# ISG ZSM PoC Proposal

# 1 PoC Project Details

## 1.1 PoC Project

| | |
|---|---|
| PoC Number:<br>*(assigned by ETSI)* | **5** |
| PoC Project Name: | On-demand Non-Public Networks (NPNs) for industry 4.0: zero-touch provisioning practices in public-private network environments. |
| PoC Project Host: | Telefónica |
| Short Description: | This PoC will showcase the ability to provision a tailored 5G private network for an industry 4.0 service, upon request (on demand), with no human intervention (zero-touch). In particular, the PoC will demonstrate the automation in the provisioning of a Public Network Integrated Non-Public Network (PNI-NPN) to enable autonomous AGV navigation in a factory for intralogistics. The private network segment, deployed within the factory premises, includes three network domains: access domain (5GNR+Wi-Fi6 technologies combined with the use of AT3S functionality), transport domain (L2 Ethernet network), core domain (5GC). The public network segment includes a pre-trained obstacle detection application to assist AGV trajectory. This application function corresponds to the data network, hosted in a PLMN operator's telco edge node.<br><br>This PoC is developed using the network and service management solutions developed in two European Commission (EC) funded projects, under the H2020 programme: 5G-CLARITY [1] and 5GZORRO [2]. The implementation of these solutions complies with the ZSM standards. More specifically, the design architecture of the use case follows ZSM 002 (ZSM framework), and the workflows governing interactions across the different ZSM services follow the recommendations captured in ZSM 003 (end-to-end slicing) and ZSM 008 (cross-domain orchestration). |

## 1.2 PoC Team Members

| | Organisation name | ISG ZSM participant (yes/no) | Contact (Email) | PoC Point of Contact (*) | Role (**) | PoC Components |
|---|---|---|---|---|---|---|
| 1 | Telefónica | Yes | **Jose Ordonez-Lucena** joseantonio.ordonezlucena@telefonica.com **Diego R. López** diego.r.lopez@telefonica.com | X | Network/ service provider | • Use case specification • PoC architecture definition • Sponsor of 5TONIC testbed |
| 2 | Fundaciò i2CAT | No | **Daniel Camps** daniel.camps@i2cat.net **Adriana Fernández-Fernández** adriana.fernandez@i2cat.net | | Supplier; test labs | • 5G-CLARITY components (see list in Table 2) • Setup and MAINTENANCE of i2CAT lab (infra and NFs) |
| 3 | NextWorks | Yes | **Giacomo Bernini** g.bernini@nextworks.it **Pietro G. Giardina** p.giardina@nextworks.it | | Supplier | • 5G-ZORRO components (see list in Table 2) • Lead integration with 5G-CLARITY |
| 4 | Interdigital | No | **Tezcan Cogalan** Tezcan.cogalan@interdigital.com **Alain Mourad** alain.mourad@interdigital.com | | Solution integrator | Obstacle detection function: implementation, training and onboarding. |
| 5 | Universidad Carlos III de Madrid | No | **Borja Nogales** bdorado@it.uc3m.es **Francisco Valera** fvalera@it.uc3m.es **Iván Vidal** ividal@it.uc3m.es | | University; test labs | • Setup and maintenance of 5TONIC lab. • Layer 2 inter-site communication mechanism. |

(*) Identify the PoC Point of Contact with an X.
(**) The Role will be network/service provider, supplier, or other (universities, research centers, test labs, Open Source projects, integrators, etc…).

All the PoC Team members listed above declare that the information in this proposal is conformant to their plans at this date and commit to inform ETSI timely in case of changes in the PoC Team, scope or timeline.

