THIS PROJECT IS PART OF THE NEXT GENERATION IoT www.ngiot.eu

Distributed Architectures in the EdgeCloudIoT Continuum

TERMINET: nexT gEneRation sMart INterconnectEd ioT

University of Western Macedonia

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Project Identity & Consortium

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- ✓ **Call**: H2020-ICT-2018-20
- ✓ **Topic**: ICT-56-2020
- ✓ **Type of action**: RIA
- ✓ **Total Budget**: € 8.000.000,00
- ✓ **Active period**: 1 Nov 2020 – 31 Jan 2024

TERMINET aims at providing a novel **next generation reference architecture** based on cutting-edge technologies such as Software Defined Networking (SDN), multiple-access edge computing (MEC), and virtualisation for next generation IoT. In addition, TERMINET introduces **new, intelligent IoT devices** for low-latency, market-oriented use cases. Finally, TERMINET intends to bring more **efficient and accurate decisions to the point of interest to better serve the final user**.

3 Industries | 5 Universities | 3 Research Centers | 15 SMEs

Consortium (26)

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Objectives

TERMINET Objectives

Six Objectives

Objective #1

Flexible, open, and decentralised next generation IoT reference architecture for new real-time capable solutions.

Objective #2

SDN-enabled multiple-access edge computing environment for IoT and mission-critical and vertical solutions.

Objective #3

Moving AI to the edge by using cutting-edge ML technologies.

Objective #4

Security by design based on attestation modelling, distributed and decentralised blockchain, and enterprise-level privacy.

Objective #5

Tactile IoT model by adding human-centric perspective and sensing/actuating capabilities.

Objective #6

Design intelligent IoT devices for new generation IoT use cases, by fostering digital business development.

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TERMINET Business Logic & Technologies

TERMINET Business Logic

Open, programmable, and agile network fabric using SDN and NFV technologies

SDN & NFV

Federated Learning Framework for training decentralized data on privacy-preserving manner

Federated Learning

AR/VR Contextual Framework, Digital Twins, IoT Devices Inventory, Haptic devices

AR/VR, Digital Twins, IoT Inventory

TERMINET Secure Vertical IoT Network Framework: Trust, privacy and authentication among the various entities, using Blockchain

Security, Privacy & Trust

TERMINET Integrated Platform

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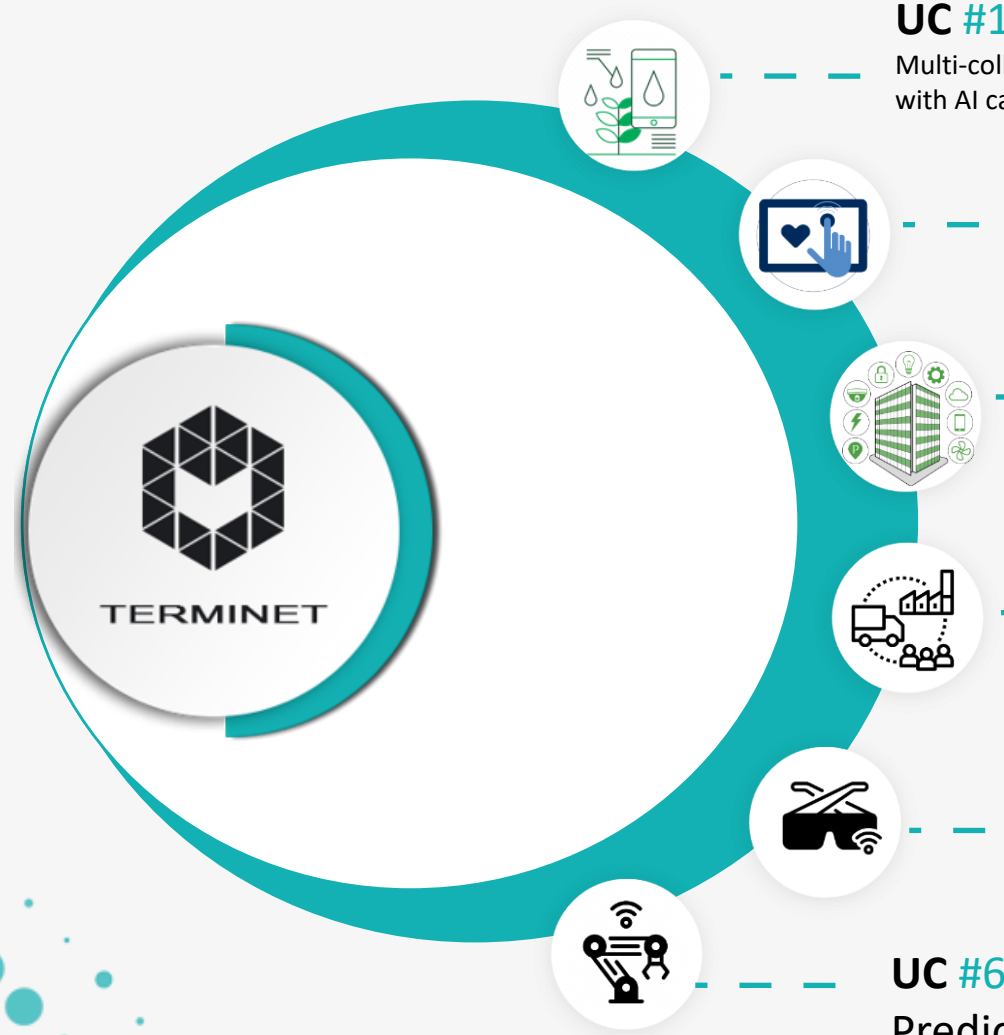
TERMINET Use Cases

