



January 18th 2022

5G PPP TB e-Workshop

E2E Solutions for experimenting 5G vertical services across the ICT-17 and ICT-19 Platforms

5Growth Integration with ICT-17
(5G-VINNI and 5G-EVE)

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5Growth: 5G-enabled Growth in Vertical Industries

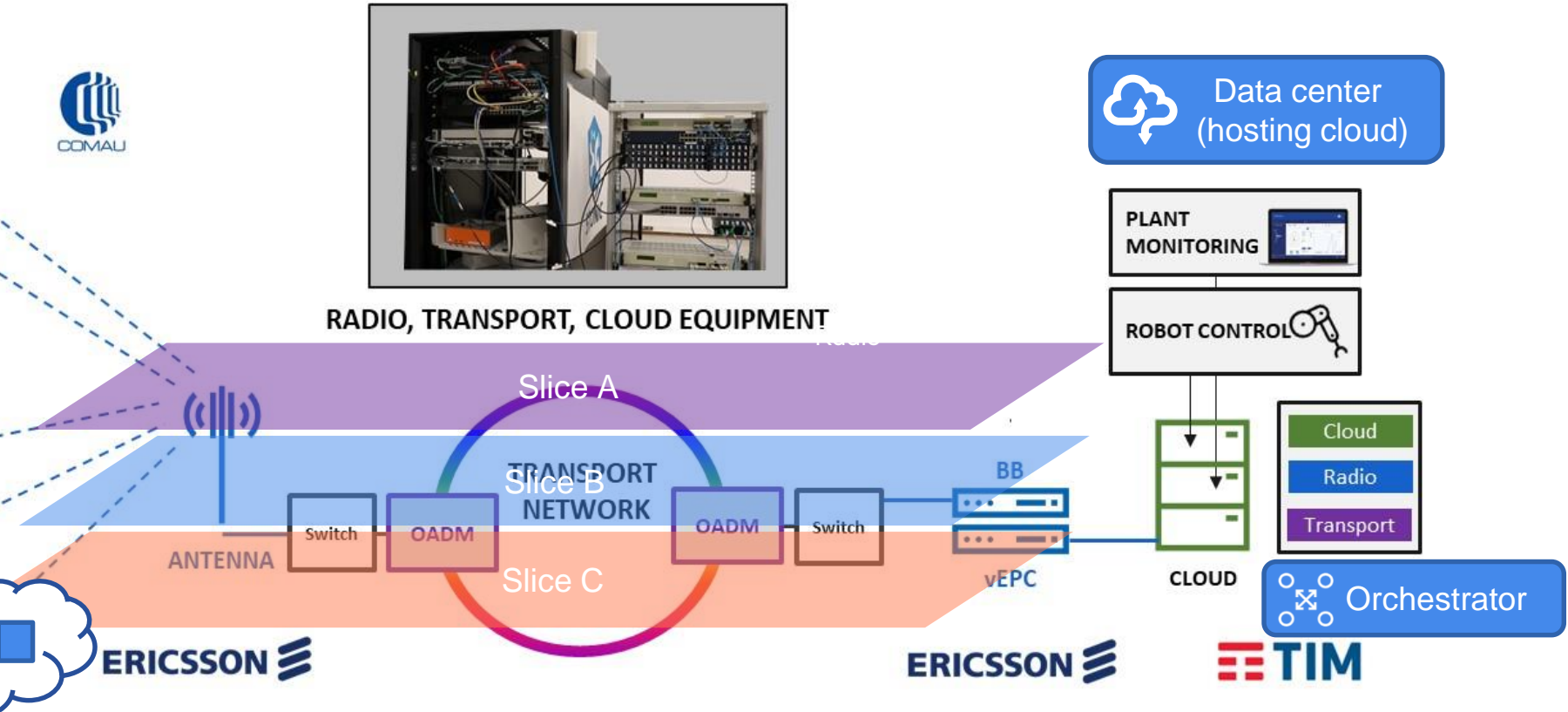
Industrial Applications

Digital Twin
Critical IoT

Telemetry & Monitoring
Massive IoT

Remote Support
Broadband IoT

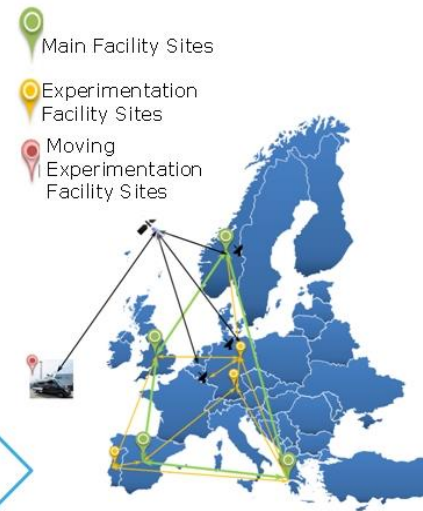
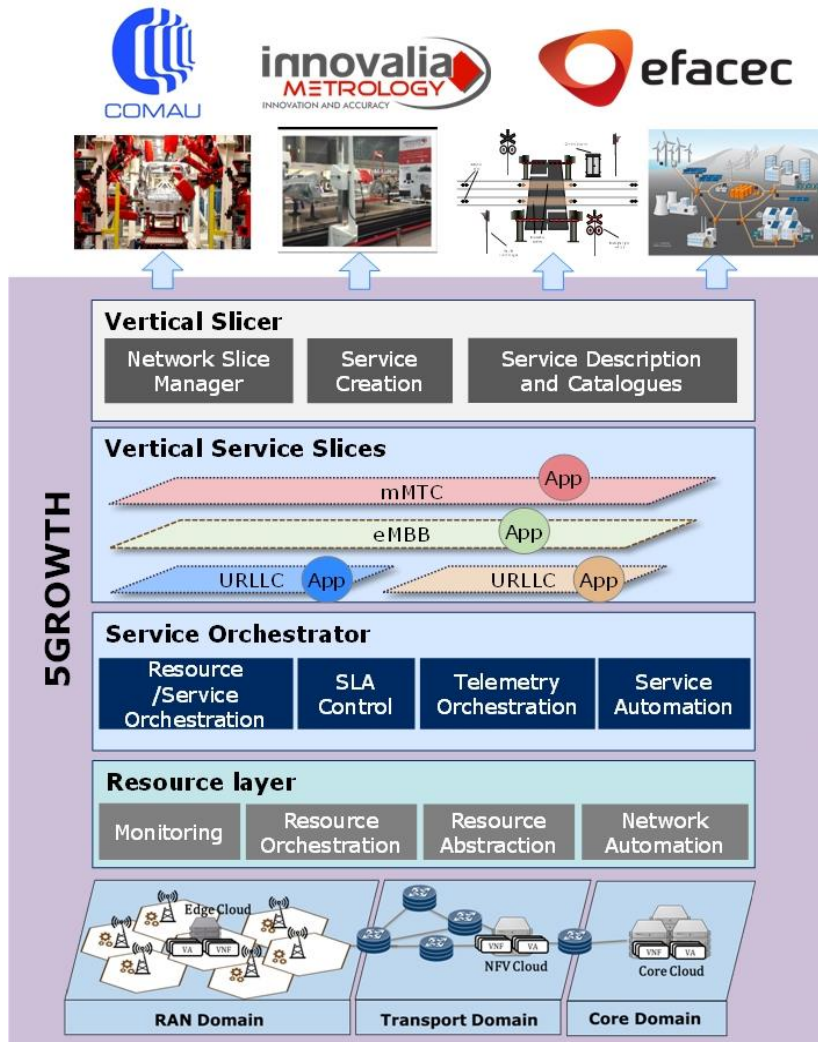
5G End-to-End Infrastructure (Radio, Transport, Cloud)