## 1.3 PoC Project Scope

### 1.3.1 PoC Topics

*PoC Topics identified in this clause need to be taken for the PoC Topic List identified by ISG ZSM and publicly available in the ZSM WIKI. PoC Teams addressing these topics commit to submit the expected contributions in a timely manner.*

| PoC Topic Code | PoC Topic Description | Related WI | Expected Contribution | Target Date |
|---|---|---|---|---|
| 2 | Automation in Multi-Stakeholder Ecosystem | ZSM-001, ZSM-003 | • Using the network slicing models and solution sets for the provisioning of a public-private 5G network, i.e. PNI-NPN, following the recommendations captured in ZSM-003. • Showcasing a PNI-NPN deployed across two administrative domains (on-premises infrastructure and PLMN infrastructure). In the proposed PoC, there | May-June 2022 |

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| | | | exists three stakeholders: vertical customer (ZSM consumer), CSP’s B2B unit (ZSM operator #1) and CSP’s MNO unit (ZSM operator #2).<br>● Using solutions from different R&D projects, developed by different parties. These solutions include vendor (commercial) and open-source products. | |
| 4 | Cross-domain user-driven E2E services | ZSM-002, ZSM-008 | ● Showcasing the end-to-end nature of the PNI-NPN, with all network domains covered: 3GPP (5GNR) and non-3GPP (Wi-Fi 6) access, transport network (L2 Ethernet), 3GPP core network (5GC) and data network (application server).<br>● Implementing ZSM management and data services providing fulfilment capabilities with management functions. The specific ZSM services to be used in the present PoC are detailed in Table 2 from Section 2.2.<br>● Integrating the management functions into individual management domains and the E2E service management domain.<br>● Demonstrating cross-domain workflows across the management functions, according to the governance captured in ZSM 008. | May-June 2022 |

### 1.3.2 Other topics in scope

List here any additional topic for which the PoC plans to provide input/feedback to the ISG ZSM.

| PoC Topic Code | PoC Topic Description | Related WG/WI | Expected Contribution | Target Date |
|---|---|---|---|---|
| A | | | | |
| B | | | | |
| <…> | | | | |
| | | | | |

## 1.4 PoC Project Milestones

| PoC Milestone | Milestone description | Target Date | Additional Info |
|---|---|---|---|
| P.S | PoC Project Start | February 2022 | |
| P.P.1 | PoC Proposal submission | March 2022 | Submission to ZSM PoC Management Team for approval. |
| P.P.2 | PoC Proposal Announce | April 2022 | Public Web announced in 5G-CLARITY and 5G-ZORRO media (web, twitter, etc.). *Once approved. |
| P.M1 | PoC internal milestone 1: inter-site connectivity up and running | March 2022 | L2 connectivity over VPN set up between facilities. |
| P.M2 | PoC internal milestone 2: user story detailed | March 2022 | Detailing workflows across different PoC components, to comply with the user story (see Table 1). |
| P.M3 | PoC internal milestone 3: test campaign | April 2022 | Specification of testing plan, with the collection of test cases to be conducted for PoC evaluation |
| P.M4 | PoC internal milestone 4: PoC execution | May 2022 | PoC components integrated and ready for evaluation. Test campaign execution. |
| P.D1 | PoC demo | June 2022 | Showcasing PoC results at 2022 EuCNC & 6G Summit (EuCNC'22). Coordinates: 7-10 June 2022, Grenoble (France). |
| P.C1 | Contribution on lessons learned | June 2022 | Collect feedback about the lessons learnt about the PoC, in order to make improvements when executing the PoC in production factory networks (see clarifications on portable testbed vs in-factory setup in Section 2.2). |
| P.C2 | Feedback to ISG ZSM on potential improvements | June 2022 | This PoC relates to ZSM 002, ZSM 003 and ZSM 008. Potential improvements of these standards, if any, might be discovered by the PoC, and will be input to contributions to (open) work items. |
| P.R | PoC Report | July 2022 | Final feedback and PoC report document for discussion within ETSI ZSM community |
| P.E | PoC Project End | July 2022 | |

NOTE: Milestones need to be entered in chronological order.

## 1.5 Additional Details

More information on the objectives, pilots and deliverables from the two projects can be found in the respective webpages: 5G-CLARITY [1] and 5G-ZORRO [2].