Use Cases



UC #1: User-Centric Devices in Smart Farming

Multi-collected and heterogeneous data coming from crops, livestock, and mixed farming systems are coupled with AI capabilities to enhance agriculture systems' sustainability.

UC #2: Pathway of Personalized Healthcare

More efficient and personalised treatments will be developed by utilizing medical knowledge from different departments inside a hospital.

UC #3: Smart, Sustainable and Efficient Buildings

Optimise energy consumption and harvesting of smart buildings.

UC #4: Prediction and Forecasting System for Optimizing the Supply Chain in Dairy Products

Provide efficient supply chain forecasting, based on different types of production and sales data.

UC #5: Group Training Surgery Using VR enabled IoT Technologies

Enhance the understanding of treatment by efficiently providing a virtual training environment for medical personnel.

UC #6: Mixed Reality and ML Supported Maintenance and Fault Prediction of IoT based Critical Infrastructure

Reduce the operational costs of the end user and the burden of maintenance engineers.

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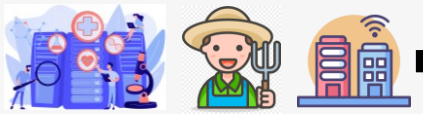
TERMINET Architecture

Stakeholders

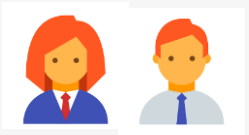
Platform

Infrastructure



IoT Vertical Stakeholders

Apps



OpenCall Stakeholders

App #1

App #2

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Distributed Federated Learning Framework

Software-defined Network Fabric

Streaming Analytics for IoT Data

Heterogenous IoT Hardware support

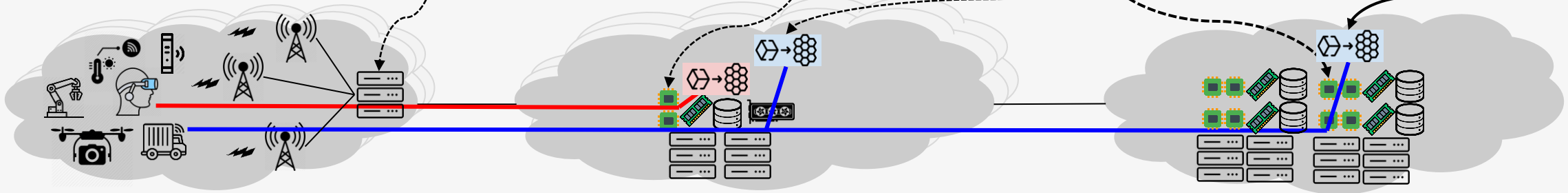
IoT to Edge to Core Cloud continuum

Multiple IoT testbeds

Collection of IoT data through software-defined gateways

Compute resources (CPU/GPU/FPGA, RAM, Storage)