Mission of the Project: Automatically build, deploy and manage different vertical industrial services over a shared End-to-End 5G system (incl. Application Domain, Infrastructure Domain, Orchestration Domain), and perform real field trials validation and demonstrations

5Growth Vision

To empower vertical industries, such as **Industry 4.0, Transportation, and Energy** with an **AI-driven Automated and Shareable 5G End-to-End Solution**



- **Develop 5Growth platform** to provide zero-touch and automated provisioning and management of vertical services ensuring their service SLAs
 - Leverage on the 5G PPP Phase 2 project 5G-TRANSFORMER (5GT) platform
 - Developing AI-driven innovations
- **Integration with ICT-17 5G End-to-End platforms (5G EVE and 5G-VINNI)**
- **Field trials to perform technical and business validation of 5G for various vertical industries (Industry4.0, transportation, and Energy)**



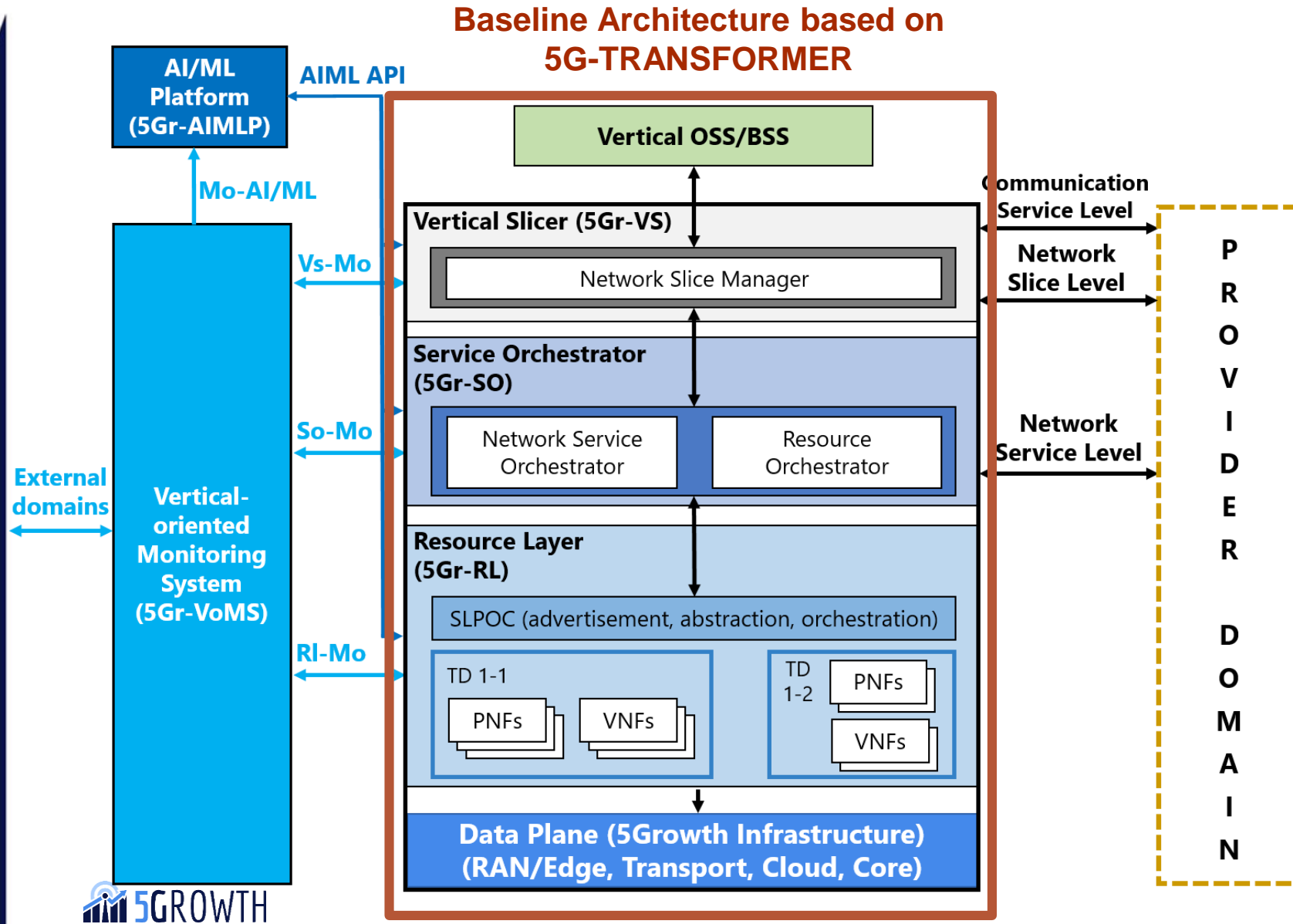
Content

- Project Innovations
 - 5Growth Platform
 - ICT-17 Integration
- Vertical Pilots
 - Use Cases
 - Pilot Deployment
 - 5G Validation
- Lessons Learned and the Way Ahead