# 2 PoC Technical Details

## 2.1 PoC Overview

After interviews with real-world industry 4.0 verticals, participants have identified the as-is situation: nowadays, autonomous Guide Vehicles (AGV) navigate autonomously in a factory, and the vertical does not know how often it does stop, and why. The objective is to PoC is to precisely allow the vertical to gain this knowledge (business intelligence), and then use it to optimize AGV trajectories (e.g., replan trajectory).

This PoC is conceived to demonstrate the use of ZSM services and associated zero-touch management capabilities to provision a private 5G network on-demand. This private 5G network will be used to enhance autonomous navigation of AGV in the shop floor of a factory, allowing a remote worker to keep track of AGV trajectory and alert him/her on unexpected incidents (also known as disturbances) that cause deviations from the planned route. When the unexpected incident happens, the AGV slows down or stops, captures a photo on what is in front of it with the on-board camera, and sends the photo to a pre-trained obstacle detection function. This application identifies that the root cause of the incident is an obstacle, and notifies the remote worker accordingly, with the coordinates where the obstacle is, together with the photo taken.

The private 5G network will not be confined to on-premises infrastructure; in fact, it will rely on the capabilities of telco edge computing to host obstacle detection function. The result is a PNI-NPN. To make an agile yet efficient provisioning of the PNI-NPN, network slicing will be used.

### 2.1.1 Use-case Description

The use of AGVs in factories and warehouses can mitigate the impact of human errors which then leads to improvements in safety, efficiency, quality and productivity of the intralogistics processes, for example in the transportation of goods. In the proposed PoC use case, the AGV has a predefined route for its movements throughout the warehouse but only the origin and destination are known, i.e. the status of the route is ignored. In particular, the AGV speed, acceleration and deceleration, as well as the specified stop points where goods are picked up or dropped are predefined. It is however necessary to assess, in near real-time, whether any incident occurs along the route, and if so, to identify its exact position and root cause. A disturbance is defined as any deviation from the planned route, be it inaccurate speed, sudden acceleration/braking, unplanned stops, or planned stops being either too short or too long. Nominal values and tolerances for all course parameters will be set by the industry customer. This way the productivity, safety and efficiency of this process can be enhanced. In the use case under consideration, it is assumed that the disturbance is the unexpected presence of an obstacle in the AGV trajectory, which forces AGV to decrease speed (meaning less productivity) or even proceed with a full stop (emergency braking).

The use case to be demonstrated in this PoC is based on an industry 4.0 pilot addressed by 5G-CLARITY project: “Enhanced AGV autonomous navigation for intralogistics (industry 4.0)”. This pilot is executed on the production shop floor of RBEF, the Bosch Factory located in Aranjuez near Madrid (Spain), and includes an AGV that is in charge of moving goods along the shop floor. The route along this indoor floor is already established, and it is shared with workers and human-operated vehicles.


**Figure 1. Aerial view of the RBEF (Robert Bosch factory floor in Madrid) that will be used for 5G-CLARITY pilot.**

Figure 1 shows the aerial view of the Aranjuez factory on which the AGV route is highlighted. The area of interest for AGV trajectory is limited to indoor environments, and it is marked in green. The AGV moves along a predetermined path (in red), which is approximately 275 m long on a flat and clean floor. The path and the stations at which the AGV stops are programmed in advance by the AGV control system. The AGV route is completely defined by the path, including the stops in which goods are left or picked up. Each route involves one of the three different loops, each having different stops:

- Loop 1 is always performed with the purpose of component unloading. The AGV stops at the predefined stations and, at every station, the components are manually unloaded by an operator. When the unloading finishes, the operator pushes a button on the AGV and it resumes its course towards the next station. If the button is not pressed after a predefined time, the AGV will resume the course on its own. Once loop 1 is finished, the AGV stops in a fixed point "P", depicted in Figure 1 and Figure 2, and checks with the factory computer system (the one that is controlling the manufacturing process) if loop 2 is to be performed. If not, it checks whether loop 3 is to be performed and, if it is not the case, the AGV navigates back to the warehouse.
- Loop 2 is a shuttle transfer of semi-finished goods within the production shop floor. It consists of only two stations, one for loading (see yellow point 1 shown in Figure 1 and Figure 2), and the other for unloading (see yellow point 2 shown in Figure 1 and Figure 2). This loop is seldom performed, in fact it is estimated to be performed once in an 8-hour shift. The AGV stop process in loop 2 is identical to the one of loop 1. When loop 2 is completed, the AGV navigates to point "P" and checks with the factory computer system if loop 3 is to be performed. If not, the AGV navigates back to the warehouse.
- Loop 3 is for picking up the finished products and transferring them to the warehouse. The factory computer system programs the AGV with the list of stations where products can be picked up (station location is predefined) and orders it to start the loop 3. Most of the stations of loop 1 are also included in loop 3. The AGV stop process in loop 3 is the same as the one of loop 1. Once loop 3 is completed, the AGV navigates to the exit and leaves the factory shop floor.

