objectives: The proposal aligns well with 5G-IANA goals but requires refinement to ensure practical implementation. A focused approach emphasizing attainable milestones would enhance its viability.

WINGS ICT Solutions evaluation summary

Feasibility: WINGS ICT Solutions' proposal is well-detailed but ambitious, with a six-month trial period that may be challenging within the project's timeline. Extensive sensor integration and stringent 5G KPIs further complicate implementation. Ensuring the availability of properly equipped vehicles and verifying the feasibility of KPIs are critical.

5G Connectivity: The proposal requires extremely low latency (<10 ms RTT) and high bandwidth (>100 Mbps UL/DL), which exceed the capabilities of the existing testbeds and most commercial networks. These requirements would be more feasible in localized environments like campus networks.

Objectives: The complexity of the proposal may hinder practical implementation within the timeframe. Simplification of the proposal and alignment with available infrastructure capabilities could enhance its feasibility.

4.2.1.2 Signed microproject agreements

Following evaluation round 1, the applicant companies selected to signed microproject agreements for Open Call 2 were:

Table 9. SMEs with signed microproject agreements in Open Call 2.

Company Legal Title	Representative	Country & Address
D.R roadsAI Ltd.	Roni Dulberg (CEO)	18 Hasivim Street, Petach Tikva, Israel
AviSense.ai Technovlastos P.C.	Gerasimos Arvanitis (CEO)	Epistimoniko Parko Patron, Stadiou P., 26500 Patra, Achaia, Greece
Diamantis AVEE	Konstantinos Diamantis (Principal Director)	3rd km of Regional Road Karditsas–Trikalon, 43100 Karditsa, Greece
FERON TECHNOLOGIES IKE (FERON)	Antonios Gkotsis (Managing Director)	30 Arachovis Street, 10681 Athens, Greece

4.2.2 Evaluation Round 2 Results

The Technical Evaluation Committee provided the following recommendation to the General Assembly on November 11, 2024 after reviewing the deliverables submitted by the applicants:

Table 10. Results recommended to and approved by the General Assembly. To revisit the case of roadsAI after requesting resubmission of written report.

Applicant	Recommended Verdict
AviSense	Accepted
Diamantis	Accepted
FERON	Accepted
roadsAI	Provisionally Accepted

The detailed proposed verdict was as follows:

(A) **AviSense, Diamantis, and FERON – Deliverable Acceptance:** All technical reviewers confirmed a successful outcome based on Demo video-recording and written report deliverables for AviSense[2], Diamantis[3], and FERON[4]. Consequently, the reviewers recommended that the consortium approve the individual written reports and video-recorded demonstrations submitted by these applicants.

(B) **roadsAI – Provisional Deliverable Acceptance:** For roadsAI, the technical reviewers agreed on accepting the video recording[5] of demonstration by roadsAI, and on *provisional acceptance* of the written report[6], contingent upon specific improvements to its written report. The required revisions included the following:

1. Adding additional details about the implementation, with a focus on how the 5G-IANA platform was leveraged.

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[2] Refer to Annex for the report. The video recording available on 5G-IANA's YouTube Channel and website [15].

[3] Refer to Annex for the report. The video recording available on 5G-IANA's YouTube Channel and website [16].

[4] Refer to Annex for the report. The video recording available on 5G-IANA's YouTube Channel and website [17].

[5] Video recording available on 5G-IANA's YouTube Channel and website [18].

[6] Originally submitted report included in the Annex.

2. Providing more context about the use case underlying the implementation.
3. Including evidence to support the video content related to the service chain and its integration into the 5G-IANA platform, such as screenshots or other forms of verification.
4. Removing an inaccurate reference regarding the unavailability of an OBU in the Telecom Slovenia testbed, as this statement was incorrect.

Timeline and Guidelines for roadsAI:

- **November 18, 2024**: Deadline for submission of the updated report, which was required to include:
  - A final revised version.
  - A version with tracked changes compared to the previous submission.

4.2.3 Final Verdict

The recommendations of the Technical Evaluation Committee were presented to the General Assembly on **November 11, 2024**. The meeting was attended by **14 out of 16 partner organizations (87.5%)**, exceeding the quorum requirement of more than two-thirds (66.7%) of the General Assembly members. All present members unanimously approved (100% of votes) the recommendations provided by the technical evaluators.

Decisions Approved by the General Assembly:

1. Approved the deliverables submitted by AviSense, Diamantis, and FERON.
2. **Authorized** the release of **final payments** to AviSense, Diamantis, and FERON. This amounts to **70% of the total awarded funding** of €20,000, equating to **€14,000**.
3. Granted provisional acceptance of roadsAI's deliverable, subject to the following process and timeline:
   - **November 18, 2024**: Deadline for roadsAI to submit the updated written report in two formats:
     - A final revised version.
     - A version with tracked changes.
   - **November 19, 2024**: Deadline for evaluators to review the updated report and provide a recommendation for the final decision.

- **November 20, 2024**: Xenofon Vasilakos communicated the final decision to the consortium.
- **November 22, 2024 (end of business)**: Deadline for all consortium partners to vote via email on the final evaluation decision and corresponding authorization of final payment release.

Successful resubmission and acceptance by roadsAI:

RoadsAI submitted the revised written report[7], as requested, on **November 18, 2024**. Following the established timeline, the evaluation committee reviewed the submission and released their recommendation to the consortium on **November 19, 2024**. The committee concluded that the final (revised) submission by roadsAI, including the written report and video demonstration, met the required standards and was accepted

Releasing final payment:

An email voting process was conducted among all consortium organizations. The consortium unanimously approved the evaluation committee's recommendation, with 100% of emailed votes in favor. Consequently, the consortium **formally approved** the deliverables submitted by **roadsAI** and authorized the **release of the final payment** to the applicant.

Table 11. Results of Open Call 2. All deliverables were accepted and all payments to participant SMEs can be released.

Microproject by	Recommended Verdict
AviSense	Accepted
Diamantis	Accepted
FERON	Accepted
roadsAI	Accepted

[7] Revised report submission included in the Annex.

5 Conclusion

The 5G-IANA project has consistently worked to promote and advance the development of automotive *Network Applications (nApps)*, fostering innovation and creating new business opportunities for *start-ups and SMEs in the automotive sector*. By leveraging 5G technologies, these enterprises have gained essential know-how to enhance their automotive-based services.

Through two rounds of *Open Calls*, the project successfully engaged third-party experimenters, including those without prior expertise in telecoms or 5G. Participants were supported in developing, deploying, and conducting realistic trials of their services as nApps within a *robust 5G environment*. Comprehensive support—encompassing mentoring, technical guidance, and access to *state-of-the-art testbed facilities* at NOKIA in Ulm, Germany, and Telekom Slovenije in Ljubljana, Slovenia—enabled participants to transform their automotive services into nApps and deploy them seamlessly on the *5G-IANA AOEP platform*.

This deliverable provides a detailed account of the organization and outcomes of the Open Calls, highlighting the impact of funded microprojects and their contributions to the broader *5G-IANA goals*. Participants achieved notable technical advancements while receiving extensive coaching to deepen their understanding of 5G technologies and refine business strategies through tailored SWOT analyses and Business Model Canvas workshops.

Overall, the completion of the two Open Calls underscores 5G-IANA's commitment to driving innovation and fostering the integration of 5G into real-world automotive applications.

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ANNEX

Proposed Microprojects

Open Call 1 - Link Robotics

5G-IANA Open Call Interest Form

General information

- Name and Surname (of contact person): Berk TURANLI
- E-mail (of contact person): Berk.turanli@linkrobotics.tech
- Is your organization characterized as an SME/start-up? Start-up
- Name of the organization: Link Robotics Inc
- Website of the organization: www.linkrobotics.tech
- Please provide a short description of your business (main activities, year of foundation, VAT number)

  Link Robotics, founded in 2016, is a deep tech startup working on AI based navigation and localization solutions with its capabilities in R&D product development and expertise in robotics field. Link Robotics Team currently consists of 4 engineers, 1 PhD, 1 Msc and 2 Junior Engineers. Link Robotics completed several R&D based national funded projects in its history and has 2 active funds one in R&D and one in Product Development. Link Robotics completed several Accelerators and maintained PoCs for products developed, under AI, Mobility and
  5G domain. Link Robotics completed a Pre-Accelerator supported by EIT Urban Mobility in 2022, and currently enrolled and will participate in future mobility thematic accelerator of EIT UM- Accelerate2Move accelerator. Link Robotics is also a part of Bilisim Vadisi Technopark ecosystem, a technopark focused on mobility vertical in Turkiye, and also has ties with Istanbul Technical University Technopark through ITU Seed, a famous incubator for tech startups. Our VAT number is [redacted]

- What is the country of establishment? Türkiye

Ambitions and development plans

- Describe the service/application or product that you plan to deploy in the 5G-IANA platform and the “use case/scenario” you would like to implement.

  VINS-RTK is a visual inertial odometry based localization system which can provide reliable position and orientation information of the vehicle real-time with the help of a monocular camera, inertial measurement unit and RTK-GNSS. It can be used as localization input for autonomous navigation of the vehicle.

The use case is a demonstration on an urban scenario, real road with traffic and pedestrians. An RTK service over Internet (NTRIP) will be used for the demonstration which can consist of a stationary RTK base station sending RTCM correction data over 5G network. The rover side will be VINS-RTK mounted on the vehicle. The product will give output the position and orientation of the vehicle while the vehicle is moving through the traffic.

- Provide more details about the experiment that you would like to run on the 5GIANA platform.

  The use case is a demonstration on an urban scenario, real road with traffic and pedestrians. An RTK service over Internet (NTRIP) will be used for the demonstration which can consist of a stationary RTK base station sending RTCM correction data over 5G network. The rover side will be VINS-RTK mounted on the vehicle, receiving the RTCM correction data by using a GSM modem and custom 5G interface card. The product will give output the position and orientation of the vehicle while the vehicle is moving through the traffic.

- What is the current stage of your product or service?
  - Idea phase
  - Under development
  - Demo
  - Prototype
  - Other: Validated Prototype

Experience

- Do you have any prior experience with EU R&D projects?

  We have applied to a Innovation call of EIT Urban Mobility - Future Mobility call.

- Have you already developed any Virtual Network Functions (VNFs) or network applications (nApps) to be utilized or are you planning to develop them? Provide more details:

  We have developed two network applications working through TCP/IP protocol. Both applications are written for Linux by using Qt platform. They were used as Graphical User Interfaces of two R&D projects.

  First of them is a stand alone 3D GUI communicating through TCP/IP and shows the position and orientation of the indoor localization system. The GUI was tested over a 5G network.
  Second one is a ROS GUI, which displays the position and orientation of the VINSRTK system on the satellite map.

- Do you have any experience with 5G technology?

Yes, we successfully finished a 5G acceleration program called 5G-Endtech in which Arcelik, Nokia and Turk Telekom were involved. We completed a proof of concept within a private network for Arcelik AGVs for our vision based indoor localization solution V-Loc in 5G network, with a successful demo day. We also obtained a grant for Proof of Concept and further development through Kosgeb as a SME instrument as parallel to PoC. We also developed a 5G enabled interface card for our product Vins RTK.

Expectations from the platform

- Why do you deem 5G essential for your solution/product?

  5G transmission latency is low compared to the LTE networks which makes it ideal for real-time applications such as V2X systems. It is ideal for NTRIP (RTK over Internet) applications.

- How do you plan to integrate 5G into your solution/product?

  By using a 5G modem and a 5G simcard, the product is capable to connect to the network and receive RTCM correction data for RTK-GNSS receiver. The GNSS position information is then used for built-in Kalman Filter variant estimator.

- What are your expectations regarding 5G connectivity (round trip time, upload and download data rate, service reliability)? How are these associated with your experiment?

  Since the NTRIP server and client work real-time, the request-response delay will be better and the packet losses / wrong packets / checksum errors will be less.

- What type of resources will be required from 5G-IANA to run your experiment? Provide rough estimates for the number of On-Board Units (OBUs), Road-Side Units (RSUs), vehicles, and amount of CPUs, RAM, storage, etc.

  One road side unit will be sufficient to run the experiment which will be an RTK base station connected to 5G network. It will send RTCM data by using NTRIP protocol.

  Also, one vehicle-preferably EV- will be used for testing the product. The product will be mounted on the top of the vehicle.

  The product already contains a GPU based computation unit, so no other computation unit is necessary.

- How much time would you need to run your experiment (not including training, pretesting activities and getting familiar with the platform functionalities)?

  For the experiment, we will need about 5 days, for safe timing.

- Do you envision that AI/ML could provide added value to your experiment/service? Our algorithm is AI based. It uses computer vision and sensor fusion techniques to estimate the state of the vehicle.
  Also, an ML based algorithm is used to improve the reliability of the product, as well.We think that the AI/ML provides added value to the experiment.

Expected impact

- What would the expected gain from experimentation with the 5G-IANA platform be?
  - X Testing of an application using 5G X o Developing a new product or service
  - Developing a new virtual network function / network application o Research purposes o Interest in the business model o Other:

- What is the expected outcome of the experimentation in the 5G-IANA platform for your business? Would you need business modelling guidance from 5G-IANA experts?

  The product will be tested under different conditions on a real traffic scenario. The outcome will be some experiments videos and real time results showing the performance of the product. Yes, we will benefit from business modeling guidance from 5G-IANA experts.

- What data do you plan to collect/generate during the experiment? Are you going to provide open access to them?

  Data to be collected: Real-time position and orientation data of the vehicle coming from the product.
  If there is a ground truth data, it will be collected, as well. We may show the data in presentations only, we don't think to provide open access to data.

Before you submit

- How did you learn about the 5G-IANA open call?

  From 5g Evolved accelerator presentation through Eirini Liotou, PhD.

- Please add any other comments you would like to accompany your application.

  Thanks for your interest.

GDPR acknowledgement

All Open Call projects will be expected to comply with the General Data Protection Regulation 2016/679 (GDPR).

Do you agree: Y/N - YES

Open Call 1 - Level 7

Submission from Level7 for the 5G-IANA (web form is not working!)

Step 1 General information

Paolo DI FRANCESCO | paolo.difrancesco@level7.it
SME | Level7 S.r.l.
http://www.level7.it | Italy

Please provide a short description of your business (main activities, year of foundation, VAT number)

Level7 is a telecom provider as well as a system integrator. Level7 provides Internet Access at national level thanks to its multiple wholesale agreements with national telecom operators, and it is interconnected at the Italian main Exchanges (Level7 has its own IP address space, and autonomous system AS197506 as well as other telecom resources and infrastructures)
Level7 aims to evolve from the simple Internet access service market, typically services with very low margins, to a more complex and vertical offering thanks to the vertical integration of added value services. However, in order to advance its offering, Level7 is first actively working on its infrastructure and in particular on its proprietary DDoS mitigation platform, called Kaleidoscope, that has been initially funded as an R&D project thanks to the SecurIT OC#1
Level7 has also its proprietary network in western Sicily (south Italy) where experimentation facilities have been built in the last years, especially in the rural use case.
Level7 is member of the 6G-IA, RIPE, NAMEX, and Assoprovider (the Italian association of small and medium ISP)

Level7 has started its operations in 2010 with the VAT [redacted]

Step 2 Ambitions and development plans

Describe the service/application or product that you plan to deploy in the 5G-IANA platform and the "use case/scenario" y implement.

Level7 wants to implement its proprietary DDoS mitigation platform on top of real 5G networks and platforms in order to implement the platform as a native 5G application.

The scenario can be described as follows:

a) Data collection: the data stream is collected and thus "described" from the networking layer (e.g. sFlow/Netflow or any similar mechanism that is able to describe the traffic)

b) The collected data is sent to a data collector (that is part of the Level7 platform)
c) The data collector sends the information to a data base that collects the data under the form of flows
d) The flows are then processed, accordingly to some criteria, in order to discriminate different type of possible "attacks" such as micro burst or massive DDoS attacks.

If some attack is found an event is generated and then sent to a log facility. If available, a countermeasure can be applied via SDN or any available API provided by the 5G-IANA project.

Provide more details about the experiment that you would like to run on the 5G-IANA platform.

The experiment is made of the following technological and logical modules:

1) A module/agent that should collect data of the network traffic that should be installed as close as possible to the user terminal, such as the access network or even installed on the OBU/RSU (this will be evaluated within the project lifetime)
2) The access network node, i.e. base station or data center should be able to store and process the data. For this reason, the module of the Kaleidoscope Level7 platform could be installed or "re-shaped" in order to run as NFV or microservices on top of the 5G-Iana facilities. The data processing is done following the "edge" paradigm in order to intercept and recognize potential micro-bursts.

It also would be interesting to use physical network parameters in order to understand if micro-bursts are correlated to the natural re-transmission of the application layer or simply bursts, i.e. DDoS attacks, that are not correlated to physical radio layer degradation.

+ Step 3 Experience

Do you have any prior experience with EU R&D projects?

Level7 has extensive experience with EU R&D project: Level7 has participated to one FP7 project as well as Level7 has won around 10 open calls in the last years that are related to networking (SDN/NFV, SDR, 5G, etc.). Here the list of the latest won open calls: SecurIT open call #1, PUZZLE open call #1,

Fed4Fire+ continuous Open Call, IST-FLAME Open Call #4 and Open Call #2, ORCA Open Call
#2, WiSHFUL Open Call #2, SoftFIRE Open Call #1

Do you have any experience with 5G technology?

Level7 has experience with 5G technologies: in the IST-FLAME open-calls Level7 has implemented a 5G core network (provided by one of the project partners) and provided support for third parties to implement experiments on top of the Level7 proprietary infrastructure in the rural use case. Level7 has also won and completed many calls related to SDN/NFV and SDR technologies. Level7 is also member of the 6G-IA

Have you already developed any Virtual Network Functions (VNFs) or network applications (nApps) to be utilized or are y
develop them? Provide more details:

Level7 has extensive experience in Kubernetes architectures as well as SDN/NFV concepts thanks to:

i) the participation to many R&D opencalls in the last years and ii) Level7 has extensive knowledge of microservices architectures

Indeed, the Kaleidoscope DDoS architecture has been thought and implemented as a microservice architecture on top of the Kubernetes environment (the Kubernetes infrastructure is provided internally by Level7)

+ Step 4 Expectations from the platfo

Why do you deem 5G essential for your solution/product?

The proposed experiment is essential for two main reasons. The first one is the possibility to validate the Kaleidoscope architecture in 5G environments in order to be sure that the architecture can be supported in 5G environments. The second one is related to the possibility to enhance the Kaleidoscope concepts with data and measures from a real 5G environment.

How do you plan to integrate 5G into your solution/product?

We plan to integrate as much as possible, the 5G concepts in our Kaleidoscope architecture under the form of the evolution of the architecture or the enhancements of new concepts coming from the 5G technologies.

What are your expectations regarding 5G connectivity (round trip time, upload and download data rate, service reliability)? How associated with your experiment?

In order to run the validation of our experiment we need:

1) few tens of Mbps in downstream and few Mbps in upstream. The requirements is related to the simulation of a DDoS attack that should saturate the link
2) constant low round trip as well as "degraded/high" round trip and packet loss. This will permit to explore new ideas such as the correlation of the radio link degradation, re-transmission and the microburst identification

We do not expect to have strict service reliability, indeed we consider that the validation process will take place in a R&D environment that could have some service interruption.

What type of resources will be required from 5G-IANA to run your experiment? Provide rough estimates for the number of (OBUs), Road-Side Units (RSUs), vehicles, and amount of CPUs, RAM, storage, etc.

We are interested in few (1 or 2) OBU, and/or 1 or 2 vehicles to do some testing of DDoS attack under the mobility scenario.

In regards to the CPU/RAM/Storage:

- For the OBU or RSU units we do not require high level of resources (just the resources to collect the data)
- For the nodes in the data center, it would be better for us to have 7 virtual machines each one with 8GB RAM and 4vCores (the more the better)

We are unsure if we are able to use 5G-IANA APIs or facilities in order to apply specific rules/filters (e.g. at SDN level) to stop the DDoS attack or any resource related to ML

How much time would you need to run your experiment (not including training, pre-testing activities and getting familiar w the platform functionalities)?

We expect to need approximately 1 month to run the experiment a couple of times. We do not need 1 month of resources, but we are considering the possibility to have from 3 to 5 sessions/slots of consecutive 4-6 hours in 1 month in order to collect data.

Do you envision that AI/ML could provide added value to y experiment/service?

The use of AI/ML technology could enhance the possibility to better support DDoS identification and interception

+ Step 5 Expected impact

What would the expected gain from experimentation with th IANA platform be?

Testing of an application using 5G

Other...

We willl evolve our internal Kaleidoscope DDoS mitigation architecture

What is the expected outcome of the experimentation in the 5G-IANA platform for your business? Would you need business modelling guidance from 5G-IANA experts?

The expected outcome from the 5G-IANA is related to the possibility to evolve and integrate the Kaleidoscope architecture toward a 5G/6G compliant architectures in order to better support the proprietary DDoS attack/mitigation solution that should be integrated into the Level7 networking infrastructure

What data do you plan to collect/generate during the experiment? Are you going to provide open access to them

We plan to collect data related to network traffic and eventually to link/radio parameters. We do not plan to provide any data for third parties

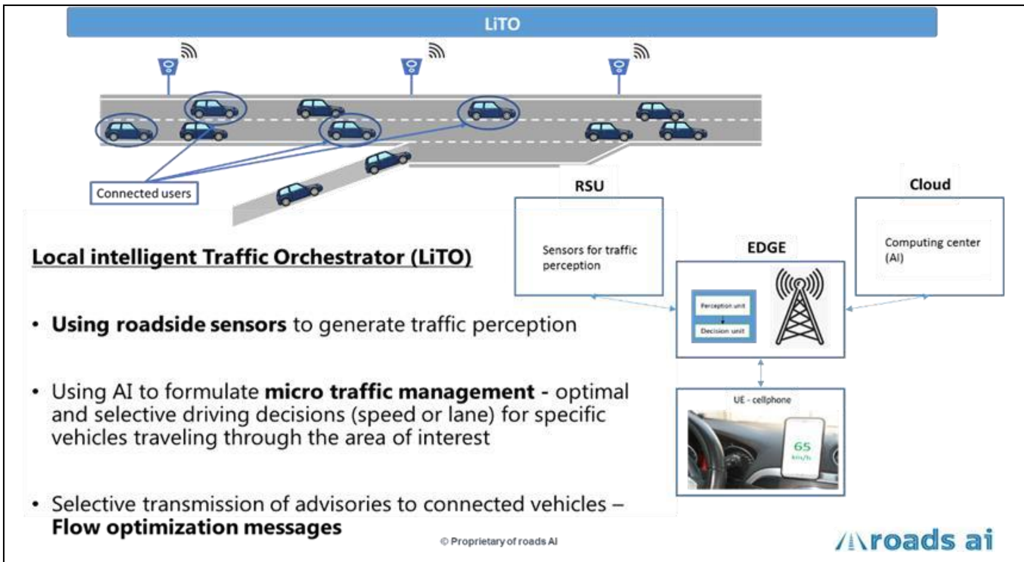
+ Step 6 Before you submit

How did you learn about the 5G-IANA open call?

We have learnt about the 5G-IANA open call via the 6G-IA

Open Call 1 - roadsAI

5G-IANA Open Call Interest Form
General information • Name and Surname (of contact person) – **Roni Dulberg** • E-mail (of contact person) –**dulberg.r@roadsai.co** • Is your organization characterized as an SME/start-up? **YES** • Name of the organization - **roadsAI** • Website of the organization – **www.roadsai.co** • Please provide a short description of your business (main activities, year of foundation, VAT number) – **roadsAI (VAT number [redacted]) was founded in 2017 and its main activity is developing advanced traffic management algorithms for connected and automated mobility** • What is the country of establishment? **Israel** **Ambitions and development plans** • Describe the service/application or product that you plan to deploy in the 5G-IANA platform and the "use case/scenario" you would like to implement. **Our product is called LiTO – Local intelligent Traffic Orchestrator. LiTO is a core intelligent element for next-generation Traffic Management Systems and it creates the ability to provide active, local, and dynamic driving guidance to specific vehicles to achieve higher traffic efficiency accompanied by an increase in safety and an improved driving experience.** **LiTO builds situational awareness as an external observer (from roadside sensors) and generates tactical driving guidance (at the edge) for individual vehicles through complex driving scenarios (such as congested corridors and bottlenecks). We are looking to use the 5GIANA platform for UC2 - maneuver coordination for automated driving.**



- Provide more details about the experiment that you would like to run on the 5G-
  IANA platform.
  We would like to run LiTO in its basic format on an actual operating 5G network to test effective latency, bit rate etc. (E2E). We propose to use the emulator to better formulate the specifications, limitations, and requirements for LiTO and the 5G network serving it.
  [For example, analysing the necessary requirements of 5G network in order for LiTO to be able to monitor and manage a road segment of 3 km long highway with 4 lanes and over 1,000 connected vehicles (with various percentage of AVs).]
- What is the current stage of your product or service?
  - Idea phase
  - **Under development**
  - Demo
  - Prototype
  - Other: ______

Experience

- Do you have any prior experience with EU R&D projects? **Yes. We participated in 5G-LOGINNOV (grant agreement No. 957400 (Innovation Action)), In the Hamburg LL.**
- Have you already developed any Virtual Network Functions (VNFs) or network applications (nApps) to be utilized or are you planning to develop them? Provide more details: **No. we are looking to develop LiTO in a 5G environment.**
- Do you have any experience with 5G technology? **NO**

Expectations from the platform

- Why do you deem 5G essential for your solution/product? **LiTO is a forwardthinking infrastructure solution that leverages the advanced capabilities of the 5G network to provide driving orchestration as a service. By harnessing the highspeed, low-latency (MEC), and high-capacity features of 5G technology, the system aims to revolutionize the intelligent driving sector**
- How do you plan to integrate 5G into your solution/product? **Our solution is designed to utilize 5G features. The bigger the coverage and higher adoption of 5G user devices - our solution will be able to implement more complex intelligent and automated driving use cases**
- What are your expectations regarding 5G connectivity (round trip time, upload and download data rate, service reliability)? How are these associated with your experiment? **There are several unresolved questions around LiTO concerning the network's capacity, specifically in terms of the maximum number of vehicles and road sensors it can accommodate. Additionally, we need to understand the impact of increased vehicle numbers on a particular road segment and how this affects latency within the network. To address these uncertainties, we suggest conducting a series of tests using an emulator. This approach will allow us to emulate realworld scenarios and assess the potential limitations of our system in a controlled environment. This way, we can determine the network's capacity and understand**

any potential implications on latency under varying levels of demand. This will be a critical step in optimizing the performance and reliability of the LiTO system ⍰ What type of resources will be required from 5G-IANA to run your experiment?

Provide rough estimates for the number of On-Board Units (OBUs), Road-Side Units (RSUs), vehicles, and amount of CPUs, RAM, storage, etc. **- 3-4 vehicles with OBU and possibly RTK. 2-3 RSU with sensors. Edge computing**

- How much time would you need to run your experiment (not including training, pretesting activities and getting familiar with the platform functionalities)? **We estimate 3-5 days**

Do you envision that AI/ML could provide added value to your experiment/service?

AI/ML are an integral component of LiTO. Although, at the moment, we don't see it as part of the first experiment, it will be interesting to investigate the potential workload that can be performed at the edge

Expected impact

- What would the expected gain from experimentation with the 5G-IANA platform be?
    - **Testing of an application using 5G** o **Developing a new product or service**

- Developing a new virtual network function / network application o Research purposes o Interest in the business model o Other: _______

- What is the expected outcome of the experimentation in the 5G-IANA platform for your business? Would you need business modelling guidance from 5G-IANA experts? **The expected outcome for roadsAI is to improve our understanding of LiTO effective limitations, capabilities and requirements from 5G networks. The knowledge gained from the experiment will help us to better cooperate with 5G community and the automotive community**
- What data do you plan to collect/generate during the experiment? Are you going to provide open access to them? **The data that will be generated through the proposed experiment will be only relevant to the LiTO system and therefore will have limited value to other applications**

Before you submit

- How did you learn about the 5G-IANA open call? **From ERTICO and on linkedIn**

- Please add any other comments you would like to accompany your application. **We are open for discussion and fine tune our proposed experiment.**

GDPR acknowledgement

All Open Call projects will be expected to comply with the General Data Protection Regulation 2016/679 (GDPR).

Do you agree: **Yes – We agree.**

Open Call 1 – RFSAT

5G-IANA Open Call Interest Form

Step 1: General information

- Name and Surname (of contact person): ***Dr Artur Krukowski***
- E-mail (of contact person): ***Artur.Krukowski@rfsat.com***
- Is your organization characterized as an SME/start-up? ***non-profit research performing SME***
- Name of the organization (legal): ***Research for Science Art and technology (RFSAT) Limited***
- Website of the organization: ***https://www.rfsat.com***
- What is the country of establishment? **Ireland (Dublin)**
- VAT number: **not-applicable by Irish laws**
- Please provide a short description of your business (main activities, year of foundation, VAT no.)

  *RFSAT Limited is a non-profit research-performing SME, established in the Republic of Ireland in **2018**, also with research office in Athens (Greece) established in **2020**. Its activities focus on research and development through national and international research funding, as well as industrial consultancy. RFSAT focuses its current activities on funded research activities on national levels as well as in European Research Framework programs, including Horizon Europe Framework and earlier ones, COST Actions, Media Europe Program, ESA industrial projects etc.*

  The list of research and development activities includes ultra-low-power techniques and optimized integrated-circuits for mobile communications and networked systems, hybrid indoor (wireless) and outdoor (GNSS with assisted and differential variants) positioning and localization systems, Geographical Information Systems (GIS), networked audio-visual systems, Virtual and Augmented Reality systems, mixed-reality user interfaces for gaming and entertainment, autonomous systems (UAS, UGV and UUV) for safety critical applications such as Critical Infrastructure (CI) protection, Cyber-Physical security systems, Machine Learning and Cognitive Artificial Intelligence (AI), Future Internet and 5G Mobile Communications etc.

  RFSAT has been strongly investing and successfully exploiting its enabling technologies in e-Health, Smart Energy/Metering application areas. Most recent work includes projects in security where research activities concentrate on autonomous day/night surveillance, area modelling (2D and 3D) and micro-embedded environmental sensing using micro-UAV/UAS aerial platforms for e.g.

Cultural Heritage protection against natural disasters and negative effects of Climate Change.

Step 2: Ambitions and development plans

- Describe the service/application or product that you plan to deploy in the 5G-IANA platform and the "use case/scenario" you would like to implement.

  As an applied research and development oriented organization, RFSAT pursues advanced applied development activities and hence expects to investigate added value in using 5G-IANA platform for spinning our new types of transport services and applications for automotive industry. Its business operation is currently to offer COTS solutions to system integrators, but subject to successful results of the project a commercial spin-off may be also considered.

- Provide more details about the experiment that you would like to run on the 5G-IANA platform.

  Our small use case would combine integration of our latest high-precision GNSS receiver developed in an ongoing EUSPA-funded project and capable of 2cm or better accuracy in RTK mode, combined with economic micro (credit-card size) synthetic radar (collaboration with Analog Devices in Ireland) for precise navigation and collision avoidance for both private and professional vehicles, but also applicable to smaller vehicles such as motorbikes, bicycles and e-scouters.

- What is the current stage of your product or service?
  - Under development

Step 3: Experience

- Do you have any prior experience with EU R&D projects?

  RFSAT as a company and the applicant contact person have been investing in EU funded projects since FP6 and currently also into Horizon Europe funded research activities in the areas of Information and Communication Technologies (ICT) in application areas of Smart Energy, e-Health systems, Secure Societies, Environmental Monitoring, Mobility services, Future Internet and Multi-Modal Transport. RFSAT participates actively in European, international and industrial research and development activities being a partner of several R&D Projects funded by the European Commission through its FP7, COST and Horizon'2020 programs.

  RFSAT Limited is also a Member of several European Technology Platforms (ETP), Industrial Associations, Special Interest Groups (SIG), Standardization bodies and Strategic Alliances. RFSAT has participated in ***six (6)*** *project funded by EU R&D framework program and* ***eight (8)*** *COST Actions, as well as in* ***twelve (12)*** *projects as SME group member and/ or industrial stakeholder.*

  Dr Krukowski has been also acting as external evaluator and expert for over 15 years, assisting European Commission in assessment of proposal submitted for funding in several funding programs, including FP7, Horizon'2020, Horizon Europe, COST Actions and various other national programs.

- Have you already developed any Virtual Network Functions (VNFs) or network applications (nApps) to be utilized or are you planning to develop them? Provide more details:

  Dr Krukowski has been involved in development of mobile communications systems since FP5 when the 1st 3G basestation has been built in a FP5-CAST project coordinated by Panasonic Europe. Since then Dr Krukowski has been involved in establishing the 5G-PPP project and continued working in various aspects of 5G and beyond.

- Do you have any experience with 5G technology?

  As a company, RFSAT has neither developed not implemented NFV or SDN types of technologies yet. However, it has been developing various nApps for domains such as security (CI, surveillance etc.), autonomous aerial vehicles, transport and currently in Precision Agriculture (ongoing AgriBIT project). Dr Krukowski has been also a Steering Board member of NetWorld2020 which has launched the 5G-PPP project with his participation.

<u>Step 4: Expectations from the platform</u>

- Why do you deem 5G essential for your solution/product?

  The 5G offers essential capabilities in terms of low latency, high throughput and easier accessibility for IoT sensors, not to mention improved reliability, accessibility and reliability - all of those being essential for automotive and other safety critical applications, such as security domain.

- How do you plan to integrate 5G into your solution/product?

  The 5G will be integrated primarily as a transceiver for supporting data transfer. However, we also plan to investigate integration with satcom transceivers in view of pursuing our development towards 6G mobile comms for areas with lower mobile coverage.

- What are your expectations regarding 5G connectivity (round trip time, upload and download data rate, service reliability)? How are these associated with your experiment?

  Our experiment has relaxed performance requirements, as compared to standard mission critical applications. Nevertheless, we plan to stress test RTT and latency to establish possible impact on our services. In terms of traffic, we expect that up to 1Mbps should be sufficient in both directions, unless we add near-R/T or surveillance data from our multispectral cameras to the mix. In such a case upload might require to be in excess of 6Mbps. The more the better, such that we might support 4k camera feeds at 30fps or more.

- What type of resources will be required from 5G-IANA to run your experiment? Provide rough estimates for the number of On-Board Units (OBUs), Road-Side Units (RSUs), vehicles, and amount of CPUs, RAM, storage, etc.

  We initially expect performing experiment of micro size to initially evaluate opportunities behind the 5G-IANA platform. Hence in the first instance we expect using one (1) OBU and one (1) RSU. We would use our own vehicle (if feasible) such that to validate possibility of rapid deployment in private vehicles. We do not have estimates currently for the CPU or RAM requirements, but assuming small size of the pilot those should not be significant.

- How much time would you need to run your experiment (not including training, pre-testing activities and getting familiar with the platform functionalities)?

  Usually, subject to everything working correctly (practically unlikely) one week should be sufficient. However, assuming a need for additional bug fixes, a second one-week test period might be required.

- Do you envision that AI/ML could provide added value to your experiment/service?

  We strongly believe that ML/DL techniques would offer added value in processing the data acquired from our sensors. We have such capabilities in-house, but if 5G-IANA could offer additional support in this area, it would be more than welcomed.

Step 5: Expected impact

- What would the expected gain from experimentation with the 5G-IANA platform be?
  - *Research purposes*
- What is the expected outcome of the experimentation in the 5G-IANA platform for your business? Would you need business modelling guidance from 5G-IANA experts?

  As explained earlier, our company pursues new research directions as its core activity. In this use case we plan to investigate possibilities of applying our precision GNSS and SAR technologies in combination with 5G mobile comms for automotive applications.

- What data do you plan to collect/generate during the experiment? Are you going to provide open access to them?

  Types of data: initially traffic, SAR raw data, vehicle computer, driver behavior, navigational data etc.

  Accessibility: we commonly offer our datasets under Open Access licensing, unless private identifiable data is involved. In such cases the anonymization is applied beforehand.

Step 6: Before you submit

- How did you learn about the 5G-IANA open call?

  Direct invitation email from SME Working Group coordinator under Networld Europe ETP.

- Please add any other comments you would like to accompany your application.

  RFSAT Limited is recognized by both the HORIZON EUROPE and Horizon'2020 framework programs as a non-profit organization on the bases of its articles of associations and company status.

GDPR acknowledgement

All Open Call projects are expected to comply with General Data Protection Regulation 2016/679 (GDPR).