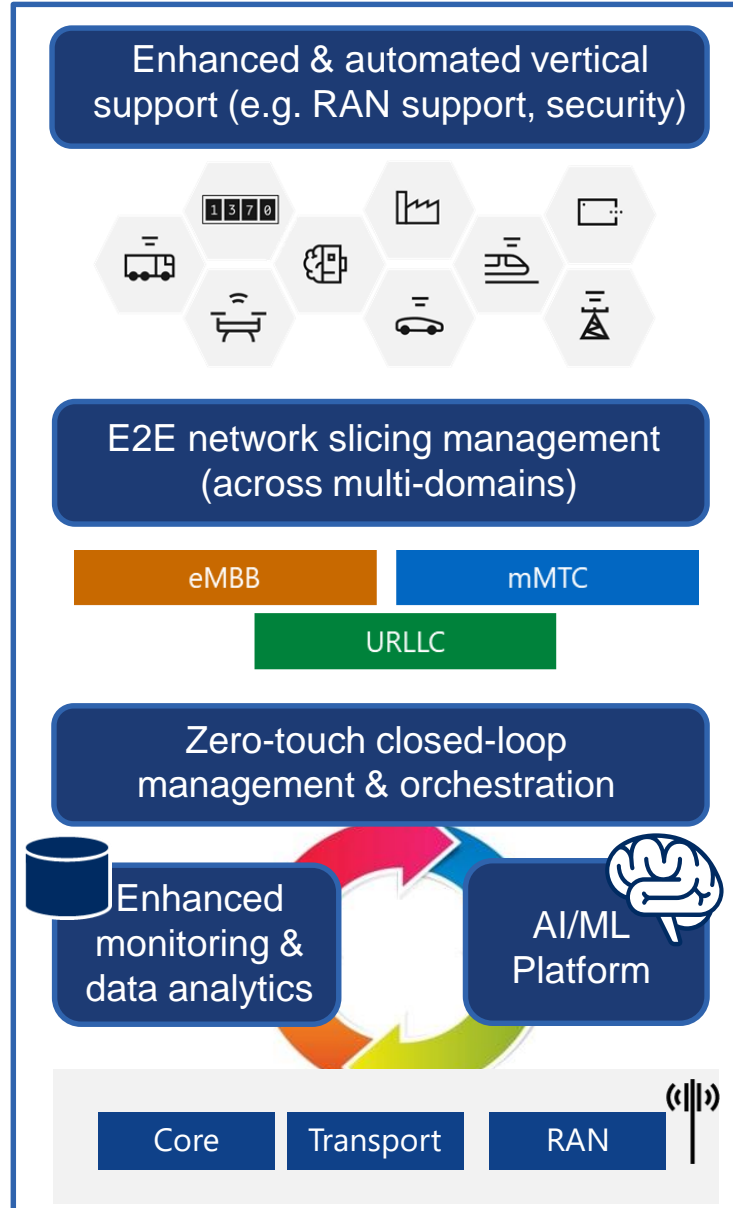


Project Innovations

5Growth Platform and Innovations



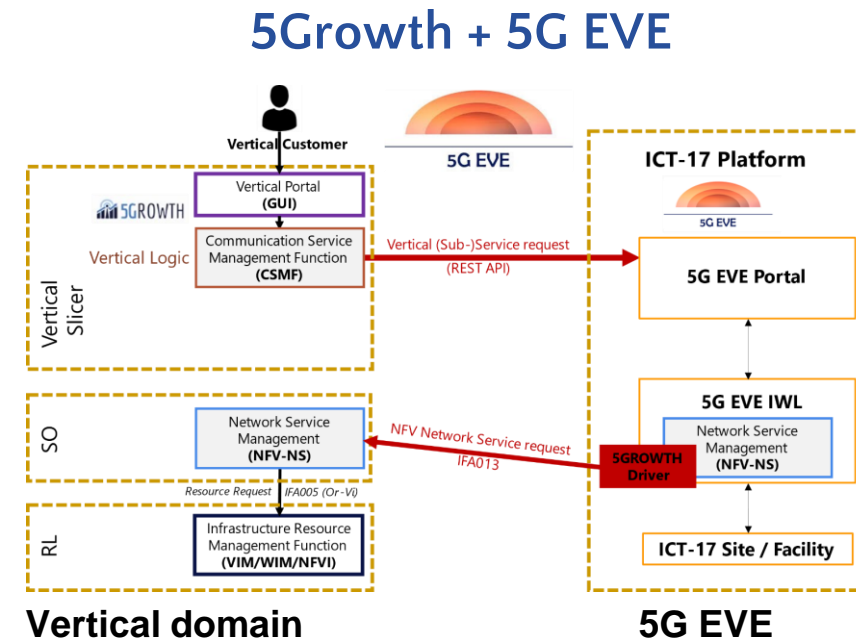
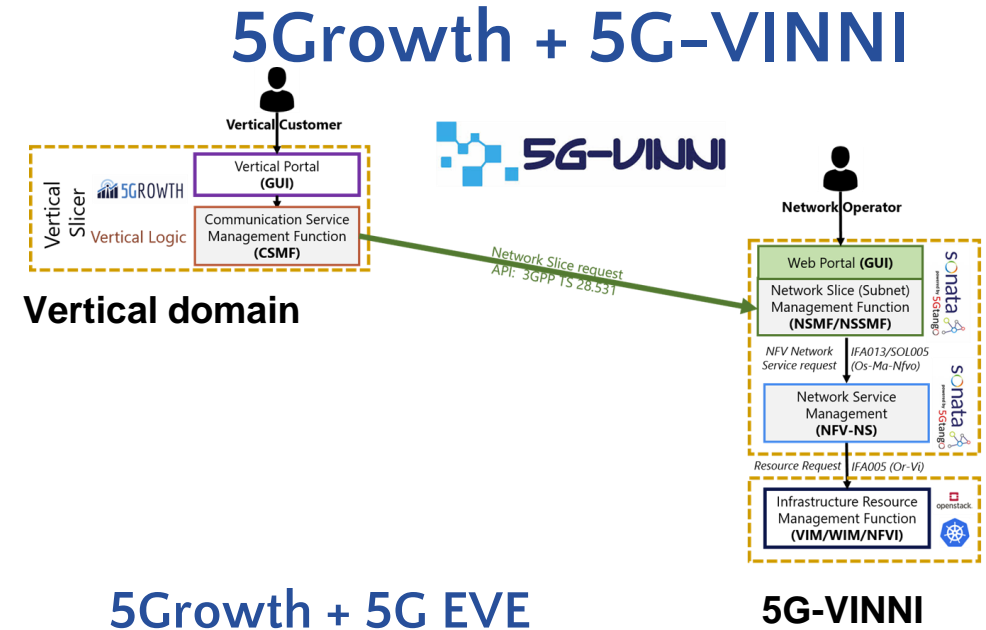
12 Innovations have been developed