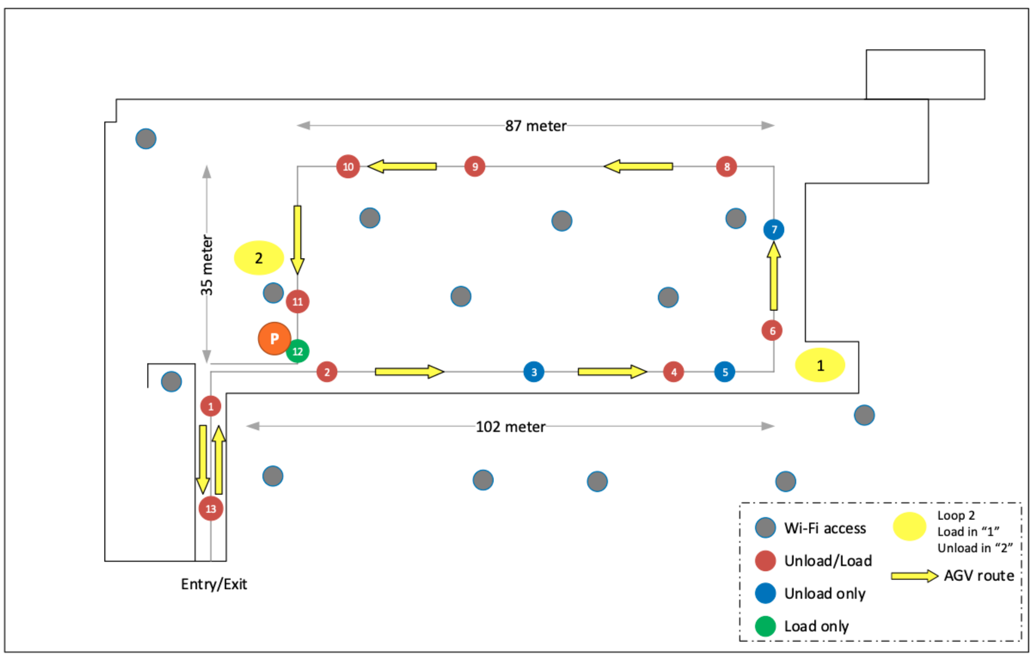


**Figure 2. AGV route in the production shop.**

To implement the PoC scenario over this factory floor, a private 5G network will be provisioned. This network will include a right-sized 3GPP Rel-15&Rel-16 system and an application function implementing obstacle detection logic. The resources and functions building up this network will be configured into a separate network slice, to ensure performance isolation and separate security domains from other services/processes running in the factory. For this network slice, 3GPP templates and procedures will be used.

Once the private 5G network is up and running, the AGV starts moving, connected to both 5GNR and WiFi at the same time (further details in Section 2.1.2). The AGV has an on-board camera that allows visualising the route ahead. When the AGV unexpectedly slows down or stops, the camera captures a photo and sends it to the application function, which identifies the cause of this anormal AGV operation as an obstacle. The information associated to this incident, including the photo of the obstacle and the associated coordinates, is stored and notified. With this material, the remote worker can take appropriate action, e.g., go to the specific location and remove the obstacle, or replan AGV trajectory.

