Beyond 5G Multi-Tenant Private Networks Integrating Cellular, Wi-Fi and LiFi, Powered by Artificial Intelligence and Intent Based Policy

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5G-PPP, Architecture WG, 22/01/2021
Outline

- Project Vision
- 5G-CLARITY Overview
- Architecture Design
- Pilots and use cases
- Take-aways & References
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5G-CLARITY at a Glance

Research Programme
Horizon 2020 5G-PPP ICT-20-2019-2020

Duration
33 months / Nov 2019 – Jun 2022

Total budget
5.7 Million Euro

Project Management Team
Project Coordinator – IHP, Germany
Project Manager – Gigasys Solutions, UK
Technical Manager – i2CAT, Spain

Corosutium
12 partners from 5 countries

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### 5G-CLARITY Motivation

**5G private networks** gaining momentum
- 3GPP Rel-16 features make 5G systems all-inclusive critical communication platform for industry digitization
- Incumbent actors (industry verticals, neutral-host and wholesale operators, etc) start making sizeable investment in private 5G networks.

For the widespread adoption of private 5G networks, it is required:
- **Seamless interworking between 3GPP 5G access and legacy technologies** (e.g. wired Ethernet, IEEE 802.11) -> backwards compatibility
- **Small operational costs** -> easy operation and flexible integration with public 5G networks (for CAPEX reduction)
- **Ever-increasing network capability portfolio** -> ICT-driven network evolution allows for OT-driven service innovation.

The mission of 5G-CLARITY project is to **develop and demonstrate a Beyond 5G (B5G) system for private networks integrating multiple wireless access technologies** including 5G, Wi-Fi and LiFi technologies, all operated through **AI-based autonomic networking**.
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5G-CLARITY Technical Innovations

LiFi technology

5GNR/Wi-Fi/LiFi multi-connectivity framework

Cm-level localization and synchronization capabilities

AI-driven and intent-based network management

Integration and interoperation of private and public networks

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Going beyond 3GPP/5G-PPP scope

Public Network Operator (NOP)

Public Communication/Digital SC (CSC/DSC)

Private Communication/Digital SC (CSC/DSC)

Private Network Operator (NOP)

Network Service Aggregator

Private network (factory, venue)

Public network (PLMN)

Infrastructure Aggregator

Out of Scope

VISP

DCSP

LTE (4G)

NR (5G)

RAT SP

WAT SP

NR (5G)

WiFi

LiFi

RAN cluster

Edge cluster

Cluster SP

Operator Support Provider(s)
5G-CLARITY Service Offering

- New roles means innovative service delivery models and unleashes rich business relationships.

  - 5G-CLARITY slicing
    - 5G-CLARITY slice = {5G-CLARITY wireless service + 5G-CLARITY compute service + 5G-CLARITY transport service}
    - 5G-CLARITY slices (on-premise infrastructure slices for multi-tenancy support) vs 3GPP slicing (network slices for multi-service support)

  - 5G-CLARITY tenants
    - Private CSP/DSP
    - Public CSP/DSP
    - Public NOP (MNO)
    - Hyperscaler

<table>
<thead>
<tr>
<th>Service Delivery Model</th>
<th>Provider → Customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAT as a Service</td>
<td>Private NOP → Public NOP</td>
</tr>
<tr>
<td>NFV Infrastructure as a Service</td>
<td>Private NOP → Public NOP</td>
</tr>
<tr>
<td></td>
<td>Public NOP → Private NOP</td>
</tr>
<tr>
<td>Slice as a Service</td>
<td>Private NOP → Public CSP/DSP or private NOP</td>
</tr>
<tr>
<td></td>
<td>Public NOP → Private NOP</td>
</tr>
<tr>
<td>Intelligence as a Service</td>
<td>Operation Support Provider → Private NOP</td>
</tr>
<tr>
<td></td>
<td>Operator Support Provider → Public NOP</td>
</tr>
</tbody>
</table>

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5G-CLARITY System Architecture

- Support of multiple types of devices
- Coexistence of purpose-built and COTS HW
- Integration with O-RAN
- Multi-WAT protocol stack

- Control and User Plane Separation (CUPS)
- RAN functional splitting
- Industry-ready transport network (Ethernet + TSN)

- Cloud-native and service oriented
- Language/ML framework independence
- Ease of use

- Service Based Management Architecture (SBMA)
- Extensibility
- MF statelessness
- Model-driven operation
- Reproducibility
- Service capability exposure
#1a - Multi-connectivity framework

- **5GCore**
- **AT3S**
- **OPF**
- **N3**
- **Standard Ethernet network**
- **5G**
- **TNGF/N3IWF**
- **5G-CLARITY integrated WiFi + LiFi L2 network**
- **L2 mobility**
- **UE-1**
- **Per UE GRE tunnels over non-3GPP**

- **Adhering to 3GPP Release 16 (AT3S) and O-RAN (rt-RIC & xApps)**
- **WiFi+LiFi integration** through TNGF/N3IWF through single SDN enabled L2 network
- **ML-driven control of AT3S bindings and policies**
#1b – non-real-time Multi-WAT Telemetry