Implementation & Proof-of-Concepts

- Vertical domain managed by the 5Growth platform
 - 5Growth GitHub (*open source at public GitHub*)
 - <https://github.com/5growth>
- ICT-17 5G Experimental Platforms
 - 5G EVE:
 - <https://www.5g-eve.eu/>
 - 5G-VINNI:
 - <https://www.5g-vinni.eu/>
- Three multi-domain interactions supported
 - Demo video: <https://youtu.be/6CRYAwS1MZO>
 - Drivers for 5G EVE and 5G-VINNI

| Drivers | Repository |
|-------------------------------------|---|
| 5Gr-VS driver towards 5G EVE | https://github.com/5growth/5gr-vs |
| 5G EVE IWL catalogue driver | https://github.com/nextworks-it/5g-catalogue |
| 5G EVE IWL Lifecycle Manager driver | https://github.com/5growth/mso-lo |
| 5Gr-VS driver towards 5G-VINNI | https://5growth.eu/redmine/projects/5growth/repository/5gr-vs |
| SONATA adaptor | https://github.com/5growth/sonata-drivers |

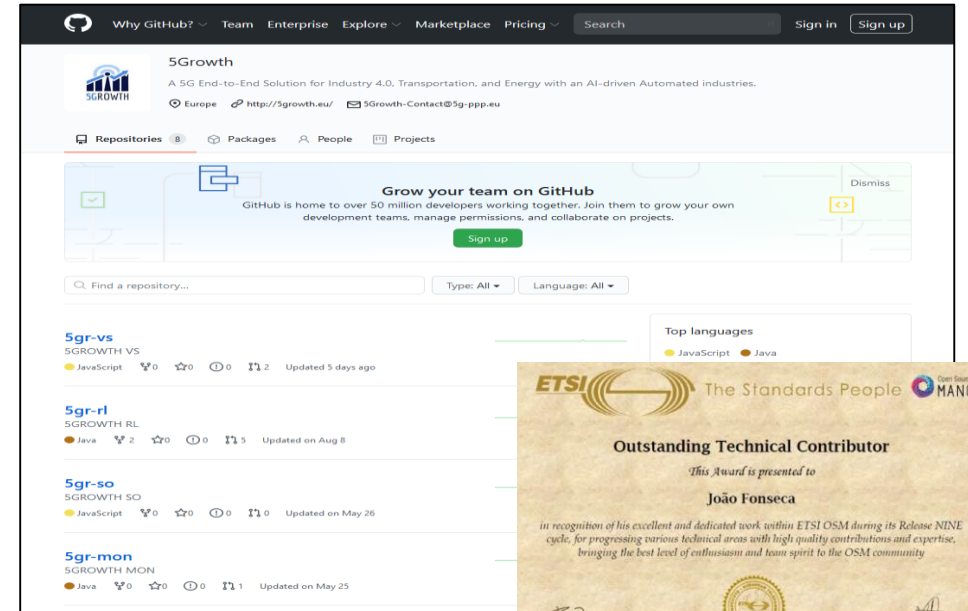


5Growth Platform Impact

- Building blocks software provided as open-source for R&D community

<https://github.com/5growth>

- Contributions to multiple Open source Projects



- Multiple 5G PPP/H2020 projects using them as a baseline



| |
|--------|
| 5Gr-VS |
| 5Gr-SO |
| 5Gr-RL |

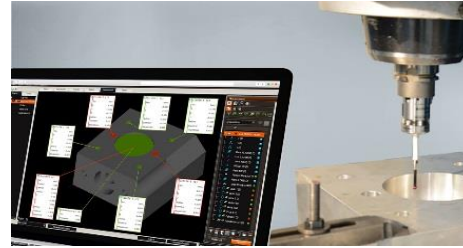




Vertical Pilots

5Growth Pilot Use Cases

Defined 9 use case applications across 4 Vertical Pilots



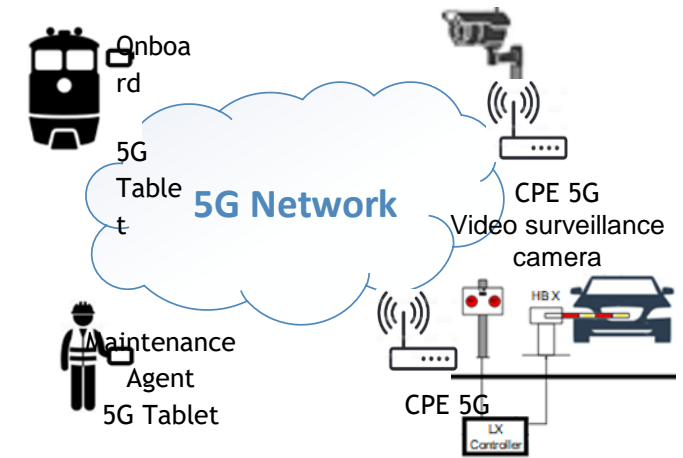
Industry 4.0: Smart factory

@ Innovalia:

- Remote Operation of equipment
- M2M collaboration for factory automation

@ COMAU

- Digital Twin
- Telemetry/Monitoring
- Digital tutorials and remote support



Transportation: Safety control of the railway level crossing

@ EFACEC_S

- Train Detection
- Video Surveillance

Energy

@EFACEC_E

- Maintenance of secondary substations on MV/LV network
- Detection of last gasp



5Growth Pilot use case requirements in comparison to current industrial solutions

| Pilot | Use Case | Solution | Service Requirements | | | | | | |
|--|--|---------------------------|--------------------------|---------------------------------------|-------------|--------------|-------------|----------------|----------------------------|
| | | | Latency | Bitrate | Packet Loss | Availability | Flexibility | Device Density | Global Device Connectivity |
| Industry 4.0 | 1) Digital Twin | Current Solution | 2-5ms | 1Gb/s | N/A | 99.99999% | Low | Low | Not Supported |
| | | 5Growth | 5-7ms | 1Gb/s | N/A | 99.999% | High | High | Optional |
| | 2) Telemetry | Current Solution | 2-5ms | 100Mb/s | N/A | 99.99999% | Low | Low | Not Supported |
| | | 5Growth | 5-7ms | 100Mb/s | N/A | 99.999% | High | High | Yes |
| | 3) Remote Support | Current Solution | Use case not supported | | | | | | |
| | | 5Growth | N/A | N/A | N/A | 99.999% | High | High | Yes |
| | 4) Connected Worker for Remote Operation | Current Solution | Use case not supported | | | | | | |
| | | 5Growth | <5ms | 10Mbps | 0.1% | 99.99% | Low | Low | Yes |
| 5) Augmented ZDM Decision Support System | Current Solution | Use case not supported | | | | | | | |
| | 5Growth | <5ms | 1Gbps | 0.1% | 99.99% | Medium | Low | Optional | |
| Transportation | 1) Train Detection | Current Solution | <800ms | No limitation (dedicated connection). | 0 | 99.99% | Very Low | Low | Not Supported |
| | | 5Growth | <10ms (one way) | 70-100Mbps | 0.1% | 99.99% | Low | Low | Yes |
| | 2) Video Surveillance | Current Solution | Use case not supported | | | | | | |
| | | 5Growth | <10ms (one way) | 70-100Mbps | 0.1% | 99.99% | Medium | Low | Yes |
| Energy | 1) Substation Maintenance | Current Solution (alarms) | <1s (GPRS) <40ms (4G) | 50kbps (GPRS) 30Mbps (4G) | 0.1% | 99.99-99.95% | Low | Low | Optional |
| | | 5Growth (alarms) | <5ms (one way) | 100Mbps | 0.1% | 99.99% | High | Low | Yes |
| | | Current Solution (video) | Use case not supported | | | | | | |
| | | 5Growth (video) | <100ms | 100Mbps | 0.1% | 99.99% | Medium | Medium | Yes |
| | 2) Last-gasp | Current Solution | Use case not supported | | | | | | |
| | | 5Growth | <5ms (one way) | 1Kbps | 0.1% | 99.99% | Low | Low | Yes |

N/A: Not Applicable

Deployment of all 5G infrastructures supporting 5Growth pilots (features)

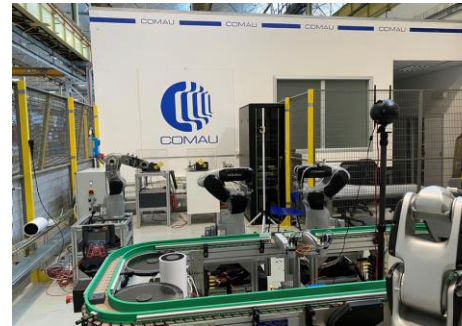
| PILOT SITE | 3GPP Rel. | 3GPP Architecture Options | Spectrum | Operator & Vendor | Access Network | Core Network | End Devices | Monitored KPIs |
|--|-----------|---|-------------------|--|---|--|-------------------------------|--|
| Italy: COMAU-TURIN | Rel 15 | <ul style="list-style-type: none"> Option 3 – NSA | 3.7 Ghz (80 MHz) | <ul style="list-style-type: none"> TIM Ericsson | <ul style="list-style-type: none"> TDD 7:3 MIMO 4x4 256QAM | vEPC -Edge Deployment (COMAU) -Central Office (TIM) | UE (OPPO) CPE (Nokia) | <ul style="list-style-type: none"> RTT Latency UL Data Rate DL Data Rate Reliability |
| Portugal: Transportation AVEIRO | Rel 15 | <ul style="list-style-type: none"> Option 2 - SA | 3.7 GHz (100 MHz) | <ul style="list-style-type: none"> Altice PT Fraunhofer Fokus& ASOCS | <ul style="list-style-type: none"> TDD 7:3 MIMO 4x4 256QAM | 5GC-Rel15 -Central Office (ITAv) | CPE (Huawei) CPE (Quectel) | <ul style="list-style-type: none"> RTT Latency UL Data Rate DL Data Rate Reliability |
| Portugal: Energy AVEIRO | Rel 15 | <ul style="list-style-type: none"> Option 2 - SA | 3.7 GHz (100 MHz) | <ul style="list-style-type: none"> Altice PT Fraunhofer Fokus& ASOCS | <ul style="list-style-type: none"> TDD 7:3 MIMO 4x4 256QAM | 5GC-Rel15 -Central Office (ITAv) | CPE (Huawei) | <ul style="list-style-type: none"> RTT Latency UL Data Rate DL Data Rate Reliability |
| Spain: 5TONIC | Rel 15 | <ul style="list-style-type: none"> Option 3 – NSA Option 2 - SA | 3.5 GHz (50 Mhz) | <ul style="list-style-type: none"> Telefónica Ericsson | <ul style="list-style-type: none"> TDD 7:3 MIMO 4x4 256QAM | vEPC & 5GC-Rel15 -Edge Deployment (5TONIC premises) -Central Office (5TONIC) | UE (Xiaomi) CPE (WNC) | <ul style="list-style-type: none"> RTT Latency UL Data Rate DL Data Rate Reliability |

Deployment of all 5G infrastructures supporting 5Growth Pilots (setups)

COMAU PILOT (TURIN)