### 2.1.2 Scope and Content of the PoC

This PoC aims at demonstrating the ability to provision a 5G private network for an industry 4.0 service, on demand, with no human intervention (zero-touch). For the proposed scenario, described in section 2.1.1, the private 5G network builds on 1) *3GPP Rel-15&16 system capabilities*, to provide the necessary performance (e.g., throughput and latency) and functional capabilities (e.g., multi-access technology support); 2) *pre-trained obstacle detection application*, to assist AGV trajectory.

The private 5G network is provisioned using a PNI-NPN approach, with part of the service components deployed on the factory premises (private network infrastructure) and the rest in a telco edge node (public network infrastructure). Following the recommendations captured in 3GPP TS 23.501 [3], the PNI-NPN is deployed and configured as an end-to-end network slice. Indeed, the network slice covers multiple network domains, namely:

- Access network. This network domain includes two wireless access technologies: 5GNR (3GPP) and Wi-Fi 6 (non-3GPP). On one hand, the 5GNR protocol stack is implemented with a small-cell gNB. On the other hand, the Wi-Fi 6 coverage is provided using Wi-Fi access points. These access technologies can be used together, leveraging access traffic steering, switching and splitting (AT3S) functionality. AT3S is a 3GPP Rel-16 feature whereby the AGV can have connectivity to both 5GNR and Wi-Fi 6 at the same time, thus allowing for enhanced data rates (e.g., by means of bandwidth aggregation) and improved reliability (e.g., by setting up back-up sessions or duplicating traffic over multiple access technologies). In this PoC, we will implement this capability with the use of Multi-Path TCP (MPTCP) proxy.
  *NOTE: The AGV has an AT3S enabled CPE to connect to this network.*
- Core Network. It is implemented with a lightweight Rel-15 5GC, right-sized for the use in private networks. The 5GC is fully virtualized.
- Transport Network. It corresponds to Ethernet fabric consisting of SDN-enabled L2 switches.
- Data Network. This domain hosts the pre-trained obstacle detection application, which is deployed after the UPF, at N6 interface.

The lower side of Figure 3 depicts the distribution of these domains across the public-private network infrastructure. As shown in the picture, all the service components are deployed within the factory boundaries, with the exception of the application function, hosted in the telco edge node; in other words, all 3GPP managed functions are executed atop the on-prem infrastructure. This infrastructure consists of a L2 Ethernet network connecting 5GNR and WiFi access points with a number of compute nodes. These nodes are in charge of providing execution environments to host virtualized workloads, including AT3S (MCTCP) proxy and 5GC.