Do you agree: **Yes**

Open Call 2 – RFSAT

General information	
Name and Surname (contact person):	Dr Artur Krukowski Director, RFSAT Limited
E-mail (contact person):	Artur.Krukowski@rfsat.com
Is your organization characterized as an SME/start-up?	Non-profit research-performing SME RFSAT Limited is recognized by the HORIZON EUROPE and Horizon'2020 framework programs as a non-profit organization on the bases of its articles of associations and company status.
Name of organization (legal):	Research for Science, Art and technology (RFSAT) Limited
Website of organization:	https://www.rfsat.com
What is the country of establishment?	Ireland (Dublin), 2018 – registered offices Greece (Athens), 2020 – R&D offices
VAT number:	Not-applicable by Irish laws
Short description of your business (main activities, year of foundation, VAT)	RFSAT activities focus on research and development through national and international research funding (such as Horizon Europe Framework and earlier ones, COST Actions, Media Europe Program, ESA industrial projects etc), as well as industrial consultancy. The list of research and development activities includes ultra-low-power techniques and optimized integrated-circuits for mobile communications and networked systems, hybrid indoor (wireless) and outdoor (GNSS with assisted and differential variants) positioning and localization systems, Geographical Information Systems (GIS), networked audio-visual systems, Virtual and Augmented Reality systems, mixed-reality user interfaces for gaming and entertainment, autonomous systems (UAS, UGV and UUV) for safety critical applications such as Critical Infrastructure (CI) protection, Cyber-Physical security systems, Machine Learning and Cognitive Artificial Intelligence (AI), Future Internet and 5G Mobile Communications etc. RFSAT has been strongly investing and successfully exploiting its enabling technologies in e-Health, Smart Energy/Metering application areas. Most recent work includes projects in

	security where research activities concentrate on autonomous day/night surveillance, area modelling (2D and 3D) and microembedded environmental sensing using micro-UAV/UAS aerial platforms for e.g. Cultural Heritage protection against natural disasters and negative effects of Climate Change. In its latest AgriBIt project, RFSAT has investigated the development of RTK corrected GNSS receivers, targeting Smart Agricultural

	applications, though with seamless applicability in any domain. Use of 3G and 4G mobile telecommunication networks has been used for transfer of RTCM messages, having proven insufficiently robust for offering continuity of 1cm positioning accuracy. This gave raise to this application and wish to establish suitability of 5G (and beyond) type of networks to mitigate shortcomings of 3G/4G in this respect.
Ambitions and development plans	
Describe the service, application or product that you plan to deploy in the 5GIANA platform and the “use case/scenario” you would like to implement.	Being an applied R&D-focussed organization, RFSAT pursues advanced applied development activities and hence expects to investigate added value in using 5G-IANA platform for spinning new types of transport/mobility services and applications, targeting variety of stakeholders, from users of cars/motorbikes to pedestrians. RFSAT business operation is currently to offer COTS solutions to

	system integrators, but subject to successful results of the project a commercial spin-off may be considered, as expected out of its ongoing AgriBIT project.
Provide more details about the experiment that you would like to run on the 5GIANA platform.	Our test use case would combine integration of our latest highprecision GNSS receiver developed in an ongoing EUSPAfunded AgriBIT project and capable of 1cm or better accuracy in RTK mode, combined with economic micro (credit-card size) synthetic TinyRAD radar (collaboration with Analog Devices in Ireland) for precise navigation and collision avoidance for both private and professional vehicles, but also applicable to smaller vehicles such as motorbikes, bicycles and e-scouters. Device has been sufficiently miniaturised to be suitable for use as a wearable or mounted on handles of bikes/motorbikes, with investigated integration into general-purpose CAN bus and/or ISOBUS. The 3G/4G use for reception of RTCM corrections has been found insufficient to reliably maintain 1cm of the positioning accuracy as AgriBIT evaluations have proven, deeming a need to investigate alternative 5G/6G options.
What is the current stage of your product or service? • Idea phase • Under development • Demo • Prototype • Other: ______	Under the development as a complete solution However, it employs an operational and already validated GNSS receiver prototype, capable of 1cm positioning accuracy
Experience	
Do you have any prior experience with EU R&D projects?	RFSAT as a company and the applicant contact person have been investing in EU funded projects since FP6 and currently also into Horizon Europe funded research activities in the areas of Information and Communication Technologies (ICT) in application areas of Smart Energy, e-Health systems, Secure

	Societies, Environmental Monitoring, Mobility services, Future Internet and Multi-Modal Transport. RFSAT participates actively in European, international and industrial research and development activities being a partner of several R&D Projects funded by the European Commission through its FP7, COST and Horizon'2020 programs. RFSAT Limited is also a Member of several European Technology Platforms (ETP), Industrial Associations, Special Interest Groups (SIG), Standardization bodies and Strategic Alliances. RFSAT has participated in six (6) projects funded by EU R&D framework program (including its UK branch) and eight (8) COST Actions, as well as in twelve (12) projects as SME group member and/ or industrial stakeholder. Dr Krukowski has been also acting as external evaluator and expert for over 15 years, assisting European Commission in assessment of proposal submitted for funding in several funding programs, including FP7, Horizon'2020, Horizon Europe, COST Actions and various other national programs.
Have you already developed any Virtual Network Functions (VNFs) or network applications (nApps) to be utilized or are you planning to develop them? Provide more details:	As a company, RFSAT has neither developed not implemented NFV or SDN types of technologies yet. However, it has been developing various nApps for domains such as security (CI, surveillance etc.), autonomous aerial vehicles, transport and currently in Precision Agriculture (ongoing AgriBIT project). RFSAT currently evaluates various 5G transceiver options in view of offering necessary performance for its systems, planning to do the same with those built by 5G-IANA project.
Do you have any experience with 5G technology?	Dr Krukowski has been involved in the development of mobile communications systems since FP5, such as of the 1st 3G base station built in the FP5-CAST project coordinated by Panasonic Europe. He has also been acting as a Steering Board member of both the NEM European Technology Platform (ETP) and Networld Europe ETP, the latter one of which has launched the 5G-PPP project with his explicit contribution, at that time as a representative of Intracom Telecom from Greece. Since then, Dr Krukowski has continued

	working on various aspects of 5G and supporting initiatives towards 6G.
Expectations from the platform	
Why do you deem 5G essential for your solution and/or product?	The 5G offers essential capabilities in terms of low latency, high throughput and easier accessibility for IoT sensors, not to mention improved reliability, accessibility and reliability - all of those being essential for automotive and other safety critical applications, such as security domain. While 3G/4G has proven unreliable in achieving sustainability of RTK-aided GNSS positioning at 1 cm accuracy, the main expectation is to validate 5G-IANA whether its 5G may be suitable to sustain its position.
How do you plan to integrate 5G into your solution and/or product?	The 5G will be integrated primarily as a transceiver for supporting data transfer. However, we also plan to investigate integration with satcom transceivers in view of pursuing our

	development towards 6G mobile comms for areas with lower mobile coverage. A feasibility study for integrated satcom/5G in the context of RFSAT positioning system is already underway, results of which could be practically validated in this project.
What are your expectations regarding 5G connectivity (round trip time, upload and download data rate, service reliability)? How are these associated with your experiment?	RFSAT experiment has relaxed expected performance requirements, as compared to standard mission critical applications. Nevertheless, we plan to stress test RTT and latency to establish possible impact on our services. In terms of traffic, we expect that up to 1Mbps should be sufficient in both directions, unless we add near-R/T or surveillance data from our multispectral cameras to the mix. In such a case upload might require to be in excess of 6Mbps. The more the better, such that we might support 4k camera feeds at 30fps or more.

What type of resources will be required from 5G-IANA to run your experiment? Provide rough estimates for the number of On-Board Units (OBUs), Road-Side Units (RSUs), vehicles, and number of CPUs, RAM, storage, etc.	We initially expect performing experiment of micro size to initially evaluate opportunities behind the 5G-IANA platform. Hence in the first instance we expect using one (1) OBU and one (1) RSU. We would use our own vehicle (if feasible) such that to validate possibility of rapid deployment in private vehicles. We do not have estimates currently for the CPU or RAM requirements, but assuming small size of the pilot those should not be significant.
How much time would you need to run your experiment (not including training, pretesting activities and getting familiar with the platform functionalities)?	Usually, subject to everything working correctly (practically unlikely) one week should be sufficient. However, assuming a need for additional bug fixes, a second one-week test period might be required. Nevertheless, the overall required length of the project would be around six (6) months, thus permitting to conclude internal development and integration with 5G-IANA, prior to the on-site validation testing.
Do you envision that AI/ML could provide added value to your experiment/service?	We strongly believe that ML/DL techniques would offer added value in processing the data acquired from our sensors. We have such capabilities in-house, but if 5G-IANA could offer additional support in this area, it would be more than welcomed.
Expected impact	
What would the expected gain from experimentation with the 5G-IANA platform be? • Testing of an application using 5G • Developing a new product or service • Developing a new virtual network function / network application • Research purposes	<u>Short-term</u>: Research purposes <u>Medium-term</u>: commercial sales of GNSS receivers <u>Long-term</u>: Integrated solutions for transport operators
• Interest in the business model • Other: _______	

What is the expected outcome of the experimentation in the 5GIANA platform for your business? Would you need business modelling guidance from 5G-IANA experts?	As described earlier, in short-terms RFSAT pursues new research directions as its core activity. In this use case we plan to investigate possibilities of applying our precision GNSS and SAR technologies in combination with 5G mobile comms for automotive applications. However, in medium to long terms, commercialisation of integrated solutions is already underway, first of its GNSS receiver and then of full integrated solution.
What data do you plan to collect/generate during the experiment? Are you going to provide open access to them?	Types of data: initially traffic, SAR raw data, vehicle computer, driver behaviour, navigational data etc. Accessibility: we commonly offer our datasets under Open Access licensing, unless private identifiable data is involved. In such cases the anonymization is applied beforehand.
Before you submit	
How did you learn about the 5G-IANA open call? Please add any other comments you would like to accompany your application.	Originally, RFSAT applied for the 1st Open Call of 5G-IANA by the direct invitation email from SME Working Group coordinator under Networld Europe ETP. At that time RFSAT has conducted initial negotiations with 5G-IANA team. However, the project could not have started due to the lack of funding from 5G-IANA, while expecting significant equipment costs to achieve its expected and challenging objectives.
Do you have any preferred 5G testbed where you would like to run your experiment (at NOKIA in Germany or at Telekom Slovenia in Slovenia)? (*Please note that any response is not binding for 5G-IANA.*)	Based on the description provided in the 5G-IANA "*Guide for Applicants*" the most suitable test site for evaluating RFSAT developments would be Nokia site in Ulm, Germany. Availability of multiple antennas within several cells offers added value in testing performance of handover during mobility within the test site. Types of frequency bands and MEC capabilities is also suitable for future transfer of experiences to local RFSAT environments in Ireland and Greece.
GDPR acknowledgement	
All Open Call projects will be expected to comply with the General Data Protection Regulation 2016/679 (GDPR).	RFSAT policy is a full compliance with both Open Access principles and the European GDPR regulation.
Do you agree: Y/N	Yes

Open Call 2 – Diamantis

5G-IANA Open Call Interest Form

General information	
Name and surname of contact person	**Michail Tzithriotis**
E-mail	**Diamantes.tech@gmail.com**
Is your organization characterized as an SME/start-up?	**YES**
Name of organisation	**K. Diamantis ABEE**
Website of organisation	**https://diamantisgroup.gr/**
Please provide a short description of your business (main activities, year offoundation, VAT number)	**Our company was established in 2022. It is is a manufacturer of urban equipment (https://diamantisgroup.gr/). Our factory has a production capacity of 100s of products per day, with the products ranging from waste bins to parking/bus shelters and LEDs. We are currently pursuing to transform our products into smart connected objects with the introduction of a 5G-based connectivity solution. PIC number [redacted], VAT [redacted]**
What is the country of establishment?	**Greece**
Ambitions and development plans	
Describe the service/application or product that you plan to deploy in the 5G-IANA platform and the "use case/scenario" you would like to implement.	

Summary

Our company is a manufacturer of urban equipment (https://diamantisgroup.gr/). Our factory has a production capacity of 100s of products per day, with the products ranging from waste bins to parking/bus shelters and LEDs. We are currently pursuing to transform our products into smart connected objects with the introduction of a 5G-based connectivity solution. In 5G-STREAM, we aim to develop and test a surveillance solution that utilizes solar-powered battery-equipped cameras.

This module once fully developed will be integrated to our product portfolio and will expand our target market to include smart cities infrastructure.

Detailed motivation & service description

In the dynamic landscape of smart cities, our project proposes the development of surveillance service tailored to the needs of urban mobility and public transportation. The envisioned service leverages the cuttingedge capabilities of 5G networks with edge/cloud computing support and advanced video analytics, for (near-)real time video processing and datadriven insights.

Our solution consists of two main parts, the cloud service part and the endpoint client part. The envisioned network application (nApp) service will perform object detection, classification and tracking, exploiting AI and video analytics. On the client side, our service/application is implemented over a prototype of Solar-powered Battery-equipped cameras (SB-CAMs), developed in-house, that will be extended with 5G connectivity. The prototype requires no external power-source to enable easy installation with simple mounting on any of our urban equipment products. Our sustainable and self-sufficient surveillance prototype can be strategically deployed with minimal environmental impact at key smart city locations (such as bus stations) capturing (near-)real time streaming data to be used by our advanced video analytics services. The SB-CAM video will be transmitted in real time via 5G to a central edge/cloud location (the 5G-IANA platform) that hosts the workload of the containerized video analytics service. In this project we focus on people detection at bus station shelters.

Impact

In this direction the proposed nApp is set to significantly enhance public transportation efficiency, while also making meaningful contributions to societal well-being and sustainability. The 5G-enabled nApp can streamline public transit operations by providing real-time data-driven insights. This can lead to optimized bus routes, schedules, and frequencies based on actual commuter demand and traffic conditions analysis, thereby reducing wait times, easing congestion and avoiding overcrowding, enhancing the overall reliability and efficiency of public transport systems. On the other hand, long-term data collection and analysis can provide valuable insights for urban planners. Patterns in population movement and public transportation usage can inform future infrastructure projects, such as where to build new bus stations or roads. Finally, by using solar power, a clean and renewable energy source, for operating cameras and 5G communications demonstrates a clear alignment with the smart city environmental goals and sustainable practices.

The proposed service, will exploit the 5G-IANA platform to efficiently leverage cloud computing resources for the support of demanding image/video processing services. The AI service, focused on people detection, will be based on opensource

solutions (e.g., YOLOV8, detectron2). In compliance with the project's toolkit, the network app starter kit will be used, to prepare the service as a Docker image (or a set of images), and package it as an application function (AF) that will be onboarded at the project's centralized registry. DevOps pipelines as described by the 5G-IANA paradigm will be followed to automate the entire software development lifecycle; from code changes-to deployment-to testing-to production.
Within the scope of this application we envision to use (and potentially augment/modify to generate new nApps) the following nApps from the 5G-IANA registry:

- Real Time Stream Delivery (RTSD)
- Object Detection Stream and Data Delivery (ODS&DD)
- Active Network Monitoring Module (ANMM)

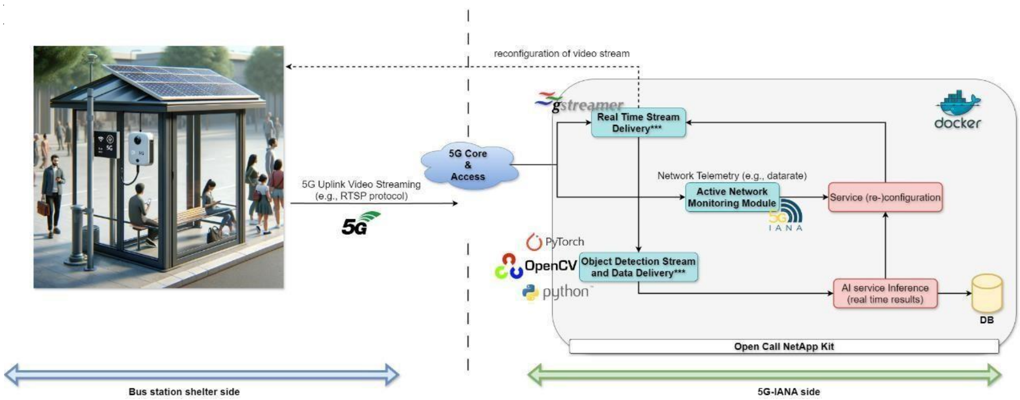
Based on the capabilities and limitations of the provisioned 5G-IANA nApps, we anticipate either fully leveraging their potential or using them as a foundational base to further develop and enhance. Particularly, RTSD may be exploited to facilitate the streaming session over 5G (e.g., via RTSP streaming protocol), between the SB-CAM and the 5G-IANA platform. ODS&DD may be used as a baseline for people detection (if supported).

To further contribute to the development of an energy-efficient nApp for smart transportation and mobility, the system will be able to adjust the streaming resolution (which affects consumption at the solarcamera/node). For example, during peak hours when the bus station experiences high traffic, the system will switch to a high-resolution stream to ensure accurate and reliable people detection. Conversely, during offpeak times or when the station is less occupied, the nApp will reduce the stream quality to conserve energy, striking a balance between functionality and sustainability.

Similarly, the ANMM 5G-IANA nApp can be leveraged to enhance the proposed nApp by providing real-time information about the network performance, such as the application data rate. This information can be utilized to intelligently adjust video quality in accordance with the current data rate.

Detailed implementation plan
The following image exemplifies the nApp kit facilitated by this Open Call in 5G-IANA, as we have described above.

Detailed implementation plan
The following image exemplifies the nApp kit facilitated by this Open Call in 5G-



As highlighted in the illustrated image (and depending on the limitation

and capabilities of the 5G-IANA network App starter kit) we envision the utilization (and/or modification) of **RTSD** and **ODS&DD**. The former will be responsible for establishing a cellular communication and receiving via 5G uplink video data from the SB-CAM installed on the bus-station. Indicatively, GStreamer stands out as an effective framework for developing video applications, employing a pipeline-based architecture that offers considerable precision in programming video services. This design facilitates detailed control over various aspects, such as video resolution, frames per second, encoding methods, buffering, and more. The latter will be the inference engine that facilitates the people detection service. Indicatively, OpenCV (or an enhanced 5G-IANA nApp detection service) can be exploited for the tasks that relate to computer vision and inference, showcasing the number of people identified in the area of interest.
The system will be further augmented with a service reconfiguration nApp. Based on the results of the inference or historical knowledge— specifically the count of people detected or expected— the module will intelligently request adjustments in video stream resolution. When a significant number of individuals are identified, indicating a crowded environment, the module will prompt for a high-resolution video stream. This highresolution feed is essential for ensuring accurate and detailed analytics in densely populated areas. Conversely, in scenarios where the monitored location is less crowded, the module will opt for a lower video resolution stream. This strategic reduction in resolution is a critical step towards energy conservation.

Additionally, if the ANMM 5G-IANA native nApp supports network telemetry (e.g., expected data rate) the re-configuration nApp can utilize this added information to further fine-tune the video service. Particularly, in scenarios where a high application data rate is detected, indicative of a robust and capable network, the module will opt for a high-resolution video stream to maximize the quality of analytics (i.e., the video inference) without concerns of network bottlenecks. Conversely, in situations where the network is experiencing lower data rates, the module will reduce the video resolution accordingly. This not only ensures efficient bandwidth usage but also minimizes the risk of overburdening the network, maintaining a smooth and uninterrupted data flow.

Privacy considerations

We are keenly aware of the privacy concerns associated with video analytics and people detection. In response to this, and if the need arises, we envision employing a method that combines advanced detection algorithms with strategic ***Gaussian blurring*** of sensitive regions in the imagery. This approach is designed to effectively obscure identifiable features (which can help anonymize individuals in video footage) while still providing the necessary analytical data. This is particularly useful in environments where individual identification is not necessary or prohibited, and the primary goal is to gather generalized data (like crowd size or movement patterns at bus station shelters).

The nApp for people detection at bus stations within our project can also be effectively localized by installing (small) single-board computers at the bus station, transforming it to a smart bus-station node. This local node could be an additional kubernetes (k8s) worker node at the 5G-IANA platform, functioning similarly to the On-Board Units (OBUs) used in the project, and being subject to relevant k8s lifecycle management operations.

Via this approach approach, data processing would occur on-site, rather than transmitting it over a 5G network, and thus data privacy concerns are addressed, reducing the risk of interception or unauthorized access. However, this would increase the energy-consumption and the overall cost of the product, so it is considered out of scope.

In light of these considerations, we have concluded that offloading data processing to the 5G-IANA platform (or an edge/cloud server) is a more viable solution than local processing at the bus station. This project approach leverages the advanced capabilities of 5G and edge/cloud computing, and alleviates the significant energy burden on the solarpowered local node. **Implementation plan**

For the purposes of 5G-STREAM we foresee the following activities

Activity 1: Familiarize with the 5G-IANA platform; 5G-STREAM functionalities and infrastructure definition and implementation planning (M01)

The objective of this activity is to conclude on the detailed implementation plan of 5GSTREAM given the capabilities of 5G-IANA. A necessary first step is to familiarize with the platform.

Outcomes of Activity

Report R1: Detailed 5G-STREAM functionalities/infrastructure description and implementation plan report (Confidential report on M01). **Milestone M1**: 5G-STREAM functionalities/architecture description completed (M01).

Activity 2: 5G-STREAM implementation and testing (M02 –M05)

This activity consists of two main objectives; the extension of our working SB-CAM with 5G connectivity and the development of the surveillance cloud service over 5G_IANA platform.

Outcomes of Activity

Report R2: Implementation and testing of proposed functionalities and operation report (Confidential report only for the 5G-IANA consortium members on M05).

Milestone M2: 5G-STREAM functionalities implemented and tested (M05).

Activity 3: 5G-STREAM evaluation & demonstration (M06)

The objective of this phase is to evaluate the performance of the platform and provide the necessary tools and reports to report the 5G-STREAM findings.

Outcome of Activity

Report R3: Description of the 5G-STREAM findings (Public report on M06). **Milestone M3**: 5G-STREAM findings report completed and published in 5GIANA website (M06).

Budget

The project will involve our two skilled employees in the field for the whole project duration. The tentative budget allocation is shown below.

Table: 5G-STREAM cost analysis

Cost category	**Cost**
1.- Personnel costs	17.000
2.-Equipment costs	3.000
Total in Euros	**20.000**

Provide more details about the experiment that you would like to run on the 5G-IANA platform.	The experimentation setup of 5GSTREAM consists of an SB-CAM connected to a public 5G network. Due to the necessary permissions to install cameras in public places, the SB-CAM deployment will be performed in a private space (e.g., our factory parking lot), targeting TRL 6 (technology demonstrated in a relevant environment). The SB-CAM will be tracking the persons moving in the parking lot. If a relative working environment can be provided in Athens by the Greek 5GIANA partners, deployment can be performed there
What is the current stage of your product or service? Idea phase Under development Demo Prototype Other: ______	Under Development. The basic prototype for local surveillance already exists. Its necessary extensions to support 5G connectivity and video analytics in the cloud are under development.
Experience	

Do you have any prior experience with EU R&D projects?	Yes. The company has recruited recently Antonis Tzounis(MSc) who is responsible for the technical developments of this project and all the smart connectivity aspects of our group. Antonis started his career as an application developer in 2002 and a scientific researcher working on software and IoT from 2007 till 2015. He has also a multi-year experience spearheading R&D and Product teams for SaaS and IoT companies in Silicon Valley, namely Centaur Analytics, RudderStack Centaur Analytics Inc.,

	RudderStack Inc. and Sitecore Inc. Antonis is an active PhD student with more than 10 publications in conferences and journals. Michalis Tzithriotis is a civil engineer with more than 12 years of experience and expertise in construction and licensing, and will undertake the construction of demonstration site and field measurements.
Have you already developed any Virtual Network Functions (VNFs) or network applications (nApps) to be utilized or are you planning to develop them? Provide more details:	As of now, we have not directly developed VNFs or nApps. However, it's important to highlight that our team has a strong foundation in virtualization technologies (e.g., Docker, Kubernetes, Helm), which are crucial underpinnings for these types of applications. This foundational knowledge positions us well to understand the requirements and frameworks of VNFs and nApps.
Do you have any experience with 5G technology?	Antonis has experience with LowPower, sub-1GHz and 2.4GHz sensor and actuator networks, lowpower multi-hop protocols on top of IEEE 802.15.4, and, embedded fog/edge devices utilizing cellular carriers and achieving connectivity in some of the most challenging regions globally.
Expectations from the platform	
Why do you deem 5G essential for your solution/product?	5G is essential for our application, particularly in terms of its high bandwidth and low latency capabilities. We plan to leverage 5G to facilitate the (near-)real time transmission of highresolution video data to the 5G-IANA cloud infrastructure, where the nApps responsible for providing the object detection service reside.

How do you plan to integrate 5G into your solution/product?	Our primary business is centered around delivering urban solutions, including bus station shelters. With the 5G_STREAM project we aim to develop products designed for smart cities and enhanced mobility. Within this project, we aim to

	develop an initial prototype enddevice (that could be installed on bus station shelters) which will be outfitted with solar-powered cameras and a 5G interface for establishing communication. The video data collected from such deployments, will be used for advanced analytics services, like object detection, as targeted by this open call. This 5G-based module once fully developed will be integrated to our product portfolio and will expand our target market to include smart cities infrastructure.

What are your expectations regarding 5G connectivity (round trip time, upload and download data rate, service reliability)? How are these associated with your experiment?	Our expectations for 5G connectivity are primarily centred on its high uplink bandwidth capabilities. We anticipate that data rates for highquality streaming will remain below 20Mbps for each deployed camera. This rate is subject to various factors, including camera type, video resolution, frame rate, encoding techniques, and more. For downlink transmissions we expect a small footprint as it entails only control and configuration commands for the camera. While our scenario is not critically dependent on low latency and can tolerate some degree of packet loss, it does require live data acquisition. Therefore, the advanced capabilities of 5G in terms of reliability and low latency are considered essential.
What type of resources will be required from 5G-IANA to run your experiment? Provide rough estimates for the number of OnBoard Units (OBUs), Road-Side Units (RSUs), vehicles, and amount of CPUs, RAM, storage, etc.	Our setup will only use compute resources available at the 5G-IANA cloud infrastructure. In terms of storage (and depending of whether we build stateful or stateless apps for our experimentation) less than 20 GB will be used. In terms of RAM, we expect about 4GB to be sufficient.

	Video analytics tasks are more effectively handled by GPU processing. If GPU-enabled Docker containers are not available on the 5G-IANA platform (as indicated in the 5G-IANA technical report), our solution will be based on CPU. The performance of video analytics (i.e., inference time) will be influenced by the number of allocated CPU cores, and we will determine the optimal allocation during the experimentation phase, if the need arises. Overall, we envision to occupy no more than 4 CPU cores.
How much time would you need to run your experiment (not including training, pre-testing activities and getting familiar with the platform functionalities)?	We envision to run our experimentation framework for the duration of about 2-weeks.
Do you envision that AI/ML could provide added value to your experiment/service?	Yes, the discussed service utilizes AI/ML for object detection, as detailed in the sections above.
Expected impact	
What would the expected gain from experimentation with the 5GIANA platform be? Testing of an application using 5G Developing a new product or service Developing a new virtual network function / network application Research purposes Interest in the business model Other: _______	Testing of an application using 5G Developing a new product or service

What is the expected outcome of the experimentation in the 5GIANA platform for your business? Would you need business modelling guidance from 5G-IANA experts?	Our objective is to deliver innovative, technologically advanced urban solutions, including state-of-the-art bus station shelters, designed for smart cities and enhanced mobility. 5GSTREAM will allow us to develop an initial prototype of a stopover shelter, which will be outfitted with
	solarpowered cameras and a 5G interface. This prototype will incorporate AI and video analytics for advanced object detection capabilities hosted on the 5G-IANA infrastructure.. Here, we will evaluate both the network and computational demands of our service, and assess the efficiency of 5G video streaming in conjunction with solarpowered cameras.
What data do you plan to collect/generate during the experiment? Are you going to provide open access to them?	The data gathered from this call will relate to the efficiency of the AI service, including metrics such as inference time per frame and inference accuracy, along with the compute and energy resource footprint (CPU, GPU, RAM, Disk, etc.) of the service. This data will be openly accessible.
Before you submit	
How did you learn about the 5GIANA open call? Please add any other comments you would like to accompany your application.	From the 5G-IANA website

Do you have any preferred 5G testbed where you would like to run your experiment (at NOKIA in Germany or at Telekom Slovenia in Slovenia)? (*Please note that any response is not binding for 5GIANA.*)	
GDPR acknowledgement	
All Open Call projects will be expected to comply with the General Data Protection Regulation 2016/679 (GDPR).	
Do you agree: Y/N	Yes

Open Call 2 – FERON

General information	
Name and surname of contact person	Konstantinos Maliatsos
E-mail	konstantinos.maliatsos@feron-tech.com
Is your organization characterized as an SME/start-up?	SME
Name of organisation	Feron Technologies
Website of organisation	www.feron-tech.com
Please provide a short description of your business (main activities, year of foundation, VAT number)	Founded in December 2015. VAT No: [redacted] FERON is a technology SME, with noteworthy 9-years of specialization on cutting-edge ICT & IoT products, and solutions. Technical Expertise: Selection and integration of connectivity technologies, protocols, and customized solutions for end-to-end communication infrastructure development; 5G/4G/Wi-Fi/IoT standards and system operation at various levels, from antenna, PHY design, radio access, up to the application design; vehicular communications, connected and automated mobility; software development on various domains (embedded, real-time, back/front-end) for complex ICT solutions; SDRs and SDNs; lab & field-based experimentation campaign design.
What is the country of establishment?	GREECE

Ambitions and development plans

Describe the service/application or product that you plan to deploy in the 5G-IANA platform and the "use case/scenario" you would like to implement.	Citizens contend daily with the challenges of navigating through traffic congestion and road hazards, where accidents stand as a prominent threat leading to fatalities and permanent disabilities. Each year, these accidents claim a staggering 1.35 million lives and cause 50 million injuries worldwide. They typically result from failures in three key areas: human error (driver), vehicle issues, and deficiencies in the road infrastructure. In the United States, studies conducted by insurance companies suggest that road conditions and hazards contribute to approximately half of the 42,000 annual traffic fatalities. Moreover, beyond the tragic loss of life, inadequate road infrastructure incurs substantial financial losses exceeding $3 billion per year. Similarly, in the EU, while there has been a declining trend in the average death rate from road accidents over the past decade, the rate remains alarmingly high at around 50 fatalities per million population annually, as reported by EUROSTAT. While human error remains a primary factor in accidents, the significance of poor road conditions and inadequate maintenance cannot be overstated, directly from road deficiencies or indirectly from drivers' responses to hazards. In response, there is a pressing need to enhance the inspection of infrastructure quality to improve driver and passenger safety. This involves: ● Prompt identification and documentation of road hazards across the entire network. ● Informing road users about identified risks and providing recommendations for safer driving practices.

- Swift reporting of hazards to relevant authorities to expedite repairs and mitigate risks.
- Identification of vehicle abnormalities to optimize maintenance procedures.

FERON application functionality: a 5G connected vehicle is becoming capable of detecting unfavorable/ bad road conditions. This is made possible through the processing of its sensor readings (from accelerometer/gyroscope etc.) by the invehicle FERON software (SW). The SW can identify gravel road conditions.

Measurements from the vehicles participating in the system are collected at the edge or cloud backend in order to fuse this information and visualize the road conditions with graphs and map layers.

Automotive usage and network orchestration relevance: The FERON application that performs the relevant "inference" could be on-demand deployed following centrally-generated triggering from the 5G-IANA NetApp platform/orchestrator. The rationale behind the FERON application usage is the need of the orchestrator for further data (i.e., justification) in view of vehicles -in the vicinity- lowering their speed.

Such information (confirming the presence of bad road) could:

1. increase the awareness of the 5GIANA orchestrator (justifying why the vehicles exhibit a "slowing-down" behavior in the vicinity.
2. proactively allocate network virtualized resources in the vicinity to support

		increased needs coming from the increasing number of vehicles (due to lower speeds).	

		3. Trigger the network to send locally early warning signals that can be possibly consumed directly by the vehicle. Thus, the traffic management entity could use the network to deploy short-term notifications/warnings for drivers approaching an area with identified road hazards, possibly utilizing the near-by MEC infrastructure or Roadside Units (RSUs). Moreover, according to point B, the existence of a road hazard is anticipated to cause increased traffic locally, which means that the network should be in-advance prepared to cope with the excess communications needs. In the course of the project, FERONs offerings includes: ● Containerized application to receive sensor data and infer the presence of bad road conditions. ● Containerized backend application for measurement storage, visualization, and interfaces for exposure of the collected/processed data to third parties (MANO, AI/ML systems, etc.). ● (If required) 5G-modem development kits (Quectel RM500Q-GL, and Quectel RM510Q-mmWave). ● LPMS-U2 Sensor Series with USB or CAN connectivity: (https://www.lp-research.com/imu/lpms-u3/) Accelerometer, Gyroscope, Magnetometer, Temperature, Humidity – Preferably, if possible or available, measurements can be collected directly by the vehicle sensors.	

Provide more details about the experiment that you would like to run on the 5GIANA platform.	● expected outcomes are: An end-to-end platform with applications and services (software) consisting of multiple components. Some tangible results/modules include: ○ A dashboard for controlling nodes and visualizing measurements. ○ The definition of an API, where third parties can connect to obtain measurements from the measurement nodes, or use/utilize the learning modules. ○ An in-vehicle service where alarms, warnings and notifications will reach the vehicle driver/owner. ○ An interface with the network orchestrator triggering reconfiguration activities. ● Datasets containing measurements used for both training and testing. Selected datasets (and depending on their utility) may be made available to the research community as Open Data for further investigations.

	• A methodology for processing the measurements through inference in order to identify and detect road hazards, and vehicle-state issues requiring attention. The results will be validated through extended tests and will be presented at the project report. FERON equips a vehicle with a set of functionalities that can capture at an earlystage abnormal behavior patterns that can indicate road hazards but can also be used as early warnings for vehicle maintenance (e.g. increased vibration, temperature or even gas emissions), which can create an automatic vehicle diagnostic tool that can

	reduce cost and time to detect and repair vehicle deficiencies. *Experiment Storyline*: Connected vehicles (at least one) are capable of detecting unfavorable/bad road conditions. Its sensor readings (from accelerometer/gyroscope etc. coming from the vehicle itself or with the use of an extra sensor provided by FERON) are processed with the in-vehicle FERON software to identify gravel road conditions or abnormal vehicle behavior. Measurements from the vehicles participating in the system are collected at the backend in order to fuse this information collaboratively, and visualize the road conditions with graphs and map layers. The FERON application that performs the relevant "inference" could be on-demand deployed following centrallygenerated triggering from the 5G-IANA *NetApp platform/orchestrator.* The rationale behind is the need/justification of the orchestrator for further data in view of vehicles -in the vicinity- lowering their speed. Such information (confirming the presence of bad road) could: 1. increase the awareness of the 5GIANA orchestrator (justifying why the vehicles exhibit a "slowing-down" behavior in the vicinity 2. proactively allocate network virtualized resources in the vicinity to support increased needs coming from the increasing number of vehicles (due to lower speeds) Thus, the traffic management entity could use the network to deploy short-term notifications/warnings for drivers approaching an	

		area with identified road hazards, possibly utilizing the near-by	

	Roadside Units (RSUs). Moreover, according to point B, the existence of a road hazard is anticipated to cause increased traffic locally, which means that the network should be prepared to cope with the excess communications needs. Our experimentation plan can be broken down into three phases gathering the following activities: *Phase I*. Familiarization, remote deployment and APIs/data acquisition testing. The environment details are becoming known and any modifications to the application are carried-out and tested. Sensors are integrated through appropriate interfaces. The 5G-IANA control-plane data (exchange) is to be tested here. *Phase II*. First physical testing and integration meeting. End-to-end deployment and testing for accurate sensor data retrieval, and computation of outcome. Communication with the 5G- IANA orchestration to be tested here. *Phase III*. Second physical testing and integration meeting. End-to-end operation and data collection. In case the remote set-up, deployment and testing is feasible and effective, we could consider having only one physical meeting instead of two.

What is the current stage of your product or service? Idea phase Under development Demo Prototype Other: ______	Our software, as well as hardware components that may be required, have been used and tested before during driving campaigns performed in cooperation with University of the Aegean in Samos Island. Moreover, INSIGHIO, a connected SME to FERON has utilized an implementation to

	an open-call project for H2020 ASSIST-IoT. Thus, we avail a type of prototype. However, some of its features (e.g., containerization or potentially APIs for receiving vehicle sensor data) will be implemented in the context of the open call (i.e., "under development")
Experience	

Do you have any prior experience with EU R&D projects?	Feron has a strong record of competing and winning (V2X-CCAM) open calls: 5GinFIRE(CV2XinFIRE) [(12/2021-04/2022)] - https://5ginfire.eu/cv2xinfire/ - ORCA Orchestration and Reconfiguration Control Architecture (NFV2X) [(01/2020 – 01/2021)] https://www.orca-project.eu/wpcontent/uploads/sites/4/2020/09/ORCA_OC3EXP_ALL.pdf - Fed4FIRE+(FIVE) [(04/2020 – 01/2022)] - WiSHFUL(SteeringWheel) [6 months, end in 2017] - ASSIST-IoT - the project was implemented by INSIGHIO company - connected to FERON SME, founded by FERON owners for IoT products. The communication subsystem was implemented by FERON. - SNS TARGET-X 5G-BenchMotiv [ongoing, till August 2024] The FERON work under those open calls involved a) the development of software modems, measurement and analysis tools for both V2X technologies (C-V2X, ITSG5) and b) as the integration of the ETSI ITS stack and the deployment of ITS applications.
Have you already developed any Virtual Network Functions (VNFs) or network applications	FERON has worked on the development and deployment of VNFs in the context of

(nApps) to be utilized or are you planning to	

develop them? Provide more details:	the following cascade funding (open-call) projects: ● CV2XinFIRE - for H2020 5GinFIRE: A VNF for network monitoring and Key Performance Indicator (KPI) collection and analysis was performed in order to advise network shift from PC5 to legacy 5G and vice versa. ● NFV2X - for H2020 ORCA: The Software Modems for C-V2X(PC5) and ITS-G5 where implemented and deployed as VNFs, feeding a remote Software Radio for transmission and reception, allowing protocol selection. Moreover, the ETSI-ITS stack was also implemented and deployed as VNF. ● 5G BenchMotiv - for Horizon EU SNS Project TARGET-X: An active benchmarking tool for 5G slices and services is implemented, where the server end is deployed as VNF at the edge or backend.