Experimental Area



Ericsson 5G Radio

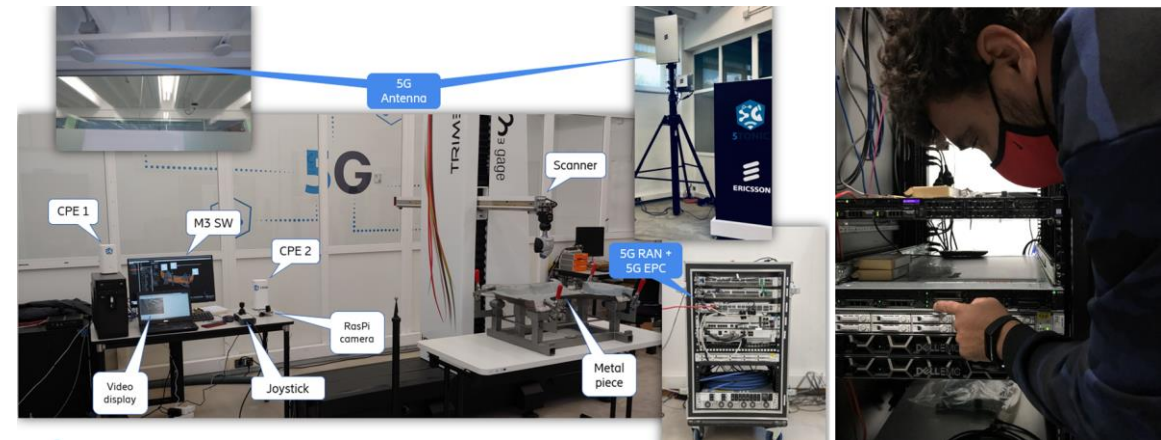
Transport and 5Growth Platform



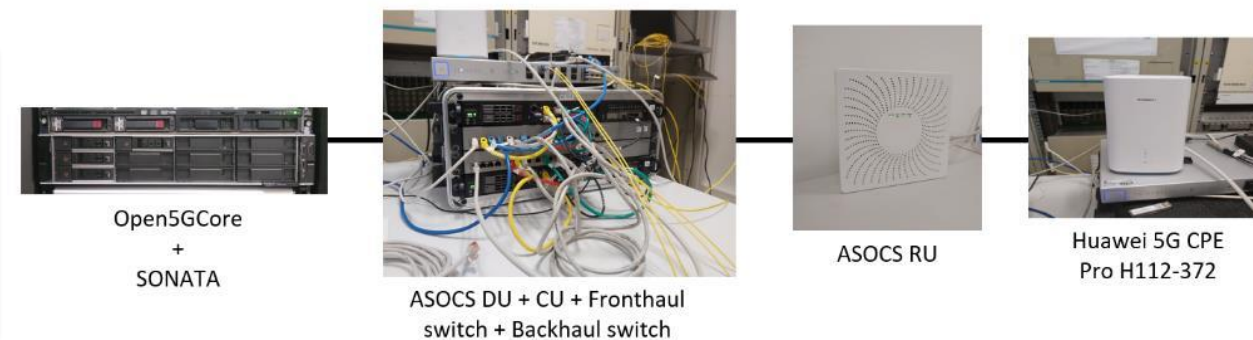
- Deployment of real vertical industrial equipment and applications
- Deployment of real 5G E2E chain using commercial 5G products
- 5Growth - ICT17 platform integration, leveraging on the E2E 5G infrastructure provided by the ICT-17 projects
- Exploring different Non-Public Networks (NPN) deployment models
- Selected 5Growth Innovations integration into all the pilots
- In-house deployment and 5G validation @Vertical Premises



INNOVALIA PILOT (MADRID)



EFACEC PILOTS (AVEIRO)



4G Antenna – Radio 2203

5G Antenna – Air 6488

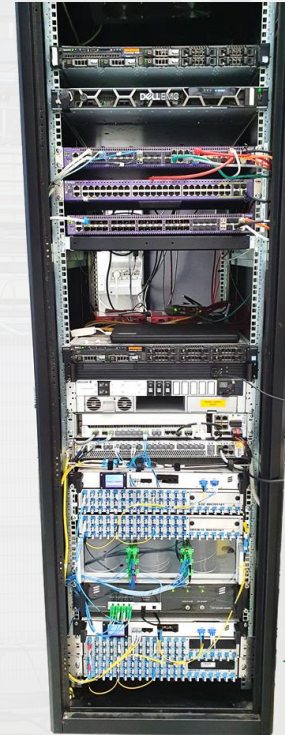
Robotic Cell

UC1 Robot

5G Terminal

5G Terminal

Radio, Transport, Application Rack



- ← Application Server
- ← Ethernet Switches
- ← Core network server
- ← Transport controller server
- ← Power supply for radio nodes
- ← 4G Ericsson BBU 5216 Baseband Unit
- ← 5G Ericsson Baseband 6330 Digital Unit
- ← WDM Multiplexer - Hub Node
- ← Coil of 10 km of optical fiber
- ← Power supply and "fiber breaker" to test protection
- ← WDM Multiplexer - Remote Node

Systems in TIM site



Switch connected to HSS



Switch connected to COMAU (VPN)

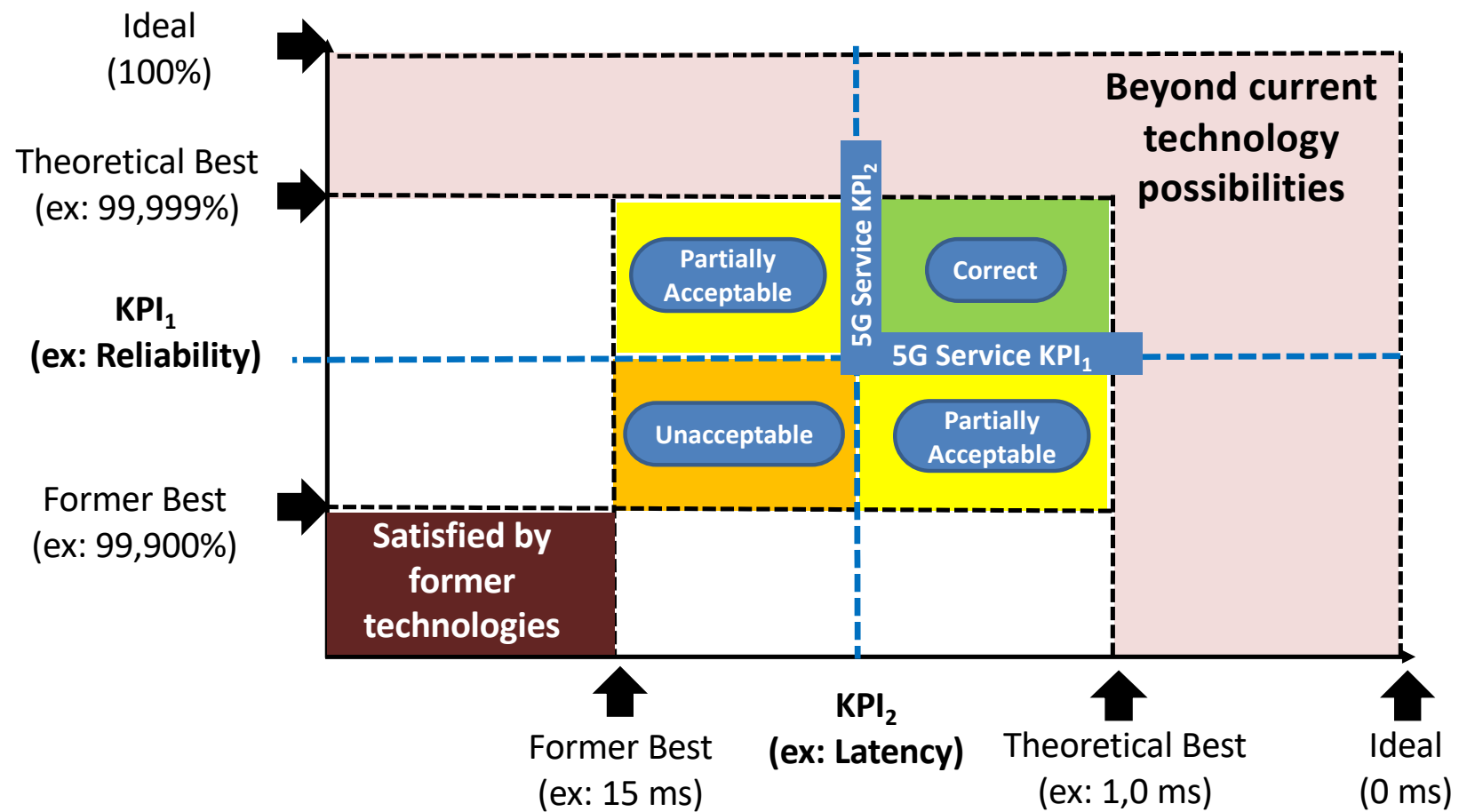
Deployment of all 5G infrastructures supporting 5Growth pilots (Validation)