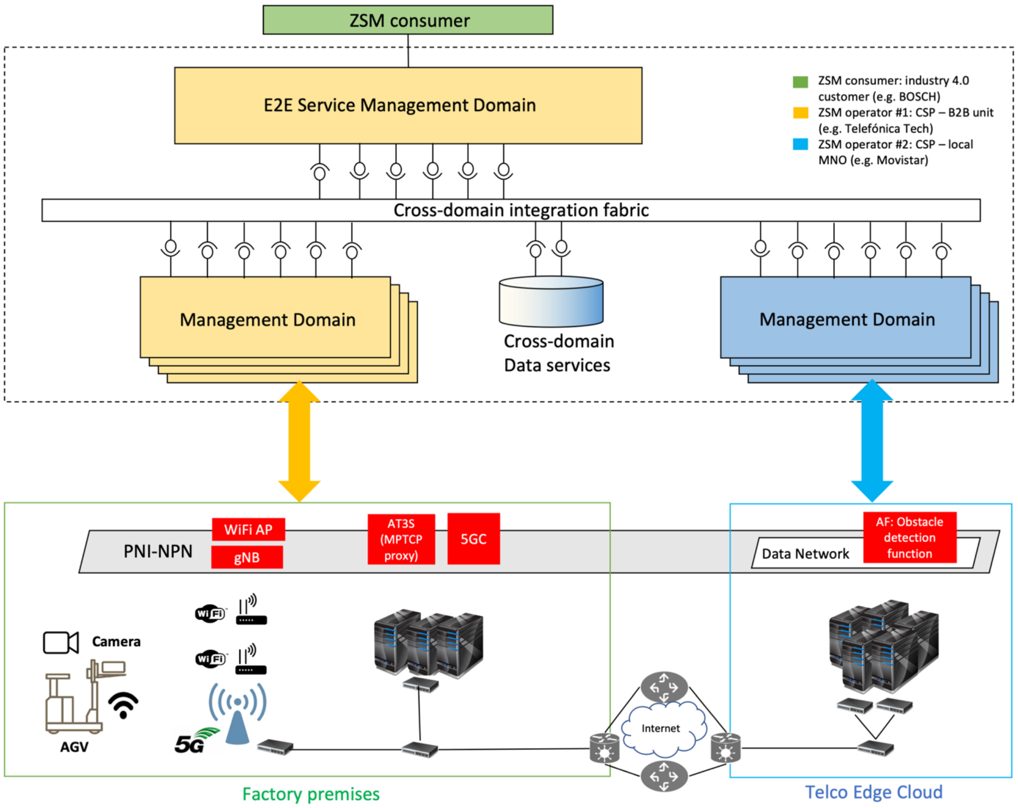


**Figure 3. Use-case realisation using ZSM framework**

The upper side of Figure 3 illustrates the management viewpoint of the scenario, and the relation with the ZSM framework. One can notice that the different infrastructures are operated by different roles:

- The on-prem resources (and functions running atop) are operated by ZSM operator #1. This role is played by the B2B unit of a CSP, who is the service provider (business contact) of the industry 4.0 vertical. This vertical, as owner of the in-factory infrastructure, plays the role of the ZSM consumer and hands the management activities over to the ZSM operator #1.
- The telco edge cloud resources (and application function running atop) are within the administrative domain of the ZSM operator #2. This role is played by the local MNO, with which ZSM operator #1 has a business agreement with.
- The typical scenario is where ZSM operator #1 and #2 are played by different units of the same CSP company. This is the assumption made for the present PoC.

In the following, the user story laying the foundations for the work to be done in this PoC is outlined.

**Table 1. PoC user story**

| User story | Description |
|---|---|
| Pre-conditions | • ZSM operator #1 (CSP's B2B unit) has a marketplace with industry 4.0 partners. These partners include vendors, solution integrators and application developers, among others.<br>• ZSM operator #1 (CSP's B2B unit) is the partner service provider for ZSM consumer (industry vertical). There exists a provider-customer relationship between ZSM operator #1 and ZSM consumer.<br>• ZSM operator #2 (CSP's MNO unit) administrates PLMN assets, scale infrastructure nodes and spectrum. |

| | |
|---|---|
| | ● ZSM operator #1 and ZSM operator #2 are units from the same CSP company. For the provision of services for B2B customers that require the use of PLMN assets, ZSM operator #1 has agreements with ZSM operator #2.<br>● There exists WAN connection between ZSM operator #1 and ZSM operator #2 facilities. This connection is Internet, and there is an on-premises SD-WAN element managed by ZSM operator #1.<br>● Obstacle detection application is onboarded by ZSM consumer into ZSM operator #1. This application is pre-trained. |
| Begins when | ● ZSM consumer issues a service order to ZSM operator #1, asking for the provision of a private 5G network fulfilling a particular set of service requirements. These requirements are captured in a SLA.<br>● Based on SLA requirements, ZSM operator #1 decides on the provisioning solution: a PNI-NPN consisting of an on-prem advanced 5G system, with the obstacle detection application deployed on the telco edge node.<br>● The PNI-NPN resources are to be allocated into an end-to-end network slice. |
| Steps | A number of workflows are executed, following the solutions and recommendations detailed in ZSM 003 (network slicing) and ZSM 008 (cross-domain orchestration). These workflows include request-response and notify-subscription messages across the PoC architecture components, and that are detailed in Section 2.2. |
| Post-conditions | ● All the managed functions building up the PNI-NPN are successfully instantiated and configured.<br>● ZSM operator #1 (CSP's B2B unit) informs ZSM consumer (vertical) that the private 5G network is set up and running.<br>● From this moment on, the use case is operative. This means that the AGV can start moving along the factory with steady speed. When the speed is reduced or AGV stops, the AGV on-board camera sends information to the application function, that is able to detect the obstacle and inform the human worker appropriately. |