Distributed AI-based IoT vertical applications

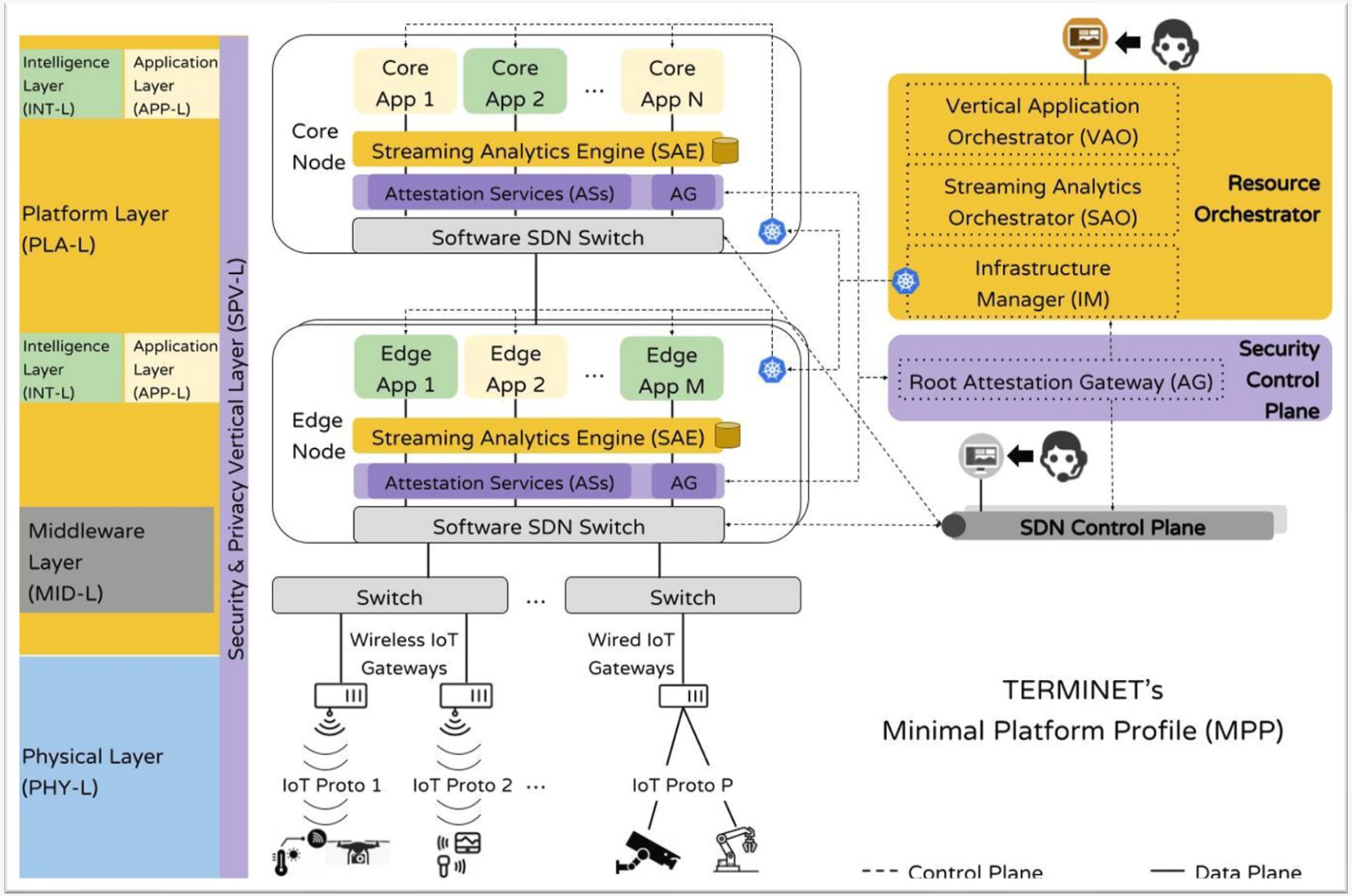


Access Domain

Edge Domain

Core Domain

TERMINET Architecture



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TERMINET Standardization Activities