Example of a cloud-based solution
#2 - 5G-CLARITY slicing approach

5G-CLARITY Service and Slice Provisioning subsystem

- WiFi/LiFi NETCONF
- 5GNR–CU NETCONF
- Transport SDN
- NFV MANO
- VIM

- Tenant 1: PLMNID-1, S-NSSAI {SSTSD-1, SSTSD-2}
- Tenant 2: PLMNID-2, S-NSSAI {SSTSD-3}
- Tenant 1: PLMNID-1, S-NSSAI {SSTSD-1}
- Tenant 2: {SSID-3}
- Tenant 1: {SSID-2}
- Tenant 1: {SSID-1}

- gNB RU+DU
- 5GNR
- Ethernet transport
- LiFi APs
- WiFi
- WAN

- AMF
- SMF
- 5GC
- N3IWF
- UPF
- AT3S-UP
- vAPP1
- vAPP2
- vAPP3

- Tenant 1: Compute chunk
- Tenant 2: Compute Chunk

- Tenant 1: PLMNID-1, S-NSSAI {SSTSD-1}
- Tenant 1: PLMNID-1, S-NSSAI {SSTSD-2}
- Tenant 2: PLMNID-2, S-NSSAI {SSTSD-3}

- Tenant 1: {SSID-1}
- Tenant 2: {SSID-3}
- Tenant 2: {SSID-3}
- Tenant 2: {SSID-3}
- Tenant 2: {SSID-3}

- Tenant 1: SSID-1 → SSTSD-1
- Tenant 1: SSID-2 → SSTSD-2
- Tenant 2: SSID-2 → SSTSD-3

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5G-CLARITY intelligence stratum based on **AI engine** (ML models) mediated with **intent engine** (simplicity for non-expert users)

- **ML models containerisation** using Docker containers

- **5G-CLARITY ML Algorithms**
  - Predicting SLA violations/success rate
  - RT-RIC: AT3S traffic routing/handover
  - RAN slicing in multi-tenant networks
  - Optimal network access problem
  - Optimal compute offloading
  - Indoor ranging with nLoS awareness
  - Resource provisioning in a multi-WAT
  - Dynamic transport network setup and compute resources provisioning
  - AI-based defect-detection in a smart factory

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5G-CLARITY Introduction
#4 - Hybrid positioning

- **mmWave + Sub-6 GHz positioning**
  - **Methods:** DL-TDOA, UL-TDOA, TWR
  - **Sub-6 GHz** expected precision of 1 meter or better
  - **mmWave** expected precision of 1 centimeter or better

- **LiFi positioning**
  - **Methods:** RSSI
  - **LiFi** expected precision of 1 meter or better (theoretically centimeter precision possible)

- **Optical Camera Communications**
  - **STEP 1:** Take photo and process LED positions
  - **STEP 2:** Decode light ID and lookup position
  - **STEP 3:** Map 2D to 3D space

- **Positioning server**
  - **Sub-6 GHz**
  - **mmWave**
  - **5G NR**
  - **LiFi**
  - **OCC**

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Smart Tourism Pilot: UNIVBRIS

Use Case:
- Museum robot assistance

Venue:
- M-Shed museum of Bristol city council

Three main narratives
- Guide robot welcomes and guides visitors to requested exposition
- On-demand surveillance of suspicious activities in the museum
- On-demand 3rd party content for scheduled private events
### Use Case:
- Connecting MES enabled production lines

### Venue:
- BOSCH factory, Aranjuez (Madrid)

### Three-step validation setup
- Portable production line testbed
- In-factory setup (w/o real OT infrastructure)
- In-factory production line (w/ OT infrastructure)
Industry 4.0 Pilot: BOSCH

Use Case:
- Tracking AGV trajectories

Venue:
- BOSCH factory, Aranjuez (Madrid)

Real-time, cm-level AGV tracking with hybrid positioning
- mmWave + sub-6Ghz positioning (DL-TDOA, UL-TDOA, TWR)
- LiFi positioning (RSSI)
- Optical Camera Communications (OCC)
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5G-CLARITY project is developing a system for B5G private networks featuring:
- 5GNR+Wi-Fi+LiFi multi-connectivity framework
- High precision localization capabilities, based on the use of hybrid positioning
- Multi-WAT slicing
- Deployment and operation of multiple NPN scenarios, with different private-public network settings
- AI based and Intent driven network & service management

Smart Tourism and Industry 4.0 pilots to be demonstrated Q2 2022
- Museum robot assistance (Bristol, UK)
- Connecting MES enabled production lines (BOSCH, Spain)
- Tracking AGV trajectories (BOSCH, Spain)

Main deliverables available at www.5gclarity.com:
- System architecture: D2.2
- Multi-connectivity framework and positioning initial design: D3.1
- Slicing design: D4.1
- 5G-CLARITY use cases: D5.1