## 2.2 PoC Architecture

While the previous section has conveyed the vision of the proposed PoC, in practice the actual demonstration is constrained by the limitations of interacting with the real production environment such as the factory in Aranjuez. Hence a two-step implementation/validation setup is proposed as follows:

- Portable testbed. It is a network environment that is used to mimic a realistic factory floor. The idea is to have such small-scale, portable testbed to do preliminary integration of different components (infrastructure resources, network and application functions, and ZSM services) and demonstrating them without any interruption to actual factory operation. It will also be used to disseminate the technology innovation in fares and conferences.
- In-factory setup. It is used to validate the scenario in a real factory environment, interacting with production IT/OT infrastructure. The integration with real factory assets is a critical activity, so before starting this step, it is required to have concluded a strict test campaign over the previous testbed. This test campaign shall consist of a number of different test cases (unit and functional tests) covering functionality, scalability and security related aspects.

According to the above rationale, the PoC proposal will be focused on the portable testbed only. Figure 4 depicts the architecture of the PoC, deployed on this portable testbed. When compared to in-factory setup (Figure 3), one can notice the following: i) i2CAT lab facility [4] provides the environment that mimics the BOSCH factory[1]; ii) 5TONIC lab facility [5] represents the telco edge node; iii) the AGV is replaced with a multi-connectivity CPE with the camara on board. The i2CAT and 5TONIC facility sites are connected using link-layer connectivity over L3VPN, as reported in [6].

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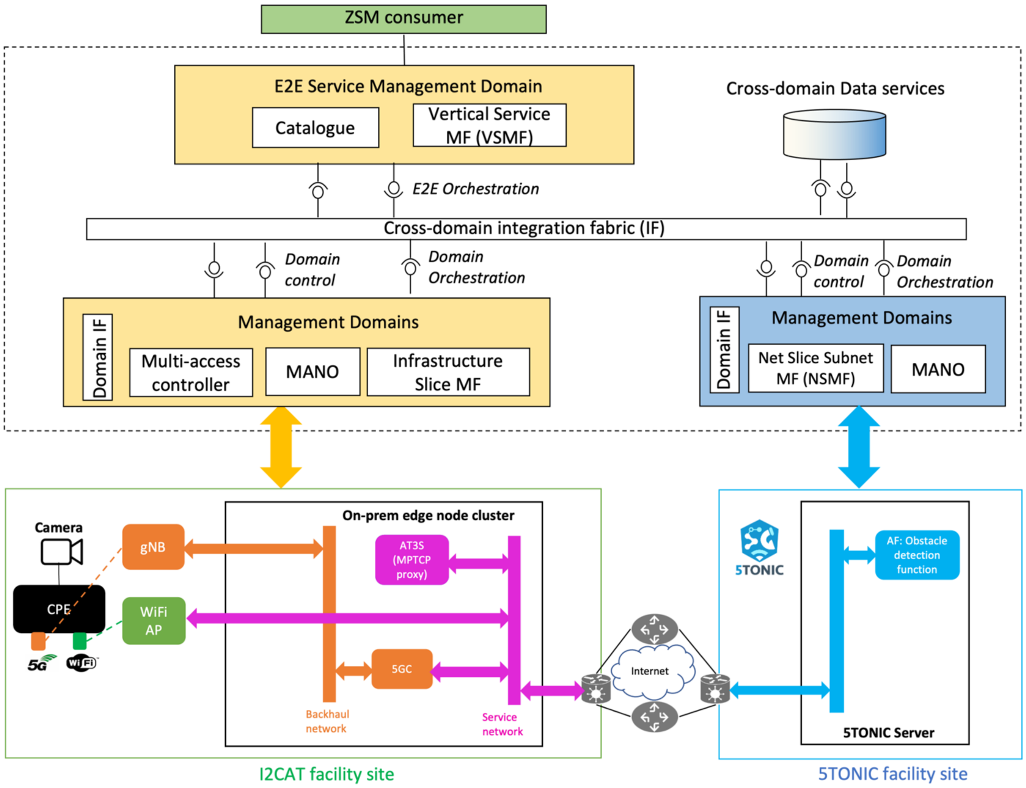