TERMINET's contributions to existing frameworks of 3rd parties

Contribution to SDN-enabled container network interfaces (CNIs) in cloud environments. ***Based on the open-source project Kube-OVN:***

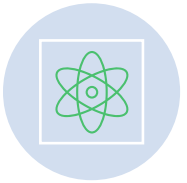
https://github.com/kubeovn/kube-ovn

Contribution to ***SDN control plane and data plane interfaces for managing OpenFlow-based networks accommodating IoT traffic*** (Derived from the TERMINET MPP deployment)

Adoption of emerging SDN technology: A ***RINA library (RINAsense) implementation for FreeRTOS:*** https://github.com/Fundacio-i2CAT/rinasense

Participate to the ***ETSI TeraFlowSDN*** open-source project for ***aligning the TERMINET SDN activities*** with this software development group

Contribution ***to application onboarding and placement***, as well as ***application lifecycle management*** based on TMForum, "Introduction to Open APIs", Available: https://www.tmforum.org/oda/about-open-apis/



Contribution to ***supporting local AI/ML model training with the use of distributed FL techniques*** based on IEEE 3652.1-2020 IEEE Guide for Architectural Framework and Application of Federated Machine Learning

Release of an ***Orchestration of Intelligent UAVs Swarm in the premise of UC1***: https://github.com/wcipAUTH/UAV-orchestrator

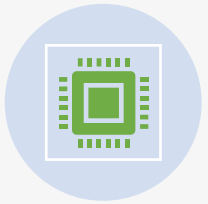
Contribution to the ***development of APIs for high-performance Virtual Reality (VR) and Augmented Reality (AR)*** in the browser.

Releasing a ***QR-scanner-for-AR-Application i***n the premise of UC6: https://github.com/Eight-Bells-Ltd/QR-scanner-for-AR-Application

TERMINET's contributions to existing frameworks of 3rd parties

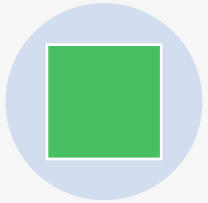
A ***reference architecture combining network softwarization and message-oriented middleware technology to provide explicit support for quality-aware Digital Twin technology in I4.0 environments and beyond:*** https://datatracker.ietf.org/doc/draft-bellavista-semantic-sdn-mom/

Contribution to ***time-sensitive communication in virtualized environments*** based on KuberneTSN: containerized TSN scheduler for Kubernetes Overlay Networks: https://github.com/MMw-Unibo/KuberneTSN



Contribution to Kubernetes Network Plumbing Working Group. Multus CNI: https://github.com/k8snetworkplumbingwg/multus-cni

Contributing ***IoT security support for logging and authorization to Hyperledger Fabric technology***



Contribution ***to remote attestation techniques, Lightweight Crypto Primitives (LCP), Control Flow Attestation.*** An ***Attestation patent*** has been filed in the premise of the project by NEC.

SHCN's ***New Generation of RTU device – Prototype***

Releasing the ***IIoT-MDW (middle-ware) enabling the open-source community to interact with the TERMINET IIoT-DI:*** https://gitlab.com/futureintelligence/terminet-iiot-di-middleware

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TERMINET Achievements & Datasets & Scientific Publications

Scientific Publications (1/4)