Do you have any experience with 5G technology?	The team leader for FERON (Konstantinos Maliatsos) is also an Assistant Professor for University of the Aegean (GR) in Wireless Communications and an accredited Trainer for Ericsson in two training-forprofessionals programs (5G NR Physical Layer, 5G NR Service-based Architecture). As a company, FERON has participated in three open-call experiment projects that involve 5G and V2X (as well as PC5-based cellular for adhoc 4G/5G networking). More specifically: ● CV2XinFIRE - for H2020 5GinFIRE (integration of radio control, parameterization and monitoring components as VNFs; experimentation for evaluation of fundamental radio, network and application-level KPIs;
	● NFV2X - for H2020 ORCA (implementation of CV2X and ITSG5 as VNFs, Radio Slicing over both V2X technology standards). ● FIVE - for Fed4FIRE+ (experimentation with the ETSI ITS stack over PC5 and 5G V2X). ● 5G BenchMotiv - for SNS Project TARGET-X (benchmarking tools for 5G networks - CCAM and industrial automation use cases).
Expectations from the platform	

Why do you deem 5G essential for your solution/product?	The proposed solution can be typically accommodated by both DSRC and cellular means. The 5G technology is relevant mainly in two ways: a) it provides important guarantees accompanied by stringent latency requirements and b) it is more suitable/since it is practically used in the cases of broad spatial scope services, potentially interacting with back-end (i.e., OEM cloud) services.
How do you plan to integrate 5G into your solution/product?	FERON seeks in the near future to enhance the proposed solution by integrating data coming from other sensors. FERON has invested effort on IoT applications and therefore its business vision is to develop a data fusion layer having as input multiple sensor readings. The corresponding data will be fused to accurately identify the vehicle and road state and offer the outcome as a standalone automotive service. Our expectation is that communicating such service would call for high reliability and low latency characteristics offered by 5G.
What are your expectations regarding 5G connectivity (round trip time, upload and download data rate, service reliability)? How are these associated with your experiment?	We would approximately* expect: • RTT<50ms • Availability>99.8% • Area traffic capacity>5Mbs __________ * Currently, we would be interested in the service total latency in order to identify potential optimization directions, rather than "pure" 5G network performance capabilities

What type of resources will be required from 5G-IANA to run your experiment? Provide rough estimates for the number of On-Board Units (OBUs), Road-Side Units (RSUs), vehicles, and amount of CPUs, RAM, storage, etc.	● ɔed vehicle with vehicle application unit (x64, x86, Atom, with typical >2GHz processor, >4GB RAM, USB3 support) – preferable Linux-based, with the ability to support dockers/containers. ● sensory equipment and defined interface to obtain the data. ○ Ideally, the application could utilize data from accelerometer, gyroscope, magnetometer, and braking response. If this type of sensor is not available by the vehicle, FERON is able to provide sensors. [if so, some integration effort will be needed] ● 5G network connectivity (to the infrastructure to access the 5G-IANA orchestrator). ● VNF deployment at the edge for measurement analysis, collection and visualization (no special requirements regarding computing or storage resources).	
How much time would you need to run your experiment (not including training, pretesting activities and getting familiar with the platform functionalities)?	We expect the feasibility of remote deployment and testing. Regardless of the progress achieved by that, we foresee two physical integration/measurement/testing sessions spanning 2-4 days each.	

Do you envision that AI/ML could provide added value to your experiment/service?	AI/ML can significantly benefit the proposed FERON service. From a business/market standpoint, the service may be developed and integrated in each vehicle; however, its operation in a certain road segment would require only a few/selected number of passing vehicles to detect the environment/road and provide the relevant notification. As such, through AI/ML techniques the number/location (or even scheduling) of the vehicles to offer such kind of information (e.g. , segment of bad road conditions) could be centrally coordinated in an automated way; thus, potentially redundant operations will be avoided. Additionally, AI/ML can exploit the measurements for the identification of types of road hazards, as well as the impact of a hazard on both vehicle and network conditions.
Expected impact	

What would the expected gain from experimentation with the 5G-IANA platform be? Testing of an application using 5G Developing a new product or service Developing a new virtual network function / network application Research purposes. Interest in the business model Other: _______	We foresee the following gains from the 5G-IANA proposed experimentation: ● Integration/testing of an in-vehicle stack (hardware/firmware/application) tailored to realise the FERON concept, including vehicle sensors, ports/interfaces for data acquisition and remotely management though 5G links. ● Integration with the 5G-IANA platform for controlling the FERON application (containers) and communicating results/notifications to the platform ● FERON stack/system "vertical" experimental evaluation ● Datasets collection containing measurements from the FERON stack (see the plan for data collection), a part of which may be publicly available to the research community as Open Data (subject to 5G-IANA confidentiality constraints).
	The above points will help FERON to increase the maturity/readiness-level of a currently available stack. The relevant stack, when enhanced with virtualisation capabilities, can become an automotive application deployed over virtualised vehicle platforms.

What is the expected outcome of the experimentation in the 5GIANA platform for your business? Would you need business modelling guidance from 5G-IANA experts?	Our experimentation will act as a basis for technical conclusions and future improvements of our software (see Section 'ambition plans'). As such, we will not require business-related guidance. In case 5G-IANA business modelling experts are interested in the proposed concept, we would be happy to discuss and share our business vision. In any case, we are interested in reviewing, updating and enriching our business plan, thus, any interaction with experts would be appreciated.
What data do you plan to collect/generate during the experiment? Are you going to provide open access to them?	We will be collecting the following types of data: • vehicle sensor data • vehicle kinematic data • network connectivity data • resources and health-status data for the FERON application (container) All above are needed to facilitate the proposed automotive use-case (see 1st page description). Having those/parts-of-those data publicly available is something we will happily discuss, respecting any confidentiality constraint posed by the consortium.
Before you submit	
How did you learn about the 5G-IANA open call? Please add any other comments you would like to accompany your application.	FERON was informed about the 5G-IANA open call through its past links to ICCS. FERON co-founders/owners used to work with ICCS. Moreover, INSIGHIO (a connected IoT company founded by FERON owners and co-founders)

	participated successfully in an H2020 ASSIST-IoT open-call coordinated by ICCS establishing further connections with the ICCS team also involved in 5G-IANA.
Do you have any preferred 5G testbed where you would like to run your experiment (at NOKIA in Germany or at Telekom Slovenia in Slovenia)? (*Please note that any response is not binding for 5G-IANA.*)	The preference is the NOKIA testbed due to the existence of slices for V2X for comparisons. Nevertheless, as long as, there is an available vehicle for tests, both testbeds are suitable.
GDPR acknowledgement	
All Open Call projects will be expected to comply with the General Data Protection Regulation 2016/679 (GDPR).	YES
Do you agree: Y/N	YES

Open Call 2 – roadsAI

5G-IANA 2nd Open Call Interest Form

General information

- **Name and Surname (of contact person) –** Roni Dulberg
- **E-mail (of contact person) –**dulberg.r@roadsai.co
- **Is your organization characterized as an SME/start-up?** YES
- **Name of the organization** - roadsAI
- **Website of the organization –** www.roadsai.co
- **Please provide a short description of your business (main activities, year of foundation, VAT number)** – roadsAI (VAT number [redacted]) was founded in 2017 and its main activity is developing advanced traffic management algorithms for connected and automated mobility

- **What is the country of establishment?** Israel

Ambitions and development plans

- **Describe the service/application or product that you plan to deploy in the 5G-IANA platform and the "use case/scenario" you would like to implement.**

  Our product is called LiTO – Local intelligent Traffic Orchestrator. LiTO is a core intelligent element for next-generation Traffic Management Systems and it creates the ability to provide active, local, and dynamic driving guidance to specific vehicles to achieve higher traffic efficiency accompanied by an increase in safety and an improved driving experience.
  LiTO builds situational awareness as an external observer (from roadside sensors) and generates tactical driving guidance (at the edge) for individual vehicles through complex driving scenarios (such as congested corridors and bottlenecks). We are looking to use the 5GIANA platform for UC2 - manoeuvre coordination for automated driving.

- **Provide more details about the experiment that you would like to run on the 5G-IANA platform.**
  We would like to run LiTO in its basic format on an actual operating 5G network to test effective latency, bit rate etc. (E2E). We propose to use the emulator to better formulate the specifications, limitations, and requirements for LiTO and the 5G network serving it.
  [For example, analysing the necessary requirements of 5G network in order for LiTO to be able to monitor and manage a road segment of 3 km long highway with 4 lanes and over 1,000 connected vehicles (with various percentage of AVs).]

- **What is the current stage of your product or service?**
  - **Idea phase**
  - **Under development o Demo**
  - **Prototype**

- **Other: ______**

Experience

- **Do you have any prior experience with EU R&D projects?**

Yes. We participated in 5G-LOGINNOV (grant agreement No. 957400 (Innovation Action)), In the Hamburg LL.

- **Have you already developed any Virtual Network Functions (VNFs) or network applications (nApps) to be utilized or are you planning to develop them? Provide more details:**

No. we are looking to develop LiTO in a 5G environment.

- **Do you have any experience with 5G technology?**

Development, deployment, and integration of network side equipment for 5G networks including DSS/ESS and pure 5G carriers. Such equipment is massively based on FPGA, Embedded and cloud computing and used by T1 mobile operators around the globe. On the UE side, working with multiple UE devices under several OS to get the most out of the 5G networks.

Expectations from the platform

- **Why do you deem 5G essential for your solution/product?**

LiTO is a forward thinking infrastructure solution that leverages the advanced capabilities of the 5G network to provide driving orchestration as a service. By harnessing the highspeed, low-latency (MEC), and high-capacity features of 5G technology, the system aims to revolutionize the intelligent driving sector

- **How do you plan to integrate 5G into your solution/product?**

Our solution is designed to utilize 5G features. The bigger the coverage and
higher adoption of 5G user devices - our solution will be able to implement more complex intelligent and automated driving use cases

- **What are your expectations regarding 5G connectivity (round trip time, upload and download data rate, service reliability)? How are these associated with your experiment?**

There are several unresolved questions around LiTO concerning the network's capacity, specifically in terms of the maximum number of vehicles and road sensors it can accommodate. Additionally, we need to understand the impact
of increased vehicle numbers on a particular road segment and how this affects latency within the network. To address these uncertainties, we suggest conducting a series of tests using an emulator. This approach will allow us to emulate realworld scenarios and assess the potential limitations of our system in a controlled environment. This way, we can determine the network's capacity and understand any potential implications on latency under varying levels of demand. This will be a critical step in optimizing the performance and reliability of the LiTO system

- **What type of resources will be required from 5G-IANA to run your experiment? Provide rough estimates for the number of On-Board Units (OBUs), Road-Side Units (RSUs), vehicles, and amount of CPUs, RAM, storage, etc.**

2-3 vehicles with OBU and possibly RTK. 1 RSU with LiDAR/Camera sensor. Edge computing.

- **How much time would you need to run your experiment (not including training, pretesting activities and getting familiar with the platform functionalities)?**

We estimate not more than a couple of days.

- **Do you envision that AI/ML could provide added value to your experiment/service?**

AI/ML are an integral component of LiTO. Although, at the moment, we don't see it as part of the first experiment, it will be interesting to investigate the potential workload that can be performed at the edge

Expected impact

- What would the expected gain from experimentation with the 5G-IANA platform be?
- Testing of an application using 5G o Developing a new product or service
- Developing a new virtual network function / network application o Research purposes o Interest in the business model o Other: _______
- What is the expected outcome of the experimentation in the 5G-IANA platform for your business? Would you need business modelling guidance from 5G-IANA experts? The expected outcome for roadsAI is to improve our understanding of LiTO effective limitations, capabilities and requirements from 5G networks. The knowledge gained from the experiment will help us to better cooperate with 5G community and the automotive community
- What data do you plan to collect/generate during the experiment? Are you going to provide open access to them? The data that will be generated through the proposed experiment will be only relevant to the LiTO system and therefore will have limited value to other applications

Before you submit

- **How did you learn about the 5G-IANA open call?**

From ERTICO and on linkedIn

- **Please add any other comments you would like to accompany your application.**

We are open for discussion and fine tune our proposed experiment.

GDPR acknowledgement

All Open Call projects will be expected to comply with the General Data Protection Regulation 2016/679 (GDPR).

Do you agree: Yes – We agree.

Open Call 2 – Neobility

General information	
Name and surname of contact person	Andrei Radulescu
E-mail	andi@neobility.co
Is your organization characterized as an SME/start-up?	Start-up
Name of organisation	Neobility SRL
Website of organisation	https://www.neobility.co
Please provide a short description of your business (main activities, year of foundation, VAT number)	Mobility startup founded in 2019. VAT no. [redacted]
What is the country of establishment?	Romania
Ambitions and development plans	

Describe the service/application or product that you plan to deploy in the 5G-IANA platform and the "use case/scenario" you would like to implement.	Neobility's NetApp, Vehicle Route Optimizer (commercially "NeoBus") is a dynamic pooled transportation service (Demand Responsive Transport - DRT) solution based on minibuses (±10 seats) that is as flexible as traditional ride-sharing, while being a fraction of the price. Using a real-time distributed solution, that runs closer to the user in edge computing, will recalculate the route continuously (continuous reoptimisation) and providing a near instantaneous response to the user's request. Using monitoring (e.g. via NEF), achieve dynamic orchestration and deployment.

Provide more details about the experiment that you would like to run on the 5G-IANA platform.	Onboard the network application and run it on a testbed on one or two testbeds.
What is the current stage of your product or service? Idea phase Under development Demo Prototype Other: ______	Other: Demonstration of a DRT (demand responsive transportation) solution in a precommercial system on a demo site that is using the 5G network (packaging, OSM orchestration, multiple slices, deployments at the edge, interacting with the NEF interface).
Experience	
Do you have any prior experience with EU R&D projects?	Yes, with 5GASP.

Have you already developed any Virtual Network Functions (VNFs) or network applications (nApps) to be utilized or are you planning to develop them? Provide more details:	Yes, using CNFs with Helm charts.
Do you have any experience with 5G technology?	Yes, working with OSM and a NEF Emulator.
Expectations from the platform	
Why do you deem 5G essential for your solution/product?	5G is not essential but preferred.
How do you plan to integrate 5G into your solution/product?	Using an integration with a NEF interface for monitoring.
What are your expectations regarding 5G connectivity (round trip time, upload and download data rate, service reliability)? How are these associated with your experiment?	RTT under 20ms. Data rate (UL/DL) 20Mbps. E2E reliability 99.9%.
What type of resources will be required from 5G-IANA to run your experiment? Provide rough estimates for the number of OnBoard Units (OBUs), Road-Side Units (RSUs), vehicles, and amount of CPUs, RAM, storage, etc.	The network application clients run on 5G smartphones (Android) – one Android application for users and one Android application for drivers. The server components require two instances with 2 vCPU with 4GB RAM, 20GB storage and 1 instance
	with 4 vCPU with 8GB RAM and 50GB storage.

How much time would you need to run your experiment (not including training, pre-testing activities and getting familiar with the platform functionalities)?	1-3 months for adapting the network application to the platform/testbed and/or new requirements and for running the actual experiment(s). Except pretesting activities and getting familiar with the platform.
Do you envision that AI/ML could provide added value to your experiment/service?	Yes. Currently the network application doesn't use any AI/ML.
Expected impact	
What would the expected gain from experimentation with the 5GIANA platform be? Testing of an application using 5G Developing a new product or service Developing a new virtual network function / network application Research purposes Interest in the business model Other: _______	Testing the network application in another platform and other testbeds than 5GASP. Interest for new business opportunities.
What is the expected outcome of the experimentation in the 5GIANA platform for your business? Would you need business modelling guidance from 5G-IANA experts?	Be able to gain recognition for having a network application that can be deployed in a production network environment. Business modelling guidance related to this specific topic might be needed.
What data do you plan to collect/generate during the experiment? Are you going to provide open access to them?	Uncertain at this moment, but we are OSS friendly and willing to provide open access.
Before you submit	

How did you learn about the 5GIANA open call? Please add any other comments you would like to accompany your application.	Recommendation from Xenofon Vasilakos. The reason for applying is to experiment with another platform besides 5GASP and other testbeds.
Do you have any preferred 5G testbed where you would like to run your experiment (at NOKIA in Germany or at Telekom Slovenia in Slovenia)? (*Please note that any response is not binding for 5GIANA.*)	No preferred 5G testbed but deploying on a testbed that has an EDGE server is preferable (e.g. Nokia testbed). Also, the deployment is with CNFs, so deploying with containers (e.g. Kubernetes/Helm charts) is mandatory.
GDPR acknowledgement	
All Open Call projects will be expected to comply with the General Data Protection Regulation 2016/679 (GDPR).	
Do you agree: Y/N	Yes.

Open Call 2 – Infolysis

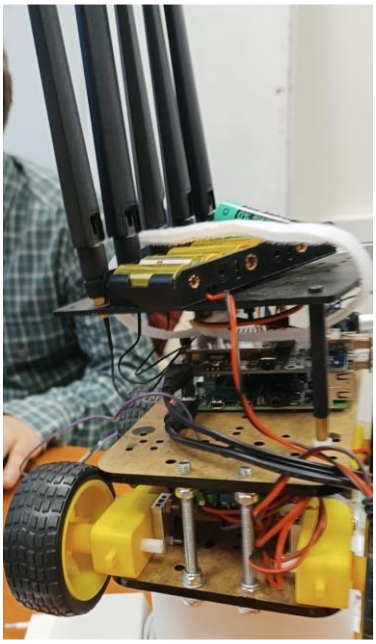
General information	
Name and surname of contact person	Vaios Koumaras
E-mail	vkoumaras@infolysis.gr
Is your organization characterized as an SME/start-up?	Yes
Name of organisation	INFOLYSIS P.C.
Website of organisation	www.infolysis.gr

Please provide a short description of your business (main activities, year of foundation, VAT number)	INFOLYSIS is an innovative SME established in 2017 (VAT [redacted]), located in Athens, Greece, specialising on the development of chatbots via its privately owned chatbot platform. INFOLYSiS provides a variety of chatbot solutions (menu-based or enriched chatbots with DL/NLP technologies) over various popular messaging apps, but also as an OTT service (web-based chatbots). Especially in Greece, INFOLYSIS was pioneering by developing and commercializing the first chatbot-based ordering system for food delivery (Link). INFOLYSiS is committed to driving research results forward by experimenting with novel technologies and advancing the chatbot applicability in innovative use-cases. INFOLYSiS' indicative research topics include 6G/B5G exposure and programmability (CAMARA, 3GPP NEF/CAPIF), edge-cloud-IoT continuum and dataspaces. INFOLYSIS is a member of CAMARA and 6G-IA. Additionally, chatbot-driven decision

	processes are researched by mapping the user intent to specific smart network decisions, realising for example hybrid access and specific level of trust with cognitive intelligence in user-centric B5G networks. In this framework, INFOLYSIS is also experimenting with V2X field and more specifically with 5Genabled UGVs, capable of being adaptable in terms of intelligence for specific missions by deploying additional software packages that upgrade their AI functionalities (e.g. for object recognition and automated steering etc).
What is the country of establishment?	Greece
Ambitions and development plans	

Describe the service/application or product that you plan to deploy in the 5G-IANA platform and the "use case/scenario" you would like to implement.	INFOLYSIS is experimenting with 5G-enabled UGVs with on-board sensors and processing capabilities, capable of being able to be upgraded on the fly with additional software packages (e.g. AI-enablers) that add extra/additional functionalities to them based on their collected data (e.g. AI-enabler for data pattern recognition etc). A first step towards these adaptable intelligent vehicles is the softwarization of their data and control unit in a distributed way, rather than in a monolithic approach. This distributed softwarisation methodology includes components that have to do both with the control of the UGV services (e.g. controlling/ remote controlling the vehicle) and the data/communication tasks (e.g. data collection, data classification etc.). For meeting this requirement, the definition of
	the network app according to 5GIANA is an excellent fit, since a network app is a composition of atomic components (AFs and NFs) that can communicate with each other and can be instantiated separately with different requirements. This is also the reason that INFOLYSIS applies to this open-call, i.e. in order to test the 5G-enabled UGV network app on top of the 5GIANA network app ecosystem.

Provide more details about the experiment that you would like to run on the 5G-IANA platform.	INFOLYSIS wishes to perform an experiment at Slovenian testbed by deploying there the Network App of the experimental 5Genabled UGV/vehicle that has developed by INFOLYSIS in order to verify and validate the performance of the distributed software components that are composing the Network App and have been already developed, namely: i) the Data Collector CNF (from the onboard sensors), ii) the Remote Controller Unit CNF (to drive the vehicle remotely), iii) the Dashboard CNF (for visualizing the data, as well as displaying recommendations based on AI-models that are applied on the retrieved data). The figure below is depicting the prototype vehicle that will be used for the experiment at the Slovenian testbed.

	 Given that all the aforementioned components have been developed to be containerised and their internal communication is required for the overall Network App realisation, the 5GIANA ecosystem seems to be the perfect match for managing and deploying these CNFs for validating purposes.
What is the current stage of your product or service? Idea phase Under development Demo Prototype Other: __Proof of Concept____	The current stage of development is a Proof of Concept implementation of the 5G-enabled Vehicle together with the respective distributed software components (i.e. Network App). Upon successful validation of the POC (and 5GIANA will assist in this validation process), then the development will continue to other UGVs, such as Quadruped Robots.
Experience	

Do you have any prior experience with EU R&D projects?	INFOLYSiS has previous experience by participating in EU R&D projects with its Chatbot Platform and its IoT virtual GW for interoperability provision. Recently the chatbot platform of INFOLYSIS has been used as UI for user-intent mapping of B5G communication systems.

Have you already developed any Virtual Network Functions (VNFs) or network applications (nApps) to be utilized or are you planning to develop them? Provide more details:	INFOLYSiS has already developed the software components of the 5G-enabled vehicle as CNFs. More specifically, the Data Collector CNF (from the onboard sensors), the Remote Controller Unit CNF (to drive the vehicle remotely), the Dashboard CNF (for visualizing the data, as well as displaying recommendations based on AI-models that are applied on the retrieved data).
Do you have any experience with 5G technology?	Yes, especially related to exposed APIs of the core network. INFOLYSIS is also closely monitoring the CAMARA initiative.
Expectations from the platform	
Why do you deem 5G essential for your solution/product?	5G is the enabling technology for our PoC, because due to its architectural elements unites both the access network technology with the computing infrastructure needed to orchestrate a distributed virtualised application (e.g. a network app) in a tight way to the available network resources.

How do you plan to integrate 5G into your solution/product?	A 5G modem [Qualcomm snapdragon X55/SIMCom 5G module SIM8200EA-M2, 5G SA, providing data rate up to 2.4 Gbps (DL) / 500 Mbps (UL)] has been already integrated within a UGV, providing both control and data plane access to the user, which means that the 5G access network is used for collecting data from the sensors of the UGV, using them as input to AI models, but also for remote controlling the UGV.
What are your expectations regarding 5G connectivity (round trip time, upload and download data rate, service reliability)? How are these associated with your experiment?	The proposed trial of the 5Genabled UGV is not performance demanding, since it requires relaxed performance metric in order to assess the proper distributed softwarisation of the vehicles components (i.e. the Network App of the connected vehicle)
What type of resources will be required from 5G-IANA to run your experiment? Provide rough estimates for the number of OnBoard Units (OBUs), Road-Side Units (RSUs), vehicles, and amount of CPUs, RAM, storage, etc.	The successful execution of the 5G-enabled UGV experim require 4 containers to be deployed in the K8s cluster of the Slovenian testbed. In terms of CPU, RAM and storage the requirements are not high, since each component is ultr
How much time would you need to run your experiment (not including training, pre-testing activities and getting familiar with the platform functionalities)?	A half-day (4 hours) will be needed to execute the exper receive measurements and data required to assess the P metrics.

Do you envision that AI/ML could provide added value to your experiment/service?	AI/ML will be used to perform an AI-assisted functionality based on the collected data. The added value to our experiment is the modularitability of the Network App, allowing different software components to be part of it and thus different AI-enablers to be feasible to be used on the fly each time, depending on the task requirements.
Expected impact	
What would the expected gain from experimentation with the 5GIANA platform be? Testing of an application using 5G Developing a new product or service Developing a new virtual network function / network application Research purposes Interest in the business model Other: _______	The expected impact of the executed experiment will be verification and validation of the developed Network App of the 5G-enabled UGV, proving its proper functionality and operation. This Network App will allow the further development and expansion of the clustered software components in the Network App, supporting the inclusion of additional AIenablers that exploit the collected data for automating a specific task.
What is the expected outcome of the experimentation in the 5GIANA platform for your business? Would you need business modelling guidance from 5G-IANA experts?	The expected outcome from the experiment execution for INFOLYSiS will be a successful transition for the monolithic software engineering that is currently used to a more distributed one, which following
	the Network App methodology will be 5G-ready and tested. This will give to INFOLYSiS a competitive advantage in building 5G-ready applications and services.

What data do you plan to collect/generate during the experiment? Are you going to provide open access to them?	Data from the sensors of the 5Genabled UGV will be collected, such as location, velocity, CPU usage, Memory Usage of the vehicle's RPi K3s. Open access to the collected data set will be provided.
Before you submit	
How did you learn about the 5GIANA open call? Please add any other comments you would like to accompany your application.	SOCIAL MEDIA INFOLYSiS, as an SME, cannot self-fund the cost required for the execution of the described experiment. Therefore, receiving the funded amount of 20K Euro from the Open Call, is mandatory for initiating any trial activity.
Do you have any preferred 5G testbed where you would like to run your experiment (at NOKIA in Germany or at Telekom Slovenia in Slovenia)? (*Please note that any response is not binding for 5GIANA.*)	SLOVENIA
GDPR acknowledgement	
All Open Call projects will be expected to comply with the General Data Protection Regulation 2016/679 (GDPR).	
Do you agree: Y/N	YES

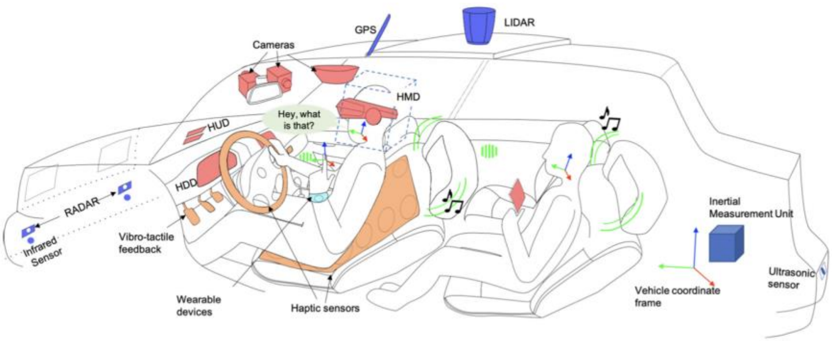
Open Call 2 – AviSense

General information	
Name and surname of contact person	Gerasimos Arvanitis (CEO)
E-mail	arvanitis@avisense.ai
Is your organization characterized as an SME/start-up?	AviSense is a start-up (SME) company. More specifically, AviSense is a spin-off originating from the Multimedia Information Processing Systems (MIPS) Group of the Industrial System Institute of the ATHENA Research Center, and the Visualization and Virtual Reality (VVR) Group of the University of Patras, both located in Greece.
Name of organization	AviSense.ai Technovlastos IKE (AviSense)
Website of organisation	https://avisense.ai/
Please provide a short description of your business (main activities, year of foundation, VAT number)	AviSense is an innovative spin-off that offers a holistic framework for collaborative, efficient and trustworthy AI-empowered intelligence in dynamic group of connected and automated vehicles. AviSense provides a comprehensive framework for AI-empowered intelligence in dynamic groups of connected and automated vehicles. It offers APIs that ensure seamless vehicular cloud-edge and active information continuum, along with robust AI models that require less data and energy to achieve high-level performance based on cooperative, active, transfer and federated learning paradigms, explainability principles, and model compression and acceleration tools. **Main activity**: Research and experimental development services in computer sciences and information **Year of foundation**: 21/06/2023 **VAT**: [redacted]
What is the country of establishment?	Greece

Ambitions and development plans	
Describe the service/application or product that you plan to deploy in the 5G-IANA platform and the “use case/scenario” you would like to implement.	Connected and Automated Vehicles (CAVs) are expected to be the cornerstone of smart mobility of the future, as key enablers for (semi)-autonomous driving. AviSense’s vision is to transform contemporary commercial vehicles from a lifeless machine to an omniscient and trustworthy partner, which acts as a co-driver, by collecting and analysing huge amounts of heterogeneous data received by various on-board sensors, such as camera, Light Detection and Ranging (LiDAR), Radio Detection and Ranging (RADAR), Global Navigation Satellite System (GNSS), etc. To effectively analyse and understand the surrounding environment of CAVs, it is required to extend their perception capabilities beyond the range of individual sensors, to boost drivers’ situational awareness and as a matter of fact their performance, safety and comfort. In this context, AviSense envisions to implement a novel strategy, combining advanced multimodal cross - view fusion of inputs from 5G-connected road agents and Copernicus imagery (offering bird’s-eye views of the environment) with images and point clouds captured by the ego-vehicle, in order to achieve sub-meter positioning accuracy, ultimately increasing both vehicle’s and driver’s situational awareness via cutting-edge explainable AI (xAI) techniques. AviSense’s current solutions (Visual/LiDAR Sensor Data Enhancement Kit, Hyper-Sensing Suite, CAVs Simulation Platform, eXtended Reality (XR) System of xAI Content) have been explicitly designed to accelerate safety, accuracy, scalability, and customisation, by combining real-time onboard sensing and satellite data. More specifically, our fusion approach aims to: i) improve the positioning accuracy of individual vehicles by developing novel graph signal processing tools for maximum exploitation of Galileo and ground visual data, ii) develop and extend cross-view localization among Copernicus images and GNSS-tagged ground images and point clouds collected by vehicle’s sensors, and iii) extend the situational awareness of drivers beyond the range of the employed sensors, through the collaboration between CAVs and Road-Side Unit (RSU)s, and the XR/AR visualisation and rendering of 5G based shared information. TRUSTCAR is an ambitious venture of AviSense aiming at propelling CAVs into the 5G era by increasing autonomy levels and enhancing safety, efficiency, and comfort indexes for vehicle occupants (i.e., drivers and/or passengers), aspiring to influence existing standards by defining metrics for cooperative awareness, setting a benchmark for the industry. One of the most fundamental tasks in Advanced Driver Assistance Systems (ADAS) is performing an analysis of the scene outside the vehicle and beyond the

range of operation of sensor or human sensory systems (e.g., recognizing vehicles ahead, estimating their velocity/trajectory, forecasting future vehicle locations).

To achieve its ambitious goals, TRUSTCAR will utilise and validate the low latency & high throughput communication infrastructure, edge/cloud processing power, and cutting-edge capabilities of the 5G-IANA testbed, to offer holistic collaborative perception solutions for CAVs and explainable AI (xAI)-based information rendering for CAV occupants, integrating a multitude of onboard and infrastructure-based sensors, heterogeneous distributed IoT devices, and an encompassing suite of AI-enabled tools. For its implementation, the proposed use case will explore and utilise 5G functionalities in the frame of the "Infrastructure, Transportation and Security & Safety (ITSS)" domain.



Cooperative Perception (CP): CAVs utilize a multitude of onboard sensors, including cameras, RADAR, LiDAR, ultrasonics, and GPS to establish a comprehensive understanding of their surroundings. However, the employed sensors have considerable inherent limitations (e.g., weathering and/or lighting conditions degrade camera performance, while active sensors are adversely affected by high humidity, occlusions, and interference), which can severely degrade CAVs performance. What is more, in real-world scenarios, the amount of local data is insufficient to derive resilient and robust learning models, due to the extremely complex and dynamic nature of the CAV's environment. Cooperative perception builds on Vehicle-to-Everything (V2X) communication infrastructure aiming to overcome these adversities by sharing knowledge among a group of interacting agents (including infrastructural elements). TRUSTCAR will investigate use-case scenarios employing the three main V2X-enabled CP approaches, namely, the early, deep, and late fusion of information. In more detail, i) ***Early Fusion*** leverages collaborative knowledge by fusing raw sensory inputs from multiple agents (e.g., onboard camera images, LiDAR point clouds) and jointly processing them to produce the system-level

	global perception; ii) ***Deep Fusion*** fuses intermediate features derived from the individual vehicles' perception framework (i.e., the feature maps produced by intermediate layers of the employed deep networks), with intermediate features of other vehicles (each utilizing local data), striking a balance between accuracy and transmission bandwidth; and finally, iii) ***Late Fusion*** fuses AI-leveraged insights (i.e., deep network outputs) produced at each agent, at the decision-making stage to produce a final global perception. **Deep learning-based multi-modal automotive scene analysis:** Object detection has evolved considerably since the appearance of deep convolutional neural networks. TRUSTCAR will utilize multi-modal approaches combining image-based with LiDAR-based object detection, using state-of-the-art deep neural networks. Some important, representative, high-performancing examples of the first branch include R-CNN, Fast R-CNN, and Faster R-CNN. Object detection in LIDAR point clouds is dominantly performed with 3D convolutional networks due to the irregularity and lack of apparent structure in the point cloud. Representative approaches include Pointpillars, PointNets, compressed Pointpillars, etc. **Cooperative/crossview localization:** Extending the V2X-CP concept, the novel paradigm of Cooperative Localization (CL) enables CAVs to exchange high-level multimodal information (e.g., relative distances extracted by the scene analysis module), in order to localize themselves inside a global or local map. Here, TRUSTCAR will use 5G communication to perform multimodal fusion across the interacting CAVs for achieving sub-meter positioning accuracy. Additionally, through advanced **cross-view fusion,** available infrastructure-generated inputs point clouds from LiDAR(s) installed on the infrastructure, offering a ***bird's-eye view*** of the environment), will be combined with images and point clouds captured by ground vehicles in order to create more accurate high-definition maps of the CAV's surroundings. The goal is to project the infrastructure-input's deep features to a ground-view point local position estimate, via an infrastructure-to-vehicle projection module. Then, a non-linear least-squares optimization procedure is applied to refine the vehicle's pose estimation by minimising the differences between the predicted and observed features. **Situational awareness of driver and AR infotainment**: In the case of semi-autonomous vehicles, it is of great importance to implement notification paradigms that direct the operators', possibly reduced, attention to the event that triggered the take-over request. The design of AR in-vehicle systems for infotainment is a challenging task. Despite the

vast number of requirements for these systems to work reliably, the integration of AR in vehicles will help drivers navigate through their environment better, and thus will be more widely adopted. In the TRUSTCAR ecosystem, the highly accurate positioning and perception information will be coupled with AR capabilities for visualising critical information in the driver's field of view. AR rendering is based on classical perspective projection, where for each 3D point (i.e., vehicle's position in the map) the pixel coordinates in the image space of the AR interface are calculated through projection and a colour is assigned indicating the object class. Interfaces used for in-vehicle visualisation include AR headset, Head-Up Display or even the car's windshield with transparent display.

(AviSense has a related patent PCT/EP2022/062954 application "*Methods for receiving, processing and AR displaying 3D objects in real-time cooperative driving conditions for situational awareness*")

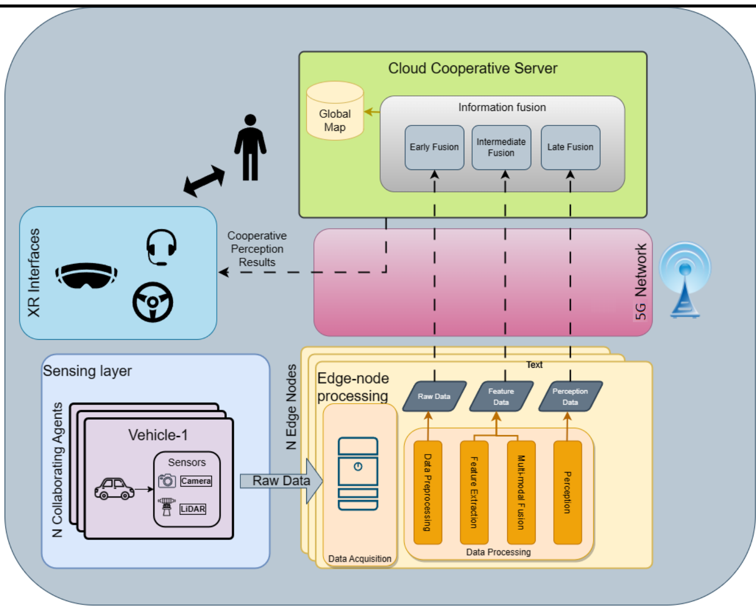
The main application components involved in the TRUSTCAR's use-case implementation are based on CAV-oriented tools provided by AviSense:

I. **AviSense Visual/LiDAR Sensor Data Enhancement Kit**: Designed to enhance the quality of low-cost visual and LiDAR sensors offering similar perception capabilities with those provided by high-speed/high-resolution cameras and LiDARs.