**Figure 4. PoC architecture. The management functions are positioned into the corresponding ZSM operator #1 and #2 owned management domains.**

For this PoC, the functions building up the PNI-NPN include: i) one gNB, providing Rel-15 5GNR protocol stack; ii) one Wi-Fi Access Point; iii) one 5GC instance, implemented using Open5GS [7]; iv) one MPTCP proxy, to terminate MPTCP connections coming from the mobile CPE and that are linked to AT3S functionality, allowing 5GNR + Wi-Fi6 connectivity; and v) one Application Function, developed by InterDigital and pre-trained with real factory obstacles.

In relation to the ZSM framework, one can notice that not all of the ZSM service categories specified in ZSM 002 are planned to be used in the PoC implementation. This is because the PoC is focused on the fulfilment activities, so only orchestration and control services are strictly required; the rest of ZSM services (e.g. intelligence, data collection, analytics, etc.) are more relevant to the assurance activities. Table 2 provides a list of the components on which ZSM services are developed in order to realize the PoC.

**Table 2. PoC components and their alignment with ZSM services**

| Management domain | Component | Provided ZSM services |
|---|---|---|
| ZSM operator #1 – E2E MD | Catalogue[1] | • E2E Orchestration<br>• E2E Data services |
| | Vertical Service Management Function (VSMF)[1] | • E2E orchestration<br>• E2E Data services<br>• Domain integration fabric |

| | | |
|---|---|---|
| | | • Supporting services (policy mgmt) |
| ZSM operator #1 – MD's | Multi-access controller[2] | • E2E orchestration<br>• Data services |
| | Infrastructure Slice Management Function[2] | • Domain orchestration<br>• Domain control<br>• Domain data services |
| | MANO stack[2]: NFVO (Open Source MANO) + VIM (Openstack) + CISM (k8s) | • Domain orchestration<br>• Domain control<br>• Domain integration fabric<br>• Supporting services (policy mgmt)<br>• Domain data services |
| ZSM operator #2 – MD's | Network Slice Subnet Management Function (NSSMF)[1] | • Domain orchestration<br>• Domain control<br>• Domain data services |
| | MANO stack[1]: NFVO (Open Source MANO) + VIM (Openstack) | • Domain orchestration<br>• Domain control<br>• Domain integration fabric<br>• Supporting services (policy mgmt)<br>• Domain data services |
| NOTE 1: The components marked with (1) are provided by the 5GZORRO project. The components marked with (2) are provided by the 5G-CLARITY project.<br>NOTE 2: Multi-access controller deals with 5GNR and Wi-Fi6, together with MPTCP proxy (AT3S functionality) allowing for their combined use. | | |

According to the above table, it is worth to mention that the solutions available in the management domains owned by ZSM operator #1 and #2 are different, despite having similar functionality. For example, the solutions providing network slice management functionality are based on different implementations. This is realistic in real-world scenarios, where different units of the same CSP work with different vendors and therefore different telco stacks, since their targeted services and customers are not the same.

## 2.3 Additional information


[1] H2020 project 5G-CLARITY [Online]. Available: https://www.5gclarity.com/
[2] H2020 project 5GZORRO [Online]. Available: https://www.5gzorro.eu/
[3] 3GPP TS 23.501, "System architecture for the 5G System (5GS)".
[4] https://i2cat.net/project-cat/industry-4-0/
[5] https://www.5tonic.org
[6] Vidal, I.; Nogales, B.; Lopez, D.; Rodríguez, J.; Valera, F.; Azcorra, A. "A Secure Link-Layer Connectivity Platform for Multi-Site NFV Services". Electronics 2021, 10, 1868. DOI: https://doi.org/10.3390/electronics10151868
[7] Open5GS, https://open5gs.org