| Case | 3GPP Standards | | Access | | | | | | Core | Application | 5G KPIs | | | |
|---|----------------------------------|---------------------------|----------------------|--|-------------------------|----------------------------|-------------------------------|---|-----------------------------------|---|-----------------|----------------------------|---|--------------------------------------|
| | 3GPP Release | 3GPP Architecture option | Band | BW (MHz) | Pattern | MIMO Layers | Modulation | Aggregation | Deployment | Deployment | UP Latency (ms) | Reliability (%) | DL Peak Data Rate (Mbps) | UL Peak Data Rate (Mbps) |
| 5G EVE: STONIC NETWORK TESTING | • Rel 14 • Rel 15 • Rel 16 | • Legacy • NSA • SA | • LB • MB • HB | • 20 • 50, • 100, • 200, • ... | • FDD • 4:1 • 7:3 | • 1 • 2 • 4 • (8) | • 256QAM (DL) • 64QAM (UL) | • Single Carrier • Carrier Aggreg. • NR+LTE | • Edge • Central | • Local Service • Central Service • OTT | E2E -RTT/2 | | | |
| | #1: 2020-05-21 | Rel 15 | NSA | MB | 50MHz | • 4:1 • 7:3 | 4 DL / 1 UL | 256QAM DL / 64QAM UL | Single Carrier | Edge | OTT | • 5 ms • 5 ms ICMP Ping | • 715 Mbps • 544 Mbps SpeedTest TCP | • 39 Mbps • 54 Mbps SpeedTest TCP |
| | #2: 2020-06-05 | Rel 15 | NSA | MB | 50MHz | • 4:1 | 4 DL / 1 UL | 256QAM DL / 64QAM UL | Single Carrier | Edge | Central Service | • 7ms • 7ms ICMP Ping | • 711 MBps -iperf3 UDP | |
| | #3: 2020-06-05 | Rel 15 | NSA | MB | 50MHz | • 4:1 • 7:3 | 4 DL / 1 UL | 256QAM DL / 64QAM UL | Downlink NR (50MHz) + LTE (20MHz) | Edge | OTT | • 7ms • 7ms ICMP Ping | • 879 Mbps • 705 MBps -SpeedTest TCP | • 39 Mbps • 54 Mbps SpeedTest TCP |
| | #4: 2020-06-10 | Rel 15 | NSA | MB | 50MHz | • 4:1 | 4 DL / 1 UL | 256QAM DL / 64QAM UL | Downlink NR (50MHz) + LTE (20MHz) | Edge | Central Service | • 6ms • 6ms ICMP Ping | • 875 Mbps -iperf3 UDP | |
| | #5: 2020-06-10 | Rel 15 | NSA | MB | 50MHz | • 4:1 • 7:3 | 4 DL / 1 UL | 256QAM DL / 64QAM UL | Uplink NR (50MHz) + LTE (20MHz) | Edge | OTT | • 6ms • 6ms ICMP Ping | • 514 MBps -SpeedTest TCP | • 91 Mbps -SpeedTest TCP |
| | #6: 2020-06-05 | Rel 15 | NSA | MB | 50MHz | • 7:3 | 4 DL / 1 UL | 256QAM DL / 64QAM UL | Uplink NR (50MHz) + LTE (20MHz) | Edge | Central Service | • 7ms • 7ms ICMP Ping | | • 93 Mbps -iperf3 UDP |
| | #7: 2020-06-05 | Rel 14 | Legacy | MB | 20MHz | FDD | 2DL / 1 UL | 256QAM DL / 64QAM UL | Single Carrier | Edge | OTT | • 12ms • 12ms ICMP Ping | • 170 Mbps • 544 Mbps SpeedTest TCP | • 41 Mbps SpeedTest TCP |

All 5Growth pilot sites' 5G set-ups are up and running, validated and characterized for network performance over several configurations

Measurement Goals and Results

- A theoretical framework can be depicted considering achievable ranges
- Metrics are collected and service KPIs validated
- Some Core KPIs can be manipulated to emulate different network conditions
- It becomes possible to establish the performance conditions that allow determining service operation
- Those conditions become the main result of experiments
- This framework is being contributed to ETSI INT TC



Pilot Deployment and Validation Campaigns

- **Successfully deployed all vertical pilots** with the real 5G infrastructure & 5G equipment and vertical applications
 - Phase I: tested in the lab environment
 - Phase II: deployed at the vertical sites
- **Completed all Pilot Validations and KPI Measurements**
 - Validation of the 5G capabilities to support vertical services at all the vertical sites
 - Validation of selected set of service and core KPIs per vertical use case through the conducted field trials