II. **AviSense Hyper-Sensing Suite**: Tailored specifically to deliver trusted perception localisation and mapping of the vehicle and other road users by processing in real-time infrastructure data fused with data from dozens of sensors of various vehicles when connectivity is available, including cameras, RADARs, and LiDARs.

III. **AviSense Multimodal Infrastructure Assistance Kit**: Designed to collect GNSS positioning information and satellite imagery for low-cost localization.

	IV. **AviSense CAV Simulation Platform**: A comprehensive simulation platform specifically crafted for developing, validating, and testing Autonomous Driving software, with a special focus on scenarios involving constrained spaces. Its highly optimized and scalable architecture makes it an ideal choice for simulating connected and AVs, also performing radio propagation in V2X communication, based on ITS-G5 standards. The traffic simulator stack consists of state-of-the-art autonomous driving and network simulators including CARLA, SUMO and Artery and can be used through the ROS bridge to easily test our solution in diverse traffic scenarios. Specifically, CARLA is the component responsible for simulating physics phenomena and rendering, SUMO handles the control and coordination of the simulated entities, and Artery is responsible for modelling and implementing V2X communication based on standard communication protocols. A Traffic Control Interface supports interactions between the three simulators V. **AviSense XR System of XAI Content**: A highly innovative system, providing drivers with personalized, non-destructive, and explainable information, delivered by the AviSense's extended vision suite, through an XR rendering system, improving drivers' situational awareness, skills, capabilities, performance, and convenience.
Provide more details about the experiment that you would like to run on the 5G-IANA platform.	The TRUSTCAR concept is built upon a multi-layer, interconnected architecture that handles the project's heterogeneity and complexity (as shown in the following figure). These are the following. The **sensing layer** encompasses all heterogeneous sensing modalities envisioned by the TRUSTCAR ecosystem (e.g., GPS, IMU, LiDAR, cameras, etc.), including both onboard vehicle sensors as well as sensors provided by the infrastructure (e.g., installed in RSUs).

	 The diagram in the above figure depicts the devices that will be part of the proposed use-case and the envisioned interactions with the cloud system and the end-user XR equipment, providing vehicle occupants with personalized, non-disruptive, and explainable information about the surrounding traffic environment in the form of suggestions and warnings for improved situation awareness, enabling a trustworthy and safe mobility experience. <u>In the initial stages</u> of the proposed use case, the environment sensing inputs will be obtained via an in-house CAVs simulator based on the open-source CARLA framework, while <u>in the final deployment of the system</u>, real on-board and infrastructure sensors are going to be utilised. The heterogeneous, multi-modal, and raw data streams produced by the sensing layer feed the **edge-node processing layer** that provides advanced AI-based processing capabilities. Each edge node is envisioned to consume locally captured multimodal sensory data, to produce a locally produced estimation of the vehicle's surroundings and ego-motion, via a comprehensive suite of cutting-edge AI-based algorithms, including: a) data enhancement via deep-unrolling based visual/LiDAR super-resolution; b) multi-modal 2D/3D object-detection (vehicles, cyclists, pedestrians, road lanes, etc.); and c) visual/LiDAR-based odometry for ego-motion estimation and SLAM (simultaneous localization and mapping). The edge-node processing layer will generate the three fundamental information flows that enable the early, deep, and late fusion schemes for creating the envisioned system-level cooperative perception information,

	in the form of an extended map. The novel attentive fusion schemes are executed in the **cloud cooperative server layer** and the map is then transmitted back to the edge nodes. Finally, 3D detectors are employed to the extended scene and occluded objects that are far beyond the operation of sensors are rendered to the driver via the XR interfaces layer. The **XR Interface layer** presents the personalised and explainable output of the processed information consisting also of a virtual assistant. TRUSTCAR will develop eXplainable AI (xAI)-based XR interfaces, providing the driver with intuitive and unobtrusive information/suggestions/warnings such as a real co-driver does.
What is the current stage of your product or service? Idea phase Under development Demo Prototype Other: ______	The current stage of our products/services are Demos. The Technology Readiness Level (TRL) of our solutions is 4-5 which means that some of our solutions have been tested and evaluated in a free-risk simulated environment and some others in real environment under restrictions.
Experience	
Do you have any prior experience with EU R&D projects?	As members of AviSense, we have 2 successfully evaluated Horizon European projects, which will start in June and November of 2024, correspondingly. However, as research scientists from two research laboratories, AviSense's members have been actively involved in (5 as PI + 2 as coordination) EU Horizon Projects with a focus on CAVs and more that 30 in total. More specifically, the core team of AviSense is presented here. **Dr. Aris S. Lalos** (Co-Founder & CSO) (https://www.linkedin.com/in/aris-lalos-85625331/) received the Diploma, M.A.Sc., and Ph.D. degrees from the Computer Engineering and Informatics Department, University of Patras (UoP), Rio-Patras, Greece, in 2003, 2005, and 2010, respectively. He is currently a Research Director at the Industrial Systems Institute (ISI), Athena Research Centre. He has been a Research Fellow at the Signal Processing and Communications Laboratory, CEID, SE, from 2005 to 2010; and the Signal Theory and Communications Department, Technical University of Catalonia (UPC), Barcelona, Spain, from October 2012 to December 2014 and at the Visualization and Virtual Reality Group, from January 2015 to June 2018. From October 2011 to October 2012, he was a Telecommunication

	Research Engineer with Analogies S. A., an early-stage start-up. In May 2018, he was elected as a Principal Researcher and in February 2023 as a Research Director at ISI. He is the author of 170 research papers in international journals (53), conferences (108), and book chapters (9). Many of these publications proposed highly novel frameworks and systems in the areas of digital communication, media processing, 2D-3D signal processing, and learning that go significantly beyond the state-of-the-art. His general research interests include model-based deep learning approaches, 2D/3D scene analysis, Distributed Signal Processing and Learning. He received the Best Demo Award in IEEE CAMAD 2014, the Best Paper Award in IEEE ISSPIT 2015, and the World's FIRST 10K Best Paper Award in IEEE ICME 2017. He acts as a regular reviewer of several technical journals. In January 2015, he was nominated as an Exemplary Reviewer of the IEEE COMMUNICATIONS LETTERS. He served as a Deputy Coordinator for the CPSoSAware H2020 EU Project and as a Technical Coordinator for the GamECAR H2020 EU Project. Furthermore, he had the role of Work Package Leader in five H2020 Projects. After 2018, he formed his own group (https://mips.isi.gr) with ISI that now counts ten active members (post-docs, Ph.D. students, and programming engineers) in research and development projects. Since 2019, he is the president of the scientific advisory board of the ISI. **Prof. Konstantinos Moustakas** (Co-Founder) (https://www.linkedin.com/in/konstantinos-moustakas-8a470012/) received his Diploma degree and PhD in electrical and computer engineering from the Aristotle University of Thessaloniki, Greece, in 2003 and 2007 respectively. During 2007-2011 he served as a post-doctoral research fellow in the Information Technologies Institute, Centre for Research and Technology Hellas. He is currently a Professor at the Electrical and Computer Engineering Department of the UoP, Head of the Visualization and Virtual Reality Group, Director of the Wire Communications and Information Technology Laboratory and Director of the MSc Program on Biomedical Engineering of the UoP. He serves as an Academic Research Fellow for ISI/Athena research centre. His main research interests include virtual, augmented and mixed reality, 3D geometry processing, haptics, virtual physiological human modelling, information visualization, physics-based simulations, computational geometry, computer vision. During the latest years, he has been the (co)author of more than 250 papers in refereed journals, edited books, and international conferences. His research work has received several awards. He has participated in more than 30 R&D projects funded by European and National funds, while he has served as the coordinator or scientific coordinator in 4 of them. He has also been a member of the organizing committee of several international conferences and a senior member of the IEEE, the IEEE Computer Society and member of Eurographics.

	Dr. Gerasimos Arvanitis (CEO) (https://www.linkedin.com/in/arvanitis-gerasimos-46048112b/) received the Diploma degree in the ECE department of UoP, the M.Sc. degree in electronics and information processing, and Ph.D. degree in geometrical 3D processing from the UoP, Greece in 2009, 2011 and 2021, respectively. From 2011 to 2015, he worked as a software programmer at the Computer Technology Institute in Patras, Greece. He is a member of the Visualization and Virtual Reality Group at the UoP since January 2016. He has participated in 6 European projects, and he acts as a regular reviewer for several technical journals and conferences. He has (co)-authored over 50 papers in refereed journals, edited books, and international conferences. His main research interests include geometry processing of 3D models, reconstruction, compression, outliers removal, feature preserving denoising algorithms, and computer graphics. **Nikos Piperigkos** (www.linkedin.com/in/nikos-piperigkos-71b897295) received the Diploma and M.Sc. degrees from Computer Engineering and Informatics Department (CEID) of UoP, Greece in 2018 and 2020, respectively. Currently, he pursues his PhD degree at the same department. Since 2017, he is a member of Signal Processing and Communications Lab of CEID. He joined the Industrial Systems Institute, Athena Research Centre and became member of Multimedia Information Processing Group in 2019. He has participated in three Horizon EU R&D projects. His research interests include cooperative localization and tracking, sensor fusion, intelligent transportation systems, distributed estimation, adaptive signal processing and learning algorithms. **Christos Anagnostopoulos** (https://www.linkedin.com/in/christos-anagnostopoulos-b2abb330/) received the Diploma degree in electrical and computer engineering from the UoP and the M.Sc. degree in integrated hardware and software systems from the Department of Computer Engineering and Informatics, UoP. For the last 13 years, he collaborates with the Industrial Systems Institute and the UoP, as a Research Fellow. He has been engaged in multiple national and European research projects. He has coauthored more than ten publications in international peer-reviewed conferences and journals. His current research interests include manufacturing systems, industrial networks, VR/AR technologies, and serious gaming. **Alexandros Gkillas** (https://gr.linkedin.com/in/alexandros-gkillas-27168514b) holds a Diploma in Electrical and Computer Engineering from UoP and a MSc in Signal and Image Processing Systems from the Department of Computer Engineering and Informatics of the same University. He is currently pursuing a PhD degree in the Department of Computer Engineering and Informatics. Since July 2021, he is also a member of the Industrial Systems Institute of Athena Research Center. He is also a member of AviSense team since 2023. His scientific interests

	include signal and image processing, distributed learning, and deep learning.
Have you already developed any Virtual Network Functions (VNFs) or network applications (nApps) to be utilized or are you planning to develop them? Provide more details:	While we have significant experience in utilizing Artery and OMNeT++ for network simulation and modelling, we have not yet developed Virtual Network Functions (VNFs) or network applications (nApps) ourselves. Our expertise lies primarily in the simulation and analysis aspects of network technologies. However, we are open to exploring the development of VNFs or nApps in the future, under the guidance of the 5G-IANA experts, as we continue to expand our capabilities and knowledge in this area.
Do you have any experience with 5G technology?	Only as users, not as a developer.
Expectations from the platform	
Why do you deem 5G essential for your solution/product?	AviSense envisions implementing and testing a novel 5G-enabled vehicular service involving AI-leveraged collaborative perception and xAI-based XR information rendering tools for CAVs. To this end, TRUSTCAR will utilize a <u>multitude of on-board and infrastructure-installed sensors</u>, <u>IoT and information rendering devices</u>, as well as <u>heterogeneous computational platforms</u>, capitalizing on the secure and modular paradigm of 5G for managing communication and computationally intensive processes, across the continuum, and facilitating timely and confidential data transfers among multiple heterogeneous components. This holistic 5G-empowered approach will enable the envisioned vehicular platform to consume multimodal and multi-agent sensory inputs, establish an AI-leveraged comprehensive perception of its surroundings - augmenting local sensing capabilities with knowledge emanating from collaborating agents - and, ultimately, enhance the situational awareness and the experience of CAV occupants, through innovative and tailored AR visual mechanisms. In this use case, there are three groups of components that are considered for its implementation. In particular, 1. The first group comprises all the components that are relevant to the data that is captured and pre-processed at the edge before it is transmitted to the involved cloud cooperative server. This group comprises the **sensing devices** (including on-board cameras and

	LiDAR, as well as, infrastructure cameras) that provide the input to the **AviSense AI-empowered software** for (a) data quality enhancement, (b) feature extraction and (c) object detection, thus, enabling the three fundamental information flows to be further processed at the cooperative cloud server. This software is executed on edge devices that comprise **NVIDIA Jetson platforms** for enabling efficient computations. 2. The second group refers to components residing on the cloud side of the overall solution and, in particular, the **AviSense AI-empowered software** for performing either early, deep, or late fusion of the corresponding information flow for generating an extended map. This software is executed on the **cloud cooperative server.** 3. Finally, the third group comprises all components relevant for providing feedback of AI-leveraged insights, suggestions to the driver. This group consists of the **AviSense AI-empowered software** that is executed at the edge nodes (i.e., vehicles) by performing multi-modal 3D object detection on the extended map received via the cloud server for augmented scene understanding by including information beyond the sensing capabilities of individual vehicles and providing it to the vehicle occupants by **AviSense xAI-based XR interfaces**. The communication between the components that are going to be deployed on the edge and the cloud will use the 5G network for interacting. 5G enables ultra-reliability, low latency and high-speed interactions, ensuring that the extended map that is produced by the cloud server, reaches the vehicles at the edge in real-time.
How do you plan to integrate 5G into your solution/product?	The growing size of cities and the ever-increasing desire for mobility is creating a complex and dynamic traffic environment in which multiple traffic agents, including various types of vehicles (e.g., cars, buses, trucks, motorcycles, bikes, etc.) and Vulnerable Road Users (VRUs), should harmonically coexist and tightly interact for achieving a fast and safe mobility experience. To this end, TRUSTCAR will demonstrate holistic collaborative perception solutions for CAVs and xAI-based information provision for CAV occupants, capitalising on multi-modal sensing modalities provided by distributed onboard and infrastructure-based sensors, and AI-enabled tools. These collaborative perception solutions build upon the edge-cloud continuum for exchanging data and extracting knowledge for each participating agent well beyond their sensing capabilities. For these solutions to become a reality, the following challenges from the automotive vertical (Application Challenge - AC) considered in the

	proposed use-case as well as the network side (Network Challenge - NC), need to be addressed: ● **AC-1:** Devise effective and cooperative fusion schemes for data captured by multiple, distributed onboard sensors over groups of vehicles (e.g., camera, LiDAR) and the infrastructure (e.g., birds-eye-view from LiDAR) to create an accurate and comprehensive view of each vehicle's state and surroundings that goes beyond the range of its sensors. ● **AC-2:** Minimise the driver response time to system suggestions and warnings via xAI-based XR interfaces that meet human reaction times in audio, visual and haptic feedback for a trustworthy and safe mobility experience. ● **NC-1:** Cooperative 4D situational awareness, building upon the exchange of huge amounts of sensing data (e.g., captured by LiDAR, cameras, etc.) across the edge-cloud continuum, require eMBB links focusing on speed, capacity and mobility. ● **NC-2:** Providing URLLC links for the Timely feedback of AI-leveraged insights, suggestions to the driver. The envisioned use-case will develop and validate both hardware/communications in-the-loop and real scenarios involving a real test vehicle and infrastructural elements. **In the former case**, simulated multi-agent (including both vehicle- and infrastructure- based) multi-modal sensory inputs will be generated utilising AviSense's comprehensive CARLA-based simulator, while the processing and exchange of data is performed on real edge in-the-loop devices (e.g., NVIDIA Jetson) that exchange information via 5G. For such scenarios, we envision utilising the 5G testbed of 5G-IANA. **In the second case**, we will utilise a real test-vehicle that fuses its locally acquired sensory inputs (camera, LiDAR) with LiDAR point-clouds from the infrastructural elements to improve its geo-localization and situational awareness (detection of occluded objects). This scenario is envisioned to be tested using a temporary installation (RSU + LiDAR) at the testbed of 5G-IANA. In optimizing realism and connectivity, the strategic deployment of the available 5G testbed's cutting-edge equipment emerges as a cornerstone. Central to both envisioned use cases is the indispensable role played by the 5G testbed. Serving as a base station within our scenarios, this unit orchestrates seamless interconnections and intercommunications among the TRUSTCAR components. Elevating the sophistication of our network architecture, the 5G testbed ensures a swift and reliable internet connection, a mission-critical element for the bidirectional exchange of

	data. To comprehensively evaluate and refine our network capabilities, the inclusion of the 5G User Equipment (UE) on board is imperative. This element will play a vital role in testing and assessing the network's performance under dynamic conditions. In parallel, recognizing the pivotal role of real-time data from the road environment, we harness the capabilities of Roadside Units (RSUs). These RSUs, integral components of our infrastructure, actively contribute by collecting crucial data from the road and seamlessly feeding it into the TRUSTCAR components via 5G-IANA's V2X communication.
What are your expectations regarding 5G connectivity (round trip time, upload and download data rate, service reliability)? How are these associated with your experiment?	**Trial requirements** The following indicative values are considered sufficient for the successful testing of the envisioned scenarios: ● Downlink throughput > 100Mbps ● Uplink throughput > 40 Mbps ● Latency < 20 ms **KPI measurements** TRUSTCAR will adopt and assess the following KPIs: ● Downlink throughput per user ● Uplink throughput per user ● Application round-trip latency ● AI/ML accuracy ● AI/ML precision ● Recall ● F1 score ● Location accuracy
What type of resources will be required from 5G-IANA to run your experiment? Provide rough estimates for the number of On-Board Units (OBUs), Road-Side Units (RSUs), vehicles, and amount of CPUs, RAM, storage, etc.	Here we list the equipment that is required for developing and testing the proposed use-case. Specifically, the devices that are outlined in the following table will be provided by the AviSense. **In-house open-source simulator for CAVs**: The simulation suite provided by AviSense, is built on the open tools CARLA, SUMO, Omnet++. The comprehensive simulation platform specifically crafted for developing, validating, and testing Autonomous Driving software, with a special focus on scenarios involving constrained spaces. Its highly optimised and scalable architecture makes it an ideal choice for simulating connected and AVs, also performing radio propagation in V2X communication, based on ITS-G5 standards. The environment generates annotated data from multiple agents and multiple sensors (image, LiDAR, GNSS, depth, V2X based on the ITS-G5 standards, etc.), enabling driver-in-

	the-loop, model-in-the-loop, software-in-the-loop, and hardware/communications-in-the-loop testing of algorithmic implementations of cooperative 4D situational awareness, localization, continual Federated Learning (FL), etc., in diverse traffic/weather conditions. **LiDAR**: Velodyne Puck VLP-16 LITE, designed for applications that demand a lower weight, it retains the Puck sensor's surround view and best-in-class performance. The Puck LITE™ is perfect for use with drones/UAVs, backpacks and other applications requiring reliability and less weight. **AR Headsets**: Meta 2, Epson BT-350, Epson BT-250, Atheer - Head-worn apparatus that allows viewers to see images superimposed onto the real environment. **VR Headsets**: Oculus rift, HTC Vive Pro, Gear VR + samsung s7, Oculus Quest - A head-worn apparatus that completely covers the eyes for an immersive 3D experience. **NVIDIA Jetson Nano**: a small, powerful computer that lets you run multiple neural networks in parallel for applications like image classification, object detection, segmentation, and speech processing. All in an easy-to-use platform that runs in as little as 5 watts. Just inserting a microSD card with the system image, boots the developer kit JetPack is compatible with NVIDIA's world-leading AI platform for training and deploying AI software, reducing complexity and effort for developers. Additionally, for testing the envisioned scenarios, TRUSTCAR would require the following resources from 5G-IANA's side: ● 5G connectivity for the small-scale hw-in-the loop tests. ● A test vehicle and an OBU for the real tests in phase 3 of the project. ● An RSU installation that could be utilized for testing the envisioned collaborative scenarios concerning crossview localization and indirect measurements of drowsiness, at phase 3 of TRUSTCAR. For this phase, the provided RSU will be fitted with a LiDAR sensor provided by TRUSTCAR.
How much time would you need to run your experiment (not including training, pre-testing activities and getting familiar with the platform functionalities)?	TRUSTCAR will implement comprehensive scenarios for AI-empowered collaborative perception in CAVs involving multi-agent/multimodal scene analysis and cooperative localization tasks, testing all three fundamental fusion mechanisms envisioned in the proposed use-case. The main deployment aspects that need to be considered for the execution of the trial, are described in the following, in the frame of the envisioned functionality executed at the edge side as well as at the cloud cooperative server side. **Data enhancement:** As a preprocessing step, TRUSTCAR will utilise AviSense's suite of AI-based data-enrichment tools (such as image and

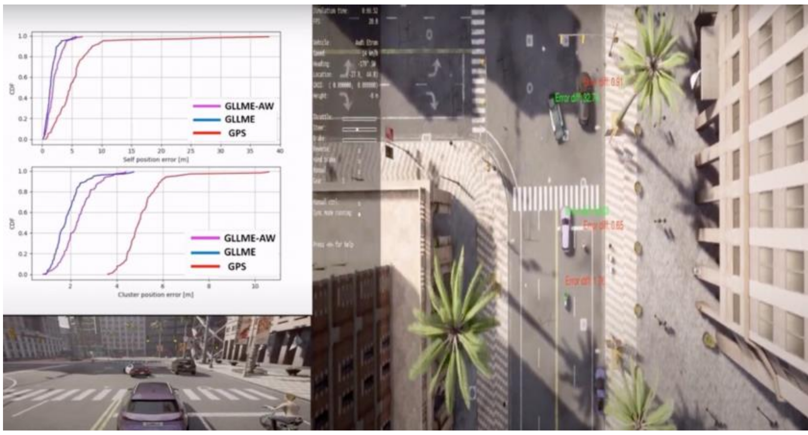
	point-could super-resolution) with the goal of increasing the resolution of input sensory streams, thus, leading to high-quality perception results from low-resolution/low-cost sensors. The employed solutions are based on novel efficient AI model architectures, bridging optimization-based methods with deep learning approaches, resulting in DNNs that are orders of magnitude smaller (up to 99.75% reduction in network parameters was achieved in the problem of LiDAR super-resolution[8]), with the same or better performance, compared to conventional data-driven approaches. **Multi-agent/Multimodal object detection:** Object detection constitutes a fundamental operation of perception systems in autonomous vehicles. The classes of interest are typically vehicles, cyclists, and pedestrians. In recent years, DNN models have contributed significantly to the improvement of object detection performance, concerning both 2D (i.e., image-based captured by visual cameras) and 3D (i.e., point-cloud based captured by LiDAR) detectors. YOLO and PointPillars constitute prime examples of 2D and 3D, respectively, DNN object detectors. Multimodal object detection takes place when fusing results obtained from multiple sensors (i.e., camera and LiDAR), while multi-agent object detection refers to fusing results from multiple collaborating agents. To this end, early, deep, and late fusion strategies are going to be investigated for the inherent trade-offs that they represent, in terms of the required communication bandwidth, processing power over the edge-cloud continuum, and achieved performance. ● Early fusion: Here, the low-resolution sensory inputs from each agent are streamed to the cloud computing server where data enhancement and the generation of fused image/point-cloud maps take place. Subsequently, multi-modal detectors are employed to the extended map, resulting in the detection of occluded objects that lie beyond the local sensing capabilities of individual agents. ● Deep fusion: Under this scenario, each agent performs data enhancement of the locally produced inputs, and executes part of the employed multimodal detector using edge-in-the-loop devices (e.g., such as NVIDIA Jetson) to produce intermediate embeddings/feature maps that are sent to the cloud, where the maps are fused (utilising novel attention-based fusion) and the final stages of the detector are executed. It is noted that the shared feature maps in this scenario are far smaller in size than the initial raw data streams.

[8] A. Gkillas, A. Lalos, D. Ampeliotis, "An Efficient Deep Unrolling Super-Resolution Network for Lidar Automotive Scenes", IEEE ICIP 2023

	● <u>Late fusion</u>: In this case, the entire enhancement/multimodal detection pipeline is executed at the edge, with the detection results being sent to the cloud for fusion and the production of the extended objects. As it is obvious, the late-fusion strategy results in the least amount of data being transmitted, at the exchange of more processing taking place at the edge/far edge of the network. **Cooperative localization:** 1) **Coarse:** In this initial step, GNSS positioning from each individual vehicle will be combined with the camera and LIDAR's pose and landmarks in a novel graph signal processing framework which exploits the properties of graph topologies in order to improve positioning accuracy and reduce the drift error of each vehicle. 2) **Fine:** In this step, we perform cross-view localization, which formulates the task as vehicles' pose optimization incorporating infrastructure LiDAR-generated BEVs of the environment. We tentatively project the BEV's deep features to a ground viewpoint from the previously coarse pose (or position) estimate by a BEV-to-ground projection module. Then, a non-linear least-squares optimization procedure is applied to refine the vehicle's pose estimation by minimising the differences between the predicted and observed features. To further increase the performance of this step, we will apply deep learning-based super-resolution of BEV and ground visual data to increase their quality. 3) **Cooperative:** In the third step, we perform a final round of multimodal fusion across a group of CAVs interacting through 5G communications. A xAI-based novel cooperative localization algorithm effectively fuses the measurements exchanged among the participating CAVs to further increase the positioning accuracy (i.e., below submeter) *or situational awareness* of CAVs. **<u>XR-based feedback</u>**: The highly accurate collaborative perception information is then coupled with AR capabilities for visualising critical information in the driver's field of view. AR rendering is based on classical perspective projection, where, for each 3D point (i.e., vehicle's position in the map), the pixel coordinates in the image space of the AR interface are calculated through projection and a colour is assigned indicating the object class. Interfaces that can be used for in-vehicle visualisation include AR headsets, Head-Up Displays or even the vehicle's windshield with transparent displays. TRUSTCAR adopts <u>a three-phase approach for trial deployment, execution and evaluation of the results</u>. ● Phase **one** that will take place in the premises of the AviSense, will be continuously deployed for the generation of data and rapid prototyping. ● Phases **two** and **three** are envisioned to take place in 5G-IANA testbeds, during the second half of the project in a limited number of runs to be arranged with the site partners.

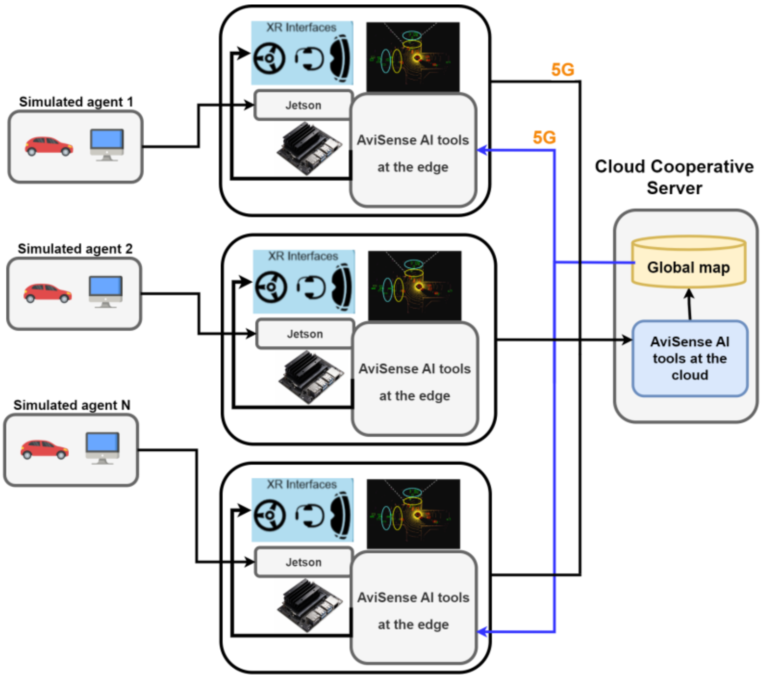
In the following, an overview of the main deployment aspects of the three phases is provided.

Phase 1: Fully-simulated scenarios. In this phase, TRUSTCAR solution will be assessed via a fully-

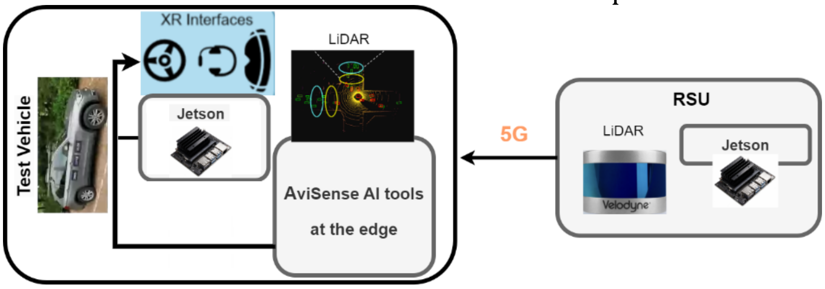


simulated traffic environment for (a) rapid prototyping and cost-effective validation of the system; (b) data generation for training of AI models; and (c) the timely identification of possible issues arising both at the application side (i.e., AI-leveraged algorithms) as well as at the communication side (i.e., simulated V2X links), thus, providing implementation guidelines and benchmark values for the adopted KPIs when the TRUSTCAR solution is to be assessed in the subsequent phases via real trials. AviSense's integrated simulated traffic environment builds upon a traffic simulator stack consisting of the state-of-the-art autonomous driving and network simulators of CARLA, SUMO and Artery/OMNET++. In more detail, CARLA is the component responsible for simulating physics phenomena and rendering, SUMO handles the control and coordination of the simulated entities, and Artery/OMNET++ is responsible for modelling and implementing V2X communications based on ETSI ITS-G5. This integrated simulation environment enables TRUSTCAR to test and assess its solutions over a diverse set of traffic scenarios. The scenarios capture different operational design domains (including rural, urban, and highway scenarios), harsh weather, day/night conditions, traffic jams and different levels of sensing modalities and infrastructure availability, also considering limitations / impairments (e.g., induced latency) of the supporting telecommunication network. It is noted that a similar approach assuming ideal communications and virtual CARLA agents running on the same computing platform (i.e., RAM: 64 GB, CPU: AMD Ryzen 9 5900X 12-Core, GPU: 2x RTX3090)[9], has been implemented by AviSense.

Phase 2: Hardware and communication in the loop scenarios. One of the basic targets of this phase is to test cooperative situational awareness scenarios whereby raw data will be captured by the CARLA-based simulated sensors while the processing and exchange of data will be performed using real HW (e.g., 5G-connected NVIDIA Jetson platforms). For such scenarios, we envision utilising the 5G-IANA testbed. This phase will test the envisioned multi-agent/multi-modal scenarios for cooperative perception and localization involving all three fundamental flows of information required for implementing the early, deep, and late fusion mechanisms envisioned in the proposed use-case. More specifically, each simulated vehicle will capture multi-modal sensory inputs (camera, LiDAR, GNSS) which will be either processed and forwarded or simply forwarded to the cloud cooperative server, along with information captured by simulated infrastructure LiDAR sensors offering a bird's-eye view of the traffic scene, for further analysis. The overall evaluation of the TRUSTCAR solution in this phase will be concluded with the intuitive and unobtrusive XR-based feedback of relevant information to the end-user.



[9] https://www.youtube.com/watch?v=vn6r1g3cQo8&ab_channel=MIPSGROUP

<table>
<tr><td></td><td>Phase 3: Trial in 5G-IANA testbed. In this final phase of the use-


case trials, the 5G-IANA testbed is envisioned to be utilised for testing an evaluating the TRUSTCAR solution and, in particular, the envisioned a) crossview localization; and b) indirect measurement of drowsiness operations already described at the beginning of this section. Here, the focus will be on the implementation and testing of vehicle/infrastructure collaborative scenarios involving the available test vehicle and RSU(s). In the first case, ground-view data generated by the vehicle will be fused with the LiDAR BEV data generated by the RSUs, concerning cooperative localization tasks, focusing on the “fine” localization step described previously. Fusion will take place at the edge (vehicle) so as to minimize latency in the produced results. The available sensing, processing and communication resources in both vehicle and RSUs will enable testing several scenarios and the measurements of the relevant KPIs, adopted for the use-case.</td></tr>
<tr><td>Do you envision that AI/ML could provide added value to your experiment/service?</td><td>Absolutely, AI/ML could provide significant added value to the services offered by AviSense.ai. Actually, all the product/services, developed by AviSense, are related with the technologies of AI/ML. AviSense, utilizing AI/ML to its implementations, has the potential to revolutionize the automotive industry and enhance its provided product/services, leading to safer, more efficient, and more enjoyable driving experiences for users.</td></tr>
<tr><td colspan="2">Expected impact</td></tr>
<tr><td>What would the expected gain from experimentation with the 5G-IANA platform be?
Testing of an application using 5G
Developing a new product or service
Developing a new virtual network</td><td>i) Testing of an application using 5G
ii) Research purposes
iii) Interest in the business model
iv) Increase the TRL of some of our solutions</td></tr>
</table>

function / network application Research purposes Interest in the business model Other: _______	
What is the expected outcome of the experimentation in the 5G-IANA platform for your business? Would you need business modelling guidance from 5G-IANA experts?	While the broader market for Intelligent Transportation Systems (ITSs) and Autonomous Vehicles (AVs) is competitive, the specific combination of features and innovations within TRUSTCAR of AviSense sets it apart. Existing solutions often focus on isolated aspects such as AR applications or geo-localization, but the comprehensive integration of these elements, coupled with cooperative awareness and innovative communication for vehicles and infrastructures, creates a unique and differentiated offering. **Business scale-up and competitive advantage output**. By introducing a new paradigm in cooperative situational awareness, AviSense has the potential to reshape the market, emphasizing on advanced fusion techniques for accurate geo-localization, sensor data enhancement and vehicle hyper-sensing that are not commonly found in current solutions. Its innovative use of LiDAR, AI, and AR technologies, coupled with real-world testing through the 5G testbed infrastructure of 5G-IANA, positions it as a ground-breaking solution. While competition exists, AviSense's innovative approach, unique feature set, and holistic integration of technologies set it on a path to break into the market with a disruptive force. The ability to provide a transformative solution that significantly advances the state-of-the-art in ITSs enhances its potential to stand out and capture market attention. There is a clear window of opportunity in this market since a) The AV market is still evolving b) There is a growing demand for AV technology, both among consumers and within industries; c) While there are established competitive players in the area, there is no single company that has completely cornered the market; d) Our solution lies in its emphasis on transparency, explainability, and passenger safety; e) The market is not limited to passenger vehicles. It includes commercial applications like autonomous delivery, transportation, and logistics, providing diverse opportunities for growth. We can capitalize on this window of opportunity by emphasizing safety continuing to focus on transparency in AI decision-making and user safety; forge partnerships and collaborations with key industry players; develop scalable solutions that can cater to various segments of the market.

	The proposed system is inherently scalable, allowing for commercialization to address structural problems across diverse applications. Its modular cloud-edge computing architecture, decentralized multi-modal fusion, and cooperative awareness engine enable seamless adaptation to various use cases. This scalability positions TRUSTCAR beyond a niche solution, paving the way for widespread adoption and commercialization in diverse applications. The cooperative situational awareness model is transferable to various sectors (e.g., human-robot collaboration) where real-time, comprehensive information processing is vital. Whether deployed in urban traffic management, rural road safety, or within smart city infrastructures, the system's scalability ensures effective solutions for structural challenges across the spectrum of ITS. Our technology is designed to be adaptable to different environments and scenarios. For example, our expertise in multimodal data processing, scene understanding, perception, and localization can be valuable in applications like industrial automation and agriculture. **Environmental output**. AviSense makes a substantial contribution to sustainable development, aligning with European policies, by improving road safety, due to the improved traffic flow and the reduced traffic congestion, and traffic collisions. Its AI-driven 4D cooperative awareness solution minimizes traffic incidents, a key contributor to the Green Deal's goal of safe and clean transport. **Economical output**. AviSense supports innovation and job creation in the intelligent transportation sector. This holistic approach aligns with European goals for a green, inclusive, and innovative future, emphasizing sustainability in environmental, social, and economic dimensions. AviSense's important goal is to improve road safety and therefore provide a significant contribution to the achievement of EU Vision Zero goal for zero fatalities in road transport by 2050. EU is among the world's leader producers of motor vehicles, and it is the area where the automotive sector represents the largest private investor in R&D. EU's automotive sector provides jobs for more than 5 million people, around 3 million jobs in vehicle manufacturing and close to 2 million workers in vehicle sales. It accounts for approximately 3% of the EU GVA and around 2.5% of total EU employment. Studies predict by 2025, there could be 14.5 million vehicles (mostly with partially automated driving functionality), including 600,000 fully AVs (12-13% of global vehicle sales) out of a total of 111 million new vehicles and that by 2035, there will be 18 million partially automated vehicles and 12 million AVs (25% of vehicle sales) out of 122 million new vehicles in total.