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2. Y. Spyridis, T. Lagkas, P. G. Sarigiannidis, V. Argyriou, A. Sarigiannidis, G. Eleftherakis and J. Zhang, 'Towards 6G IoT: Tracing Mobile Sensor Nodes with Deep Learning Clustering in UAV Networks', Sensors 21(11) - Special Issue 6G Wireless Communication Systems, 2021, https://doi.org/10.3390/s21113936
3. P. D. Diamantoulakis, P. S. Bouzinis, P. Sarigannidis, Z. Ding, G. K. Karagiannidis, 'Optimal Design and Orchestration of Mobile Edge Computing with Energy Awareness', IEEE Transactions on Sustainable Computing, 2021, https://doi.org/10.1109/TSUSC.2021.3103476
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5. V. Kelli, P. Sarigiannidis, V. Argyriou, T. Lagkas and V. Vitsas, 'A Cyber Resilience Framework for NG-IoT Healthcare Using Machine Learning and Blockchain', IEEE International Conference on Communications (ICC), 2021, https://doi.org/10.1109/ICC42927.2021.9500496
6. I. Sinisioglou, P. Sarigiannidis, V. Argyriou, T. Lagkas, S. Goudos and M. Poveda, 'Federated Intrusion Detection In NG-IoT Healthcare Systems: An Adversarial Approach', IEEE International Conference on Communications (ICC), 2021, https://doi.org/10.1109/ICC42927.2021.9500578
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9. I. Siniosoglou, V. Argyriou, S. Bibi, T. Lagkas, and P. Sarigiannidis, 'Unsupervised Ethical Equity Evaluation of Adversarial Federated Networks', ARES 2021: The 16th International Conference on Availability, Reliability and Security, 2021, https://doi.org/10.1145/3465481.3470478
10. V. Kelli, V. Argyriou, T. Lagkas, G. Fragulis, E. Grigoriou and P. Sarigiannidis, 'IDS for Industrial Applications: A Federated Learning Approach with Active Personalization', Sensors 2021; 21(20) - Special Issue Emerging Trends in Wireless Sensor Networks, 2021, https://doi.org/10.3390/s21206743

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11. V. K. Papanikolaou, N. A. Mitsiou, P.D. Diamantoulakis, Z. Ding and G. K. Karagiannidis, 'Hierarchical Multiple Access (HiMA) for Fog-RAN: Protocol Design and Resource Allocation', IEEE Transactions on Wireless Communications, 2021, https://ieeexplore.ieee.org/document/9505308
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16. A. Sabbioni, et al. "DIFFUSE: A DIstributed and decentralized platForm enabling Function composition in Serverless Environments." Computer Networks, vol. 210, p. 108993, Jun. 2022, doi: 10.1016/j.comnet.2022.108993
17. D. Pliatsios, S. K. Goudos, T. Lagkas, V. Argyriou, A.-A. A. Boulogeorgos, P. Sarigiannidis , "Drone-Base-Station for Next-Generation Internet-of-Things: A Comparison of Swarm Intelligence Approaches", IEEE Open Journal of Antennas and Propagation, 2021.
18. D. Pliatsios, T. Lagkas, V. Argyriou, A. Sarigiannidis, D. Margounakis, T. Saoulidis, P. Sarigiannidis , "A Hybrid RF-FSO Offloading Scheme for Autonomous Industrial Internet of Things", IEEE INFOCOM 2022 - IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), 2022.
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21. D. Pliatsios, P. Sarigiannidis, T. D. Lagkas, V. Argyriou, A.-A. A. Boulogeorgos, and P. Baziana, “Joint Wireless Resource and Computation Offloading Optimization for Energy Efficient Internet of Vehicles,” IEEE Transactions on Green Communications and Networking, vol. 6, no. 3. Institute of Electrical and Electronics Engineers (IEEE), pp. 1468–1480, Sep. 2022. doi: http://dx.doi.org/10.1109/TGCN.2022.3189413

22. A. Liatifis, P. Sarigiannidis, V. Argyriou, and T. Lagkas, “Advancing SDN: from OpenFlow to P4, a Survey,” ACM Computing Surveys. Association for Computing Machinery (ACM), Aug. 26, 2022. doi: http://dx.doi.org/10.1145/3556973