Validation Campaigns

- ❑ **First validation campaign: Feasibility**
 - Including tooling and data infrastructure
 - Report data on initial measures and service KPI mappings
- ❑ **Second validation campaign: Experiment control**
 - Integration with ICT-17 infrastructures
 - Measures and mapping enabled by ICT-17 integration
 - Impact of a limited set of innovations
- ❑ **Third validation campaign: Vertical focus**
 - Integration of ICT-17, and 5Growth Platform at vertical premises
 - Full measure and mapping analysis
 - Impact of selected innovations
- ❑ The challenge of addressing COVID consequences
 - The higher the remote control, the lower the expected effects

Pilot Deployment & ICT-17 Integration

| | | First validation campaign: Feasibility | Second validation campaign: Experiment control | Third validation campaign: Vertical focus |
|--------------------------------|---|--|---|---|
| 5G infrastructure | E2E 5G up & running at each experiment. site | 5G infra tuned and upgraded at experiment. sites | 5G radio infra deployment at vertical premises | 5G core and cloud deployment at vertical premises |
| Pilot Applications | At least 1 UC per pilot is fully implemented | Implemented Pilots tuned. Additional UC's | All pilots' UCs are implemented and integrated | All pilot UC's are tuned & upgraded |
| 5Growth platform | 5Growth-ICT17 integration developed | 5Growth-ICT17 tested & demo 5Growth innovs | 5Growth selected innovations integrated in pilots | 5Growth selected innovations integrated in pilots |
| Pilot Integr-Deploy -Execution | Manually integrated Pilots executed | Semi-automated deployed Pilots executed | Fully-auto deployed Pilots executed | Fully-auto deployed Pilots at Vertical premises |
| Pilot Testing & Validation | Manually-monit. 5G+Vert. KPIs T&V Campaign #0 | Semi-auto monit. 5G+Vert. KPIs T&V Campaign #1 | Fully-auto monit. 5G+Vert. KPIs T&V Campaign #2 | Fully-auto monit. 5G+Vert. KPIs T&V Campaign #3 |

Highlight of Achievements of 5Growth Pilots

5Growth project has made significant contributions to multiple 5GPPP white papers

"Business Validation in 5G PPP Vertical Use Cases" – (June 2020)

"Empowering Vertical Industries through 5G Networks" – (September 2020)

"Edge Computing for 5G Networks" – (February 2021)

"AI and ML – Enablers for Beyond 5G Networks" – (May 2021)

"Service performance measurement methods over 5G experimental networks" – (May 2021)

"Delivery of 5G Services Indoors – the wireless/wire challenge and solutions" (September 2021)

"5G PPP – View on 5G Architecture V4.0" – (November 2021)

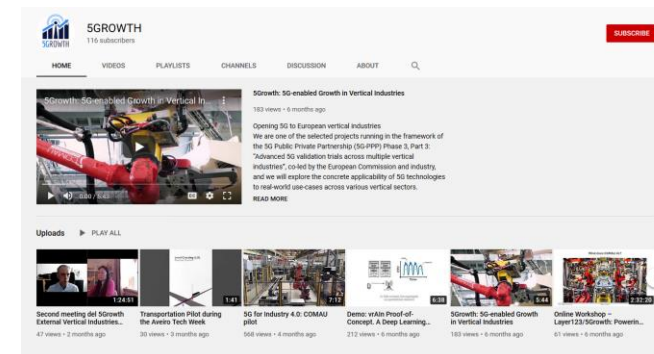


A remarkable achievement in this respect is the selection of the **5Growth Pilots** in the top 10 list of the **5G Infrastructure PPP T&Ps Brochure**.

- COMAU Pilot ("5Growth – Industry 4.0: Low-latency on a shared Network") selected among the top ten of the 5GPPP Infrastructure Trials and Pilots brochure No. 2 in 2020.
- COMAU Pilot ("5Growth – E2E Transport-aware Orchestration") selected among the top ten of the 5GPPP Infrastructure Trials and Pilots brochure No. 3 in 2021.
- INNOVALIA Pilot ("5Growth: Industry 4.0 Remote Operation of Metrology Machinery over 5G") selected among the top ten of the 5GPPP Infrastructure Trials and Pilots brochure No. 3 in 2021.

All vertical pilot videos will be available online

- <https://5growth.eu/video-gallery/>
- <https://www.youtube.com/5GROWTH>





Lessons Learned & The Ways Ahead

Lessons Learned

- The ICT-17 platforms (5G EVE and 5G-VINNI) have been used to support 5Growth vertical service deployment in all pilots, the provided 5G capability by the ICT-17 platforms have been validated in the pilots over several configurations.
- The ICT-17 platforms APIs are mainly provided at the Northbound towards the verticals or other 5GPPP projects for the purpose of 5G validation and experimentation, but the support for the interaction at the lower layers are rather limited, and this aspect has been deeply explored by 5Growth.
- 5Growth explored multiple levels of multi-domain solutions to inter-connect the vertical domains (ICT-19 platform) with the public network domain (ICT-17 platform), this enables more interaction and flexibility for vertical service deployment and management, especially supporting different Non-Public Network (NPN) deployments.
- 5Growth interacted with the ICT-17 platforms through their provided APIs and portals, but specific drivers have been developed for the interactions
 - 5Gr-VS driver towards 5G EVE and 5G-VINNI for on-boarding, instantiation and lifecycle management of vertical services
 - The 5G-EVE Interworking Layer (IWL), we developed 5Gr-SO driver as part of the SBI of 5G-EVE IWL component (Adaptation Layer)
 - However, the interaction is still not fully dynamic, not yet possible for the closed-loop service management
- Different new stakeholders are emerging in B5G/6G, especially with private NPN networks, there are still open challenges for the MNOs and infrastructure providers to expose their network management and re-configurability capabilities. This needs tighter cooperation and interaction among the different stakeholders (verticals, service providers, cloud and network infrastructure providers, MNOs).



The Ways Ahead

5Growth project is going to finish in February 2022, however, further impact and exploitations will be explored beyond the project lifetime

- Further exploitation opportunities of the commercial 5G products as well as vertical products through industrial events, patents, SDOs.
- Further exploitation of developed 5Growth innovations, Programmable and orchestrable monitoring, methodology and tooling concepts (e.g. Data infrastructure and aggregator)
- Consolidation of experiment descriptors
 - Reproducibility and test environments
- Data infrastructures as the backbone for digital twins
 - For the network itself
 - As a service to network users



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