	The **Social impact** of TRUSTCAR can be summarized regarding: i) The reduction of deaths, the severity of crashes, and the number of accidents due to distracted driving; ii) Improvement of road safety, due to improved traffic flow and reduced traffic congestion, and traffic collisions; iii) It can reduce the stress level of the drivers. It has been proved that a reduced drivers' stress level can lead to a reduced risk of collision; iv) Improvement of driving experience, support the physical interaction and change the "need to travel" to: "wish to travel". v) Increase the feeling of trust and acceptance of drivers for the new technologies of XAI and AR. vi) Environmentally, it promotes efficient traffic management, reducing congestion and emissions. It would be beneficial for us to have guidance from 5G-IANA experts to develop more our business modelling?
What data do you plan to collect/generate during the experiment? Are you going to provide open access to them?	In TRUSTCAR, all data to be collected are either synthetically generated by the in-house CAVs simulator of AviSense (during phases 1 and 2) or captured by actual sensors (during phase 3). Data types include time series, images, and LiDAR point clouds. No personal data will be collected during the trial, and our intention is to make all collected data publicly available using suitable repositories like the IEEE Dataport. If it is feasible and allowed by the rules of the specific program, we plan to provide the collected/generated data during the program, in open access.
Before you submit	
How did you learn about the 5G-IANA open call? Please add any other comments you would like to accompany your application.	ESA BIC Greece (We are one of the selected teams for incubation) Elevate Greece
Do you have any preferred 5G testbed where you would like to run your experiment (at NOKIA in Germany	No, we do not have any specific preference regarding the selected 5G testbed.

or at Telekom Slovenia in Slovenia)? (*Please note that any response is not binding for 5G-IANA.*)	
GDPR acknowledgement	
All Open Call projects will be expected to comply with the General Data Protection Regulation 2016/679 (GDPR).	AviSense acknowledges ethical considerations, particularly concerning data privacy and security. The system involves the processing of real-world data, raising concerns about personal information and surveillance. To mitigate this, we adhere to GDPR principles, ensuring data anonymization and secure transmission. More specifically, personal data will be anonymized and aggregated wherever possible, minimizing the risk of identifying specific individuals. We will implement clear consent mechanisms for data collection ensuring that individuals are aware of and agree to the use of their data. We will implement ethical AI practices, including bias detection and fairness assessments, ensuring that the system's decision-making processes are transparent, unbiased, and accountable. Additionally, AviSense commits to regular ethical reviews, fostering responsible innovation. The implementation aligns with EC ethical guidelines, ensuring ethical principles guide every aspect of the AviSense.
Do you agree: Y/N	Yes

Open Call 2 – Wings

General information	
Name and surname of contact person	Sokratis Barmpounakis
E-mail	sbarmpounakis@wings-ict-solutions.eu
Is your organization characterized as an SME/start-up?	SME
Name of organisation	WINGS ICT SOLUTIONS SA
Website of organisation	https://www.wings-ict-solutions.eu/
Please provide a short description of your business (main activities, year of foundation, VAT number)	WINGS is an SME based in Athens, Greece (VAT Number: [redacted]) that develops end-to-end digital solutions and transformation for vertical business sectors; Environment (air quality, natural disasters), Utilities and Infrastructures (energy/water/gas, transportation, construction), Production & Manufacturing (food, factories/logistics), Service Sectors (health, education/culture, government, security/defense), as well as Smart Cities. To achieve these results, WINGS exploits advanced technologies, such as Artificial Intelligence, Big Data, Cloud technologies, Telecommunication Networks (4G, 5G and beyond, Wi-Fi, Lora, etc.), advanced visualization techniques (Augmented / Conceivable Reality (AR / VR), mobile applications, etc.) aiming to provide extremely reliable solutions that help businesses improve their decision-making processes, expand their knowledge through detailed forecasting and predictive analytics, increase their efficiency and in the end, focusing on customer satisfaction.
What is the country of establishment?	Greece
Ambitions and development plans	
Describe the service/application or product	**The Driver Health Monitoring and Automated Intervention System (DHMAIS)** represents a significant advancement in

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<td>that you plan to deploy in the 5G-IANA platform and the “use case/scenario” you would like to implement.</td>
<td>road safety technology, with its ability to continuously monitor the health status of drivers in real-time using a comprehensive array of sensors and devices. By integrating cabin temperature, CO_2, humidity, and biometric sensors, along with an in-cabin camera, DHMAIS captures a holistic view of the driver's well-being. This data is then analyzed by edge-based computer vision algorithms to assess the driver's health condition and detect potential dangers, ensuring proactive measures can be taken to mitigate risks.

The seamless integration of all sensors and devices, coupled with the utilization of 5G-enabled communication, enables DHMAIS to provide continuous assessment of the driver's vital signs, fatigue levels, and cognitive state. Through analysis of high definition-based facial expressions, eye movements, and body posture, the system can detect subtle indicators of potential health risks or impairment, allowing for timely interventions to be implemented. In cases of emergencies or imminent danger, DHMAIS can autonomously intervene by alerting or triggering the driver, initiating automated safety measures, or notifying emergency services. Moreover, the system serves as a platform for remote monitoring and intervention by healthcare professionals, ensuring that drivers experiencing health-related issues on the road receive timely assistance and support, ultimately contributing to safer roads and enhanced driver well-being.</td>
</tr>
<tr>
<td>Provide more details about the experiment that you would like to run on the 5G-IANA platform.</td>
<td>More specifically, in DHMAIS we are targeting to utilize the following components (COM#) to develop a couple of application (AF#) and network functions (NF#):

Primary components
<table>
<tr><th>Component</th><th>Description</th></tr>
<tr><td>Cabin Temperature Sensor</td><td>Monitors the temperature inside the vehicle cabin.</td></tr>
<tr><td>CO2 Sensor</td><td>Measures the level of carbon dioxide (CO2) concentration within the vehicle cabin</td></tr>
<tr><td>Humidity Sensor</td><td>Measures the relative humidity level inside the vehicle cabin.</td></tr>
</table>
</td>
</tr>
</table>

Biometric Sensor	Measures specific biometrics of the driver
In-Cabin Camera	A camera mounted inside the vehicle to capture the driver's facial expressions and overall physical condition
Edge Server	An edge computing server installed within the vehicle or nearby to process sensor data and run computer vision algorithms in real-time.
5G Network	Provides high-speed, low-latency connectivity for transmitting data between the vehicle and external servers if necessary

Currently identified primary application functions (AFs)

AF#	**Description**
AF#1 Video Encoding/Decoding	Encodes and decodes video streams captured by the in-cabin camera for real-time analysis.
AF#2 Sensor's Data Analysis	Analyzes data from cabin temperature, CO2, and humidity sensors to monitor the driver's environment for potential health hazards.

	AF#3 Object Detection with Deep Learning	Utilizes computer vision algorithms to detect signs of driver drowsiness or impairment based on facial expressions, eye movements, and body posture.
	AF#4 Vehicle Condition Warning Service	Generates warnings or alerts in case of detected health events or risks, such as drowsiness or poor air quality, to prompt appropriate responses from the driver.
	AF#5 Remote Driving Central Control	Coordinates remote interventions or actions, such as adjusting ventilation or alerting emergency services, based on detected health issues or safety risks.
	AF#6 Remote Driving Module	Interfaces with vehicle control systems to execute remote commands or interventions, ensuring seamless integration with the vehicle's operational mechanisms.`

AF#7 Wearable device for automated intervention	Smart device mounted on the driver connected with the control system, extracting either visual or vibration alerts in emergency situations.

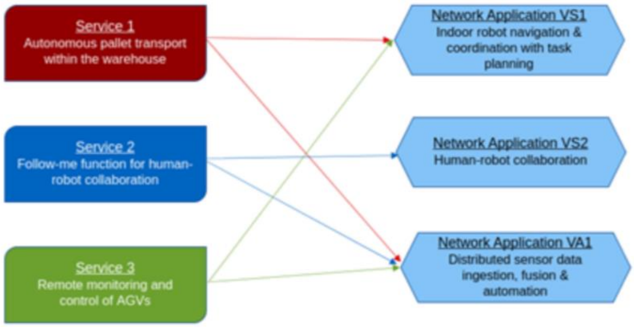
Currently identified primary network functions (NFs)

NF#	Description
NF#1 Sensor's Data Capturing	Captures data from cabin temperature, CO2, and humidity sensors for real-time analysis by the system.
NF#2 Actuator Interface	Interfaces with vehicle systems to execute actions or interventions in response to detected health events or risks, ensuring timely and appropriate responses.
NF#3 Long-Distance Data Communication	Facilitates bidirectional communication between the driver health monitoring system and remote control interfaces, ensuring real-time transmission of data and commands.

The expected outcomes (EO#) of our proposed solution are categorized as follows:

- **EO#1:** Demonstrate the effectiveness of DHMAIS in real-time monitoring of driver health status and detection of potential health risks or impairment.
- **EO#2:** Validate the accuracy and reliability of computer vision algorithms in analyzing in-cabin video feeds and detecting signs of driver impairment.

	- **EO#3:** Showcase the responsiveness and effectiveness of automated interventions in mitigating health risks and ensuring driver safety. - **EO#4:** Provide insights into the feasibility and scalability of deploying DHMAIS on the 5G-IANA platform for widespread adoption and impact in real-world applications.
What is the current stage of your product or service? Idea phase Under development Demo Prototype Other: ______	The envisioned product will offer a robust Driver Health Monitoring and Automated Intervention System (DHMAIS) foreseen to seamlessly integrate via respective open APIs with the respective CCAM systems in the mid-term. The specific product will be part of the WINGSChariot suite (https://www.wings-ict-solutions.eu/wingschariot/), which is already commercially available. The TRL of the described DHMAIS is currently at 5 and the target is for it to reach 6-7 until the end of the open call project execution.
Experience	
Do you have any prior experience with EU R&D projects?	WINGS has participated in more than 40 EU projects (FP7, H2020, Horizon Europe, SNS-JU, etc.), undertaking the roles of the Project Coordinator, Technical Manager, WP leader, Task leader. Also, WINGS, leveraging its powerful integrator services' expertise, has undertaken key PoC leader roles. Indicatively, WINGS has been the PoC leader of the EU 6G Flagship projects HEU Hexa-X and SNS-JU Hexa-X-II, the Technical Manager of HEU FOR-FREIGHT and FLEXI-cross projects, the Project Coordinator of VITAL-5G, WP leader in SNS-JU TrialsNet and others.
Have you already developed any Virtual Network Functions (VNFs) or network applications (nApps) to be utilized or are you planning to develop them? Provide more details:	Besides its project coordination roles, WINGS showcases advanced technical developments within VITAL-5G. WINGS deploys several end-to-end scenarios in the Athens 5G-Testbed, offering the services depicted in the following figure, leveraging respective network applications. Under the scope of 5G-IANA open call, WINGS aims to reuse the most relevant ones, along with critical components (see following list of AFs/NFs) developed within 5G-IANA.

	 As a core of the Athens trial site, the 5G SA ecosystem comprises the following components: - **User Equipment (UE)**, i.e., an AGV, a dedicated sensor Gateway with attached environmental sensors and video camera. - **Radio Access Network (RAN)** with a dedicated gNodeB with two cells installed in a selected area of the DIA warehouse. - **Transport and Core network**. - **A Cloud compute resource server** that hosts the Network Application platform, designed and deployed to provide Network Function Virtualization (NFVI) resources for hosting and orchestrating Network Applications tailored to Assisted Vessel Transport use case, by using Open-Source MANO (OSM)-based orchestrator and OpenStack/Kubernetes. - **A testing room** with a gNodeB (not shown in the picture), with similar configuration and located in the OTE premises. The partner/experimenter can choose to conduct preliminary experiments/tests in this facility before moving to the DIA warehouse
Do you have any experience with 5G technology?	WINGS has extensive experience with 5G technologies having contributed to several EU-funded projects. Indicatively, as part of the VITAL-5G project, WINGS led the internal experimentation in the Athens (GR) facility to investigate and evaluate the envisioned AGV-based services of the project over 5G connectivity at a GR experimental facility. The GR site instantiated three different AGV-based services within a warehouse based on the development of three Network Applications, namely VA1-Distributed sensor data ingestion fusion & automation, VS1-Indoor robot navigation & coordination with task planning and VS2-Human robot

	collaboration. In order to thoroughly evaluate the performance of the three provided services, as well as that of the respective Network Application, nine (9) test cases were defined to be executed during the GR trials. In the next table, the assets (NetApps, functions, datasets) we developed/produced during the execution of the Use Case are indicated:

Asset	**Type of asset**	**Description**
Distributed sensor data ingestion fusion & automation (VA1)	NetApp	Responsible for the data ingestion and two-way communication with on-site equipment, decision support using rules and inference, monitoring and field assistance.
Digital Twin & simulated warehouse environment which includes virtual Automated Guided Vehicles (AGVs)	Facility	Experiment execution using the digital twin and simulated warehouse environment with virtual AGVs.
Partial access to AGVs	Facility	Agreed and coordinated access to the AGVs (indoor robotic platform) in the Athens trial facility will be possible.
Data from mounted sensors in the warehouse	Data	The Environmental Sensors pack provides data from sensors (temperature, humidity, vibration, luminosity) deployed on various locations in the warehouse environment. The data will be available in the form of open datasets.

Non-sensitive historical data from warehouse and AGV operations	Data	Open datasets with non-sensitive historical data from warehouse and AGV operations to be available on Zenodo.
Pre-configured 5G slices	5G testbed	5G slices provisioned during the third-party experimenters' trials. Different network slices (eMBB and uRLLC) to be provisioned in a pre-configured manner.
New 5G slices to be provisioned	5G testbed	5G slices provisioned during the third-party experimenters' trials. Different network slices (eMBB and uRLCC) to be provisioned in a dynamic manner.
Asset	Type of asset	Description
Distributed sensor data ingestion fusion & automation (VA1)	NetApp	Responsible for the data ingestion and two-way communication with on-site equipment, decision support using rules and inference, monitoring and field assistance.
Digital Twin & simulated warehouse environment which includes virtual Automated Guided Vehicles (AGVs)	Facility	Experiment execution using the digital twin and simulated warehouse environment with virtual AGVs.
Partial access to AGVs	Facility	Agreed and coordinated access to the AGVs (indoor robotic platform)

		in the Athens trial facility will be possible.
Data from mounted sensors in the warehouse	Data	The Environmental Sensors pack provides data from sensors (temperature, humidity, vibration, luminosity) deployed on various locations in the warehouse environment. The data will be available in the form of open datasets.
Non-sensitive historical data from warehouse and AGV operations	Data	Open datasets with non-sensitive historical data from warehouse and AGV operations to be available on Zenodo.
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New 5G slices to be provisioned	5G testbed	5G slices provisioned during the third-party experimenters' trials. Different network slices (eMBB and uRLCC) to be provisioned in a dynamic manner.
Network KPIs from monitoring platform on 5G testbed	Results	Measurement logs on network KPIs from executed experiments provided through the Vital-5G monitoring platform.
Network KPIs from monitoring	Results	Measurement logs on network KPIs from executed experiments

	<table><tr><td>platform on 5G testbed</td><td></td><td>provided through the Vital-5G monitoring platform.</td></tr></table>
Expectations from the platform	
Why do you deem 5G essential for your solution/product?	5G is indispensable for our use case due to its transformative capabilities in enabling **high-speed, low-latency connectivity**, which is paramount for real-time monitoring and intervention in the transportation domain. The **ultra-low latency** provided by 5G networks ensures rapid transmission of data between deployed IoT devices and central monitoring systems, facilitating timely detection of potential health hazards or safety risks. This is crucial for the DHMAIS, where swift interventions can prevent accidents and ensure the well-being of drivers and passengers. Additionally, the **high data rates** offered by 5G enable the transmission of large volumes of data from in-cabin cameras, sensors, and other sources, allowing for comprehensive analysis and decision-making to optimize the cabin environment and ensure passenger and road safety. Moreover, 5G empowers our use case with unprecedented **reliability and scalability**, essential for deploying our solution in diverse and dynamic transportation environments. The reliability of 5G connectivity ensures continuous monitoring and intervention capabilities, even in high-traffic areas or remote locations where network congestion or signal degradation may occur. This reliability is critical for maintaining the effectiveness of our system and ensuring uninterrupted operation, especially in emergency situations where every second counts. Additionally, the scalability of 5G networks allows us to deploy our solution across a wide geographic area, accommodating varying levels of traffic and connectivity requirements.
How do you plan to integrate 5G into your solution/product?	WINGSChariot solution, which is the overarching suite that will also support the proposed system to be showcased within 5G-IANA OC project, has already partially integrated 5G capabilities, using a 5G Gateway, via which the OBU device and camera connect to the backend servers of WINGS for data ingestion and further processing. Integrating with 5G, we can collect and transmit increased data volumes from high definition in-cabin cameras and complementary sensors within the vehicle to our

	central monitoring system in real-time. This means we can monitor the driver's health status continuously and respond immediately to any potential issues. Integrating 5G in the solution allows low latency to transmit/receive and analyze data and detect any signs of impairment or health issues quickly. This will enable us to initiate automated interventions or alerts without delay, ensuring the safety of the driver and others on the road. One of the critical objectives of the experimentation in 5G-IANA infrastructure will be to study in detail the e2e network and application KPIs and assess the scalability potential (and potential constraints) when targeting to upscale this application to hundreds/thousands of drivers (this will be estimated via extrapolation and analytical approach, leveraging the results from 1 or more OBUs/vehicles).
What are your expectations regarding 5G connectivity (round trip time, upload and download data rate, service reliability)? How are these associated with your experiment?	For our use case, we have specific expectations regarding the performance metrics of 5G connectivity, which are crucial for the successful operation of our DHMAIS. Firstly, we expect 5G to provide **ultra-low latency** with **round trip times** of less than **10ms (KPI#1)**. This low latency is essential for ensuring real-time communication and responsiveness between sensors, devices, cameras and the central monitoring platform. Achieving this level of latency will enable swift interventions with **fast responsiveness** less than **100ms (KPI#2) for automated intervention** and **order of some seconds (KPI#3) for manual intervention** in the occurrence of health hazards or safety risks, ensuring the safety of drivers and passengers. In addition to low latency, we anticipate 5G to deliver **high upload and download data rates**, with speeds of at least **100 Mbps for upload (KPI#4)** and **1 Gbps for download (KPI#5)**. These high data rates are crucial for rapid transmission of data between vehicles-IoT devices and external servers, facilitating the exchange of video streams, sensor data, and other information critical for real-time analysis and decision-making. By meeting these data rate requirements, 5G connectivity will enable the system to process the large volume of data generated by in-cabin cameras, sensors, and other sources efficiently, ensuring timely detection and response to potential health hazards or safety risks. Moreover, we expect 5G

<table>
<tr><td></td><td>connectivity to offer exceptional reliability, with a minimum uptime of 99.9% (KPI#6) and minimal network congestion. Reliable connectivity is fundamental for maintaining continuous monitoring and intervention capabilities, especially in high-traffic areas or remote locations where network reliability may be challenged.</td></tr>
<tr><td>What type of resources will be required from 5G-IANA to run your experiment? Provide rough estimates for the number of On-Board Units (OBUs), Road-Side Units (RSUs), vehicles, and amount of CPUs, RAM, storage, etc.</td><td>The described UC requires:

1. One OBU with CO_2/Humidity/Temperature sensors with 5G connectivity (in line with the 5G-IANA 5G RAN frequency configurations)
2. One vehicle with OBU capabilities
3. One in-vehicle camera compatible with 5G connectivity (can be provided by the experimenter if not available by the 5G-IANA infrastructure)
4. Edge/Cloud resources comprising as minimum 1 CPU (Intel i5 Gen. 13, as minimum), RAM: 16GB, Storage: 500GB, GPU: 1 unit (in-house testing for computer vision tasks has been carried out using an AMD Ryzen Threadripper 3970X 32-Core Processor with 125GB RAM, in order to process 1 frame and generate the related inference every 5,5 seconds, so something equivalent would be satisfactory)</td></tr>
<tr><td>How much time would you need to run your experiment (not including training, pre-testing activities and getting familiar with the platform functionalities)?</td><td>
<table>
<tr><th>Phases</th><th>M1</th><th>M2</th><th>M3</th><th>M4</th><th>M5</th><th>M6</th></tr>
<tr><td>1. Device configuration and design of experiment</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2. Executing the experiment</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3. Data collection, analytics, feedback, recommendations</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4. Showcasing, real demo</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5. Dissemination and exploitation</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6. Final Reporting</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Due to our experience in numerous 5G and beyond projects (H2020 5G-EVE, HEU Vital5G, HEU Hexa-X, SNS-JU Hexa-X-II,</td></tr>
</table>

	TrialsNet, etc.) we expect that minor to xzero pre-training and familiarisation period would be needed.
Do you envision that AI/ML could provide added value to your experiment/service?	We strongly believe that AI/ML holds immense potential to enhance the value and efficacy of our demonstration. AI/ML algorithms can play a pivotal role in **analyzing the vast amounts of data** collected from sensors, cameras and other sources in real-time, allowing us to extract meaningful insights and detect patterns that may not be apparent through traditional methods. For instance, machine learning models can process data from cabin temperature sensors, CO_2 sensors, and humidity sensors to identify correlations between environmental conditions and driver behavior/fatigue level, enabling us to **develop predictive models for potential health hazards or safety risks.** By leveraging AI/ML, we can create more sophisticated and accurate algorithms for **object detection, facial expression analysis, eye/body fatigue, and cognitive dysfunction**, enhancing the system's ability to detect signs of driver impairment, distraction, or fatigue with greater precision and reliability. Moreover, AI/ML can enable the system to adapt and learn from new data and experiences, improving its performance and effectiveness over time. Through **continuous learning** and refinement, machine learning models can optimize interventions and responses based on real-world feedback, ensuring that the system remains adaptive and responsive to changing conditions and scenarios. Additionally, AI/ML techniques such as **reinforcement learning** can enable the system to autonomously adjust its behavior and decision-making strategies in response to evolving circumstances, further enhancing its ability to ensure driver and passenger safety and well-being.
Expected impact	
What would the expected gain from experimentation with the 5G-IANA platform be? Testing of an application using 5G Developing a new product or service Developing a new virtual network	- **Testing of an application using 5G:** Expected gain from experimentation with the 5G-IANA platform indicates a focus on validating the performance, reliability, and scalability of the DHMAIS in a real-world 5G environment. By conducting experiments on the 5G-IANA platform, the aim is to assess how well the DHMAIS application utilizes 5G connectivity to monitor driver health status, detect potential risks or impairment, and autonomously intervene to ensure driver safety. 5G is an enabler for WINGS products and

function / network application Research purposes Interest in the business model Other: _______	the experimentation within 5G-IANA infrastructure will provide valuable insights into the feasibility and effectiveness of deploying DHMAIS in practical settings, paving the way for broader adoption of similar 5G-enabled applications in the transportation sector. - **Developing a new product or service:** Expected gain from experimentation with the 5G-IANA platform indicates a focus on innovation and commercialization. Through experimentation, the goal is to refine and optimize the DHMAIS to create a robust and market-ready solution that leverages 5G connectivity for enhanced road safety and driver well-being. By developing DHMAIS as a new product or service, there is potential to address pressing transportation safety challenges and meet market demand for advanced driver monitoring and intervention systems.
What is the expected outcome of the experimentation in the 5G-IANA platform for your business? Would you need business modelling guidance from 5G-IANA experts?	The expected outcome of conducting experimentation in the 5G-IANA platform for our business is multifaceted. Primarily, we anticipate gaining valuable insights into the **feasibility, scalability, and performance** of our DHMAI system in a real-world 5G-enabled environment. By leveraging the advanced capabilities of the 5G-IANA platform, we aim to validate the effectiveness of our solution in monitoring and ensuring the well-being of drivers and passengers in various driving conditions. Additionally, we expect to identify potential areas for refinement and optimization, allowing us to enhance the system's capabilities and tailor it to meet the specific needs and challenges of modern transportation ecosystems. Moreover, the experimentation in the 5G-IANA platform presents an opportunity for us to showcase our technology and demonstrate its value proposition to potential stakeholders, including automotive manufacturers, fleet operators, and transportation authorities. By validating our solution in a real-world 5G-enabled environment, we aim to **attract investment, partnerships, and commercial opportunities** that will enable us to scale our business and bring our innovative technology to market. In this regard, we would greatly benefit from business modeling **guidance from 5G-IANA experts**. Specifically, we would welcome their expertise in refining our business model, assessing market opportunities, and identifying potential revenue streams and partnership opportunities. Additionally, guidance on **regulatory compliance**, **intellectual property management,** and

	commercialization strategies would be invaluable in navigating the intricacies of bringing our innovative solution to market.
What data do you plan to collect/generate during the experiment? Are you going to provide open access to them?	During the experiment, we plan to generate and gather a wide range of data to support the operation and evaluation of our demonstration. This includes: - **Behavioral driver's data:** Data collected from in-cabin cameras, such as facial expressions, eye movements, and body posture, to assess driver alertness, attentiveness, and potential impairment. Also, data from biometric sensors and wearable devices which are transferred to the central platform. - **In-cabin environment data:** Data from sensors monitoring cabin temperature, CO_2 levels, humidity, and air quality to evaluate environmental conditions and detect potential health hazards or safety risks. - **Vehicle data:** Data from vehicle sensors monitoring speed, acceleration, engine performance, tire pressure, and other parameters to assess vehicle's health and performance. - **Network performance data:** Data related to the performance of the DHMAIS, including latency, data transmission rates, upload/download speed and reliability metrics. Regarding open access to data, we recognize the importance of transparency and collaboration in advancing research and innovation in the field of transportation safety. Therefore, we are committed to providing open access to anonymized and aggregated data from our experiment, subject to privacy and data protection regulations. By making our data openly accessible to researchers, developers, and other stakeholders, we aim to foster collaboration, drive innovation, and contribute to the development of new technologies and solutions that improve road safety and transportation efficiency. Additionally, open access to data allows for independent verification of our findings and promotes trust and credibility in our research efforts. We will work closely with 5G-IANA and other relevant stakeholders to ensure compliance with data privacy regulations and establish appropriate mechanisms for data sharing and access.
Before you submit	

How did you learn about the 5G-IANA open call? Please add any other comments you would like to accompany your application.	From the 5G-IANA website and the project's partners emails.
Do you have any preferred 5G testbed where you would like to run your experiment (at NOKIA in Germany or at Telekom Slovenia in Slovenia)? (*Please note that any response is not binding for 5G-IANA.*)	As long as both testbeds can support the indicated NFs and AFs, provide the relevant cloud, virtualisation resources, 5G NR access and Edge-RAN is able to offer <20ms e2e network latency, no specific preference between the two testbeds is highlighted.
GDPR acknowledgement	
All Open Call projects will be expected to comply with the General Data Protection Regulation 2016/679 (GDPR).	WINGS is fully compliant with GDPR policies. All national and European GDPR policies are followed, and respective procedures have been developed and are following within the company in internal and external activities. A Data Protection Policy is established within WINGS, defining the procedures to be followed before performing tests with human participants and their personal / private data. Moreover, the Data Protection Authority of Greece is the official organisation, to which the company reports all incidents regarding data protection issues, through its officially appointed Data Protection Officer. Moreover, the company has a security policy based on ISO27001 which includes, among others, the above procedures both for the physical security of employees and third parties and for the security of data processed, handled, and stored in/from the company.
Do you agree: Y/N	Y

Written Reports

Open Call 1 - Link Robotics

Introduction

In this report, the experiments in Nokia Research Center, Ulm/Germany for the Link Robotics' protoype VINS-RTK are introduced in scope of a 5G-IANA Micro Project and the experimental results taken are discussed.

Figure 1 VINS-RTK mounted on the test vehicle

The VINS-RTK is a prototype which uses an Inertial Measurement Unit (IMU), a monocular camera and RTK-capable Global Navigation Satellite System (GNSS) receiver to calculate the position, orientation and velocity of the vehicle. Is uses Multi-State Constraint Kalman Filter (MSCKF) and capable of giving the real-time output at 10 Hz.

Service setup description

The service is a localization system for robots and autonomous/connected vehicles. It uses a monocular camera, inertial measurement unit (IMU) and RTK-capable (Real Time Kinematics) GNSS (Global Navigation Satellite System) receiver. Also, inside the enclosure, there is a 5G GSM modem from Simcom (SIM8200EA) connected to a custom interface card.

Hardware Components

A brief description of hardware components are as follows, as shown in Figure
:

- Camera: For visual-inertial algorithm, a monocular camera is required to track the visual features and extract meaningful information about ego-motion of the vehicle/enclosure.
- Inertial Measurement Unit: For accurate and reliable localization, the combination of IMU and camera gives satisfying results with and without GNSS information. If it is used without GNSS or if the GNSS signal is poor, the IMU-camera combination will continue to give good localization information.

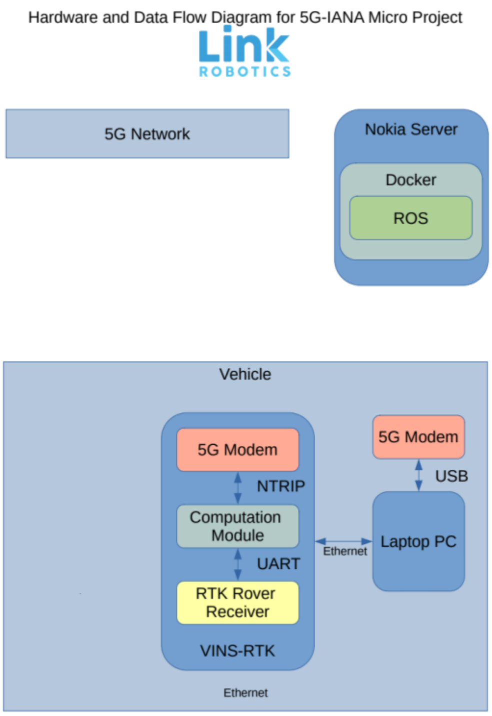


Figure 2 Hardware and Data Flow Diagram

- **RTK-GNSS Receiver:** Real Time Kinematics is a technique for improving the accuracy of GNSS output from meters to centimeters by using a ground station. Also, it is known as differential GPS. The technique can be used both by using a ground station and RF-modems and over Internet by using a subscription-based RTK service. In the project, RTK service used was Hexagon Smartnet Internet RTK service.

  The receiver used in the enclosure is capable of working in both normal GNSS and RTK modes. It is assembled onto the interface card.

- **Computation module:** Nvidia Jetson Xavier NX computation module is used in the product enclosure for visual-inertial navigation algorithm. It outputs the current position of the vehicle at 10 Hz. The camera is connected to the Jetson carrier board over MIPI interface. Also, the RTK-GNSS and IMU devices are connected to a custom interface board. This interface board has an MPU System on Module (SoM) and custom interface software to maintain RTK navigation data. The IMU and RTK navigation data are sent to the Jetson over high speed UART port.

- **5G Interface card:** The 5G interface card is connected to the Jetson hardware over UART, as explained in the computation module section. The interface card includes an STM32MP1 MPU SoM, 5G GSM modem from Simcom which is connected to the MPU over USB port, UART connection to IMU and a RTK-capable GNSS receiver from U-blox which is connected to the MPU over UART.

  The main task of the 5G interface card is to get RTCM (Radio Technical Commission for Maritime Services) correction data over NTRIP protocol (Network Transport of RTCM over Internet Protocol) from Internet RTK servers over 5G GSM network and to send them to the GNSS receiver in order to obtain RTK corrected GNSS position data. After the GNSS data is come to the MPU, it is sent over the Jetson UART port to the Jetson hardware along with the IMU data.

Software Components

Also, the software components include the Computer Vision Software and Sensor Software which is the Network Application in the project. They can be summarized as follows:

- **Computer Vision Software:** The computer vision part includes a MSCKF (Multi-State Constraint Kalman Filter) to extract meaningful localization data by using camera and IMU along with RTK-GNSS sensors. The details of the algorithm are not explained here.

  This part of the software stack is running on the Jetson hardware on Robot Operating System (ROS noetic). Also, there is a interface driver software running on ROS, which reads the communication UART port between Jetson and 5G interface card.

- **Sensor Software (the Network Application): The** sensor software is running on the MPU on the 5G interface card. It includes a custom GNSS driver which resolves NMEA protocol and sends the RTCM correction data to the host computer (Jetson hardware) and a custom IMU driver interfacing the IMU hardware.

  The whole sensor software is capable of receiving the IMU data at 200Hz and the GNSS data at 4Hz simultaneously. The both data are sent over the UART.

For 5G-IANA project, the software would send also the position and orientation of the vehicle to the Nokia servers. Some other software connected to the Nokia servers can easily obtain the data and will be able to use the data for its own purposes. This part is still under development.

The Application Functions (AF) of the software are summarized above. The Network Function (NF) of the software can be explained here.

The main part of the software which takes the responsibility for network function (NF) is the Sensor Software. As explained briefly in the aforementioned section, it sends a NTRIP protocol request and waits for the answer from the Internet-RTK server over the 5G GSM network. After the response is received, the software starts receiving RTCM data from the Internet. When the connection is dropped, the software automatically tries to reconnect and resend the NTRIP request.

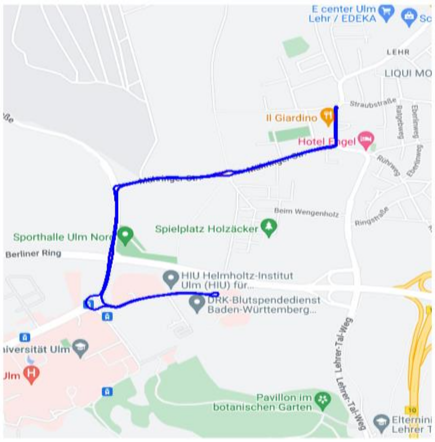
Traffic Flow

To mention about the Traffic Flow for the Sensor Software, there is mainly bi-directional traffic flow for NTRIP protocol. The software send a request packet over IP which contains NMEA-GGA sentence and receives RTCM correction data.

- **The content of the request packet:** Host IP, NMEA-GGA sentence, authentication information (username and password given by the Internet RTK service)
- **The content of the response packet:** RTCM v3 correction data (depending on the service used the protocol version may change)

Scenario description

The experiments are done near the campus of University of Ulm where the 5G coverage of Nokia private GSM network is available.



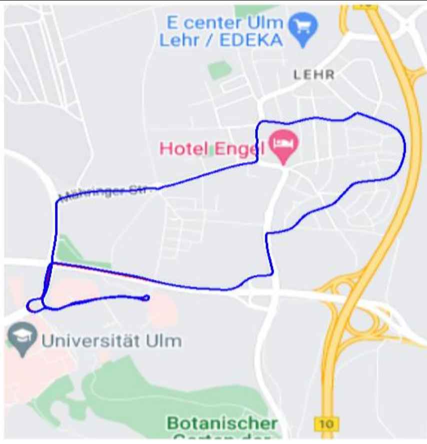


Table 14 Driven paths for the two experiments

For the two experiments to be explained, there are two driving paths near the University of Ulm given in Table .

Pre-conditions

The pre-conditions were:

- The presence of the Internet RTK subscription: The RTK service bought from Hexagon is used.
- The presence of 5G private GSM network coverage: In some regions, there was no network coverage, which was a known issue. The private network of the Nokia with a sim card from Nokia is used.
- The weather conditions: The weather was rainy and cloudy which affected the GNSS signals slightly. As a result, some regions GNSS signal was poor and the RTK receiver was not giving the output at its best (1-2 cm). The possible reason for this issue is that because of cloudy weather, the satellite view was not perfect during the whole experiment.
- Compass angle: The compass angle is extracted at the start of the experiment from the IMU sensor but it can give a yaw offset because of the possible hard and soft iron magnetic field effects for the magnetometer. The software could automatically calibrate the IMU yaw angle and gave correct heading angles.

- Initial position: The initial position of the vehicle is taken from the GNSS measurements.
- Satellite Map service: The free map service from Google maps is used.

Various Steps for Experiments

The steps followed in the experiments are as follows:

1) Mounting the enclosure onto the vehicle by using vacuum suction cups

2) Connecting the cables (power, ethernet, GNSS and GSM antennas)

3) Powering on the device by using a Li-Po battery

4) After the device is powered up, the RTK service is checked.

5) Waiting for RTK service and GNSS to settle (might take about 15 minutes)

6) Opening up the Graphical User Interface (GUI) and checking the accuracy of the GNSS from covariance values (they should be below 10 centimeters)

7) Checking the camera image and adjusting the exposure according to the ambient light

8) Starting the main software and checking if the algorithm is running correctly

9) Opening up the ROS nodes necessary for debugging such as saving the data for future purposes

10) The device is ready for driving.

Validation/Evaluation Objectives

In the experiments, the validation/evaluation objectives are as follows:

- The performance of the sensor driver software:

  The driver software should run reliably and giving centimeter RTK-GNSS output accuracy (1-2 cm) at best.

  It should output GNSS data at 4Hz and IMU data at 200Hz.

- The performance of the VINS-RTK:

  The software should give reliable and instantenous localization information.

  During RTK-fix, it should give a few centimeters of accuracy at best.

  During RTK-float or GNSS-fix, it should continue giving the correct localization.

  During dead-reckoning, it should continue giving relative localization with respect to the last position.

  The output rate should be 10Hz. The latency of the software should be about 50 ms average.

Metrics

The VINS-RTK software output should give 1-2 centimeters accuracy during RTK-fix depending on the environmental factors such as weather conditions, visible satellites and network coverage.

The cumulative error of the VINS-RTK should be below 1% when running with Internet RTK service even if the RTK is not available in some regions.

Assessment

The assessment of the product performance is done with two ground experiments. A van vehicle from Nokia was used. The enclosure is mounted onto the vehicle by using vacuum suction cups. Two cables for ethernet and power were used. There was a Li-po battery for powering the device.