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32. G. Siachamis, Ch. Kaliakatsos, G. Stavropoulos, K. Votis, D. Ioannidis, a nd D. Tzovaras " A Decentralized Secured Data sharing Framework for IoT Networks CERTH," 2022 IEEE 8th World Forum on Internet of Things (WF-IoT), Yokohama, Japan, to be published

Scientific Publications (4/4)

33. E. Villar-Rodriguez, M. A. Pérez, A. I. Torre-Bastida, C. R. Senderos, and J. López-de-Armentia, “Edge intelligence secure frameworks: Current state and future challenges,” Computers & Security, vol. 130, p. 103278, Jul. 2023, doi: 10.1016/j.cose.2023.103278.
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40. A. Liatifis, D.Pliatsios, P. Radoglou-Grammatikis, T. Lagkas, V. Vitsas, N. Katertsidis, I. Moscholios, S. Goudos, and P.Sarigiannidis, ‘’Edge Intelligence with 5G/6G Networks’’, EU-IoT & ICT-56 OA Book: Shaping the Future of IoT with Edge Intelligence: How Edge Computing Enables the Next Generation of IoT Applications, Accepted by River Publishers
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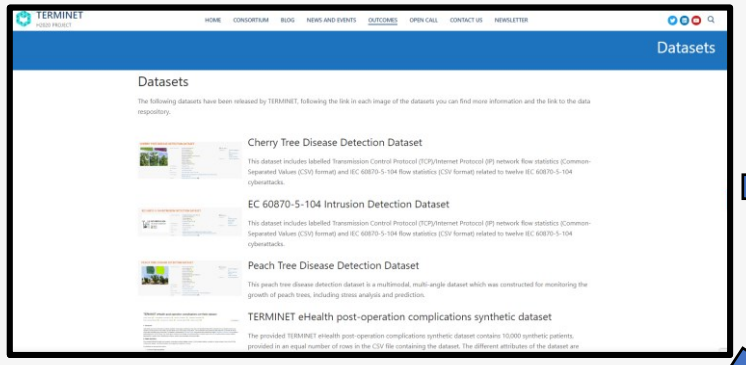
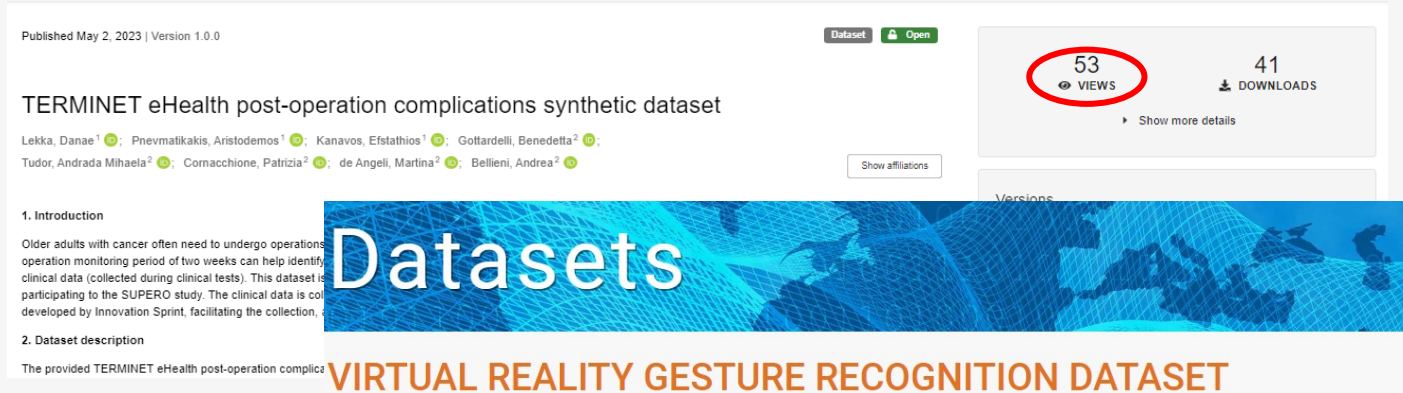
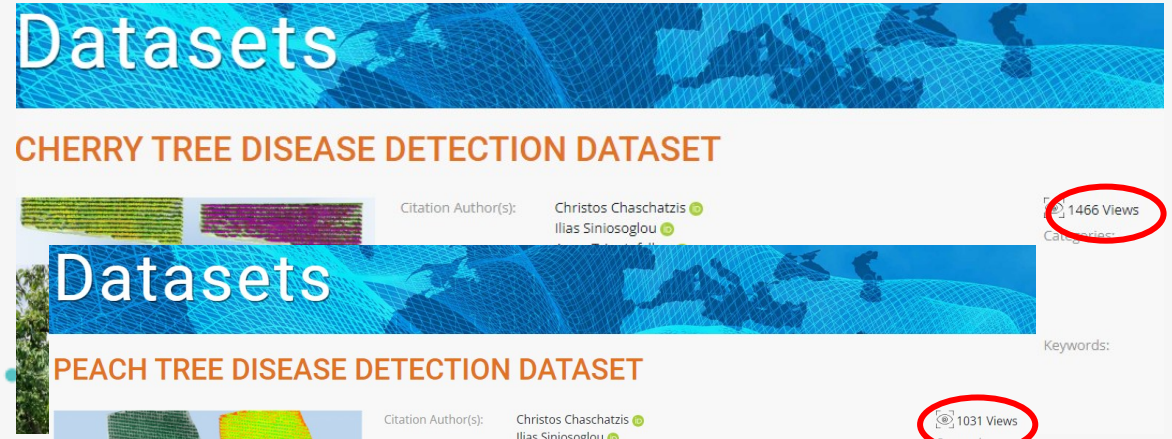
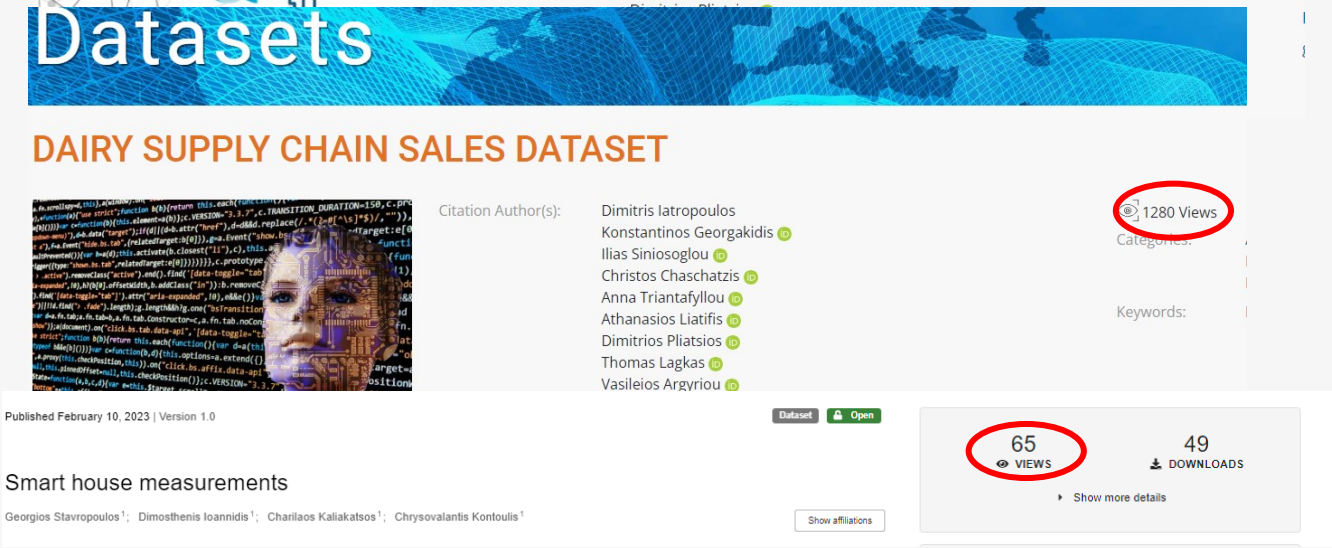
Public Datasets in TERMINET's Website









Thank you for your attention!

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