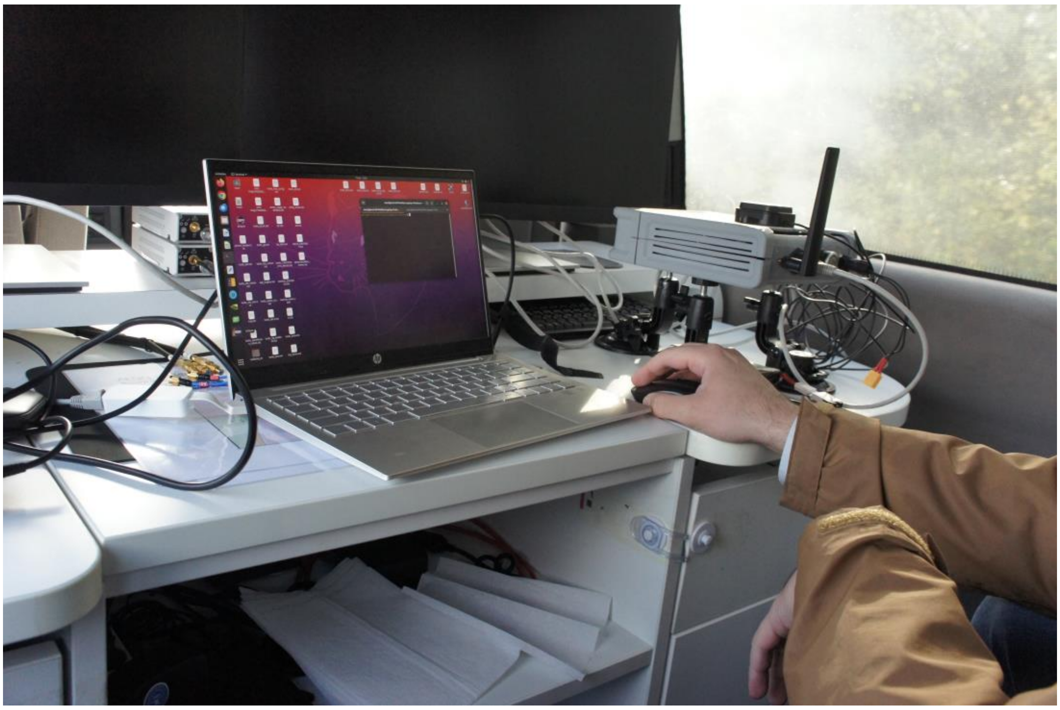


Figure 3 Inside the test vehicle with ground station PC and VINS-RTK enclosure

In the Figure , the product enclosure along with the ground station laptop are shown inside the test vehicle.

The software inside the enclosure is run while the vehicle is driving inside the pre-defined path. The vehicle is driven by a person from Nokia manually.

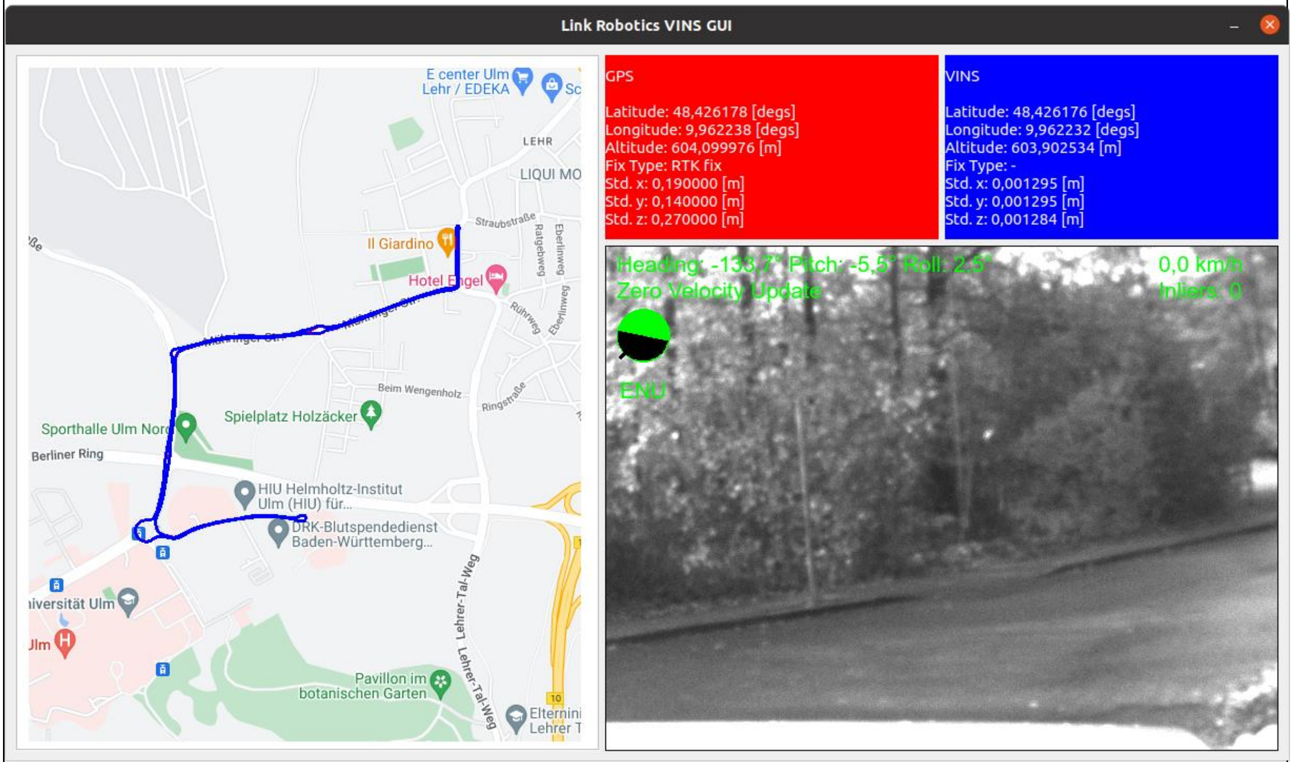


Figure 4 Test results for the experiment 1

In this section, two test results are given which are conducted near the university campus. Along the whole paths the 5G coverage was available except for some regions. In these regions, the RTK service cannot be reached, so the fix was only GNSS fix giving accuracy about 1 meter.

Within the 5G covered regions, the GNSS receiver was able to go into RTK mode which can give below meters accuracy depending on the factors such as satellites in view, the large buildings, trees etc. The RTK could perform about 1 centimeter accuracy at best.

In the regions with low quality GNSS coverage, e.g. no 5G coverage, the software could perform and continued giving the position-orientation information.

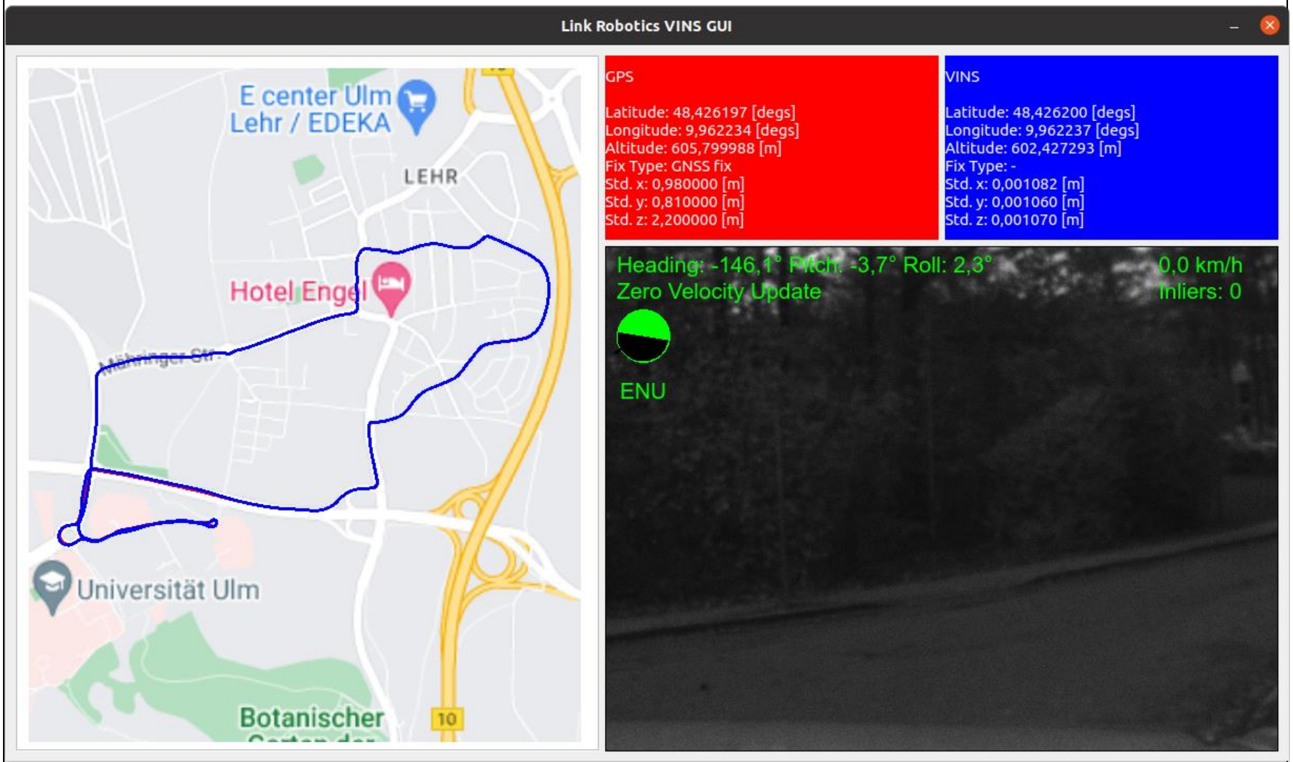


Figure 5 Test results for the experiment 2

In figures and , the two output trajectories of the software are given from two experiments.

The path length of the first experiment was about 4.3 kilometers. The accuracy was about 1 cm when RTK was available (at best). Also, the RMS error for the whole trajectory was measured as 0.75 meters including the regions with 5G outage (no RTK) compared to the GNSS output. It corresponds to 0.02% cumulative RMS error with respect to the distance traveled.

The path length of the second experiment was about 5.7 kilometers. The accuracy was about 1 cm when RTK was available (at best). Also, the RMS error for the whole trajectory was 2.84 meters including the regions with 5G outage (no RTK) compared to the GNSS output. It corresponds to 0.05% cumulative RMS error with respect to the distance traveled.

Experiment #1	**Experiment #2**

Cumulative Error	0.02%	0.05%
Absolute Accuracy	1-2 cm with RTK-fix	1-2 cm with RTK-fix
Software Latency	~ 50 ms	~ 50 ms

Table 12 Evaluations

In Table , the evaluations of the results after the two experiments are summarized.

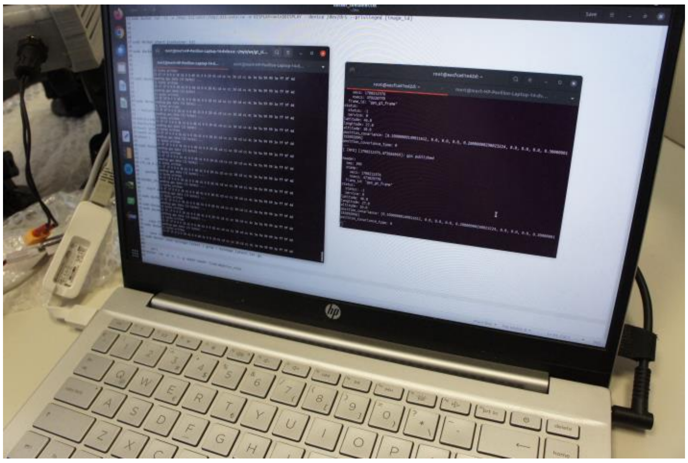


Figure 6 Connection test between the Nokia Server and ground station PC

In addition to the ground experiments, another test on the 5G network is performed. In this test, as shown in Figure , a connection between the ground station PC and Nokia server over the VPN is established. An example data -GPS coordinates at 10 Hz- is sent over the connection. On the Nokia server, a server running in docker image is receiving the data and publishing the data inside the ROS operating system at 10 Hz. This experiment demonstrates the scenario in which the VINS-RTK would send the position-orientation data over the 5G network to the Nokia server. On the server, the data could be stored in a database or published / sent to another software such as a Graphical User Interface (GUI) or used by a software on the 5G-IANA platform.

<u>Feedback on the 5G-IANA platform</u>

The localization of the vehicle is a crucial aspect especially in autonomous driving and vehicle tracking applications.

A possible use case is that the calculated output of the VINS-RTK can be stored on Nokia servers, or can be consumed real-time on the server according to the application. To achieve this goal, a TCP server software maintained on the docker environment can be integrated to the system. The VINS-RTK would send the estimation outputs over private network to the Nokia servers. Another software would connect to the Nokia servers, e.g. from a PC, and run a GUI or use the position/orientation information for its own purposes such as data collecting, analysing the traveled path or velocities. Also, it can used on the vehicle computer as an input of another sensor fusion engine for autonomous driving to improve the quality of the localization.

Results and Future Works

According to the experimental results, the VINS-RTK can perform well real-time under hard conditions such as rain and 5G outage. It can give centimeter accuracy where the RTK service is available. Also, when RTK service is lost, it is able to continue its operation.

All in all, the hardware and software of the VINS system is verified on the real and hard conditions in Nokia Research Center at Ulm and successful results are obtained.

In future, the software will be extended to send the position and orientation of the vehicle to the Nokia servers while the vehicle is driving. Also, the prototype can be integrated into the navigation stack of a test vehicle for autonomous driving use cases.

Moreover, the prototype can be used as a vehicle tracking device which will send the position-orientation data to a server, e.g. Nokia servers. The data can be either stored in the server or used without being stored. Then, a software, e.g. a GUI, will query the data from the server and show the position/orientation of the vehicle on the screen. By this way, multiple vehicles can be tracked from a single node.

Open Call 2 – Diamantis

Introduction

Overview of the use case

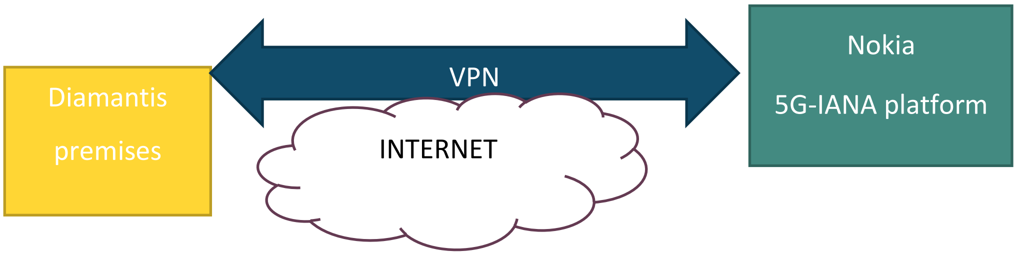
In the dynamic landscape of smart cities, 5G-STREAM proposes the development of surveillance service tailored to the needs of urban mobility and public transportation. The envisioned service leverages the cutting-edge capabilities of 5G networks with edge/cloud computing support and advanced video analytics, for (near-)real time video processing and data-driven insights.

5G-STREAM solution consists of two main parts, the cloud service part and the end-point client part. The network application (nApp) service performs object detection, classification and tracking, exploiting AI and video analytics. On the client side, our service/application is implemented over a prototype of Solar-powered Battery-equipped cameras (SB-CAMs), developed in-house supporting 5G connectivity. The prototype requires no external power-source to facilitate easy installation with simple mounting on any of our urban equipment products.

Our sustainable and self-sufficient surveillance prototype can be strategically deployed with minimal environmental impact at key smart city locations (such as bus stations) capturing (near-)real time streaming data to be used by our advanced video analytics services. Although 5G-STREAM focuses on people detection at bus station shelters, we plan to reuse the same module in all our smart city product line, namely bicycle stations, waste bins and lighting poles and as a surveillance solution for PV parks.

The NOKIA testbed has been selected to host our service, as it provides all the necessary components for our experiments and an advanced 5G SA core. In the Nokia testbed, 5G modems, Servers, and 5G-IANA components are networked and hence enable us to test different setups, namely executing our service at the end-device vs at the cloud.

Finally, Nokia has expressed their interest in the energy efficiency aspects of 5G-STREAM, as the 5G user equipment energy consumption is rather high, and it would be a valuable result to investigate of ways to reduce it.



Connection directly to IANA back-end platform (netapps)

Objectives

High level objectives

develop innovative connected surveillance solutions for smart cities

evaluate the potential of 5G to enable standalone deployments via computing offload to the cloud;

enhance public transportation efficiency by integrating our solution to bus stops.

Technical objectives

develop a Solar-powered Battery-equipped camera module with a 5G interface;

develop a containerized AI and video analytics service for advanced object detection;

evaluate the performance of the 5G-STREAM solution and its energy requirements.

Project Timeline

In 2024, we (the Diamantis group) decided to transform our products into smart connected objects. In this direction, we designed a prototype surveillance module in which all data processing was executed on-site to enhance our urban equipment products. Our initial experimentation indicated that such a solution suffers from increased energy-consumption and if there is no access to electricity, the overall cost of the product was prohibitive.

Through the 5G-IANA open call, we identified the opportunity to develop and test a surveillance solution that outsources the AI compute-intensive tasks to the cloud and operates with solar-powered battery-equipped cameras. This module once fully developed will be integrated to our product portfolio and will expand our target market to include smart cities infrastructure.

For the purposes of 5G-STREAM, we have completed the following activities

Activity 1: Familiarize with the 5G-IANA platform; 5G-STREAM functionalities and infrastructure definition and implementation planning (M01)

The objective of this activity was to conclude on the detailed implementation plan of 5G-STREAM given the capabilities of 5G-IANA. A necessary first step was to familiarize with the platform.

Activity 2: 5G-STREAM implementation and testing (M02 –M05)

This activity consists of two main objectives; the extension of our working SB-CAM with 5G connectivity and the development of the surveillance cloud service over 5G_IANA platform.

Activity 3: 5G-STREAM evaluation & demonstration (M06)

The objective of this phase was to evaluate the performance of the platform and provide the necessary tools and reports to report the 5G-STREAM findings.

5G-STREAM use case: Design and Implementation tasks		M1	M2	M3	M4	M5	M6
A.1	Familiarize with the 5G-IANA platform; 5G-STREAM functionalities and infrastructure definition and implementation planning						
A.2	5G-STREAM implementation and testing						
A.3	5G-STREAM evaluation & demonstration						Final Report

Ms1 Ms2 Ms3

Integrations Ready

Milestone M1: 5G-STREAM functionalities/architecture description completed (M01).

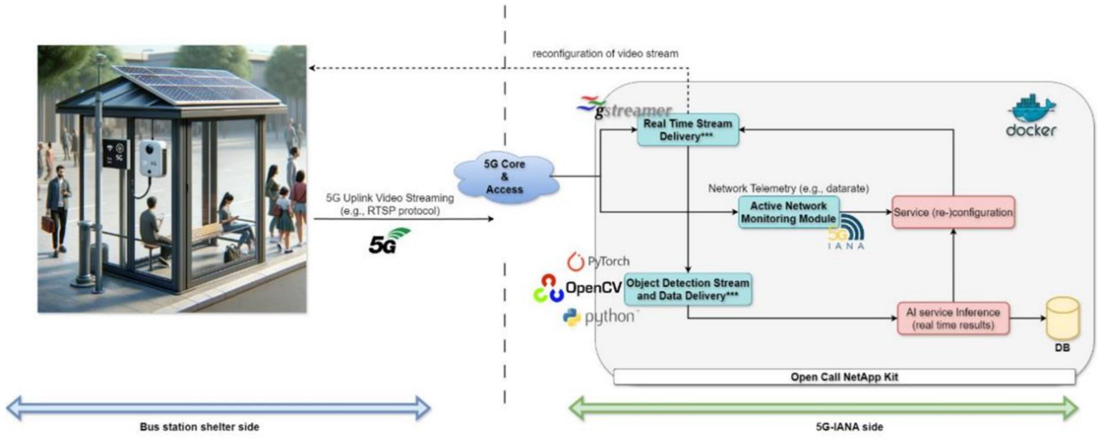
Milestone M2: 5G-STREAM functionalities implemented and tested (M05).

Milestone M3: 5G-STREAM findings report completed and published in 5G-IANA website (M06).

Demonstration

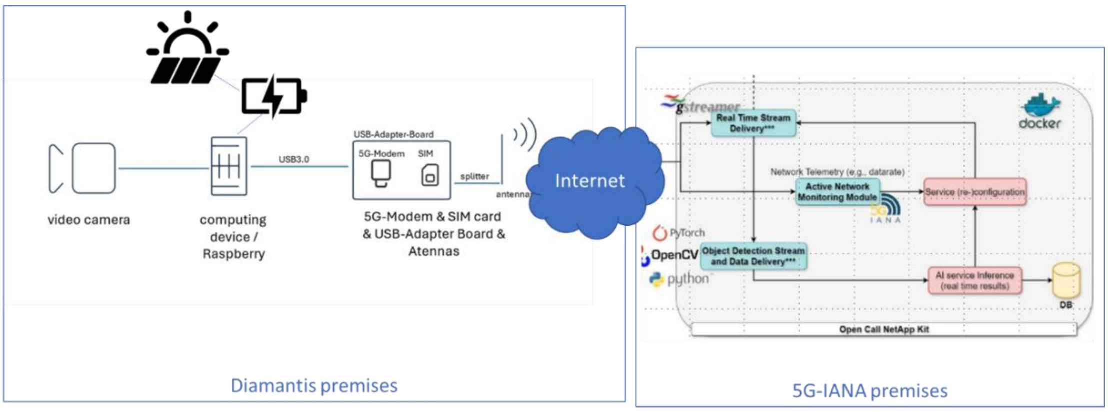
Setup

Our envisioned scenario is that of people counting in a 5G self-sufficient bus stop. No access to external power sources is needed, as our bus stop is solar-powered and has integrated surveillance capabilities. As depicted in the Figure, the processing is performed at the 5G-IANA platform.



The details of the deployed 5G-Stream AI service is depicted below. A major differentiation point of our setup is that the end-point is located in a different country (Greece) of the Nokia testbed. Our service is not latency-critical so this has no impact to our evaluation results.

An overview of the 5G-STREAM project and its vision can be found in [1].



Our end-point module consists of a basic processing unit (Raspberry Pi 5), a solar panel of 10W and a battery of 10Ah. We have developed a containerized service for human presence detection based on YoloV8, which supports flexible execution anywhere (at the edge or the cloud).

For comparison purposes, we have evaluated also a baseline solution in which the Raspberry PI 5 hosts the whole 5G-STREAM AI service.

5G-STREAM supports offloading execution to a remote host. Reproducing our demo would require the following steps and functional components:

Installed Wireguard on Pi 5, in order to be able to access the container holding the 5G-Streamer AI service when deployed on the 5G-IANA platform and transmit the RTP frames from the Pi.

Raspberry Pi 5 prepared as a Gstreamer server for transmitting frames to the 5G-IANA platform and offload the AI processing tasks

Reads frames from Wide camera to create an RTP stream

RTP stream transmitted over 5G to a remote server were the 5G-Streamer AI service resides

5G-Streamer AI service deploys a Gstreamer client listening for RTP/TCP traffic, and forwards the frames to the AI application for inference

The 5G-STREAM service container has been built with Docker on Ubuntu 22 OS. Docker-compose and Maestro-compose files have been prepared. The size of the resulting image is ~7GB compressed. The service can utilize CPU or GPU, but in our experiments on the 5G-IANA platform CPU only has been used.

Demonstration & qualitative analysis

For the evaluation of the proposed solution, we have used the following parameters. The same video of 25 sec is used for inference with a frame rate of up to 2fps. An advanced trained model is used for execution in the cloud, whereas for standalone execution a much smaller model has been used (to achieve timely inference).

In 5G-STREAM we have evaluated 2 different solutions. The baseline solution consists in a standalone 5G device for processing at the Edge

- In this setup, the edge device performs all the processing locally.
- This approach, while independent, has an average power consumption of approximately 7 watts.
- To support this, we would need at least a 100W solar panel and a battery capacity of 10Amberhours, ensuring reliable operation in all conditions.

5G-STREAM promotes a more advanced alternative solution that is based on remote execution at the Cloud

- Here, we keep the edge device lightweight by only streaming video data, offloading AI processing tasks to the 5G-IANA platform over 5G.

- This option is highly efficient, consuming on average less than 0.7 watts of power.
- As a result, it requires significantly simpler hardware, with less than 10W solar panels installed and a battery capacity of just 1Amberhour.

Overall, our 5G-STREAM solution by utilizing the 5G-IANA platform achieves a 10 times cost reduction and higher detection accuracy.

Detailed evaluation results and demonstration of the 5G-STREAM prototype can be found in [2].

Exploitation of Results

Updated business plan

5G-IANA enabled us to assess the potential of the 5G-STREAM solution. In the next year the plan is to optimize the overall performance of our solution and transform our device into a fully integrated product. The performance optimization includes both the capabilities of the end device but also the detection accuracy of the service.

According to the revised business plan, the service will be provided as an once off payment incorporated in the cost of acquiring the necessary equipment. The cloud service will be executed on a public cloud.

Regarding the smart bus stations through the integration with a Traffic Management Center solution, 5G-STREAM is set to significantly enhance public transportation efficiency, while also making meaningful contributions to societal well-being and sustainability.

Challenges and feedback to Open Call organisers

Due to significant delays in the announcement of the Open Call results (mid May), there was less than 6 months time left for the execution of the project. Given also the summer break, the timely execution of the project became particularly challenging.

Despite the challenging setup, the consortium has been always responsive and willing to help with any technical issues that came up. Besides, the advanced capabilities of the 5G-IANA platform and the inherent support of cloud services made integration easy.

It is strongly recommended that the future experimentation platforms become more open to the experimenter, providing authorised used with the necessary rights and tools to perform the experiment without the heavy involvement of the consortium. This would increase significantly its uptake and adoption by third parties.

Summary Conclusion & Future Plans

5G-STREAM has been a very promising exploration endeavor for the Diamantis group. Starting from the date that we learned about this opportunity from the 5G-IANA website, the team compiled a clear implementation plan to expand our product catalog.

Our smart bus stations, powered by 5G-STREAM solution, enable adaptive public transport services by detecting the number of people waiting at each station, making public transport more efficient and responsive. Our plan is to integrate our solution with commercial Traffic Management Centers to support dynamic planning of bus routes and their frequency.

Based on a market analysis conducted with the help of 5G-IANA consortium, many more opportunities for 5G-STREAM in the context of smart cities could arise. The increasing global investments in smart city infrastructure is driven by governmental incentives. Besides, the 5G-STREAM solutions could be of interest to municipalities as it can be adapted for various applications, including waste management, public safety, and renewable energy monitoring. Overall, global Smart Cities market size is projected to grow from approximately USD 600 billion in 2023 to USD 2500 billion by 2032

In the following 1-3 years, we expect that the majority of our products will be equipped with a smart module to transform them into smart connected objects. Alternative more efficient modes of communication like LPWAN and Ambient IoT will also explored for the least demanding use cases.

References to Multimedia Content

[1] Short Video of the 5G-STREAM vision- https://we.tl/t-mwzLZ546e5

[2] Video of the whole setup and 5G-STREAM demonstration- https://we.tl/t-kpn8Y1zkfn

Surface Anomaly Detection System

By FERON Technologies

Introduction

Overview of the use case

This project focuses on developing an innovative smart IoT system for the automotive domain designed for real-time road condition monitoring and anomaly detection, with a particular emphasis on identifying bumps and potholes. The system represents a significant step forward in the application of IoT and 5G technologies to improve urban infrastructure management and road safety.

The core of the system consists of an On-Board Unit equipped with a vehicle motion sensor, a GNSS module and a 5G modem, , working in tandem to provide high-precision data about road surface conditions. The LPMS-UTTL2 sensor (accelerometer, gyroscope, magnetometer), known for its accuracy in motion tracking, captures detailed information about vehicle movement, including vibrations and sudden changes in acceleration and orientation that might indicate the presence of road anomalies. This data is complemented by precise location information from the GNSS module, allowing for the mapping of detected anomalies with high geographical accuracy – and send through 5G to the network edge for storage, visualization and decision-making.

Nokia's testbed in Ulm, Germany, was chosen as the demonstration site for several compelling reasons. Firstly, Nokia's facility offers a state-of-the-art 5G infrastructure, which is crucial for the system's requirement of moderate-speed, low-latency data transmission. The advanced network capabilities at this testbed allow for pushing the boundaries of real-time data processing and transmission, showcasing the full potential of this IoT solution. Secondly, the Ulm testbed provides a controlled yet realistic urban environment. This setting allows for the simulation of various real-world scenarios and road conditions using a test vehicle, giving valuable insights into how the system would perform in actual city environments. The road types and conditions available at the testbed enable comprehensive testing of the anomaly detection algorithms under different circumstances. Lastly, Nokia's reputation as a leader in 5G technology and their expertise in IoT applications make their testbed an ideal platform for validating the system. The collaboration with Nokia's team and access to their cutting-edge facilities significantly enhance the credibility and robustness of the demonstration.

1.2 Objectives

The project is driven by a set of ambitious yet achievable objectives, encompassing both high-level goals and specific technical aims.

High-level objectives:

1. Develop a robust, real-time road condition monitoring system: The primary goal is to create a system that can continuously and reliably monitor road conditions. This system should operate seamlessly in various environmental conditions and be capable of processing and transmitting data in real-time, providing up-to-date information on road status.
2. Enhance road safety by early detection of road anomalies: By identifying potholes and other road irregularities promptly, the system aims to significantly contribute to road safety. Early detection allows for timely maintenance, reducing the risk of accidents and vehicle damage caused by poor road conditions.
3. Demonstrate the potential of 5G technology in IoT applications for smart cities: Through this project, the aim is to showcase how 5G technology can revolutionize urban infrastructure management. By leveraging the high-speed, low-latency capabilities of 5G, the project intends to illustrate the transformative potential of advanced connectivity in creating smarter, safer cities.
4. Provide a scalable solution for urban infrastructure management: The system is designed with scalability in mind, aiming to offer a solution that can be easily deployed across various urban environments. This scalability is crucial for the widespread adoption of smart city technologies.

Technical objectives:

1. Integrate the FERON OBU including the 5G module, the sensor, and GNSS for precise road surface tracking: The technical goal is to seamlessly integrate the sensor with a high-precision GNSS module. This integration should result in a system capable of capturing detailed motion data synchronized with accurate location information, providing a comprehensive picture of road conditions. All data are transmitted to the backend using low-latency 5G networs.
2. Implement an advanced algorithm to detect road anomalies, focusing on potholes: The aim is to develop a sophisticated algorithm that can accurately identify potholes and other road anomalies. This algorithm should be capable of distinguishing between various types of road irregularities, minimizing false positives while maintaining high detection accuracy. The decision algorithm is executed at the network edge in order to be able to fuse information by many vehicles.

2\. Achieve near real-time data processing and transmission using 5G infrastructure: Leveraging the 5G network, the objective is to achieve data processing and transmission with minimal latency. The target is a system that can collect, process, and transmit data within milliseconds, enabling true real-time monitoring and rapid response capabilities.

3. Develop an interface for visualizing measurements: Creating an intuitive and informative user interface is crucial for the practical application of the system. The aim is to develop a dashboard that clearly visualizes detected road anomalies, their locations, and severity levels, making it easy for road maintenance teams and city planners to interpret and act on the data.

4. Ensure system reliability and accuracy under various conditions: The system should maintain high levels of accuracy and reliability across different weather conditions, traffic situations, and road types. This objective involves rigorous testing and fine-tuning of the hardware and software components to ensure consistent performance.

5. Implement edge computing capabilities for efficient data handling: To optimize system performance and reduce network load, the project aims to incorporate edge computing techniques. This involves processing data locally where possible, sending only relevant information to the cloud, thereby improving overall system efficiency and response times.

6. Integrate the solution over the 5G-IANA service orchestration framework

7. By achieving these objectives, the project aims to deliver a cutting-edge solution that not only addresses the immediate challenge of road condition monitoring but also paves the way for future innovations in smart city technologies and urban management.

2 Project Timeline

The project idea was first conceived in 2022 with a diploma thesis conducted for University of the Aegean. Several implementation steps as far as the OBU integration is concerned were performed in the course of a small project with a cooperating company (https://assist-iot.eu/2023/03/06/iotempowered-road-anomalies-detection-in-real-time-by-insigh-io-open-caller/) in 2023. While an extension towards 5G and service/container-based deployment was planned, we were informed for the 5G-IANA Open Call 2 at the first quarter of 2024 (around March 2024). The application proposal was submitted by the end of March 2024.

The notification of acceptance was received by mid-May, and the project practically and unofficially kicked-off with the first teleconference with the technical mentoring team mid-June (note: the official start of the project is July).

The project phases are the following:

- Duration 1M (July 2024) - System design and adaptation to the 5G-IANA platform objectives. (Milestone 1 Design completed)
- Duration 1.5M (August 2024 - 15 September 2024) – Development of the OBU, containerization of components, and development of the MEC services. (Milestone 2 Core development completed)
- Duration 1M (15 September – 15 October 2024) – Integration with the 5G-IANA platform and particularly the Nokia testbed, Demonstration of the solution at 5G-IANA facilities. (Milestone 3 Demo completed)

- Duration 0.5M (15 October – 1 November 2024) – Result analysis and report preparation. (Milestone 4 Report submitted)
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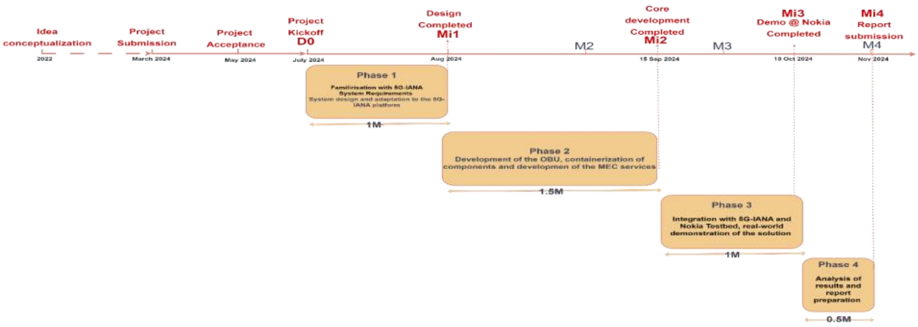


Figure 1: Project timeline

This system represents a comprehensive solution for early detection and notification of road surface anomalies. Its development aims to enhance road safety and prevent vehicle damage through an automated monitoring and notification system. The system's innovation lies in leveraging modern sensor technologies and telecommunications for real-time information provision, while its architecture is based on modern containerization technologies for optimal performance and scalability. The system architecture is presented in Figure 2. It includes a) an OBU for the measurement collection, preprocessing and communication through 5G, b) a set of services executed at the OBU, c) a set of services executed at the edge servers of the facilities, d) the 5G-IANA network and net apps. Each service identified in Figure 2 was implemented as an individual container or it was containerized as a group. Details for the exact development and implementation are presented below.

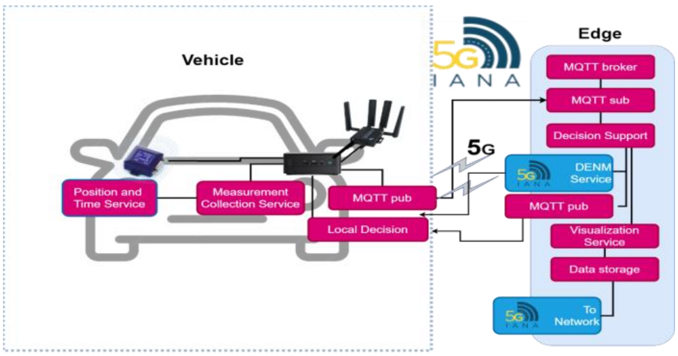


Figure 2: System Architecture

On-Board Unit (OBU)

The system's central unit is based on a portable computer functioning as an On-Board Unit (OBU).

For the demo, a laptop with Ubuntu 22.04 Operating System was used for simplicity and in order to have continuous monitoring through its display.

Sensor: The system incorporates the advanced LPMS-UTTL2 multi-axis sensor, which combines a triaxial accelerometer with a measurement range of ±16g, a triaxial magnetometer with a measurement range of ±4800µT, and a triaxial gyroscope with a measurement range of ±2000°/s. This robust sensor provides precise motion tracking and orientation measurements with a sampling rate of up to 400Hz. Its low-power consumption and compact design make it ideal for road condition monitoring applications. The sensor's high accuracy in detecting linear accelerations and angular velocities allows it to effectively identify road surface irregularities like bumps and potholes by

Figure 3: Sensor

measuring sudden vertical accelerations and vibrations experienced by vehicles.

The Quectel LC76G Series Compact GNSS Module is a versatile positioning solution that supports multiple global navigation satellite systems including GPS, GLONASS, BeiDou, and Galileo. With its -167dBm tracking sensitivity and position accuracy of 2.5m CEP (Circular Error Probable), it provides reliable location data even in challenging urban environments. The module's compact form factor (10.1 × 9.7 × 2.4 mm) and low power consumption make it particularly suitable for integration into road monitoring systems, allowing precise geolocation tagging of detected road anomalies. As far as the 5G modems are concerned, the project uses Quectel modules through their Evaluation Boards. This selection is made because the specific boards are much more than plane 5G modems. Quectel offers evaluation boards designed to help developers and engineers evaluate and prototype with their 5G modules.

Figure 5: Quectel GNSS module.

These boards are essential for testing the capabilities of Quectel's 5G modules in various applications, such as IoT, mobile broadband, and industrial automation, thus they are used for: module testing and development, prototyping, and debugging and integration for both 5G modules and the network. Communication with the modules is performed using AT commands (Attention commands) used to control modems. Quectel's 5G modules can be controlled and configured using AT commands. These commands are crucial for interacting with the module's functions, such as setting up connections, sending/receiving data, configuring, and monitoring various network parameters. The module in was used for tests in the development stage, however, during demo, the preconfigured Quectel module that was provided by the Nokia facility was used

Figure 4: The RMU500-EK 5G module

At the OBU, the following services are executed:

- **OBU Container 1: The measurement collection service and local decision. The data collection and processing procedure implements a high-performance data stream management system. The sensor data is collected using the OpenZen library** (https://bitbucket.org/lpresearch/openzen/), an open-source library developed by LP-Research Inc., which provides a robust interface for accessing IMU sensor data with high precision and reliability. The OpenZen library enables seamless communication with the LPMS-UTTL2 sensor at 100Hz sampling frequency, while GPS data is collected at 5Hz to provide accurate georeference of events. The OpenZen library facilitates efficient data acquisition through its standardized API, ensuring consistent and reliable sensor readings. The library handles the lowlevel communication protocols with the LPMS-UTTL2 sensor, providing access to calibrated sensor data including acceleration, angular velocity, and magnetic field measurements. The local filtering functionalities included reduction of the sampling rate to reduce unnecessary 5G traffic. More specifically, when the measurements locally indicate with high-confidence that no event is triggered (no bumps/pothole, baseline behaviour), measurement rate is also reduced to 5Hz to avoid network flooding. The programs are developed in Python. The measurements are forwarded to the MEC using an MQTT publisher (registered at the projects MQTT broker.
- OBU Container 2: The position and time service. The GNSS module is used to retrieve the exact location and timestamp for each measurement. The reading of the GNSS measurements is done from the corresponding serial port with the use of a serial port communications API (pyserial for python). Since the sensor and GNSS measurements are

asynchronous, they are also timestamped using the system clock. During measurement analysis at the MEC, each sensor measurement is mapped to the closest GNSS measurement using the system clock timestamp.

-

MEC Processing

The system utilizes four critical open-source components for data processing, storage and visualization. Each of these components was containerized and installed as a service at the 5G-IANA MEC at the Nokia testbed.

MEC Container 1 - The MQTT Broker: The MQTT protocol's architecture proves particularly advantageous for sensor-based monitoring systems, orchestrating the distribution of inertial measurement unit (IMU) sensor data and geographical positioning system (GNSS) coordinates through a hierarchical topic structure. The protocol specification defines three distinct Quality of Service (QoS) levels: Level 0 (At most once delivery), Level 1 (At least once delivery), and Level 2 (Exactly once delivery). The current implementation utilizes QoS Level 1, establishing an optimal balance between transmission reliability and system performance. Additional protocol features include message retention capabilities and Last Will and Testament (LWT) functionality, enabling state preservation and connectivity monitoring respectively. The Mosquitto broker implementation provides an efficient and resource-conscious solution that satisfies the system's message distribution requirements while maintaining essential functionality for reliable data transmission. During the test, at the MQTT broker:

- Two topics are created: IMU Data, and GNSS Data
- Two publishers are feeding the two topics, from the OBU Container 1 and the OBU Container 2 correspondingly.
- One subscriber is registered to both topics – the anomaly detection service at the MEC.
- One more topic (Anomaly data) and one more publisher is created from the MEC – in case of

MEC Container 2 – Telegraf: Telegraf functions as our primary data collection and processing agent, implementing specialized plugins for MQTT subscription and sensor data ingestion. Its processing capabilities include comprehensive data normalization, statistical aggregation, outlier detection, and temporal downsampling. The system features robust buffering mechanisms for handling network interruptions, supporting multiple output formats and destinations. Additionally, it provides built-in monitoring, self-diagnostics, and automatic retry mechanisms for failed operations. In our project, its role was limited, i.e., mainly the consumption of measurements and the feeding of the influx database.

MEC Container 3 – Influxdb 2.0: InfluxDB 2.0 serves as the system's time-series database, optimized for handling high-throughput sensor data. The database implements custom retention policies to efficiently manage data volume while maintaining historical records of detected anomalies. Its timeseries optimized structure allows for efficient querying of sensor data based on temporal patterns, with appropriate sharding and indexing mechanisms to maintain performance even with large datasets. The database stores at three different backets (sensor, gnss, and anomalies):

- raw sensor measurements (all types, gyro, acceleration, magnetometer at three axes each, and OBU system time for match making).
- GNSS data (longitude, latitude, time, and OBU system time for match making)
- Processed anomaly events, enabling both real-time analysis and historical

MEC Container 4 – Grafana: Grafana serves as our visualization platform, delivering sophisticated real-time data visualization through interactive dashboards with auto-refresh functionality. It supports mixed data source visualization, custom panel plugins, and advanced geospatial mapping with multiple layers. The platform includes a comprehensive alerting system with multiple notification channels, template variables for dynamic dashboards, and role-based access control. Its annotation system enables detailed event marking and correlation, while providing API access for automated dashboard management. A dashboard was automatically generated to display in semi-real time (update measurements every 3 seconds) for all sensor measurements (mainly gyroscope and acceleration). Investigation of the visualized sensor behaviour indicated that decision making should mainly rely to z-axis acceleration and angular speed.

Docker Configuration and Integration

The containerization of these components is achieved through a carefully orchestrated Docker implementation. The Mosquitto container is configured with a custom mosquitto.conf file that enables persistent sessions, sets message size limits to 100KB for efficient resource usage, and implements TLS 1.3 security with client certificate authentication. The Telegraf container utilizes a specialized telegraf.conf that defines input plugins for MQTT subscription, processors for data transformation, and output plugins for InfluxDB writing, with buffer sizes optimized for our 5-100Hz data rate. The InfluxDB container is configured with specific retention policies and continuous queries for efficient time-series data management, implementing automated data downsampling and cleanup procedures to maintain optimal storage utilization while preserving data integrity. The Grafana container's configuration includes provisioned dashboards through grafana.ini and dashboard.yaml files, with automatic data source configuration and preset visualization templates. All containers are networked through a dedicated Docker network with defined resource limits and restart policies, ensuring system stability and optimal resource utilization. In order to avoid use of volumes for configuration file upload, updated containers were created with preinstalled configuration files. This means that upon deployment everything is done automatically:

- The broker services are exposed and ready to service the OBU.
- The telegraf is ready to forward incoming traffic (measurements and GNSS) to the proper buckets of the influxdb.
- The database service stores all incoming data to appropriate buckets and tables.
- The visualization service is automatically configured to pull data from the database buckets and present them to a 9-panel automatically configured dashboard.

- As a technical summary, we have:
- The MQTT Client Container implements a Python client using the Paho-MQTT library. Data from the LPMS-UTTL2 sensor is collected through the OpenZen library at 100Hz sampling rate, while GPS data is acquired via serial communication at 5Hz.
- The MQTT Broker Container is based on the Mosquitto broker, configured for optimal performance with Quality of Service (QoS) level 1, ensuring reliable message delivery. It supports TLS 1.3 for secure communication and includes authentication mechanisms for system protection.
- The Telegraf Container is configured with custom plugins for optimal processing of incoming data, including temporary storage in case of database connection failure. It also applies filters and transformations to prepare data before storage.
- The InfluxDB Container uses InfluxDB version 2.0, with custom retention policies for data volume management and continuous queries for automatic statistics aggregation. The database is optimized for time-series data performance, with appropriate shards and indexing.
- The Grafana Container provides customized dashboards for real-time data visualization, with interactive graphs and maps displaying the location of anomalies.
- The solution flow is the following:
- The sensors continuously monitor the road surface.
- At a bump or pothole, the measurements of acceleration and angular velocity – experience peaks and increased variance. This is reported through measurements and the anomaly is captured through the change in the measurement behaviour.
- As mentioned, real-time monitoring is achieved through an MQTT-based communication system, where sensor data is continuously processed against these thresholds. When measurements exceed any of the defined thresholds, the system immediately registers an anomaly event, triggering the notification process to alert relevant stakeholders about the detected road condition.

MEC Container 5 – Anomaly Detection: The detection algorithm employs carefully calibrated thresholds to identify road anomalies based on different types of vehicle movements. Through extensive testing and analysis of sensor readings, the thresholds were established to effectively

differentiate between normal road conditions and actual anomalies. or detecting vertical movements typically associated with potholes, the system monitors the Z-axis acceleration with a threshold set at ±1.5g. This threshold was chosen as it effectively captures significant vertical displacements while filtering out minor road surface variations and normal vehicle suspension movements. Values exceeding this threshold strongly indicate the presence of substantial road surface irregularities that could pose risks to vehicles. Vehicle stability and orientation changes are monitored through dual gyroscope readings, with thresholds set at ±5.0 degrees for both roll and pitch movements. This dualgyroscope approach provides redundancy and improved accuracy in detection. The 5-degree threshold was determined to be optimal as it is sensitive enough to detect sudden vehicle orientation changes caused by road anomalies, yet robust enough to ignore normal driving maneuvers such as gentle turns or slight inclines. The system processes readings from both gyroscopes independently, comparing roll and pitch measurements to ensure reliable anomaly detection while minimizing false positives.

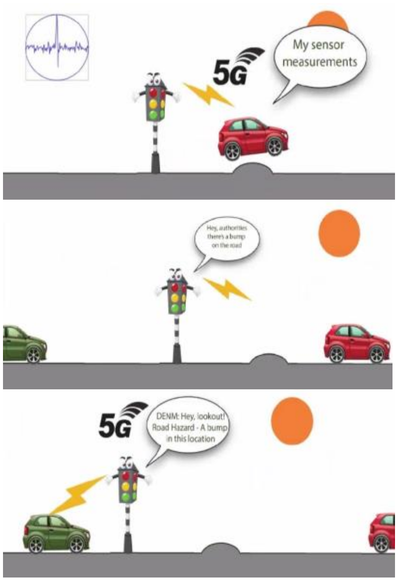
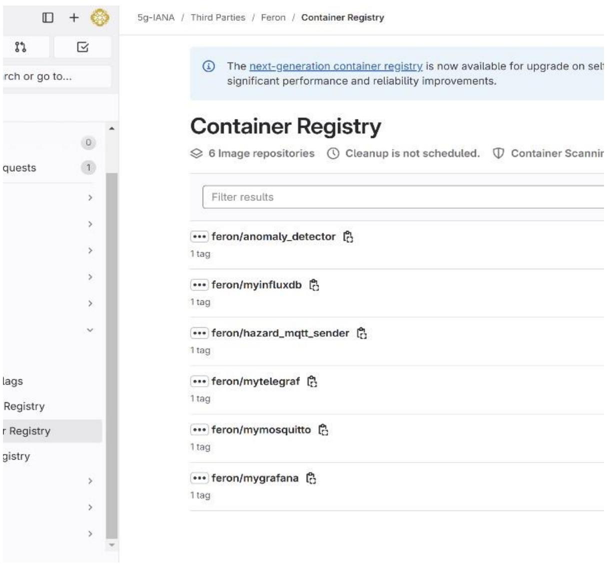


Figure 6: The operational concept

In a different approach, instead of pre-defining thresholds that are depended on the vehicle, we utilized concepts from unsupervised learning. This means that initially measurements are recorded setting up a baseline as far as the vehicle road behaviour is concerned. The baseline is used to calculate the measurement variance for the three axis of the gyroscope and accelerometer. Then decision for anomaly was taken if outliers are identified exceeding 6 standard deviations from the average behaviour. In this case the alarm is triggered. OR and AND decisions fusing the measurements from the various sensors and axes were created – however, practice indicated that the AND rule performs significantly better in terms of false alarms.

Deployment at 5G-IANA:All containers were uploaded to the 5G-IANA repository, and a maestro compose file was compiled and corrected/improved with the help of the 5G-IANA coaching team. After debugging, we were able to deploy successfully all services and verify the communication of all components using the 5G-IANA orchestrator at the Nokia Testbed MEC.



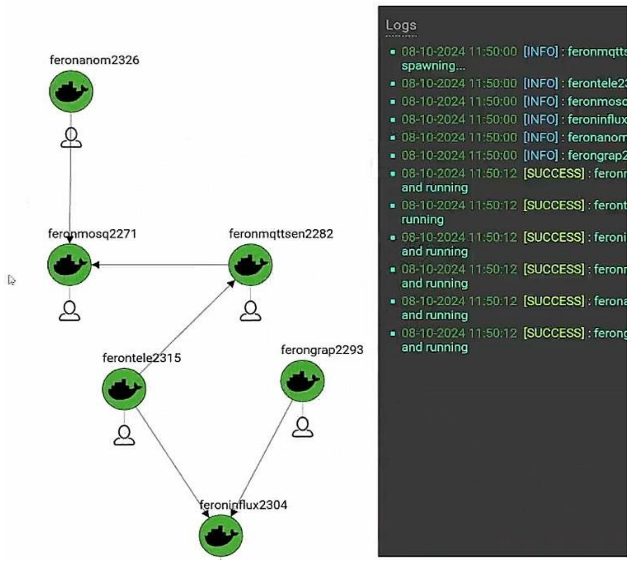


Figure 8: FERON services at the 5G-IANA container registry. Figure 7: 5G-IANA orchestrator view of the deployed services.

User Notification using the 5G-IANA DENBS Network Function.

5G-IANA offers a variety of network and application functions that can be used in conjunction with own functions and services. One of the is the DENBS implemented by LINKS, that was used as a notification system from the project. The DENBS by LINKS is based on the 5G Decentralized Environmental Notification (DEN) standard, implementing the DENM (Decentralized Environmental Notification Messages) protocol according to ETSI EN 302 637-3 standard.

Notifications include:

- Precise event coordinates (latitude, longitude)
- Millisecond-accurate timestamp
- Type of event (in our case: Road Hazard / pothole)
- Recommended actions for drivers (slow down).

Interaction with the service is performed through an HTTP RESTful API using post or update requests when a bump or pothole is identified. The DENM message publisher was installed at the MEC and it was triggered after the detection of a road surface anomaly.

In order to verify the dissemination of the DENM messages, a DENM receiver was installed at a virtual OBU (vOBU) that uses the RESTful API to read new incoming messages. LINKS provided docker compose files with all configurations for the deployment of the service at the MEC and the listener at the vOBU. The docker compose files were transformed into maestro-compose files by the Ubitech supporting team and the services were successfully deployed from the orchestrator. The call of the service was integrated at MEC Container 5 using the “requests” python package. Calls were triggered every time an anomaly was identified.

Experimentation process:

- First end-to-end trials and tests were performed in Feron premises in Greece, using simple Docker containers.
- During Phase 3 of the project, remote connection with the Nokia facility was established through the provided VPN connection, and integration activities with the Ubitech coaching/supporting team were performed. A dummy measurement service was successfully deployed, and verification of operation was performed.
- Real-world tests, and demonstration of the solution was performed at 7 and 9 of October 2024, at Ulm in Germany, at the Nokia Research Center using the Nokia 5G-IANA test vehicle with connectivity through the Nokia 5G SA experimental network. The full demo video with the measurements can be found in [1], while some indicative photos are presented below.

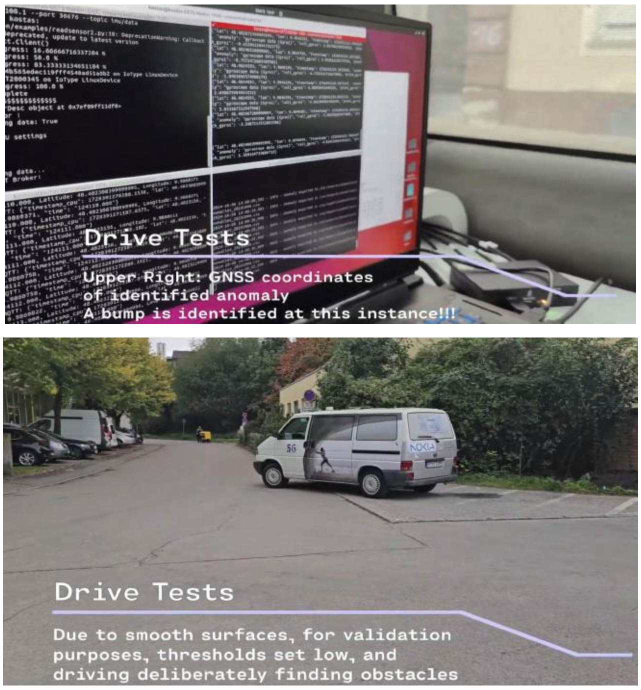


Figure 9: Pictures from the Demo measurements @ Nokia/Ulm

3.2 Demonstration & qualitative analysis

In Figure 10, the identified road hazards during the drive tests in Ulm using the Nokia test vehicle are presented. The performance of the system was satisfactory. All measurements were successfully stored, visualised and analysed according to the experiment plan. It is noted that generally, the road conditions in Ulm are quite good, and during the first test no road hazards were detected. Thus, we selected to reduce the thresholds in order to produce alarms in a more sensitive way, and we ask the vehicle operator to deliberately "hit the pavement" when possible, to cause disturbances at the measurements. These results are presented in the figures below.

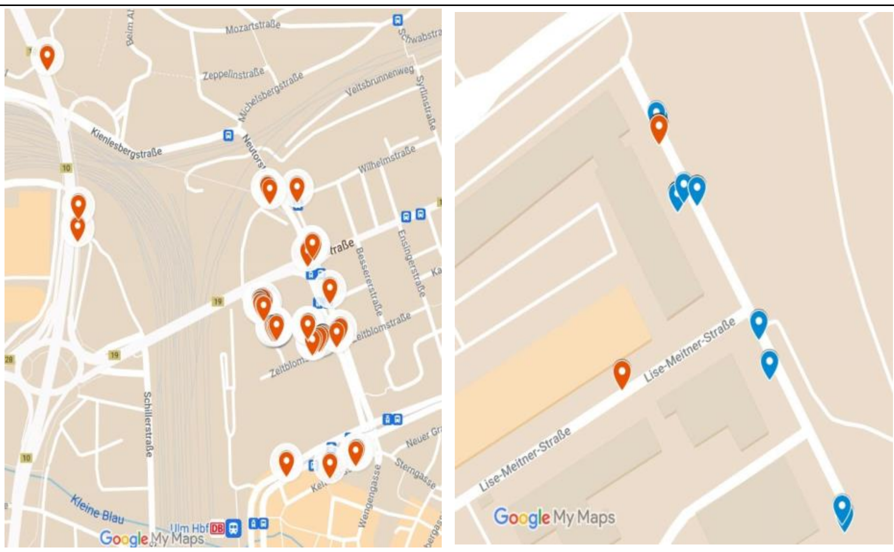
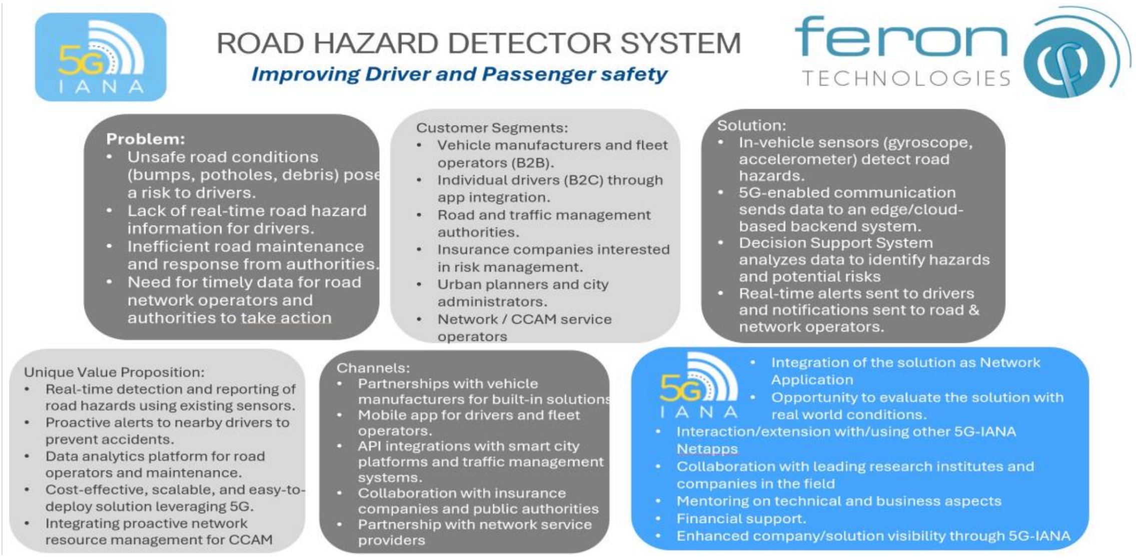


Figure 10: Maps with the identified Road Hazards during tests

4 Exploitation of Results

• How 5G-IANA boosted the **business plan**

As presented in [2], 5G-IANA provided resources to evolve FERON's solution and the opportunity to showcase the functionality and performance of our solution. The business plan for our solution, in conjunction with the 5G-IANA experience is presented in the simplified business canvas below:



• How the following proved to be **useful** / have **added value**

o Open Call 2 organisation, from announcement to the end

The Open Call 2 organisation was very good. The timelines were kept, the communication was frequent but not redundant, the services from the testbeds and the orchestrator were exceptional.

o 5G-IANA Coaching Sessions

Through the coaching sessions, we were able to timely identify and resolve issues with the development and integration of our solution. The tutorials on the use of 5G-IANA services were useful, as well as the presentations of the testbeds and their facilities. The coaches were fully informed and capable to guide us towards a successful experiment.

o The Open Application Experimentation Platform

The experience of the use of the Nokia testbed was extremely positive. We had full support from the Nokia personnel. We were able to work full days to complete our demos. The network performance was stable and more than sufficient for our experiments. The test vehicle was suitable for the demonstration, and we were able to complete a set of meaningful tests. Moreover, the communication and interaction with the orchestrator/management team (by Ubitech) was very effective and efficient.

• Challenges faced by 3rd party participants

No significant challenge. The main problem was that the schedule was pressed timewise. Moreover, we had to prepare videos as a review (where we had no particular experience and it was time consuming).

• Constructive suggestions for future Open to External Experimentation Calls.

A small criticism would be that the grant of 20k€ is considered low in comparison with other similar open calls. Moreover, a slightly increase in the project duration (e.g. 6 months) would be useful. This would allow SMEs also to participate in dissemination activities (independently or as part of the 5GIANA ecosystem).

As far as dissemination activities are concerned, the organization of an open-day workshop for the project that would include presentations and demonstration by the open-callers would be a good idea.

5 Summary Conclusion & Future Plans

The 5G-IANA 2nd Open Call was spotted through existing common communication channels with ICCS (the 5G-IANA coordinator). As an SME with an existing solution at the automotive vertical, we were encouraged to participate in the Open Call.

The overall experience with 5G-IANA was positive.

- All components worked without any operational discount or workaround.
- We were able to perform real tests over a real-world but controlled environment with full support by the consortium (at the backend and on site).
- Our solution was transformed according to the microservice-based architecture promoted by 5G and 5G-IANA and successfully tested.

Future plans include:

- Investigation of commercial exploitation of the solution through partnerships and contacts at the industry.
- New projects – to further exploit and evolve the solution. We already submitted an open-call proposal based on the Road Surface Anomaly Detection System with the objectives:
- To scale it up – with the inclusion of multiple vehicles.
- To exploit artificial intelligence for a more accurate, systematic way to identify road hazards – as well as classify types of road hazards using the measurements.
- To include new features with the inclusion of passenger smartphone sensors and vehicle sensors.

6 References to Multimedia Content

[1] Full demo recording with voiceover: https://drive.google.com/file/d/1B82NifpRGAb7xjJjlmNG7VzhBq0HRMD/view?usp=sharing [2] Short video (2-2.5 minutes) for dissemination, including business impact from 5G-IANA https://drive.google.com/file/d/1Fv4kLmirPkujscMcOiRkydcyF7cVs2_7/view?usp=sharing

Open Call 2 – roadsAI (first submission)

1. Introduction

1.1. Overview of the use case

The objective of our use case was to assess the LiTO system's ability to provide real-time driving advisories within a connected vehicle environment. Specifically, the system aimed to help a driver adjust speed based on the distance and speed of a bus exiting a station. This setup allowed us to evaluate the effectiveness of our advisory system in improving road safety and efficiency through real-time decision-making and low-latency communication.

We selected the Telekom Slovenia testbed for practical reasons, such as its flexibility in scheduling and reduced restrictions around camera use, time of day, and weekend access. Additionally, we found the testbed itself to be well-suited to our needs, with reliable 5G connectivity that supported our testing requirements. The Telekom Slovenia team was also helpful and supportive throughout the process, providing valuable assistance that contributed to the success of our demonstration.

1.2. **Objectives**

High-Level Objectives

The primary objective for 5G-IANA was to deploy our solution on an actual 5G network, operating fully locally without reliance on the internet. This deployment allowed us to evaluate the LiTO system's real-time advisory capabilities and to ensure it could function effectively within a fully connected, low-latency environment, paving the way for future advancements in road safety and traffic management.

Technical Objectives

The technical objectives focused on assessing key performance metrics, including effective end-to-end latency, bit rate, and network stability under real-world conditions. The demonstration required the system to detect and recognize two connected vehicles within a specific scenario and to generate and transmit a real-time driving advisory to one of the vehicles. These objectives provided insights into the system's readiness for integration with connected vehicle environments and its potential to support automated driving applications.

2. Project Timeline

- Throughout Open Call 2 Participation (starting from conceiving the idea and submitting)

- Key milestones and project phases

Key milestones

Idea Conception and Open Call 2 Proposal Submission:

Developed the concept for a real-time advisory system using 5G technology to enhance road safety. Prepared and submitted the proposal to Open Call 2, outlining the technical and strategic vision for the LiTO system within the 5G-IANA platform.

LiTO App and Backend Development:

Developed the Android app with dual-mode functionality (OBU/RSU) for data transmission and advisory reception, and built the backend in Python to process real-time telemetry and generate advisories.

Exploitation Workshop and Business Plan Development (July 2024):

Participated in an exploitation workshop on market analysis and business modeling, followed by individual sessions with the 5G-IANA team. Together, we developed a business plan with a SWOT analysis and Business Model Canvas (BMC), strengthening our strategy for future market viability.

Backend Deployment on 5G-IANA VM:

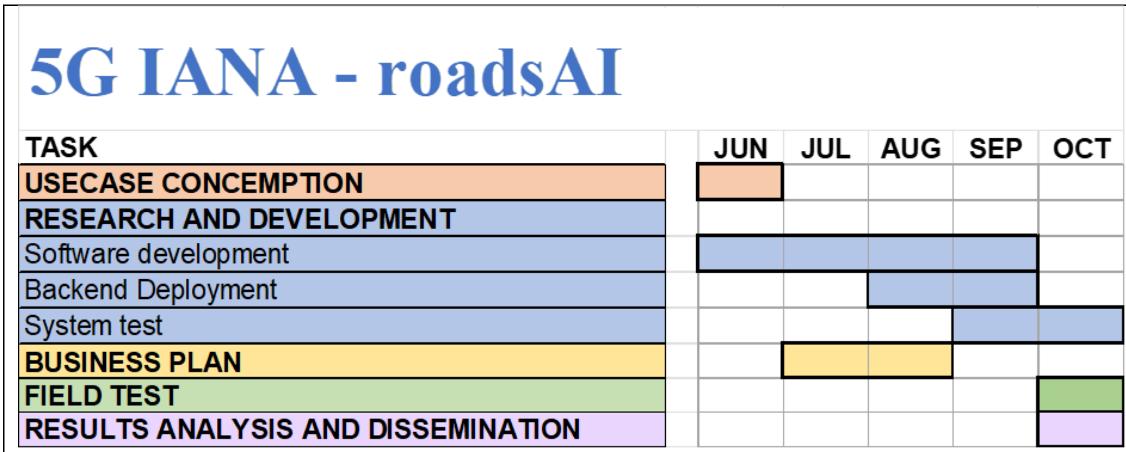
Gained access to the 5G-IANA platform, where we deployed and configured the backend on a Linux VM within the MEC environment, enabling fast data processing and advisory transmission over Telekom Slovenia's 5G network.

Initial Integration and Testing in Israel (September 2024):

Completed an end-to-end system test in Israel, confirming communication between the Android app, backend, and 5G setup, and refining components prior to the main demonstration.

On-Site Setup and Demonstration in Slovenia (October 2024):

Set up the system at Telekom Slovenia's testbed, finalized connectivity checks, and conducted the demonstration on October 9, successfully validating real-time advisory performance across multiple test scenarios.



3. Demonstration

3.1. Setup

Setup and scenario

The LiTO technology demonstration aimed to advise drivers on adjusting driving speed based on the distance and speed of a bus exiting a station. To accomplish this, we collected telemetry data from a connected car (acting as the Onboard Unit, or OBU) and a non-connected bus (simulated as a Roadside Unit, or RSU). This data was processed in real time, allowing the LiTO algorithm to calculate optimal speed advisories, which were then transmitted to the driver of the connected vehicle.

Due to testbed limitations—namely, the absence of physical RSU and OBU devices—our setup used a native Android app to simulate both roles. Configurable settings allowed the app to operate as either an OBU or RSU, transmitting telemetry data and receiving advisories when in OBU mode. Advisories were presented visually on the app screen and as audible alerts, ensuring they were both noticeable and actionable for the driver.

We deployed a Virtual Machine (VM) within the 5G-IANA infrastructure to function as the Multi-access Edge Computing (MEC) platform, supporting low-latency processing and decision-making. This VM hosted a Python-based web server with POST and WebSocket endpoints, managing data from both the OBU and RSU. The MEC's role was essential for running the LiTO algorithm and sending real-time speed advisories back to the driver. All devices were connected via Telekom Slovenia's 5G network, with the Android devices equipped with 5G SIM cards for fast and reliable communication within the cell coverage area.

Technologies and Methodologies

The demonstration relied on the following technologies and methodologies:

- Linux Virtual Machine (VM) – Hosted the MEC and served as the processing hub for LiTO.
- Python-based Web Server – Managed data exchange between the OBU, RSU, and the backend.
- Native Android App – Configurable as either OBU or RSU to simulate the connected and non-connected vehicle roles.
- 5G SIMs and Mobile Phones – Provided by the 5G-IANA platform.

1. Dates, Rehearsals, and Preparation

Before the demonstration in Slovenia, we rehearsed and tested the system in Israel under similar conditions on September 26, 2024. This rehearsal allowed us to validate the functionality and refine the setup before the field test.

On October 8, we arrived at Telekom Slovenia's labs to set up the system, install the app on the devices, and review the test plan with the local team. The full demonstration was conducted on October 9, during which multiple test runs were performed under varying conditions to evaluate the LiTO system's performance in real-time advisory delivery.

2. Technical Description of the Demonstration

Two Android devices running the app were installed in separate vehicles, one representing the connected car (OBU) and the other the non-connected bus (RSU). The RSU device, which only sent telemetry data, communicated with the server using POST requests for one-way data transmission. In contrast, the OBU device required bidirectional communication to receive advisories, achieved through WebSocket connections.

The server, based on Python, hosted multiple endpoints to facilitate communication with both the OBU and RSU, as well as to support debugging and data collection for post-demo analysis.

3.2. Demonstration & qualitative analysis

The 5G-IANA field test at Telekom Slovenia evaluated LiTO's ability to provide real-time driving advisories based on the proximity and speed of a bus. Key findings from the demonstration are outlined below.

3. Latency and Responsiveness

The network achieved an average latency of 59 milliseconds with minimal variability, enabling rapid transmission of advisories. Combined with a calculation time of just a few milliseconds, this low latency supports potential applications with automated driving systems that require fast, precise communication.

4. **Network Coverage and Reliability**

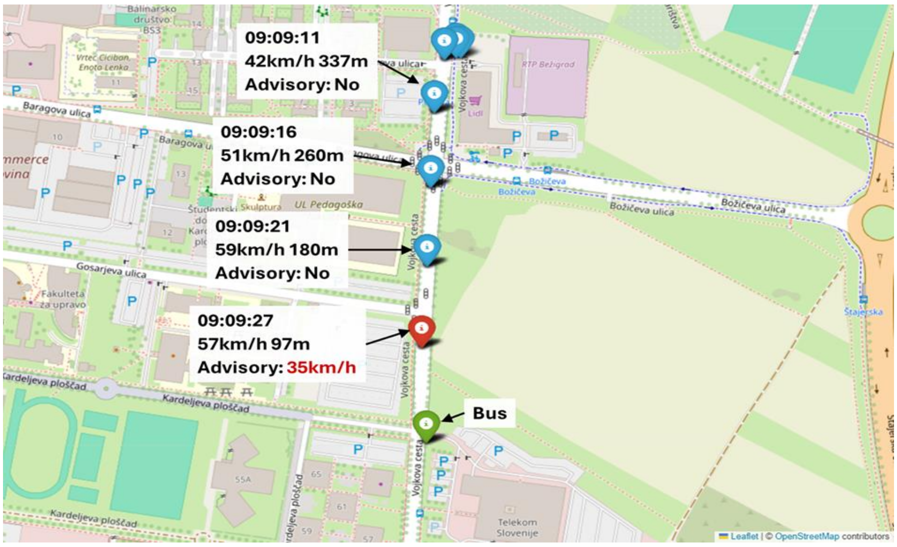
Telekom Slovenia's 5G network provided stable and uninterrupted coverage, supporting consistent data flow between the connected car and server. This reliability ensured the system operated smoothly, with no interruptions in data transmission.

5. **Advisory Timing and Effectiveness**

Advisories were delivered at optimal moments, allowing the driver to adjust speed smoothly as the car approached the bus. The image below shows how advisories were calculated and delivered based on the car's location, with an example advisory issued at 09:09:27, prompting the driver to slow down to 35 km/h. This timely advisory enabled smoother deceleration, highlighting the system's potential to enhance road safety by providing actionable information.

6. **Summary**

Overall, the LiTO system effectively delivered real-time advisories with minimal latency and high reliability. These results highlight the system's capability to support safer and more efficient driving through timely, data-driven speed recommendations.



Car and bus locations with real-time advisories from one of the test runs. The blue markers indicate the car's position and speed at various times, while the red marker shows the point where an advisory was issued, recommending the driver slow down to 35 km/h. The advisory was calculated based on the distance and speed of the bus (green marker) to allow smooth deceleration without sudden braking.

4. Exploitation of Results

7. How 5G-IANA Boosted the Business Plan

8. The 5G-IANA program provided invaluable insights that significantly strengthened our business plan. Beyond the knowledge gained, we also developed concrete tools, including a SWOT analysis and Business Model Canvas (BMC), which will serve as foundations for our future exploitation strategy. The combination of focused guidance and these strategic assets took us a substantial step forward, resulting in a refined and actionable plan for market positioning.

9. Open Call 2 Organization

The organization of Open Call 2, from the announcement to completion, was generally well-executed. Clear guidelines were provided throughout, ensuring that participants understood expectations and timelines.

10. 5G-IANA Coaching Sessions

The coaching sessions offered valuable project initiation support, with a clear breakdown of milestones, due dates, and deliverables. The team appreciated the structured guidance, although there was room for improvement in communication responsiveness. Slack messages sometimes experienced delays, while email communications were generally well-managed, with prompt responses.

11. Open Application Experimentation Platform

While the Open Application Experimentation Platform held promise as a valuable tool, we could not leverage it due to limitations in the testbed environment and unforeseen technical issues with the platform's services. As a result, we opted for an alternative solution, using a simple Linux VM to ensure project continuity.

11. Challenges Faced by 3rd Party Participants

One significant challenge involved uploading and deploying our server as a container within the platform's environment. Due to these technical constraints, we implemented a workaround by utilizing a straightforward Linux VM as an alternative solution to keep the demonstration on schedule.

12. Constructive Suggestions for Future Open to External Experimentation Calls

For future Open Calls, we recommend enhancing platform stability and communication responsiveness, particularly in dedicated support channels like Slack. Improving technical documentation and support for container deployment would also help external participants overcome integration challenges more smoothly. Additionally, providing more flexible testbed resources could allow for better adaptation to varying project requirements.

5. Summary Conclusion & Future Plans

Our engagement with 5G-IANA already began in 2023, when we were awarded a place in the 1st Open Call. Although circumstances prevented us from executing the project at that time, we were pleased to join the 2nd Open Call, which provided a valuable platform for both technical and strategic growth.

We achieved significant technical progress through our participation, deploying our LiTO system on a 5G network for the first time and validating its capability to deliver real-time driving advisories. Additionally, the program provided valuable business insights through SWOT analysis and business plan mentoring, positioning us more effectively for future commercialization and deployment.

Overall, our experience with the 2nd Open Call has advanced both our technical and strategic readiness. Moving forward, we are better prepared to capitalize on these developments in our next phase, applying the lessons and resources gained through 5G-IANA to strengthen our market position and bring innovative solutions to connected vehicle ecosystems.

6. References to Multimedia Content

Full demo -

09 OCT Telecom Slovenja Ljubljana.mp4

Short video -

IANA short draft _captions.mp4

Open Call 2 – roadsAI (final, revised resubmission)

1 Introduction

1.1 Overview of the use case

The objective of our use case was to assess the LiTO system's ability to provide realtime driving advisories within a connected vehicle environment. Specifically, the system aimed to help a driver adjust speed based on the distance and speed of a bus exiting a station. This setup allowed us to evaluate the effectiveness of our advisory system in improving road safety and efficiency through real-time decision-making and low-latency communication.
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Participated in an exploitation workshop on market analysis and business modeling, followed by individual sessions with the 5G-IANA team. Together, we developed a business plan with a SWOT analysis and Business Model Canvas (BMC), strengthening our strategy for future market viability.

Backend Deployment on 5G-IANA VM:

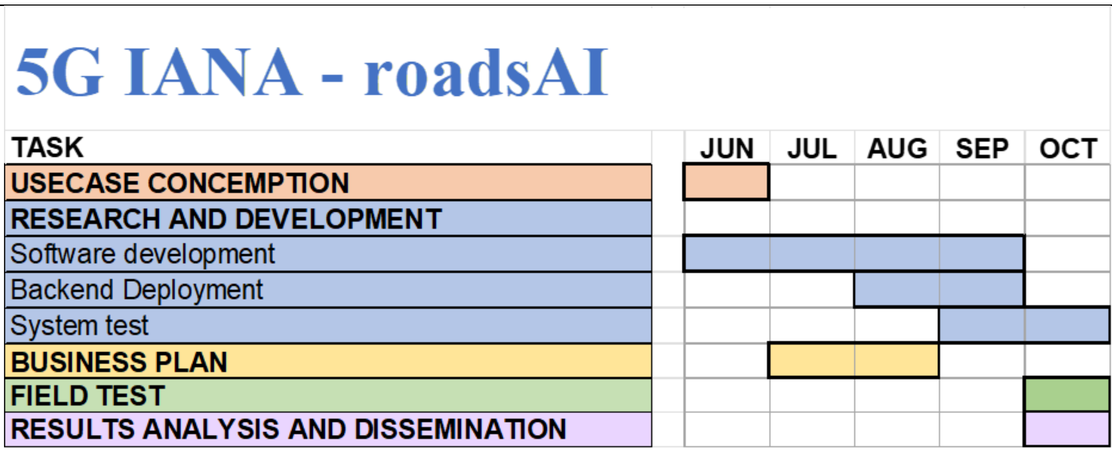
Gained access to the 5G-IANA platform, where we deployed and configured the backend on a Linux VM within the MEC environment, enabling fast data processing and advisory transmission over Telekom Slovenia’s 5G network.

Initial Integration and Testing in Israel (September 2024):

Completed an end-to-end system test in Israel, confirming communication between the Android app, backend, and 5G setup, and refining components prior to the main demonstration.

On-Site Setup and Demonstration in Slovenia (October 2024):

Set up the system at Telekom Slovenia’s testbed, finalized connectivity checks, and conducted the demonstration on October 9, successfully validating real-time advisory performance across multiple test scenarios.



3 Demonstration

3.1 Setup

Setup and scenario

The use case demonstrates how 5G-enabled LiTO technology improves traffic flow and road safety by facilitating real-time communication between vehicles and infrastructure. When a bus begins moving from a stop, speed advisories are calculated for a following car based on real-time telemetry. These advisories ensure the car adjusts its speed smoothly to match the bus's acceleration, avoiding sudden braking or delays. By leveraging 5G's ultra-low latency and high reliability, the system optimizes driving efficiency and passenger comfort while reducing potential risks in urban traffic scenarios.

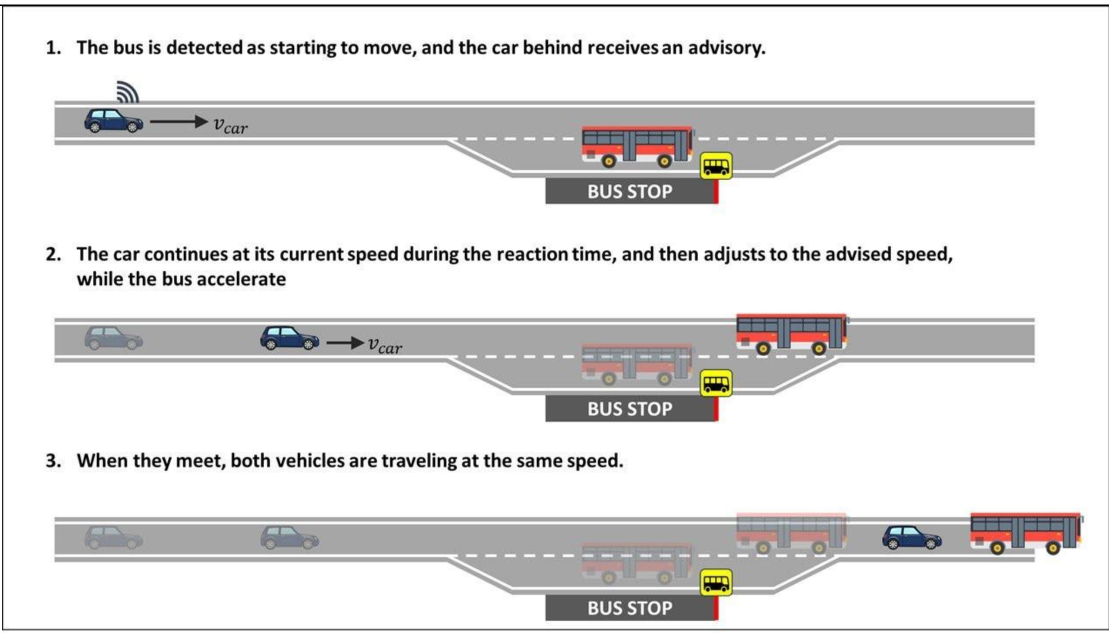


Illustration of the LiTO use case. a connected car receives real-time speed advisories to align with a bus's acceleration, ensuring smooth traffic flow and avoiding abrupt maneuvers. This highlights the system's ability to enhance driving coordination using real-time telemetry and 5G communication.

Our setup utilized the testbed's devices, with a native Android app installed to enable their functionality. The app allowed the OBU to transmit telemetry data and receive realtime speed advisories calculated by the system. Advisories were presented visually on the app screen and as audible alerts, ensuring they were both noticeable and actionable for the driver. This implementation demonstrated seamless integration with the 5G-IANA platform, leveraging the capabilities of the provided OBU and RSU devices to deliver real-time communication and advisories.

We deployed a Virtual Machine (VM) within the 5G-IANA infrastructure to function as the Multi-access Edge Computing (MEC) platform, supporting low-latency processing and decision-making. This VM hosted a Python-based web server with POST and WebSocket endpoints, managing data from both the OBU and RSU. The MEC's role was essential for running the LiTO algorithm and sending real-time speed advisories back to the driver.

All devices were connected via Telekom Slovenia's 5G network, with the Android devices equipped with 5G SIM cards for fast and reliable communication within the cell coverage area.

Technologies and Methodologies

The demonstration relied on the following technologies and methodologies:

- Linux Virtual Machine (VM) – Hosted the MEC and served as the processing hub for LiTO.
- Python-based Web Server – Managed data exchange between the OBU, RSU, and the backend.
- Native Android App – Configurable as either OBU or RSU to simulate the connected and non-connected vehicle roles.
- 5G SIMs and Mobile Phones – Provided by the 5G-IANA platform.

1. Dates, Rehearsals, and Preparation

Before the demonstration in Slovenia, we rehearsed and tested the system in Israel under similar conditions on September 26, 2024. This rehearsal allowed us to validate the functionality and refine the setup before the field test.
On October 8, we arrived at Telekom Slovenia's labs to set up the system, install the app on the devices, and review the test plan with the local team. The full demonstration was conducted on October 9, during which multiple test runs were performed under varying conditions to evaluate the LiTO system's performance in real-time advisory delivery.

2. Technical Description of the Demonstration

Two Android devices running the app were installed in separate vehicles, one representing the connected car (OBU) and the other the non-connected bus (RSU). The RSU device, which only sent telemetry data, communicated with the server using POST requests for one-way data transmission. In contrast, the OBU device required bidirectional communication to receive advisories, achieved through WebSocket connections.
The server, based on Python, hosted multiple endpoints to facilitate communication with both the OBU and RSU, as well as to support debugging and data collection for post-demo analysis.

3.2 Demonstration & qualitative analysis

The 5G-IANA field test at Telekom Slovenia evaluated LiTO's ability to provide real-time driving advisories based on the proximity and speed of a bus. Key findings from the demonstration are outlined below.

3. Latency and Responsiveness

The network achieved an average latency of 59 milliseconds with minimal variability, enabling rapid transmission of advisories. Combined with a calculation time of just a few milliseconds, this low latency supports potential applications with automated driving systems that require fast, precise communication.

4. Network Coverage and Reliability

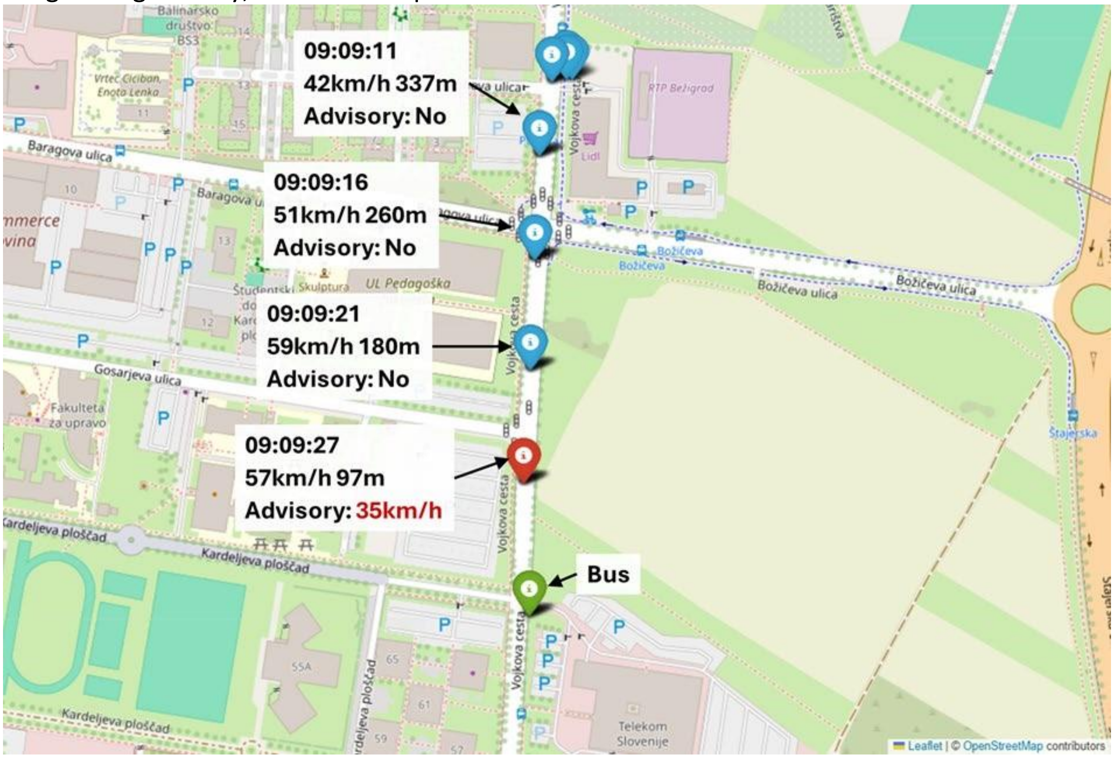
Telekom Slovenia's 5G network provided stable and uninterrupted coverage, supporting consistent data flow between the connected car and server. This reliability ensured the system operated smoothly, with no interruptions in data transmission.

5. Advisory Timing and Effectiveness

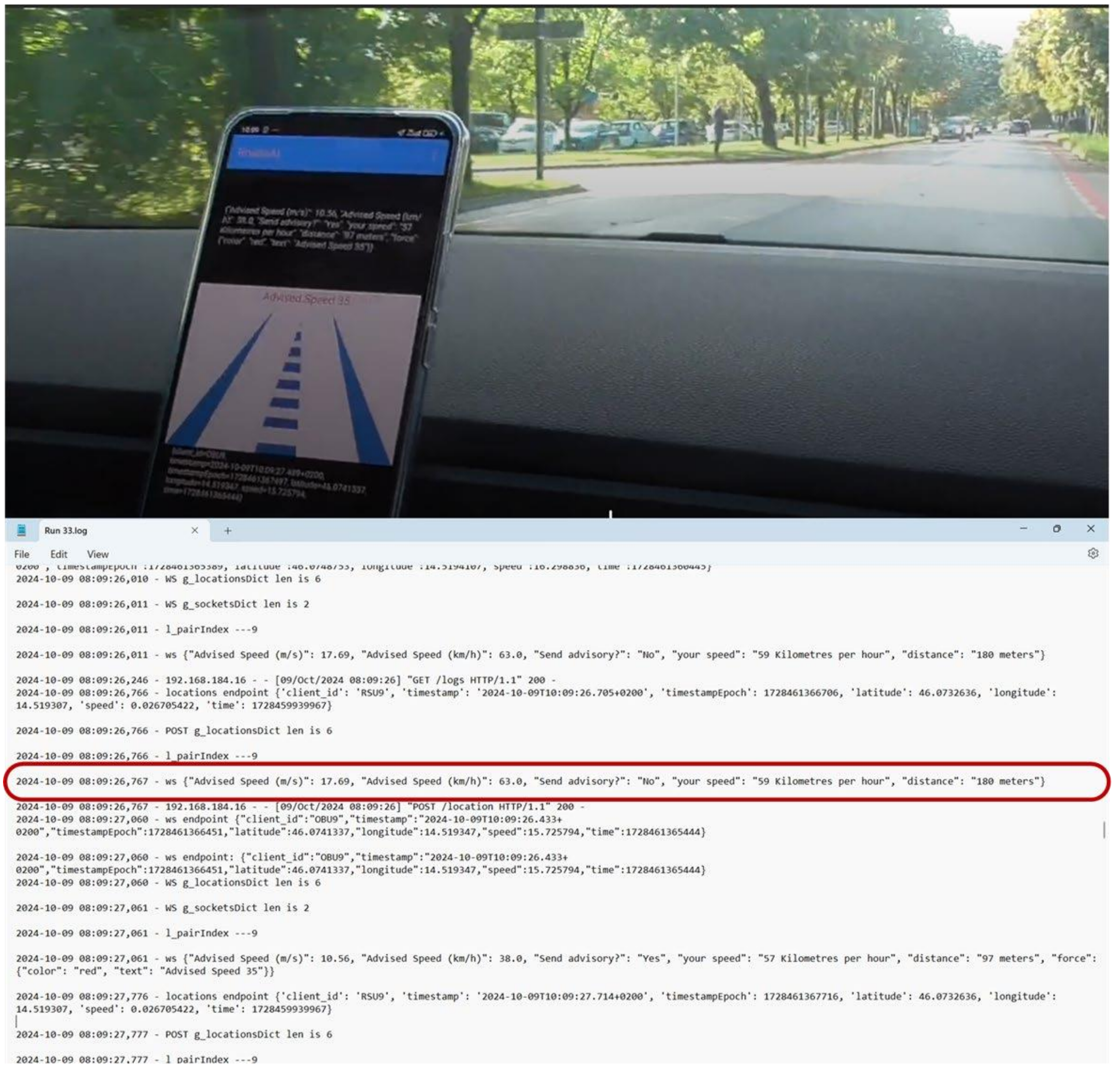
Advisories were delivered at optimal moments, allowing the driver to adjust speed smoothly as the car approached the bus. The image below shows how advisories were calculated and delivered based on the car's location, with an example advisory issued at 09:09:27, prompting the driver to slow down to 35 km/h. This timely advisory enabled smoother deceleration, highlighting the system's potential to enhance road safety by providing actionable information.

6. Summary

Overall, the LiTO system effectively delivered real-time advisories with minimal latency and high reliability. These results highlight the system's capability to support safer and more efficient driving through timely, data-driven speed recommendations.



Car and bus locations with real-time advisories from one of the test runs. The blue markers indicate the car's position and speed at various times, while the red marker shows the point where an advisory was issued, recommending the driver slow down to 35 km/h. The advisory was calculated based on the distance and speed of the bus (green marker) to allow smooth deceleration without sudden braking.



Snapshot showing the real-time advisory system in action, captured during the demonstration at the test bed. The upper section displays the Android app running on the device in the car, presenting the advised speed visually, while the lower section highlights the corresponding log entry received at the VM. The highlighted log shows that the advisory message was processed on the 5G INANA platform and sent at the recorded time, including performing real-time telemetry and advisory calculations.

4 Exploitation of Results

7. How 5G-IANA Boosted the Business Plan

8. The 5G-IANA program provided invaluable insights that significantly strengthened our business plan. Beyond the knowledge gained, we also developed concrete tools, including a SWOT analysis and Business Model Canvas (BMC), which will serve as foundations for our future exploitation strategy. The combination of focused guidance

and these strategic assets took us a substantial step forward, resulting in a refined and actionable plan for market positioning.

9. Open Call 2 Organization

The organization of Open Call 2, from the announcement to completion, was generally well-executed. Clear guidelines were provided throughout, ensuring that participants understood expectations and timelines.

10. 5G-IANA Coaching Sessions

The coaching sessions offered valuable project initiation support, with a clear breakdown of milestones, due dates, and deliverables. The team appreciated the structured guidance, although there was room for improvement in communication responsiveness. Slack messages sometimes experienced delays, while email communications were generally well-managed, with prompt responses.

11. Open Application Experimentation Platform

While the Open Application Experimentation Platform held promise as a valuable tool, we could not leverage it due to limitations in the testbed environment and unforeseen technical issues with the platform's services. As a result, we opted for an alternative solution, using a simple Linux VM to ensure project continuity.

12. Challenges Faced by 3rd Party Participants

One significant challenge involved uploading and deploying our server as a container within the platform's environment. Due to these technical constraints, we implemented a workaround by utilizing a straightforward Linux VM as an alternative solution to keep the demonstration on schedule.

13. Constructive Suggestions for Future Open to External Experimentation Calls

For future Open Calls, we recommend enhancing platform stability and communication responsiveness, particularly in dedicated support channels like Slack. Improving technical documentation and support for container deployment would also help external participants overcome integration challenges more smoothly. Additionally, providing more flexible testbed resources could allow for better adaptation to varying project requirements.

5 Summary Conclusion & Future Plans

Our engagement with 5G-IANA already began in 2023, when we were awarded a place in the 1st Open Call. Although circumstances prevented us from executing the project at that time, we were pleased to join the 2nd Open Call, which provided a valuable platform for both technical and strategic growth.

We achieved significant technical progress through our participation, deploying our LiTO system on a 5G network for the first time and validating its capability to deliver real-time driving advisories. Additionally, the program provided valuable business insights through SWOT analysis and business plan mentoring, positioning us more effectively for future commercialization and deployment.

Overall, our experience with the 2nd Open Call has advanced both our technical and strategic readiness. Moving forward, we are better prepared to capitalize on these developments in our next phase, applying the lessons and resources gained through 5G-IANA to strengthen our market position and bring innovative solutions to connected vehicle ecosystems.

Thanks to the capabilities provided by the 5G-IANA platform, this use case successfully demonstrated how real-time telemetry and advisory systems can enhance traffic flow and safety. By utilizing the platform's features, such as low-latency communication and seamless device integration, we showcased the feasibility of deploying this use case in real-world scenarios. Building on this success, we plan to further develop and offer this use case as a connected vehicle solution in future projects. The demonstrated approach will serve as a foundation for integrating similar use cases into broader intelligent transportation systems, leveraging the advanced capabilities of the 5G-IANA platform.

6 References to Multimedia Content

Full demo -

[09 OCT Telecom Slovenja Ljubljana.mp4]

Short video -

[IANA short draft _captions.mp4]

Open Call 2 – AviSense

1 Introduction

1.1 Overview of the use cases

We used the Telekom Slovenije Testbed for testing and implementation. We developed two use cases: Cooperative Localization and Crossview Geolocalization, both designed to leverage 5G capabilities for enhancing real-time situational awareness and precise localization of Connected and Automated Vehicles (CAVs). To test these systems, we used simulated data produced by our simulator framework.

The Telekom Slovenije Testbed was chosen due to its advanced 5G infrastructure and capabilities, which align well with our needs for testing real-time, high-bandwidth applications in CAVs. The testbed offers a stable environment with low latency and high-speed connectivity, essential for developing and validating our Cooperative Localization and Crossview Geolocalization use cases. By using this setup, we could effectively simulate real-world conditions and push the boundaries of our solutions, leveraging 5G to enhance situational awareness and localization precision in CAVs.

1.1.1 Cooperative Localization

Cooperative Localization aims to develop novel distributed and multi-modal fusion methods to achieve efficient 4D situational awareness, enhancing both ego and neighboring vehicle localization. The approach models a swarm of CAVs as an undirected connectivity graph, using star topologies for simplicity and efficiency. The system fuses four multi-modal measurements —self-position, distance, azimuth, and inclination angles— through the Graph Laplacian operator, creating a unified and compact localization framework. Efficient and fast communication between vehicles is essential to this approach, ensuring that the necessary data is shared in real-time, leveraging the low-latency capabilities of 5G networks.

The proposed method focuses on distributed and cost-effective local awareness solutions that can also be extended to other multi-agent systems, such as indoor ground robots, underwater robots, and unmanned aerial vehicles. The framework incorporates practical automotive challenges like data association, dynamic topologies, missing object detection, and network quality, providing robust performance in real-world scenarios. It supports collective 3D position estimation in a distributed manner, extending beyond ego-centric localization to deliver comprehensive situational awareness for the entire vehicle swarm. Furthermore, the approach minimizes complexity by avoiding iterative measurement exchanges, maintaining accuracy while optimizing both computational and communication resources.

1.1.2 Crossview Geolocalization

Crossview Geolocalization aims to solve the problem of precisely localizing a vehicle-mounted camera by comparing ground-level imagery with overhead satellite maps, advancing beyond traditional image retrieval techniques to achieve accurate pose estimation. The architecture is comprised of the following modules.

- **Feature Extraction:** Two Convolutional Neural Networks (CNNs) separately process the ground and satellite images to extract deep, multi-scale features. These features are robust, viewinvariant, and discriminative, enabling effective feature correspondence. The multi-scale approach supports a coarse-to-fine optimization process, improving the chances of avoiding local minima and finding the global optimum solution.

- **Geometry Projection Module:** This component maps the deep features from the satellite perspective to the ground view using an approximate geometric transformation based on the relative camera pose. This transformation is crucial for bridging the domain gap between the two distinct image views.
- **Differentiable Pose Optimization:** The module integrates a differentiable Levenberg-Marquardt (LM) algorithm into the pipeline to iteratively refine the camera's pose. By minimizing the discrepancy between the projected satellite features and the observed ground-level features, the system optimizes the camera pose in an end-to-end manner. The refinement begins with coarse features and progressively integrates finer details, allowing both broad searches and precise pose adjustments for improved accuracy.

1.2 Objectives

The objectives focus on utilizing advanced 5G capabilities to achieve high-precision, low-latency localization and situational awareness for connected and automated vehicles through Cooperative Localization and Crossview Geolocalization systems

1.2.1 High level objectives

Cooperative Localization

- **Enhanced Situational Awareness:** Achieve accurate 3D localization for the ego vehicle and its neighboring connected vehicles by utilizing V2V communication over 5G. This extends the perception range beyond individual sensors, improving overall situational awareness crucial for autonomous driving.
- **Low-Latency Cooperative Localization:** Leverage 5G's ultra-low latency capabilities to ensure real-time V2V data exchange, allowing for quick updates and precise localization adjustments in dynamic traffic environments.
- **Efficient Use of 5G Network Resources:** Ensure efficient and effective use of 5G bandwidth for V2V communication, optimizing the exchange of high-fidelity sensor data for precise and low-latency localization updates while maintaining network efficiency.
- **Low-Latency Performance:** Utilize the 5G network's capabilities to maintain an end-to-end processing time within 100 milliseconds, including data transmission and localization updates.

Crossview Geolocalization

- **High-Precision Localization:** Achieve accuracy by optimizing feature extraction and geometry projection, ensuring reliable pose estimation in diverse environments and speeds.

- **Efficient 5G Bandwidth Utilization:** Optimize data compression and transmission to balance high-resolution imagery quality with efficient 5G bandwidth usage for accurate localization.
- **Cloud Integration for Pose Refinement:** Offload intensive tasks to the cloud using 5G, ensuring seamless, low-latency pose refinement for continuous, real-time accuracy.

1.2.2 Technical objectives

Both:

- Dockerization and Deployment: Containerize all components using Docker for ARM devices, ensuring compatibility, efficient deployment, and scalability within the test environment.
- Testing and Integration: Validate the integrated system in a testbed setup to ensure seamless interaction between all components and real-time performance using 5G capabilities.

Cooperative Localization

- Localization Error Reduction: Achieve a 30% reduction in localization error[10] compared to the baseline SLAM output, focusing on scenarios where only two vehicles participate in the cluster.

CrossView GeoLocalization

- Lateral and Longitudinal Error Reduction: Reduce both lateral and longitudinal localization errors, optimizing the system for precise vehicle pose estimation in dynamic environments.

2 Project Timeline

The project had two phases:

Phase **one** took place in the premises of the AviSense, will be continuously deployed for the generation of data and rapid prototyping.

Phase **two** took place in 5G-IANA testbeds, during the second half of the project to be arranged with the site partners.

Key milestones are:

- AviSense was informed, by the 5G-IANA project coordinator, that its proposal is provisionally accepted (11 July).
- The AviSense project officially began, following the submission of the required signed documents (18 July).
- OC2 interview round, between AviSense and the partners of the 5G-IANA, took place (24 July).
- Exploitation workshop took place (30 July).
- Phase one started (1 August).

[10] Absolute Trajectory Error

- Market analysis and business plan model was provided to the 5G-IANA partners from AviSense (13 August).
- Access to the 5g-IANA UBITECH GitLab was granted to AviSense (11 September).
- Phase two started (12 September).
- Short dissemination video and slides presentation was prepared and provided from AviSense (30 September).
- On-site experiments and demonstrations were conducted at the Slovenian testbed (1-2 October).
- Video demo was created and submitted (31 October).
- Final report was submitted (31 October).

3 Demonstration

3.1 Setup

The deployment took place in the Telecom Slovenia research lab. Specifically, it was carried out on the Edge server, which is directly connected to the User Plane Function (UPF). This ensured optimal integration with the network infrastructure. The containers were deployed on an eMBB-type slice, which supports an uplink throughput rate of up to 100 Mbps, offering high-performance capabilities essential for the deployment.

In terms of network performance, the average Round-Trip-Time (RTT) between a User Equipment (UE) and the Edge server within the 5G network, operating on the n78 band, was recorded at 15 ms. It is worth noting that no actual UE equipment was used during this process, but the network environment was still fully operational and optimized for low-latency communication.

The majority of the work was conducted remotely from our facilities. However, to carry out a rehearsal for the specific use case, we visited Telekom Slovenije's premises on October 1 and 2. This visit allowed us to collaborate directly, ensuring that the set-up and implementation were aligned with the project requirements.

Cooperative Localization

We gathered data from the CARLA simulator during a scenario where two vehicles travel at a moderate speed on a highway, maintaining a relatively constant distance from each other. Both vehicles consistently stay within each other’s line of sight, with their separation remaining below the detection range of our algorithm. Each vehicle is equipped with a 64-channel LiDAR, an IMU, and a GNSS receiver, ensuring that the virtual data generated includes the outputs from these sensors.

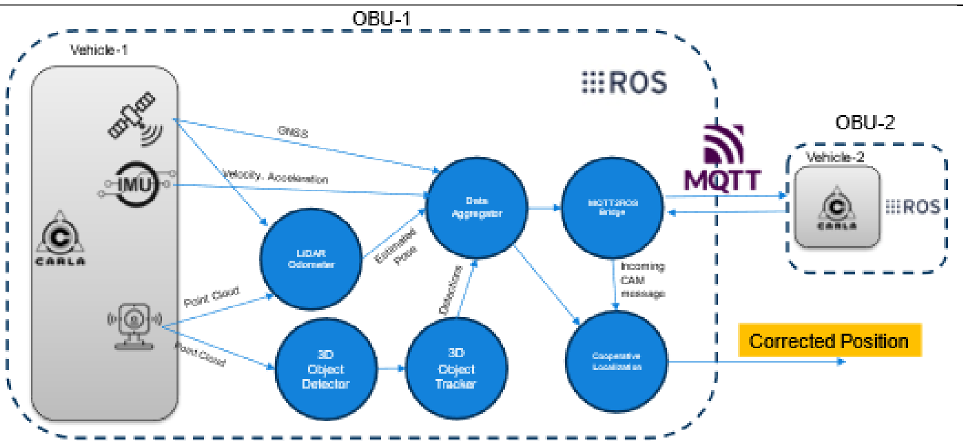


Figure 15: Cooperative Location System Overview.

We utilized two virtual OBUs to host the components running in each virtual vehicle. All the components were implemented as ROS nodes. These nodes, as depicted in Figure 1, are:

- **3D Object Detector**: This node takes the LiDAR point cloud as input and estimates the bounding boxes of the surrounding objects.
- **3D Object Tracker**: This node tracks detected objects over time using the bounding boxes provided by the 3D Object Detector and maintains object identities.
- **LiDAR Odometer:** This node processes the LiDAR point cloud to estimate the vehicle's pose and track its movement over time.
- **Data Aggregator:** This component collects and integrates information from the GNSS, IMU, LiDAR Odometer, and 3D Object Tracker to provide a comprehensive estimate of the vehicle's state.
- **MQTT to ROS Bridge:** This node manages communication between the vehicles, handling incoming CAM (Cooperative Awareness Messages) and transmitting data using MQTT to facilitate ROS integration.
- **Cooperative Localization Module:** This module processes information from both vehicles to correct the position of the ego vehicle based on shared data, improving localization accuracy resulting in a corrected position.

Crossview Geolocalization

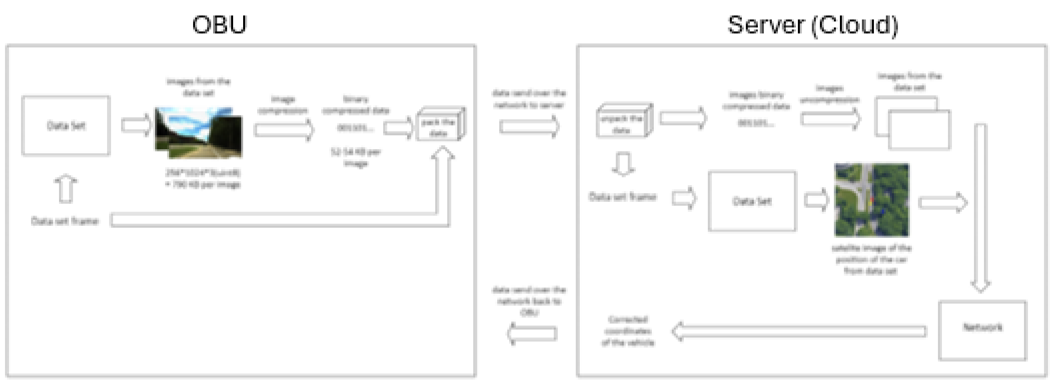


Figure 16: CrossView GeoLocalization System Overview.

Figure 16 illustrates the data processing workflow between the On-Board Unit (OBU) and the Server (Cloud) in the context of vehicle localization using image data. We deployed the server in a third-party cloud infrastructure because the testbed did not have a GPU-enabled server available. Here's a detailed explanation:

OBU Side:

- Data Set Frame: The OBU retrieves images from its onboard dataset. These images are typically captured by vehicle-mounted cameras, and in this case, they are of size 256 × 1024 × 3 (with 8 bits per channel), resulting in approximately 790 KB per image.
- Image Compression: To minimize bandwidth usage, the images undergo compression. This reduces the size of each image significantly.
- Binary Compressed Data: The compressed image data is converted into a binary format. This process reduces the image size to approximately 52-54 KB per image.
- Data Packing: The binary compressed data is then packed and prepared for transmission over the network to the server.

Server (Cloud) Side:

- Data Reception: The server receives the data sent from the OBU and unpacks it to retrieve the binary compressed image data.
- Image Decompression: The binary data is decompressed to reconstruct the original image format for further processing.
- Data Set Integration: The decompressed image is then matched against the server’s dataset, which contains satellite images or map data corresponding to the vehicle’s position.
- Coordinate Correction: By comparing the received image with the server's dataset (satellite images), the server determines the vehicle’s precise position and corrects any localization errors.

- Data Transmission Back to OBU: The corrected coordinates are sent back over the network to the OBU, ensuring that the vehicle has an accurate, real-time understanding of its location.

3.2 Demonstration & qualitative analysis

The demonstration aimed to showcase the functionality and performance of the Cooperative Localization and Crossview Geolocalization systems within the Telekom Slovenije Testbed. It focused on deploying the system components on the platform, feeding in data, and logging the outputs to evaluate the impact and validate the effectiveness of our methods.

System Performance:

- The demonstration validated the effectiveness of the Cooperative Localization system in achieving satisfactory (~10Hz) 3D situational awareness. The system successfully utilized Vehicle-to-Vehicle (V2V) communication over the 5G network to exchange relative position, distance, and angle information between the vehicles, ensuring enhanced localization updates with minimal latency.
- The Crossview Geolocalization system effectively integrated ground-level images and overhead satellite data through a cloud-based server setup, providing accurate position correction and pose estimation. Despite the absence of a GPU-enabled server in the testbed, the third-party cloud deployment ensured the system's operation within acceptable latency limits.

Network and Latency Evaluation:

- The systems operated under the 5G network's low-latency environment, maintaining an average round-trip-time (RTT) of 15ms, which is consistent with the requirements for real-time vehicle communication and localization. This ensured that the vehicles' localization and situational awareness updates occurred in near real-time.
- The eMBB-type slice used for the deployment provided sufficient bandwidth (up to 100 Mbps), enabling efficient data transmission and high-fidelity sensor data exchange between vehicles and the cloud server without noticeable delays.

System Behavior and Responsiveness:

- The Cooperative Localization system demonstrated its capability to adapt dynamically to changes in the vehicles' relative positions, maintaining accurate tracking even when the vehicles adjusted speed or direction.
- The Crossview Geolocalization framework efficiently processed image data and integrated it with satellite maps for accurate position corrections, confirming the system's adaptability and accuracy in diverse simulated traffic scenarios.

Challenges Encountered:

- The lack of GPU-enabled servers in the testbed posed a challenge for optimizing the Crossview Geolocalization system. However, the use of a third-party cloud server enabled the demonstration to proceed with acceptable performance levels.
- Limited preparation time impacted our ability to fully integrate and optimize all components, but the demonstration still highlighted the core functionalities of both systems, offering insights into areas for future improvements.

4. Exploitation of Results

The 5G-IANA initiative has been instrumental in enhancing AviSense's business model by:

- Enabling real-world testing
- Providing technical guidance
- Fostering strategic partnerships within the communication expert

5G-IANA's infrastructure, particularly the 5G testbed, has allowed us to validate and refine our key technological features (TRL4 → TRL5), such as cross view geo-localization, cooperative localization and situational awareness, and advanced multimodal data fusion.

This rigorous testing has been pivotal for our commercialization efforts, ensuring that our product not only performs under real-world conditions but also stands out in terms of safety, reliability, and scalability.

The business guidance provided by 5G-IANA has contributed significantly to our competitive advantage, crafting a business model that emphasizes safety, transparency, and innovation -three critical factors that resonate with stakeholders in both consumer and industrial markets.

Furthermore, the partnership with 5G-IANA has enhanced our credibility, positioning AviSense as a leader in driving the next generation of sustainable and safe transportation solutions.
The Open Application Experimentation Platform presented some challenges for integration into our workflow. We relied heavily on Ubitech for support in utilizing, deploying, and executing our solution within the testbed environment. The challenges primarily stemmed from the limited time available for us to familiarize ourselves with the platform.

Challenges faced by 3rd party participants

- **Limited Preparation Time:** We were informed about the testbed requirements at the end of July, leaving us with a very limited timeframe, including the month of August. Despite this, we did our best to adapt and prepare under these constraints.
- **Lack of GPU-Enabled Devices:** The absence of GPU-enabled devices in the testbed restricted our ability to fully integrate and test our data-driven solutions, which rely heavily on GPU resources for efficient processing.

5. Summary Conclusion & Future Plans

We discovered the 5G-IANA second Open Call through various outreach efforts, including industry networks, online platforms, and dedicated newsletters for Connected and Automated Vehicles (CAVs) and 5G technology initiatives. The Open Call's focus on 5G-based solutions for automotive applications aligned perfectly with our goals at AviSense. Given our work in solutions for enhancing CAV situational awareness, we were highly motivated to apply and explore the call’s possibilities to further develop and validate our Cooperative Localization and Crossview Geolocalization use cases.

6. References to Multimedia Content

- Full demo recording (10-20 minutes)
- Short video (2-2.5 minutes) for dissemination, including business impact from 5G-IANA